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THE FULLY ECONOMIC EVLUATION FOR TRANSPORT INFRASTRUCTURE PROJECT

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Abstract: By combining with the contingent valuation method and the fully economic evaluation approach, a new model for transport project evaluation is constructed. Different from the traditional cost-benefit analysis (CBA), this new model can easily transform the non-market goods into monetary terms and incorporate them onto the evaluation process. In the empirical case of Pinling interchange, two scenarios, with and without traffic regulations, are constructed. The estimation results show that by comparing with the fully economic evaluation approach, the traditional CBA would underestimate the environment effect and cause a biased policy decision. Moreover, since the resident interest groups could gain significant benefits, they incline to form pressure groups to lobby for the regulation release. On the other hand, although the water-use interest group bears the relative high cost at aggregate level, only a slight amount is paid by the individual that explains their indifferent attitude.

Key Words: fully economic evaluation, contingent valuation method, freeway interchange, transport project evaluation, interest group

1. INTRODUCTION

The interest groups for a freeway interchange are usually varied; especially, their interests are often conflicted. Generally, a new freeway can save travel time for road users and promote business activities around interchange areas. In principle, the residents in the vicinity of a potential interchange location may incline to welcome an interchange plan due to the increase of accessibility and the potential promotion of business activities. Yet, other interest groups, such as the whole city residents or environmentalists, sometimes tend to disapprove of the plan with concerns such as air quality decline or environment damage. Conflict is raised at this moment.

Cost-Benefit Analysis is the most frequent way to reconcile those interest conflicts and determine whether the implementation of the plan or not. However, most of the external costs were not included in the past studies (e.g. Kelvin, 2000; Talvitie, 2000; Brathen and Hervik, 1997) that may ignore the disadvantaged minority and bias the final decision. To fairly evaluate a transport infrastructure project, a more comprehensive analysis approach is needed. Nakamura (2000) first brought up the idea of *fully economic evaluation* which covers various items of impact including not only monetarily measurable effect but also non-monetary effect or intangible ones. A fully economic evaluation model represents more comprehensive evaluation than Cost-Benefit Analysis in a narrow sense. This paper, therefore, adopts this approach to construct the evaluation model for a freeway interchange plan.

The interest groups of the Pinglin Interchange of Taipei-Ilan Freeway are chosen as the case study in this paper. The Pinglin Interchange of Taipei-Ilan freeway was originally designed as an exclusive exit; that is, for emergency and local people use only. The applied regulation was to protect the water quality of Feitsui Reservoir, which is located at Pinglin and supplies drinking water to Taipei area. Meanwhile, the Pinglin residents strongly favor an interchange without any regulation such that the accessibility and potential commercial benefits can be maximized. Consequently, the full economic evaluation approach is crucial in this case to take monetary value of environmental goods into consideration, calculate social net benefit of interchange building, and then a comparison with the traditional CBA approach is analyzed.

The remaining of this paper is organized as follows: Section Two analyzes the issues of interchange use with and without regulations; Section Three constructs the fully economic evaluation model; Section Four analyzes the Pinglin Interchange case; and the conclusion is drawed on Section Five.

2. Issues of Interchange Use with and without Regulations

Freeway interchange use in environmental sensitive areas involves several evaluation issues that are quite different from a normal transport infrastructure project.

2.1 Alternatives of Regulations

Most of the interchanges are operated without any regulations; however, some regulations could be applied in order to achieve a special purpose such as the prevention of environmental damage or the protection of confidential military areas. The basic explanations of those two alternatives are described in Table 1.

Table 1. Alternatives of Regulations

Alternatives	Explanation
Without regulations	Vehicles can go in and go out of freeway via interchange without regulation.
With regulations	Interchange is set up for specific purposes by different kinds of vehicles or vehicles flow.

2.2 Interest Groups and Effect

The interest groups for interchange use can be classified into three types: road users, roadside communities and regions, and public sectors (Lee Jr., 2000; Morisugi, 2000; Quinet, 2000; Rothengatter, 2000). On the other hand, the possible effect of interchange use includes five dimensions: road use, environment, regional economy, project cost, and public service cost. For each dimension, several factors are consisted as shown in Table 2.

