# An Economic Analysis of Constructing an Additional Ramp Along the Existing National Freeway Within the Nantou Area

Tung-Tsan Chen[1], Yao T. Hsu[2]

[1] Associate Professor, Department of Construction Engineering, National Quemoy University, No.1 University Rd., Kinmen County, 892, Taiwan, R.O.C., Email: tungtsan@nqu.edu.tw

[2] Associate Professor, Department of Transportation Technology and Management, Fung Chia University, Taiwan, R.O.C., Email: hsuyt@fcu.edu.tw

**ABSRRACT:** In order to solve the traffic congestion problems around Nantou area, the roadway network should be completely reviewed, especially for the National Highway 3's interchange system. The key assess is the Zucih bridge located at the edge of the Nantou city with the station 228K+500 on the National Freeway 3. Well constructed interchange system will definitely improve the traffic congestion problem in Nantou City. After that the Nantou County will possess the advantages for developing the industrious field. The purpose of this study is to conduct a quantifiable and non-quantifiable benefit-cost analysis of the construction project in order to evaluate the economic benefits of the location and route of the Nantou interchange. To do this, benefit-cost ratio(B/C) and net present value(NPV) will be used as quantifiable indicators, while for non-quantifiable indicators (such as land value, property value, and commerce benefits) more concrete figures will be used when possible in order to fully understand the economic benefits of this project. Further steps were taken to analyze the feasibility of the proposed construction. The findings of our research are to be used to contribute to the project's construction team.

## INTRODUCTION

Construction on the National Highway 3 began in 1987, and in 2004 it was open for use. Running through northern and southern Nantou, the highway plays an important role as a transportation thorough way throughout the area. However, after opening the thorough way to traffic use, it was found that the unsatisfactory location of certain sections of the interchange brought considerable inconveniences to road users.

Nantou City currently uses the Nantou interchange to join National Freeway 3, but due to the interchange's location in the northern most regions of Nantou City, city traffic must first travel by way of Provincial Highway 3 in order to join the interchange. Also, because the Nan Kung Industrial Zone is located in the most northern region on the west side of the Provincial Highway 3, the highway is frequently accessed by large vehicles. Therefore, during peak commuting hours, the Nantou interchange and the surrounding roads often experience congestion. In

particular, Provincial Highway 3 and the Zhongxing Rd. section of Provincial Highway 14B experience the worst congestion. Therefore, in order to solve the traffic problems in and around Nantou City and make a more complete road system in the Nantou living area, it is in necessary to review National Highway 3 and the Nantou area interchange system.

This study's economic benefit analysis is current to the year 2007 with 2040 set as the target year and 2023 as the intermediate period. Its purpose is to provide an economic benefit analysis of the feasibility of constructing an additional interchange to directly link Nantou District roads to National Highway 3 so as to provide a fast and convenient transportation system in the Nantou Region, as well as consider the project of connecting East Min Rd and Jhongjheng Rd. with Zucih bridge to allow the future transportation network to form a complete system (see Fig.1).


**Fig.1 Assess the area of Nantou section of the road system around**

## ECONOMIC BENEFIT ANALYSIS

### Indicators of Economic Assessment

This economic assessment uses benefit-cost analysis to monetize and compare the costs and benefits of the project, and seeks to understand the economic feasibility of the implementation plan through assessment indicators such as net present value (NPV), and benefit-cost ratio (B/C) (Greene and Wegener, 1997).

**Net Present Value**

Net present value is a convenient and widely used method for assessing public construction investment projects because it takes into account the time value of money as well as the cost and benefit of the project's entire lifespan. During the assessment period, the difference between the present value of the total benefit stream and the present value of the total cost stream is measured (Luis and Luis, 2008). When the benefit is greater than the cost, the investment plan is conducive to the use of social resources. The method of calculation is as follows:

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+i)^t} \quad \text{.....(1)}$$

The formula, NPV = net present value
Bt = benefits of the period t years
Ct = cost of the period t years
n = assessment years
i = discount rate

