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To cite this article: Yu-Chen Chien and Cheng-Hung Wu 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **291** 012045

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A Design Optimization Index for Two Types of Cycleways

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Abstract. Amid rising environmental awareness, sustainable and low-carbon traffic tools are attracting considerable attention. Increasing worldwide use of bicycles for both leisure and basic transportation has increased the importance of public bicycle-related infrastructure, notably cycleways. This paper proposes a Design Optimization Index for two types of cycleways, i.e., those that are used primarily for commuting, and those that are mostly for leisure. Based on a literature review, the researchers initially developed 27 impact factors. Then, through the fuzzy Delphi method of collecting and refining advice from a group of experts, these were integrated into a five-part structure consisting of “security”, “convenience”, “environmental friendliness”, “comfort” and “attractiveness”, which can be further broken down into 16 factors in the case of commuter cycleways, and 15 factors in the case of leisure cycleways.

1. Introduction

Due to the greenhouse effect, global warming, rising oil prices and other related issues, numerous countries are devoting increasing attention to environmental protection and sustainable environmental management. Low-carbon cities and green transportation combine the promotion of energy conservation, carbon reduction, environmental protection and human health. Bicycles, being environmentally friendly and pollution-free, have re-emerged as a popular means of transportation. In Taiwan in recent years, the government has actively promoted a range of pro-bicycle policies, and according to 2017 Ministry of Transport statistics, 54.1% of households own bicycles. The 2006 Qianli Bike Road and Wanli Trail Implementation Plan aimed to promote the active involvement of local governments in the development of local cycleway networks and the integration of these networks into a national system. As of 2015, the total length of Taiwan cycleways reached 5,889 km. With the aim of aiding the ongoing development of the cycleway system and bicycle-friendly cities in Taiwan, and improving the overall service level experienced by cycleway users, this study provides a detailed examination of the existing and optimal design characteristics of two distinct types of cycleways: i.e., one type tailored for people who commute to work or school, and another designed especially for leisure use by residents and tourists. To understand the environmental and facilities requirements of these different types of bikeway, and to provide for the optimal design and construction of such bikeways in the future, this study will apply the Fuzzy Delphi method to arrive at a design index that includes impact factors for both cycleway types. The research results are expected to support better-informed future bikeway policy and maintenance decisions.



2. Literature review

2.1 Taiwan bikeway types

Bikeways can be divided into three types according to their settings/functions: commuting, leisure, and competition [1]. Among these, the competition type has never been systematically introduced in Taiwan, and races carried out on the existing bikeways would undoubtedly be dangerous [2]. Therefore, this paper excludes competition bikeways from consideration.

2.1.1 Commuter bikeways

For the most part, Taiwan's commuter bikeways are closely integrated into the wider transportation system, and consist of convenient cycle routes aimed at improving urban green transportation networks while meeting the day-to-day travel needs of workers and students. Most of these routes are planned in conjunction with railways, streets, and sidewalks to connect core metropolitan areas with their residential hinterlands.

2.1.2 Leisure bikeways

Leisure bikeways are intended to provide a relaxation function and vital links in Taiwan's sightseeing/tourism network. As a system, they connect various attractions, scenic spots and monuments; encourage people to experience multiple tourist attractions that are in close proximity to one another; and construct a linear space with ecological, cultural, leisure, sightseeing and landscape functions.

2.2 Design index and impact collection

This study reviewed all the current policy literature relevant to the planning, design, and construction of bicycle lanes and bicycle road systems in Taiwan, and the Taichung Cycling Road in particular [1,3,4,5]. This yielded a five-part index of such policies' key factors, comprising "safety", "convenience", "environmental friendliness", "comfort" and "attractiveness". This first level can be further subdivided into 27 impact factors relating to the two types of cycle lanes' design, updating, and post-use evaluation.

Table 1. Optimal Cycleway Design Index and Impact Factors

Design Index	Interpretation and Impact Factors
1. Safety	The impact of cycleway planning, design and protection measures on the safety of bicycle users. Its eight impact factors are: 1-1 Route clarity, 1-2 Safety-barrier facilities, 1-3 Lighting, 1-4 Warning flags, 1-5 Emergency contact methods, 1-6 Lane-net width, 1-7 Safety-net height, and 1-8 Drainage.
2. Convenience	The degree to which cycleway planning and design and the surrounding route-information facilities make users' experience easier. Its five impact factors are: 2-1 Mileage signs, 2-2 Guide boards, 2-3 Bike-rental services, 2-4 Accessibility of mass transit, and 2-5 Bicycle route interconnectedness.
3. Environmental friendliness	The extent to which a cycleway's environmental planning and design enable it to coexist with nature. Its five impact factors are: 3-1 Shade/greening, 3-2 Clean environment, 3-3 Bike parking space, 3-4 Exclusion of certain vehicle types, and 3-5 Low-impact development.
4. Comfort	The impact of cycleway planning and design decisions on users' ride comfort. Its five impact factors are: 4-1 Bicycle rest station, 4-2 Avoidance of delays, 4-3 Flatness, 4-4 Reduced slope interference, and 4-5 Reduced climate disturbance.
5. Attractiveness	The effect of cycleway planning and design features on cyclists' willingness to ride. Its four factors are: 5-1 Surrounding landscape, 5-2 Peripheral tourism resources, 5-3 Landscape diversity, and 5-4 Air quality.

3. Research methods

In this study, the Fuzzy Delphi method was used to screen the factors. The advantages of this approach to brainstorming are that the experts consulted can remain anonymous, which reduces the potential impact of their group membership and enables them to think independently, and that it has no space constraints. According to Delbecq, Van de Ven and Gustafson (1975) [6], the ideal number of Delphi members is five to nine, with having more or fewer indirectly affecting the accuracy of the results. Therefore, this study conducted an expert questionnaire survey with six respondents, whose professional expertise covered urban planning, urban design, engineering, architecture and landscape design.