As for the road users, time saving, vehicle operating cost saving and accident reduction are positive. Some may concern that the increasing road use would result in more accidents; yet, in our case, the new Taipei-Ilan freeway is safer than the use of the original expressway between Taipei and Ilan (TNEEB, 2004). On the other hand, the roadside community and region, which represent the water users in our case, may concern about the water pollution generated from the invasion of increasing traffic flow. Furthermore, the additional traffic flow resulted from the release of regulations would produce more air pollution, water pollution and noise which are classified into the environment dimension. In addition, the regional economy would be promoted including more employment opportunities, income increase, and property value added. As for the public sectors, project cost and public service cost are needed to pay; the former one refers to the construction cost and maintenance cost, and the latter one refers to the waste disposal cost.

Road users are further classified into two subgroups: residents and non-residents. Although interchange use for road users on the road use dimension can bring positive effect, the residents can use the interchange either with or without regulations; moreover, the regional economy improvement only has positive effect on residents. These two features distinguish the resident and the non-resident road users.

Table 2. Effect and Interest Group Matrix

Effect		Interest groups			
		Road users		Water users	Public sectors
		Residents	Non-residents		
Road use	Time saving	+	+		
	Vehicle operating cost saving	+	+		
	Accident reduction	+	+		
Environment	Air pollution	−	−		
	Water pollution	−	−	−	
	Noise	−	−		
Regional economy	Employment, income and property value increase	+			
Project cost	Construction cost				−
	Maintenance cost				−
Public service cost	Waste disposal				−

Note: '+' refers to benefits, '−' refers to costs, and blank cells refer to neutral impact.

3. FULLY ECONOMIC EVALUATION MODEL

The fully economic model is developed on this section to evaluate the difference of the interchange use between with and without regulations as shown in Table 3. The monetary value for each factor in the dimensions is going to be calculated that will be further explained in the following analysis; thereafter, the difference between two alternatives for each factor can be directly derived. Consequently, the alternative 1 (without regulation) is more preferred if the summation of the last column is positive while the alternative 2 (with regulation) is more preferred if the summation of the last column is negative.

Table 3. Notation and Evaluation Matrix

Effect		Without regulation (A1)	With regulation (A2)	Δ (A1-A2)
Road use	Time saving (TS)	TS_1	TS_2	ΔTS
	Vehicle operating cost saving (VO)	VO_1	VO_2	ΔVO
	Accident reduction (AR)	AR_1	AR_2	ΔAR
Environment	Air pollution (AP)	AP_1	AP_2	ΔAP
	Water pollution (WP)	WP_1	WP_2	ΔWP
	Noise (NS)	NS_1	NS_2	ΔNS
Regional economy	Employment, income and property value increase (RE)	RE_1	RE_2	ΔRE
Project cost	Construction cost (CC)	CC_1	CC_2	ΔCC
	Maintenance cost (MC)	MC_1	MC_2	ΔMC
Public service cost	Waste disposal (WD)	WD_1	WD_2	ΔWD

3.1 Monetary Evaluation for Non-Environmental Effect

We first evaluate the non-environmental effect of freeway interchange use either without or with regulations. The non-environmental effect includes four dimensions: road use, regional economy, project cost and public service cost.

3.1.1 Road Use

One of the major effects of interchange use could contribute to the convenience of road use. In this paper, time saving, vehicle operating cost saving and accident reduction are the three types of effects to be evaluated.

1. Time Saving

ΔTS for the non-resident road users could reduce travel time by utilizing the interchange use while no regulations are applied.

$$\Delta TS = \sum_{m=1}^{2} \sum_{i=1}^{2} \sum_{j=1}^{2} T_{mij} * D_j * \Delta S * VT \tag{1}$$

where:

ΔTS = annual cost saving due to reduced traveling time

T_{mij} = trips of trip purpose i by mode type m at time period j

D_j = days of time period j

ΔS = time saved between A1and A2

VT = the value of the travel time

Daily trips are partitioned into weekday group and non-weekday group. In addition, two types of trip purposes and two types of mode types are classified.

i = trip purpose i = 1 means passengers stopping off in local en route to another destination
i = 2 means passengers making the journey specifically to visit local
j = time period j = 1 means weekends and public holidays
j = 2 means weekdays
m = mode type m = 1 means passenger cars
m = 2 means coaches

2. Vehicle Operating Cost Saving
Vehicle operating cost saving includes time and income dependent costs of vehicle operators, mileage-dependent depreciation, mileage dependent running costs (fuel, tires). The reduced travel distance could save the vehicle operating cost. ΔVO for the non-resident road users could reduce travel distance by utilizing the interchange use while no regulations are applied. We denote ΔK as the travel distance saved between A1 and A2.

