Recreational Cycling Routes Investment Selection- Hsinchu Technopolis Case by Applying ZOGP

Hsin-Wen CHANG [a] Hung-Nien HSIEH [b]

[a] *Associate Professor, Head of Department of Leisure and Recreation Planning and Management, Chung Hua University, Taiwan.*
[a] *E-mail: hwchang@chu.edu.tw*
[b] *Associate Professor, Department of Architecture and Urban Planning, Chung-Hua University, Taiwan.*
[b] *E-mail: planner@chu.edu.tw*

ABSTRACT：Recreational cycling facilities are gaining increased attention with regard to the creation of social infrastructure and sustainable development in Taiwan. Cycling routes are fast becoming a major tourist attraction in both urban areas and the countryside. In response, governmental institutions have to determine the most effective means to evaluate and select new routes. In addition, they must allocate resources for this development, despite budgetary restrictions and considerations of availability. This study applies Fuzzy Delphi Method to identify the criteria for the evaluation of cycling routes in the Hsinchu Technopolis with the support of two other methodologies: the Analytic Network Process, which helps to determine the weight of importance for routes, and Zero One Goal Programming that helps to find investment solutions for the routes, once identified. The research results illustrate the utility of the combined use of these three methodological instruments as they pertain to governmental decision making processes.
Keywords: Recreational Cycling, Cycling Routes, Analytic Network Process (ANP), Zero One Goal Programming (ZOGP)

1. INTRODUCTION

Since 2002, Taiwan has been experiencing a surge in popularity for recreational cycling followed by a steady stream of investment from central and local governmental institutions. At the same time many researchers have been arguing that the topography and climate of the island make Taiwan less conducive to bicycle commuting than was once believed. Nonetheless, national trends have emerged including green mode planning that regards the bicycle as an environmentally desirable option for outdoor recreation and tourism (Chang and Chang, 2003).

Cycling in Taiwan has evolved from a functional form of transportation to a form of outdoor recreation, in response to increased demand for leisure activities. In such an environment, the National Sports Council launched a plan to establish a system of bikeways to encourage the development of local green industry based on the development of tourism and transportation. Following the establishment of the national development plan the government is committed to investment in such projects. (Chang and Chang, 2008)

The Tourist Double Plan has also stressed the importance of building a national bikeway system and the Department of Construction and Administration of Minister of the Interior are acting as sponsoring organizations in directing the development of cycling lanes in every county and town, in conjunction with "New Features for Cities and Counties Construction Plan". In addition, The Ministry of Education has drawn up a plan to encourage students to walk to school and use bicycles around campuses (Chang and Chang, 2008).

A Former Premier proposed a plan to construct 1,000 km of bike paths and several thousand walking paths around the island, and this trend has been reinforced by the results of the 2008 governmental elections. To stimulate cycling activities and the use of bicycles in Taiwan, three promotional programs have been established: First, the construction of the Bicycle Industrial Park in Central Taiwan has been initiated with the combined cooperation of the bicycle industry and the central and local governments. This park will host a "bicycle mall" that will be used as a marketing channel for bicycle related products and hosting promotional activities to encourage more cycling tourists to visit the island.

Second, the trendy activity of "Cycling the Island" will be continually promoted. "Cycling the Whole Island" has become a motto targeting all Taiwanese citizens regardless of age. Through the promotion of frequent one week trips, people from 7 to 70 years old have begun cycling and getting to know the island. Youngster are another target, and the nation expects 16 year-olds boys and girls to participate in cycling at least 100 km, with 18 year-olds cycling 200 km, and 20 year-olds cycling the entire island.

Third, the central government has been trying to connect cycling routes from county to county. So far, the northern cycling route from Keelung to Hsinchu through the mountains and along the coastal has been targeted to increase the space for cycling.

The authors emphasize the research objective in helping public sectors to evaluate their investment priority by applying useful methodology, via the successful empirical studies in Taiwan's experiences.

2.THE IMPORTANCE OF DEVELOPING RECREATIONAL CYCLING IN HSINCHU TECHNOPOLIS

This study focuses on the Hsinchu Technopolis, that is, a metropolitan area with a high concentration of high-tech industry. It is home to the Hsinchu Science-based Industrial Park (HSIP) which is the center of science and technology industries and a regional magnet for high-tech talent. With over 30 years of Science Park development, the Hsinchu Technopolis has earned a worldwide reputation as "Asia's Silicon Valley" making up a flourishing high-tech industrial development, with production soaring to 40 billion U.S. Dollars annually. This area is famous for high-end technology, higher education, and high incomes (Chang and Chang, 2008).