The questionnaire items used a 11-point Likert scale; the higher the score from 0 to 10, the more important the impact factor is, according to the respondent's professional experience of each of the two types of cycleway. The statistical data were collected using Microsoft Excel 2010 software according to double-triangle fuzzy and grey-area test methods, yielding G_i values for the degree of expert consensus. The arithmetic means of these G_i values were then used as threshold values for the screening of evaluation factors, and any factors below those thresholds removed from further consideration. The average G_i value of the commuter bikeway factors was 6.55, and of the leisure bikeway factors, 6.92. The post-screening factors and their G_i values are ranked in Table 2, below.

Table 2. Experts' Ranking of Commuter Bikeway Impact Factors

Design index	Impact factor	Expert consensus value (G_i)
Safety	1-4 Warning flags	9.14
	1-6 Lane-net width	8.00
	1-3 Lighting	7.75
	1-8 Drainage	7.67
	1-7 Safety-net height	7.35
	1-2 Safety-barrier facilities	6.92
Convenience	2-4 Accessibility of mass transit	7.75
	2-3 Bike-rental services	7.08
Environmental friendliness	3-2 Clean environment	7.17
	3-3 Bike parking space	6.75
	3-4 Exclusion of certain vehicle types	6.73
	3-1 Shade/greening	6.58
Comfort	4-3 Flatness	8.08
	4-4 Reduced slope interference	7.33
Attractiveness	5-4 Fresh air	7.18
	5-1 Surrounding landscape	6.67

Table 3. Experts' Ranking of Leisure Bikeway Impact Factors

Design index	Impact factor	Expert consensus value (Gi)
Safety	1-4 Warning flags	8.00
	1-6 Lane-net width	7.75
	1-1 Route clarity	7.67
	1-7 Safety-net height	7.33
	1-8 Drainage	7.10
Convenience	2-1 Mileage signs	7.08
	2-3 Bike-rental services	6.92
Environment friendly	3-1 Shade/greening	7.67
	3-2 Clean environment	7.25
	3-5 Low-impact development	7.18
Comfort	4-3 Flatness	7.58
	4-1 Bicycle rest station	7.42
Attraction	5-2 Peripheral tourism resources	7.83
	5-3 Landscape diversity	7.65
	5-4 Fresh air	6.92

4. Results and discussion

4.1 Safety

For both types of bikeway, factors 1-4 (Warning flags) and 1-6 (Lane-net width) were deemed the first and second most important safety factors by the expert panel. Factor 1-5 (Emergency contact methods) was removed from both types of bikeway after screening. In terms of the difference between the two types of bikeway, a higher priority was assigned to commuter bikeways' factors 1-3 (Lighting), 1-8 (Drainage), 1-7 (Safety-net height) and 1-2 (Safety barrier facilities). Due to their frequent use by foreign tourists, meanwhile, leisure bikeways' highest safety priorities included 1-1 (Route clarity).

4.2 Convenience

For commuter bikeways, the experts' consensus was that factor 2-4 (Accessibility of mass transit) was the most important, indicating that the planning of such bikeways should be integrated with mass-transit planning to maximize the efficiency of the overall transportation. Somewhat surprisingly, second most important factor for commuter bikeways was 2-3 (Bike-rental services); in other words, despite 54.1% of Taiwan's households (and a higher percentage of regular commuters) owning their own bicycles, the inconvenience of carrying bikes on mass transit means that bike-rental facilities still have an important role to play for some of these users. For leisure bikeways, the experts ranked 2-1 (Mileage signs) first, followed by 2-3 (Bike-rental services).

4.3 Environmental friendliness

In the environmental friendliness category for commuter bikeways, the expert consensus ranked 3-2 (Clean environment) first, followed by 3-3 (Bike parking space), 3-4 (Exclusion of certain vehicle types) and 3-1 (Shade/greening). For leisure bikeways, the experts placed the highest value on 3-1 (Shade/greening), followed by 3-2 (Clean environment) and 3-5 (Low-impact development).

4.4 Comfort

For both types of bikeway, the experts agreed that 4-3 (Flatness) had the highest importance, i.e., that all bikeways should be solid and smooth, including in the transitional areas between different types of pavement. The comfort factors for commuter bikeways also included 4-4 (Reduced slope interference); and for leisure bikeways, 4-1 (Bicycle rest station). Factors 4-2 (Avoiding delays) and 4-5 (Reduced climate disturbance) were both excluded from both types of bikeways' factors following screening, as being either unimportant or too difficult to achieve.

4.5 Attractiveness

On the attractiveness index for commuter bikeways, the expert consensus was that 5-4 (Fresh air) should be ranked first, on the grounds that such routes should be as free as possible of busy motor vehicle traffic; followed by 5-1 (Surrounding landscape). In the leisure bikeway category, the experts ranked 5-2 (Peripheral tourism resources) most highly, followed by 5-3 (Landscape diversity) and 5-4 (Fresh air).

5. Conclusion

Having established the five main categories of factors critical to the planning and design of Taiwan's two main types of cycleway via a literature review, this study's Fuzzy Delphi approach arrived at 16 key sub-factors for the design and maintenance of commuter bikeways, and 15 for leisure bikeways. These results can usefully inform the design, renewal, and evaluation of both these types of bikeway, notably by reducing construction and maintenance costs through de-emphasizing features of relatively low importance. It is therefore hoped that this work will contribute to the overall improvement of Taiwan's urban green-traffic networks.

6. References

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