$$\Delta VO = \sum_{m=1}^{2} \sum_{i=1}^{2} \sum_{j=1}^{2} T_{mij} * D_j * \Delta K * CO_m \tag{2}$$

where:
ΔVO = annual vehicle operating cost saving
ΔK = travel distance saved between A1 and A2
CO_m =the cost of the traveling distance saved by mode type *m*

3. Accident Reduction
The accident cost is mileage-dependent. The interchange use without regulations could divert traffic to safer road types as discussed above. ΔAR for the non-resident road users could reduce accidents by utilizing the interchange use while no regulations are applied.

$$\Delta AR = \sum_{m=1}^{2} \sum_{i=1}^{2} \sum_{j=1}^{2} T_{mij} D_j * \Delta K * AC_m \tag{3}$$

where:
ΔAR = annual cost saving from reduction in accidents
AC_m = the accident cost saved by mode type *m*

3.1.2 Employment, Income and Property Value Increase

The additional passengers are encouraged to visit local places with the interchange would bring economic benefits to the area including more employment opportunities, income increase and higher real estate values. Those improvements are directly derived from the consumption of non-resident road users while the size of the local economy is small such that the multiplier effect would not operate to any significant extent. For the purposes of this study, therefore, the increase in income from the non-resident road users is used to measure the economic benefits with the use of the interchange. ΔRE results from increase in annual revenue from the non-resident road users.

$$\Delta RE = \sum_{i=1}^{2} \sum_{j=1}^{2} V_{ij} * D_j * CS_i \tag{4}$$

where:

ΔRE = increase in annual revenue from passengers

V_{ij} = trips of trip purpose *i* at time period *j*

CS_i = consumption by the passengers *i*

3.1.3 Project Cost

The project cost comes from the construction cost and the maintenance cost.

1. Construction Cost

The difference between A1 and A2 for the construction cost is denoted with ΔCC .

2. Maintenance Cost

The freeway surface is more likely to be deteriorated with the introduction of additional traffic flow from the release of regulations for the interchange use. The maintenance cost of the freeway resulted from the interchange use will increase. We denote ΔMC as the maintenance cost and ΔMS as the difference of the maintenance cost between A1 and A2.

$$\Delta MC = L * \Delta MC \tag{5}$$

where:

ΔMC = annual maintenance cost

L = length from the interchange to local downtown

ΔMS = the difference of maintenance cost between A1 and A2

3.1.4 Public Service Cost

The spending on waste disposal for the local government is going to increase due to additional visitors. We define ΔWD as the increase cost of waste disposal and ΔW_j as the increase of the volume of waste produced at time period *j*.

$$\Delta WD = \sum_{j=1}^{2} \Delta W_j * D_j * CW \tag{6}$$

where:

ΔWD = increase in annual cost of waste disposal

ΔW_j = increase in the volume of waste produced at time period *j*

CW = cost of waste disposal

3.2 Monetary Value of Environmental Impacts

3.2.1 Elicitation

The contingent valuation method is a simple, flexible non-market valuation method and has been widely used in cost–benefit analysis and environmental impact assessment (Venkatachalam, 2004). We use a double-bounded dichotomous choice (DB–DC) approach (Alberini et.al, 1997) to estimate the contingent valuation (CV) for air pollution, noise and water pollution. Within the questionnaire, respondents are asked if they would be willing-to-pay a specific amount ('yes–no') in support of an environmental good; if the answer is "yes", then a follow-up question with a higher amount would be raised. On the contrary, if they refuse the initial bid then in the second round they will be asked for a smaller amount.

The proposed evaluation model is anchored in the willingness-to-pay responses to such dichotomous choice questions. The underlying idea reflects the respondent evaluation of his utility within two stages: with and without control plan. If they think that their CV for the described scenario exceeds the stated bid, they would accept to pay; otherwise they would reject. The observed respondent's decision upon the two bid amounts is offered to them in sequence as a proxy variable for the unobserved CV (t_{CV}). For each respondent, four possible response outcomes is faced: "yes – yes", "no – no", "yes – no" and "no – yes". The complete elicitation procedure is shown in Figure 1.