The Hsinchu Technopolis includes Hsinchu city and Hsinchu County, with a local population of 400,000 in the city and 600,000 in the county. From this combined population, approximately 130,000 employees (over one-seventh) work in the Science Park.

Due to the development of the Science Park the area enjoys the highest average household income in Taiwan, with car ownership among the highest. Hsinchu County has 342 cars per thousand people Hsinchu city has 322 cars per thousand people. This glut of automobiles has compelled researchers to conduct studies to find solutions to this problem, and the government to promote green transportation campaigns, particularly in cycling (Chang and Chang, 2008).

Recreational cycling is frequently cited by high-tech workers as a favored method of relaxation and adventure in the exploration of new surroundings as well as a mode of transportation by which they can interact with nature. In contrast to polluting automobiles, bicycles are quiet, with no emissions and limited environmental impact on the sensitive environment. High-tech workers also regard cycling as a highly social activity for those searching for adventure and new challenges in their outdoor activities (Chang and Chang, 2009). Hsinchu coastal zone is home to the largest wetlands in northern Taiwan, with native species including crabs, birds, and plants. It is protected by law against undesirable development owing to its special scenic and environmental value.

In addition to improving its investment in the environment, city and county governments are also working enthusiastically to improve leisure and recreational environment by establishing cycling routes to enhance the quality of life and attract new high-tech workers.

Starting in 2002, Hsinchu city government began establishing 17 km of dedicated bike lanes along the beautiful Hsinchu coastline. This project was completed at the end of 2005.

The Hsinchu county government has more natural resources than the city government, but suffers from budget limitations. With a land area of 1428 square km, Hsinchu County includes 13 towns with diverse terrain, climates, and a flourishing agriculture industry. The majority of citizens are of Chinese origin with an abundance of Taiwanese and Aboriginal descendants; making the county a major center of culture and history. (Chang and Chang, 2003)

The transformation from agriculture to science and technology and the combination of traditional culture with modern trends has altered Hsinchu County fundamentally. The county enjoys the presence of a cultural center, stadium, coastal area, food court, and 300km/hr High-Speed Railway Station, offering many opportunities as a living place for high-tech workers and regular citizens alike. Additionally the local government has introduced a series of leisure and recreational activities based on the special native features of the area, namely national scenic areas, a national park and the always well visited and appreciated hot springs.

So far, the total length of the cycling routes in Hsinchu stretches 300 km, but the entire scheme is limited by budgetary restrictions. This has made it necessary to establish an evaluation system to help the public sector in the decision making process regarding future construction.

Overall, with trends in green development, people in Taiwan have come to value outdoor recreational activities, particularly recreational cycling. Both central and local governments are enthusiastically promoting recreational cycling as well as enhancing local culture through cycling events.

The authors apply FDM, ANP and ZOGP methods in this study. The research method used here is Fuzzy Delphi Method (FDM) and Analytic Network Process (ANP). The purpose of FDM is sifting fit criteria in cycling route evaluating, and ANP is for structuring the weight of criteria.

3.SELECTING CYCLING ROUTES AND PRIORITIZING INVESTMENT

The authors were planning 3 cycling routes on behalf of the county government: the Taoyuan County-Hsinfeng-Chupei-Hsinchu city route, the Hsinchu city-Chupei-Chutung route, and the Chutung-Peipu-Ermei-Miaoli County route. The locations of these three cycling routes are shown in Figure 1 and their length, construction; planning and projected costs are shown in Table 1.