**Benefit-Cost Ratio**

The benefit-cost ratio uses the difference between the net present value of the benefits and the net present value of the costs as an analytical assessment of the feasibility of the project. When the benefit-cost ratio (B/C) value is greater than 1, the investment is economically feasible. The larger the ratio is the better. If the B/C value is less than 1, then the investment is not worth it (Boardman et al, 1996; Getzner, 2008). The formula for the benefit-cost ratio is as follows:

$$R = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C^t}{(1+i)^t}} \quad \text{.....(2)}$$

The formula, R = ratio of benefits
Bt = benefits of the period t years
Ct = cost of the period t years
n = assessment years
i = discount rate

**Economic Benefit Assessment**

The construction of the ramp in Nantou City and the Zucih bridge, in addition to enhancing the performance of transport outside of Nantou, can also effectively improve transport accessibility in the Nantou area and therefore can lead to overall area development. However, discount rate, assessment period, inflation trend, etc. must first be considered (Wang and Luo, 2010; Roberts and Goodwin 2002).

**Discount Rate**

Discount rate is used to convert the costs and benefits of different years into a monetary value of the base year. Usually, depending on the investment preferences of investors, the interest rate of investment and other factors, the discount rate varies. Therefore the market interest rate is usually used as a reference to calculate the discount rate. In recent years, with continuous adjustment of the central bank deposit rate, government bond interest rates have continued to weaken, which should reduce the discount rate. After having economically evaluated the construction project, the government will generally, in view of the results, decide whether or not to promote a specific construction project or decide which projects to promote first. Thus, this study, with reference to the discount rate, should be considered with an assessment of general transport investment and from a consistent standpoint (Sáez and Requena, 2007). Based on this, a 5.0% discount rate will be used for the relevant assessment.

Using the 2007 currency value, the total benefits and costs were analyzed according to discount rates at 1%, 3%, 5%, 8%, 11%, 14% and 17% (see Table 6.1 below).

**Table 6.1 Comparison of the Total Benefits and Costs of Each Discount Rate**

| Discount Rate | Total Benefit | Total Cost | NPV | B/C |
|---|---|---|---|---|
| Currency in 2007 | 959,045.80 | 117,540.13 | 841,505.67 | 8.16 |
| 1% | 782,133.33 | 114,028.29 | 668,105.04 | 6.86 |
| 3% | 534,441.52 | 109,877.72 | 424,563.80 | 4.86 |
| 5% | 378,113.68 | 104,191.91 | 273,921.77 | 3.63 |
| 8% | 239,066.36 | 99,230.09 | 139,836.27 | 2.41 |
| 11% | 161,086.96 | 95,294.39 | 65,792.57 | 1.69 |
| 14% | 114,509.97 | 91,887.89 | 22,622.08 | 1.25 |
| 17% | 85,008.03 | 89,087.89 | -4,079.86 | 0.95 |

Note: According to different discount rate analyses monetary unit : NT$ 10,000

### Yearly Benefit Analysis

Having summarized above the cost of building an additional interchange and a linking road(main construction costs including engineering design, land acquisition and compensation for demolition, construction, etc.) and of improving the efficiency estimates (travel time saving benefits, travel cost saving benefits, cost saving benefits etc.) according to net present value, benefit-cost ratio, and other indicators, further research into the feasibility, as well as the merits, of implementing the building project is necessary. The criteria for determining the assessment indicators are as follows:

(1) A benefit-cost ratio of 1 is the critical value. Greater than 1 indicates that the construction project is economically feasible. Any value otherwise is not.

(2) A net present value of 0 is the critical value. Greater than 0 indicates that the construction project is economically feasible. Any value otherwise is not.

Preliminary estimates of the project sub-annual benefit are shown in Table 6.2. At a 5% discount, the total benefit in estimated travel time and travel distance savings during the 30 year period between 2011-2040 is about NT$3.7811 billion, the total cost about NT$1.0419 billion, the net present value about NT$2.7392 billion, and the benefit-cost ratio (B/C) about 3.629.