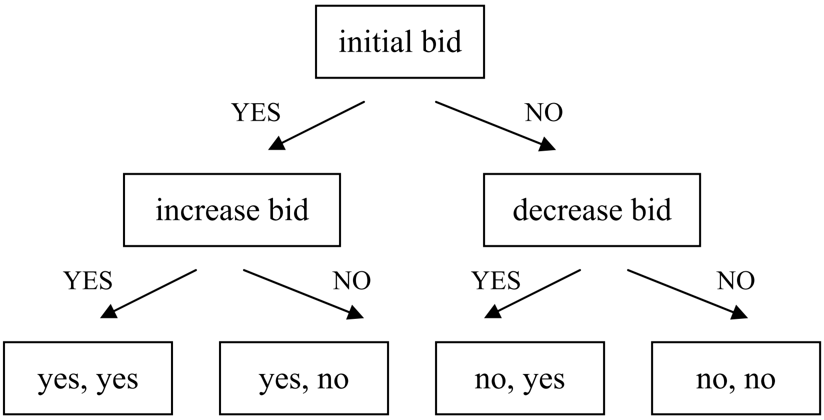

Figure 1. Survey Elicitation Question: Double Dichotomous Choice Format

3.2.2 Estimation of CV

Model coefficients are estimated using maximum likelihood techniques (Barton, 2002). The log-likelihood function for the DC–DB model is defined as follows:

$$\ln L = I_0 \ln F(0) + I_{nn} \ln[F(A_1), F(0)] + I_{ny} \ln[F(A), F(A_l)] + I_{yn} \ln[F(A_h), F(A)] + I_{yy} \ln[1, F(A_h)] \quad (7)$$

Here I is an indicator function taking the value of one when responses are in relevant category (y='yes', n='no', 0=true zero); otherwise, zero. In addition, F is the chosen cumulative density function. In this study the lognormal and truncated normal distributional assumptions as the selected treatments of zero CV were tested. The CV estimation is identified as

lognormal : $E[W] = e^{\mu + \frac{1}{2}\sigma^2}$ (8)

truncated normal: $E[W] = \mu + \sigma \dfrac{\phi(-\mu/\sigma)}{1 - \Phi(-\mu/\sigma)}$ (9)

where E[w]=expected CV; μ =location parameter; σ =scale parameter; ϕ =standard normal p.d.f; Φ =standard normal c.d.f.

Since air pollution and noise is a kind of regional environmental pollution, passengers only can feel when they stay there. Therefore, it is necessary to convert time of visitor stay into "man-days" equivalence. The stay time is different by the difference of trip purpose. We define MD as the number of man-days spent by non-resident road users and E_i as the average days of per stay for trip purpose *i*.

$$MD = \sum_{j=1}^{2} V_{ij} * D_j * E_i \tag{10}$$

where:
MD = the number of man-days spent by non-resident road users
E_i = average days of per stay for trip purpose *i*

4. THE EMPIRICAL STUDY

4.1 CV for Environment Effect

4.1.1 Survey

Between May to July of 2004, we interviewed 466 people in Taipei city (including Pinglin Township) about their value on air pollution, water pollution and noise. Provided the two scenarios, with and without the regulations of the Pinglin Interchange use, the answers to the questions enabled us to estimate CV as a function of the characteristics of the respondents.

4.1.2 Result

The CV of water user and residents to the environmental change by the survey is shown in Table 4. The CV to air pollution (CV_{AP}) is NT$10,124/man/year; to noise (CV_N) is NT$11,938/man/year; and to water pollution (CV_{WP}) is NT$103/man/year.

Table 4. CV for Environment Effect

	Index A1-A2 *	CV(NT$/man/year in 2004)
Air pollution	SO_2 :0.6~0.8ppb NO_2 :0.7~1.0ppb CO,0.06ppm TSP:4.6~6.3µg/ m^3	10,124
Water pollution	BOD & SS:0.0026~0.0068 mg/l $NH_3 - N$:0.0008~0.0021mg/l TP :0.0001~0.0003 mg/l	103
Noise	0.09~9.4db(A)	11,938

Note: * TNEEB, 2003

4.2 Input Parameters

The target year is set as 2011. It is assumed that there are 110 non-working days (weekends and public holidays) in each year, and 255 working days; it is also assumed that the population of Pinglin Township will stand at 6,207 in 2011, and that the number of people relying on Feitsui Reservoir for their water supply in that year will be 3,831,341 (TNEEB, 2004). The parameters for the full economic evaluation in the case study are shown in Table 5.