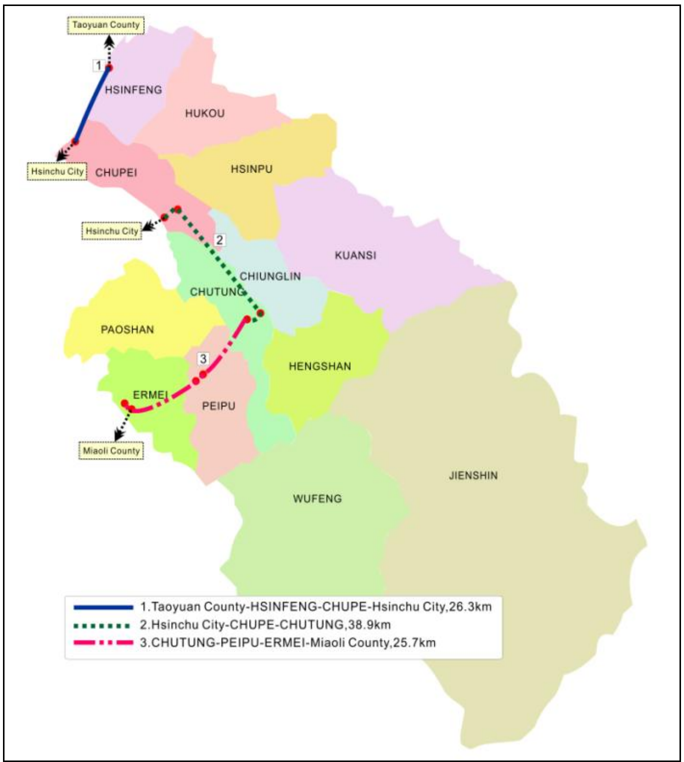


Figure1. Locations of the 3 selected cycling routes in Hsinchu Technopolis

Table 1. Estimates: length and costs of the 3 cycling routes in Hsinchu Technopolis

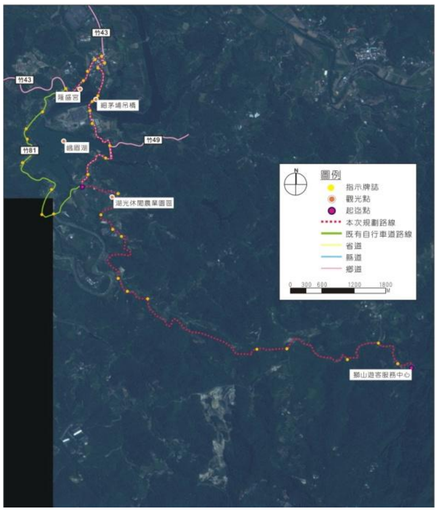
Unit: 10,000 NTD = 300 USD

Name of cycling route	Length(km)	Construction fee	Planning and design fee
Taoyuan County-Hsinfeng-Chupei-Hsinchu city route	26.3	1350	108
Hsinchu city-Chupe-Chutung route	38.9	1679	134
Chutung-Peipu-Ermei-Miaoli County route	25.7	1580	126
Total	90.9	4609	368

Table 1 shows that it will be cost 3.68 million New Taiwan Dollars for the planning and design and 46.09 million NTD for the construction of the 3 cycling routes. However, the eagerness of local authorities to go ahead with this construction has been met by budgetary restrictions from central government as well as their own local funding. This study applies a three step process to determine the optimal solutions regarding the selection of investment alternative for these cycling routes.

Taoyuan County- Hsinfeng- Chupei-Hsinchu city route

Hsinchu city-Chupe-Chutung route



Chutung-Peipu-Ermei-Miaoli County route

The Fuzzy Delphi Model (FDM) is systematic procedure for collecting opinions from groups of experts, and determines the degree of interdependence among those opinions. (Ishikawa et al 1993; Murray et al 1985) This study used the information obtained from the FDM and the ANP to formulate Zero One Goal Programming (ZOGP), allowing us to determine the cycling routes prior to searching for solutions regarding the selection of investment alternative for cycling routes.

Step One: *Defining the evaluation criteria through Fuzzy Delphi Method (FDM)*
The Delphi method comprises a systematic survey for the collection of opinions from experts. In this study, nine specialists in tourism, transportation and cycling were invited to answer a series of questions with regard to cycling.

The questionnaire was designed with 6 objectives: Traffic Safety; Cycling Environment; Recreation Environment; Environmental Quality; Accessibility; and Maintenance Management and Service. These objectives were obtained from previous studies (Hsieh and Chang, 2009). A total of 28 criteria are under 6 objectives, were discussed primarily through group brain storming. After establishing this evaluation structure, 28 criteria were evaluated by nine experts. The structure of the evaluation criteria for investment in cycling routes is shown in Figure 2.

Through the application of FDM, the opinions of experts were collected, and then the 28 criteria were determined through statistical analysis. Half of the criteria were chosen by passing the threshold established at 6.58, (Table 2). A standard network for the research structure is illustrated in Figure 3.