**Table 6.2 Benefits of Constructing a New Ramp in the Nantou Area**

| Item | Classification | Monetary Value ( NT ) | Notes |
|---|---|---|---|
| 1 | Total Benefit (discounted) | 1,041,919,100 | |
| 2 | Total Cos t (discounted) | 3,781,136,800 | |
| 3 | Total Benefit | 9,590,458,000 | |
| 4 | Travel Time Savings | 5,392,168,600 | |
| 5 | Travel Distance Savings | 4,198,289,400 | |
| 6 | Net present value | 2,739,217,700 | |
| 7 | Benefit ratio (B/C) | | 3.629 |

Note：At 5% discount

## EVALUATION OF ALTERNATIVES

### Original Plan

In order to relieve heavy traffic in the specified area, an elevated connecting road (at least more than 4.6 km long) is to be built along the Miaoluo river bank to the current Nantou interchange. The cost of this two-way, four lane road, not including land acquisition fees and compensation for the demolition, is about NT$2.5 billion.

**Comparing Alternatives**

In this research summary, the project to build an on and off ramp is estimated at NT$1 billion, which, when compared to the original plan, would save NT$1.5 billion. However, the required future annual maintenance cost is estimated to be more and this does not include the increase in travel cost due to diverting southbound traffic.

**Sensitivity Analysis**

In view of the above assumed factors of economic benefit analysis, there still exists many uncertainties. Therefore, this study conducted a sensitivity analysis of the variables (factors such as the construction cost, land acquisition cost, operating cost, inflation cost, discount rate, time value of money, travel cost and the time value of goods) which could possibly affect the assessment results in order to understand how a change in each factor could affect the economic benefit analysis (Helton et al. 2006). Overall, while conducting an analysis of the affects of variations in variables, if the change in a factor does not affect the possibility of plan implementation, then this factor can be considered stable and controllable. Otherwise, a risk management assessment should be carried out on those that are not stable and controllable.

**Discount rate changes in the sensitivity analysis**

The higher the discount rate, the higher the cost of investment, and the lower the economic benefits of investment. This project is feasible at a discount rate under 17%. However, at a 17% discount rate the NPV would be NT$40.8 million, and all economic indicators show the project to be infeasible (see Table 6.3 below).

**Table 6.3 Sensitivity Analysis of Changes in Discount Rate**

| Item | Discount Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1% | 3% | 5% | 8% | 11% | 14% | 17% |
| Total Benefit | 7,821.33 | 5,344.42 | 3,781.13 | 2,390.66 | 1,610.86 | 1,145.09 | 850.08 |
| Total Cost | 1,140.28 | 1,098.77 | 1,041.91 | 992.30 | 952.94 | 918.87 | 890.88 |
| B/C | 6.859 | 4.864 | 3.629 | 2.409 | 1.690 | 1.246 | -0.046 |
| NPV | 6,681.05 | 4,245.65 | 2,739.22 | 1,398.36 | 657.92 | 226.22 | -40.80 |

Note: Monetary unit: NT$ 1,000,000

**Construction cost variance in the sensitivity analysis**

This project's construction cost is a large portion of the total cost. In order to facilitate the understanding of their impact on the assessment results, the construction cost was analyzed at variances between -20% and +20%. Furthermore, we can observe the changing qualities of the economic benefits in relation to the

construction cost. After statistical analysis, it was concluded that the variance in construction cost between -20% and +20% is economically feasible (see Table 6.4 below).

**Table 6.4 Sensitivity Analysis of Variances in Construction Cost**

| Item | Variation in Construction Cost | | | | |
|---|---|---|---|---|---|
| | -20% | -10% | 0% | 10% | 20% |
| Total Benefit | 3,781.13 | 3,781.13 | 3,781.13 | 3,781.13 | 3,781.13 |
| Total Cost | 842.90 | 942.41 | 1,041.91 | 1,141.43 | 1,240.94 |
| B/C | 4.486 | 4.012 | 3.629 | 3.313 | 3.047 |
| NPV | 2,938.23 | 2,838.72 | 2,739.22 | 2,639.70 | 2,540.19 |

Note : Calculated at 5% discount on the basis of currency change monetary unit : NT$ 1,000,000

**Operating and maintenance cost variance in the sensitivity analysis**

Although the operating and maintenance cost is a smaller percentage of the total cost, any variation could affect the assessment results of the economic benefits. The operating and maintenance cost was analyzed at variances between -20% and +20% to show the changing qualities of the economic benefits. After statistical analysis, it was concluded that a variance in operating and maintenance cost between -20% and +20% is economically feasible (see Table 6.5 below).