Table 5. Input Parameters

The target year: 2011
The population relying on Feitsui Reservoir for their water supply: 3,831,341 persons (2011)
The population of Pinglin Township: 6,207 persons (2011)
D_1 = 110 days/year, D_2 = 255 days/year
T_{111} = 3949 trips, T_{121} = 1536 trips, T_{211} = 1528 trips, T_{221} = 672 trips T_{112} = 285 trips, T_{122} = 40 trips, T_{212} = 107 trips, T_{222} = 15 trips,
ΔS = 30 minions
VT = NT$167 / hrs (2011)
ΔK = 15 km
CO_1 = NT$6.6 / km (2011), CO_2 = NT$6.7 / km (2011),
AC_1 = NT$0.78 / km (2011), AC_2 = NT$2.34 / km (2011)
V_{11} = 3,942 persons, V_{12} = 2,038 persons, V_{21} = 1,733 persons, V_{22} = 284 persons
CS_1 = NT$ 209 / tourist (2011), CS_2 = NT$ 123 / tourist (2011)
E_1 = 0.08 man-days, E_2 = 0.17 man-days
CV_{AP} = NT$ 10,124 / man / year (2004) , NT$ 11,629 / man / year* (2011)
CV_{WP} = NT$ 103 / man / year (2004) , NT$ 118 / man / year* (2011)
CV_N = NT$ 11,938 / man / year (2004) , NT$ 13,714 / man / year* (2011)
L = 15 km
ΔMC = NT$30,000 / km (2011)
ΔW_1 =2.2 tons / day, ΔW_2 =0.78 tons / day,
CW= NT$2,300 per ton

Note: * refers to the annual growth rate based on the Taiwan Central Bank's interest rate for one-year term deposit accounts (2%)

4.3 Result Analysis

The estimation results of the effect of the Pinglin Interchange use with and without regulations with the constructed fully economic evaluation model is shown in Table 6. In addition to the full economic evaluation of the two scenarios, the table also shows the net value to different interest groups. The non-resident road users obtain the most benefit and water users bear the most cost while the total net effect is negative.

Table 6. Estimation Results

Effect		Interest groups				
		Road users		Water users	Public sector	Sub-total
		Residents	Non-residents			
Road use	Time saving	0	95,749			95,749
	Vehicle operating cost saving	0	158,006			158,006
	Accident reduction	0	20,430			20,430
	Sub-total	0	274,185			274,185
Environment	Air pollution	-72,177	-3,861			-76,038
	Water pollution	-734	-39	-452,530		-453,304
	Noise	-85,114	-4,553			-89,667
	Sub-total	-158,025	-8,453	-452,530		-619,009
Regional economy	Employment, income and property value increase	331,152				331,152
	Sub-total	331,152				331,152
Project cost	Construction cost				0	0
	Maintenance cost				-4,500	-4,500
	Sub-total				-4,500	-4,500
Public service cost	Waste disposal				-1,019	-1,019
	Sub-total				-1,019	-1,019
Net Benefit		*173,127*	*265,732*	*-452,530*	*-5,519*	*-19,191*

Note: NT$ thousands per year in 2011

Of five effect dimensions, the benefit generated from regional economy and the cost resulted from environment effect are the two crucial items for a freeway interchange evaluation as shown in Table 7. In addition, the effect of the vehicle operating cost saving is the most positive within the road use dimension while the effect of the water pollution is the most negative within the environment dimension.

Table 7. CBA with respect to Each Dimension

Effect			Value
Benefit	Road use	Time saving	95,749
		Vehicle operating cost saving	158,006
		Accident reduction	20,430
		Subtotal	274,185
	Regional economy	Employment, income and property value increase	331,152
	Total		605,337
Cost	Environment	Air pollution	-76,038
		Water pollution	-453,304
		Noise	-89,667
		Subtotal	-619,009
	Project cost	Construction cost	0
		Maintenance cost	-4,500
	Public service cost	Waste disposal	-1,019
	Total		-624,528

Note: NT$ thousands per year in 2011

4.4 Discussion

4.4.1 Difference between the Fully Economic Evaluation and the Traditional CBA

The estimation results for the fully economic model, in which the environment effect is included, are quite different from those for the traditional CBA as shown in Table 8. The project evaluation gives a net benefit of NT$600 million per annum if the environment effect is not considered; however, the project is not worth being implemented with the negative benefit, NT$19 million if the environment effect is included.