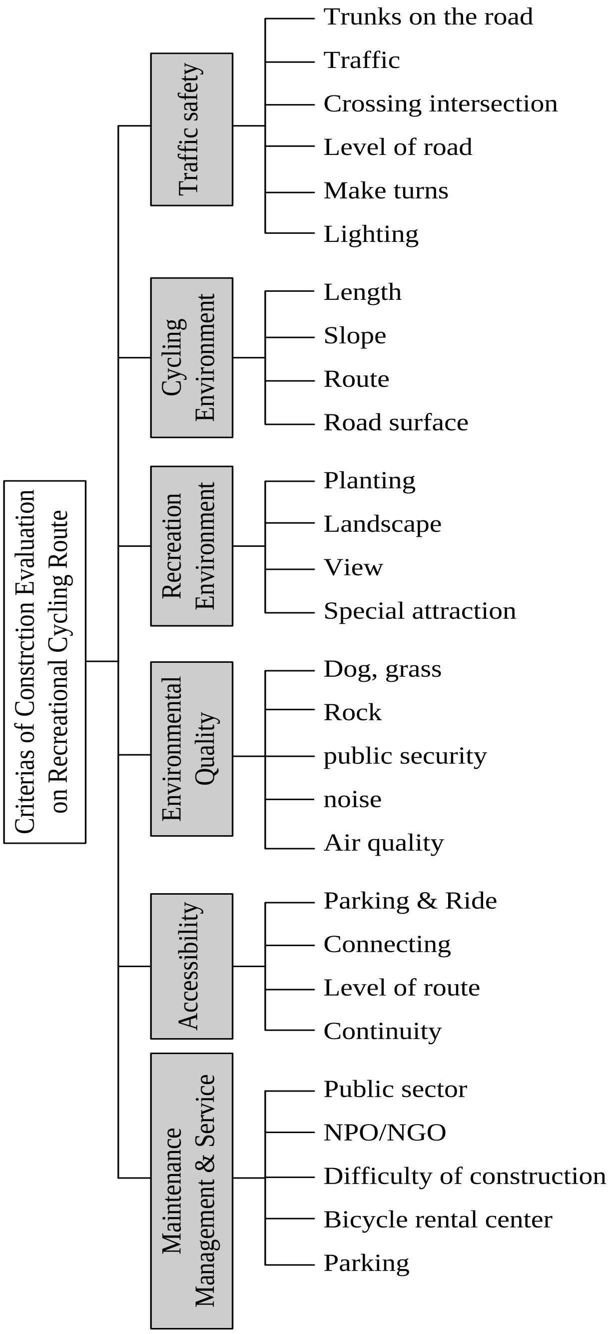


Figure 2. The criteria for evaluation of investment in cycling routes

This study applies Fuzzy Delphi Method to identify the criteria for the evaluation of cycling routes in the Hsinchu Technopolis. This research decided the threshold value is 6.58 according to previous study (Wey and Chiu, 2013), therefore 14 factors were choose in this study.