**Table 6.5 Sensitivity Analysis of Variances in Operating and Maintenance Cost**

| Item | Changes in Operating and Maintenance Cost | | | | |
|---|---|---|---|---|---|
| | -20% | -10% | 0% | 10% | 20% |
| Total Benefit | 3,781.13 | 3,781.13 | 3,781.13 | 3,781.13 | 3,781.13 |
| Total Cost | 1,032.55 | 1,037.24 | 1,041.91 | 1,046.60 | 1,051.28 |
| B/C | 3.662 | 3.645 | 3.629 | 3.613 | 3.597 |
| NPV | 2,748.58 | 2,743.86 | 2,739.22 | 2,734.53 | 2,729.85 |

Note : Calculated at 5% discount on the basis of currency change monetary unit : NT$ 1,000,000

## CONCLUSIONS AND RECOMMENDATIONS

The building of a ramp at the National Highway 3's 228k+500 section in Nantou will increase traffic in the area and change the route of transport. Thus, in order to enhance the systems accessibility and improve the efficiency of transport in the area, an operations benefits analysis of the additional ramp was conducted. The transportation benefits include saving travel time, travel cost, production cost, etc.

**Benefit Analysis Conclusion**

This comprehensive analysis estimates the costs and benefits(the saving of travel time, travel cost, production cost, etc) of the construction of the ramp and connecting roads, which both present implementation policies that are necessary and feasible, and that:

(1) Could establish a better network of roads within the residential area of Nantou which would improve transportation accessibility and convenience.

(2) Could link such areas as Nantou City, Chung Hsing New Village, Chungliao, Ming Jian County (the Pine Ridge tea producing area) and Tsaotun; open up the area to potential development; and promote its tourist industry.

(3) Could strengthen the network of roads in the residential areas, improve the regions standard of living, and set up a core urban community both convenient and accessible.

**Benefit Analysis Recommendation**

Well planned interchange system will be able to keep all the traffic flow going around the roadway network. Therefore, the on and off ramp on the Zucih Bridge with the good alignment to connect the local roadway are really needed in order to improve the traffic congestion problem in the Nantou area. According, the area economy will develop through the local logistics system.

**REFERENCES**

Boardman, A. E., Greenberg D.H., Vining A.R., Weimer D.L., (1996). "Cost- Benefit Analysis: Concepts and Practice Upper Saddle River." NJ: Prentice Hall.

Getzner, M., (2008) "Uncertainties and the precautionary principle in cost–benefit environmental policies" *Journal of Policy Modeling*, Vol.30 (1): 1-17

Greene, D., and Wegener, M. (1997) "Sustainable Transportation" *Journal of Transport Geography*, Vol. 5 (3): 177-190.

Helton, J. C., Johnson, J. D., Sallaberry, C.J., and Storlie, C.B. (2006). "Survey of sampling-based methods for uncertainty and sensitivity analysis" *Reliability Engineering and System Safety*, Vol. 91 ( 10-11): 1175-1209.

Luis G.. J., Luis B. P. (2008). "Multi-criteria cash flow modeling and project value-multiples for two-stage project valuation." *International Journal of Project Management*, Vol. 26 (2): 185-194.

Roberts R., Goodwin P. (2002). "Weight approximations in multi-attribute decision models" *Journal of Multi-Criteria Decision Analysis*, 11: 291-303.

Sáez, C. A., Requena, J. C. (2007). "Reconciling sustainability and discounting in Cost–Benefit Analysis" *Ecological Economics*, Vol. 60 ( 4): 712-725.

Wang, Y. M., Luo, Y. (2010). "Integration of correlations with standard deviations for determining attributes weights in multiple attribute decision making." *Mathematical and Computer Modelling*, Vol. 51 (1-2): 1-12.