Table 8. Difference between the Fully Economic Evaluation and the Traditional CBA

Approach	Road use	Environment	Regional economy	Project cost	Public service cost	Net benefit of project
Fully economic evaluation	*274,185*	*-619,009*	*331,152*	*-4,500*	*-1,019*	*-19,191*
Traditional CBA	*274,185*	*0*	*331,152*	*-4,500*	*-1,019*	*599,818*

Unit: NT$ thousands per year in 2011

4.4.2 Conflicts between Interest Groups

The benefits of the regulation release all accrue to residents and passengers while the costs will be borne by water-users and by the public sector as shown in Table 9. One might expect that the protests from water-users, who have to bear negative benefit of minus NT$452,530,000 per annum, would be stronger than those from local residents, who will benefit by a significantly smaller amount (NT$173,127,00 per annum). In reality, yet, while the local residents do organize pressure groups to push for the regulation release of the interchange use, the water-users has been muted.

Table 9. Net Benefit for Interest Groups

Interest groups	Resident road users	Non-resident road users	Water users	Public sector	Total
Net benefit	173,127	265,732	-452,530	-5,519	-19,191

Unit: NT$ thousands per year in 2011

The reason for this situation becomes clear if one calculates the benefit accruing to individual rather than to entire interest groups. The degree of incentives for different interest groups would be varied depending on the opportunity cost being faced. As shown in Table 10, while the net benefit accrues to particular interest groups on the average of the population, the local residents stand to benefit due to the regulation release of the interchange is NT$27,892 per person per year; on the other hand, the potential loss amount for the water users is reduced to only NT$118 per person per year by sharing with the large amount of users.

Table 10. Average Net Benefit to Individual Members for Interest Groups

Interest groups	Residents	Water users
Net benefit derived from the plan (NT$ thousands per year)	173,127	-452,530
Population	6,207	3,831,341
Average benefit per person (NT$ per year per person)	27,892	118

The prospect of receiving benefits that would be very high in per capita terms has provided the residents of Pinglin Township with sufficient incentive to form a powerful pressure group to push for the regulation release of the Pinglin Interchange use. By contrast, the fact that the negative benefit per head for the water users is so small such that the water users do not concern about the issue. Most of the time they may not realize that they would be required to bear extra cost as a result of the regulation release of the interchange use. The water users thus constitute a silent majority in this case. Individuals within the public sector have no reason to concern about the size of public expenditure, because it has no direct impact on their own personal well-being (Downing, 1984); the only possible push may come from the pressure groups.

5. CONCLUSIONS

This study aims to apply the fully economic evaluation approach to estimate the benefits and costs of the Pinglin Interchange use with and without regulations as well as the impact on different interest groups. The estimation results of the empirical study show that whether the inclusion of the monetized environment effect or not in a cost-benefit analysis can provide a dramatic impact on the results of the analysis. In the case of the Pinglin Interchange use, the net annual benefit in 2011 would be NT$600,000 per year while the environment effect is excluded; on the other hand, the net annual benefit is minus NT$19,000 per year while the environment effect is included in the evaluation process.

The benefits obtained from regional economy and the costs generated from the environment effect are the two crucial items in the evaluation process of the freeway interchange use. The empirical study shows the total benefit is NT$605,337,000 resulted from road use and regional economy. In addition, the effect of the vehicle operating cost saving is the most positive within the road use dimension while the effect of the water pollution is the most negative within the environment dimension.

As regards the benefits to individual interest groups, all of the positive benefits from the regulation release would accrue to road users while the negative benefits would be borne by the water users and by the public sectors. However, on a per capita basis, individual residents could potentially benefit to the tune of additional NT$27,892 income every year, while the potential cost to the individual water user would be only NT$118 per year. It can be seen that Pinglin residents have a strong incentive to form pressure groups and lobby for the regulation release of the interchange use. Lacking such strong incentive, the water users have become a silent majority.

The use of fully economic evaluation approach can throw more light on the conflicts between interest groups, but it cannot, in and of itself, solve the problems that underlie these conflicts. Many countries have established a platform for interaction and communication between interest groups (Habermas, 1989). Working through this platform, individual interest groups can bargain with one another on the basis of their own opportunity cost, lobbying other interest groups to agree to their proposals, and thereby achieving an equitable distribution of benefits between interest groups. This mechanism could also be used to resolve cases where the needs of local economic development and the needs of environmental protection come into conflict.

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