Table 2. The results of FDM

Criteria		a^i		MIN c^i		MAX o^i		AVE			Z^i	G^i (BY EXPERTISES)
		min	max	min	max	min	max	a^i	c^i	o^i		
Traffic safety	1. Trunks on the road	5	10	1	8	7	10	8.23	4.88	9.22	3.34	7.42
	2. Traffic	7	10	1	7	7	10	7.91	4.39	8.65	4.26	7.00
	3. Crossing intersection	3	10	1	7	5	10	6.47	3.40	7.67	2.27	5.85
	4. Level of road	5	8	4	7	6	10	6.76	5.13	8.02	1.89	6.52
	5. Make turns	5	7	1	5	7	8	5.97	3.47	7.16	5.69	6.81
	6. Lighting	2	7	1	5	4	10	4.37	2.56	6.13	2.57	4.47
Cycling Environment	1. Length	3	8	1	7	5	10	6.03	4.14	7.84	1.69	6.00
	2. Slope	5	9	3	7	7	10	6.83	5.34	8.20	2.87	7.00
	3. Route	6	9	5	7	7	10	7.08	5.53	8.22	2.70	7.00
	4. Road surface	6	10	1	6	7	10	7.61	4.19	8.65	5.47	6.52
Recreation Environment	1. Planting	6	10	1	6	7	10	7.03	3.93	8.08	5.16	6.66
	2. Landscape	6	9	4	7	7	10	7.52	5.47	8.63	3.16	7.00
	3. View	6	8	4	6	7	9	7.11	5.24	8.40	4.16	6.35
	4. Special attraction	5	9	3	7	6	10	6.73	4.93	7.89	1.96	6.48
Environmental Quality	1. Dog, grass	3	10	1	7	5	10	6.34	3.16	7.56	2.40	5.80
	2. Rock	5	10	1	9	6	10	7.67	4.48	8.61	1.13	7.10
	3. public security	3	10	1	7	5	10	6.65	3.58	7.99	2.41	5.93
	4. noise	3	10	1	9	5	10	5.93	4.16	7.42	-0.74	6.33
	5. Air quality	6	10	3	9	8	10	7.47	5.85	8.69	1.84	8.18
Accessibility	1. Parking & Ride	6	10	1	6	7	10	7.21	4.30	8.52	5.23	6.53
	2. Connecting	7	9	4	8	8	10	7.96	6.30	9.10	2.80	8.00
	3. Level of route	3	9	1	5	5	10	5.61	3.30	7.40	4.10	5.00
	4. Continuity	6	10	1	7	7	10	7.49	4.12	8.52	4.40	7.00
Maintenance Management & Service	1. Public sector	7	10	1	7	8	10	7.78	4.51	8.83	5.33	7.75
	2. NPO/NGO	5	8	3	7	6	9	6.20	4.25	7.50	2.25	6.35
	3. Difficulty of construction	5	8	3	7	7	9	6.76	4.85	8.24	3.39	7.00
	4.Bicycle rental center	5	9	3	7	7	10	6.81	5.22	8.07	2.85	7.00
	5. Parking	4	8	3	7	6	9	6.57	4.98	7.92	1.95	6.49
No of factors		14									threshold	6.58
7.00：> threshold value 6.58												

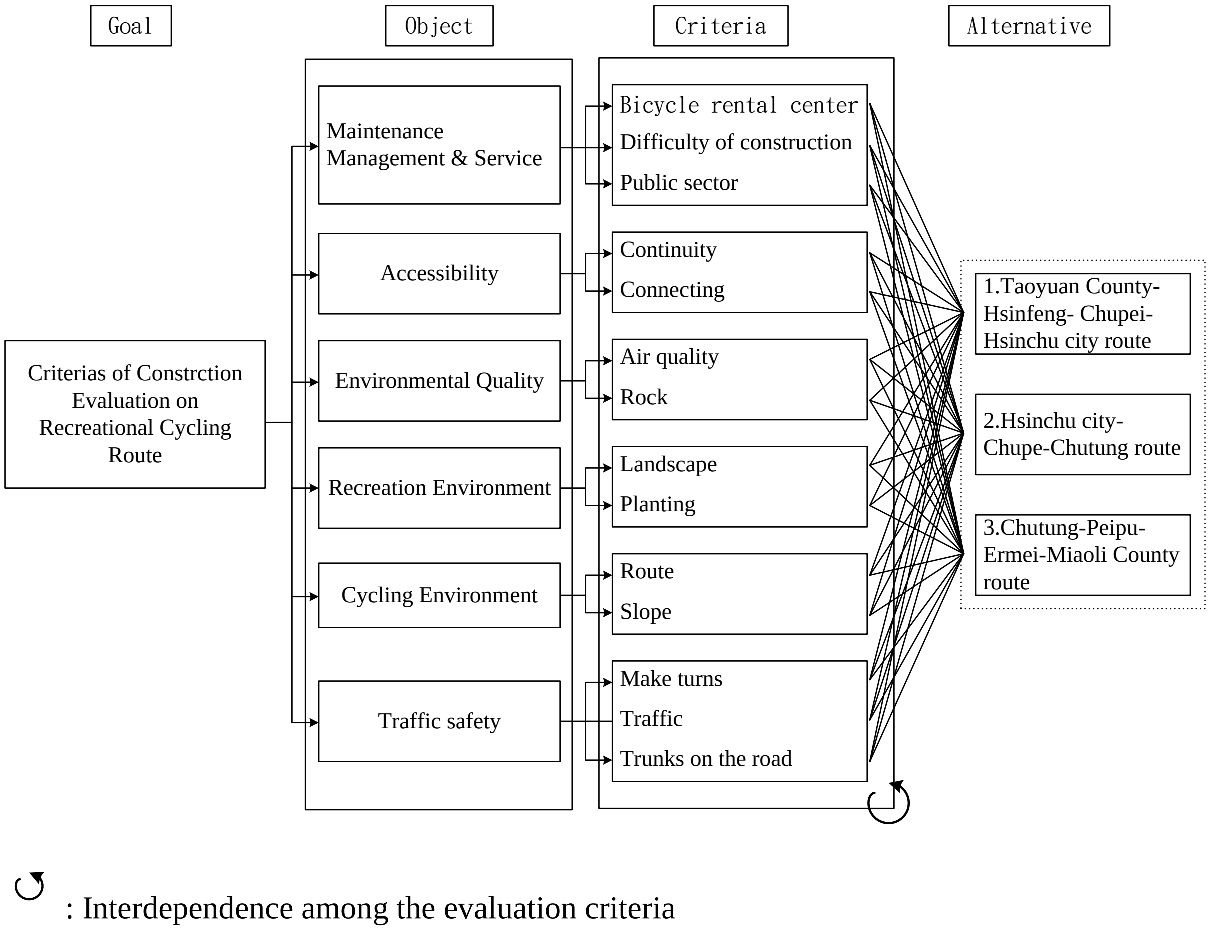


Figure 3. A Standard Network for the Structure of the Research

Step Two: *Determining weights through the application of Analytic Network Processes (ANP)*
Analytic Network Process (ANP) was suggested as a means to solving the problem of dependence on criteria. Structuring a problem involving functional dependence allows for feedback among clusters which make up a network system. ANP addresses the issue of relative importance within a set of activities in a multi-criteria decision process. The process itself utilizes pair wise comparisons of project alternatives as well as pair wise comparisons of multiple criteria (Wey and Wu, 2007, 2008). Following computation, the score and weight of each cycling route are shown in Table 3.

Table. 3 The score and weight of each cycling route

Name of cycling route	Weight（w_i）
1.Taoyuan County- Hsinfeng- Chupei- Hsinchu city route	0.332
2.Hsinchu city-Chupe-Chutung route	0.241
3.Chutung-Peipu-Ermei-Miaoli County route	0.427
Total	1

The score was subject to construction fees and planning and design fees. If each of the 3 cycling routes needed to be built, it would cost the county government 49.06 millions NTD in construction fees; and another 36.8 million NTD in planning and design fees. With scarcity limited budget, the county government has no choice but to prioritize its investment in cycling, as performed in the third step.

Step Three: *Using Zero One Goal Programming (ZOGP)to determine cycling routes prior to selecting investment solutions*

The information obtained from the ANP was used to formulate a ZOGP model. The solution of the ZOGP provided a pattern for allocating resources for alternative cycling routes. ZOGP has been applied in a variety of ranked resource selection schemes, such as the selection of urban renewal projects (Wey and Wu, 2007, 2008).

One advantage of ZOGP is the fact that it permits consideration of limited resources and other restrictions on the selection process that must be rigidly observed in the selection of cycling route projects. It also permits the calculation of ranking among included cycling route projects based on the ANP ranking system (Wey and Wu, 2007, 2008).

The ZOGP model for cycling route selection can be stated as follows:
The goal of ZOGP model（pl_1）:

Minimize the variables in positive deviation regarding the constructions costs of cycling routes（d_1^+）

Minimize the variables in positive deviation regarding the planning and design costs of cycling routes（d_2^+）

According to ANP, the weights of 3 cycling routes were: w_i = （0.332, 0.241, 0.427）
To formulate the second goal of ZOGP（ pl_2 ）:

Minimize variables in negative deviation of cycling route 1（ d_3^- ）; weight=0.332

Minimize variables in negative deviation of cycling route 2（ d_4^- ）; weight=0.241

Minimize variables in negative deviation of cycling route 3（ d_5^- ）; weight=0.427

The formulation of the second goal of the model is as follows:

$$(pl_2) = 0.332d_3^- + 0.241d_4^- + 0.427d_5^- \quad (1)$$

The ZOGP model is based on the selection of 3 cycling routes (x_j) from the ANP determined weights (w_j) for corresponding di^-.

The larger the w_j is, the more likely that the corresponding cycling route will be selected. By using weighted ZOGP as a decision tool, multiple objectives can be handled and the total deviation from the desired goals can be minimized (Wey and Wu, 2007, 2008). Therefore the formulation of the ZOGP model is as follows:

$$X_1 + d_3^- = 1, \quad X_2 + d_4^- = 1, \quad X_3 + d_5^- = 1 \quad (2)$$

If x_j = 1 then the jth cycling route will be selected, and if x_j = 0 then the j^{th} cycling route will not be selected. (Wey and Wu, 2007, 2008)

$$Min \quad d_1^+ + d_2^+ + 0.332d_3^- + 0.241d_4^- + 0.427d_5^- \quad (3)$$

According to the county government, funds would be allocated as follow:

Planning and design fees - 1.44 million of New Taiwanese Dollars NTD.

Construction fees - 18 million of New Taiwanese Dollars (NTD)

This data was computed by ANP values, and the constraints on the goals for this empirical cycling route investment selection were formulated based on the investigation of the authors. The results are shown in Table 4.

There are two obligatory goals followed by flexible goals and decision variables:

To utilize as much as possible of the maximum 18 million construction budget for 3 cycling routes construction.

$$1350X1 + 1679X2 + 1580X3 + d_1^- - d_1^+ = 1800 \quad (4)$$

To utilize as much as possible of the maximum budget of planning and design budget for 3 cycling routes.

$$108X1 + 134X2 + 126X3 + d_2^- - d_2^+ = 144 \qquad X_j = 1 \text{ or } 0 \quad j = 1,2,3 \quad (5)$$

Table. 4 Zero-One Goal Programming (ZOGP); ANP denotes model formulation

ZOGP model formulation	GOAL
Minimize *Z*=	
$pl_1(d_1^{+} + d_2^{+})$	Satisfies all goals.
$pl_2(0.332d_3^{-} + 0.241d_4^{-} + 0.427d_5^{-})$	Select highest ANP weighted cycle routes.
$pl_3(d_6^{-} + d_6^{+})$	Use 18 million NTD construction fee for all cycle routes selected.
$pl_4(d_7^{-} + d_7^{+})$	Use 1.44 million planning and design fee for all cycle routes selected.
Subject to	
$1350X_1 + 1679X_2 + 1580X_3 + d_1^{-} - d_1^{+} = 1800$	Avoid exceeding maximum construction budget.
$108X_1 + 134X_2 + 126X_3 + d_2^{-} - d_2^{+} = 144$	Avoid exceeding maximum planning and design fee.
$X_1 + d_3^{-} = 1$ $X_2 + d_4^{-} = 1$ $X_3 + d_5^{-} = 1$	Select route 1 Select route 2 Select route 3

4. CONCLUSIONS: SELECTIONS FOR INVESTMENT IN RECREATIONAL CYCLING ROUTES

4.1 Result Analysis

This study addresses such concerns and proposes the application of fuzzy Delphi method (FDM) to define the evaluation criteria of cycling routes, combined with analytic network process (ANP) to determine the weights of considered alternatives and Zero One Goal Programming (ZOGP) as a concrete solution to the selection of cycling routes.

The result is summarized as follows: Cycling route 3 was chosen, and cycle routes 1, 2 were not chosen.

This route will cost 2.2 million NTD less in construction fees than the initial allocation fee, shown as（$d_1^- = 220$）. It will cost 0.18 million NTD less in planning and design fee than the initial allocation fee, shown as （$d_2^- = 180$）.

The priority of the cycling route that government should allocate is as follows:

Route 3（0.427）＞ route 1（0.332）＞ route 2（0.241）

4.2 Conclusions

The government is eager to establish a cycling route network in Taiwan; however, budgetary restrictions from the central government make it necessary to establish a system to prioritize investment for the selection of the optimal network. In accordance with this goal, the Hsinchu County Government commissioned the authors of this paper to draw up the first feasibility study and cost projections for this area.

With budgetary restrictions in place, it has become obvious to the county government that objective decision-making systems are necessary to choose between a diversity of possible cycling routes.

The opinions of nine experts were derived from fuzzy Delphi method (FDM) with a full consideration of their degree of interdependence. Analytic Network Process (ANP) was used to determining the weights of the 3 cycling routes with the score subject to restrictions in the fees for construction, planning and design. Based on those 3 cycling routes, the ZOGP model was then applied to determine the priority of the cycling routes in which government expenditure should be allocated.

As a result of the combined used of these three methodologies this study found that 2.2 million NTD construction fee could be deducted from the initial allocation fee ($d_1^- = 220$) as well as 0.18 million NTD from the initial planning and design projections ($d_2^- = 180$).

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