# Criteria and Methods for Effective Route Planning in Inter-Area Bikeways

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## ABSTRACT

The Korean government started to pay attention to the bicycle as a green transportation means to solve urban traffic problems caused by its automobile-centered road traffic policy and is establishing a plan for installing bike lanes first in the more developed areas. A number of municipal governments have installed bike lanes connecting short sections but the lanes are not used for everyday-life purpose. In the case of bike-friendly countries, bike culture has been settled with the use of leisure bikes increased. As for Korea, it is possible to build a network of bike lanes for leisure riding and for exploration of ecological culture across Korea based on topography centered on the four major rivers. In this regard, this study selected evaluation indicators for the basic design stage of the selection of routes for inter-area bikeway and suggested a relevant methodology, and applied the methodology for evaluation in a case study. The study considered the characteristics of leisure bikes to select the evaluation indicators and conducted AHP analysis. Through the analysis, the importance of five indicators for selection was estimated and applied, and in comparing the data surveyed, it was assumed that each item follows normal distribution and the normal distribution was standardized to calculate weight. The methodology of evaluating route selection for inter-area bikeway in this study proposed detailed evaluation criteria for the selection of routes for leisure bike lanes, which have yet to be established, and is expected to help policymakers' decision making.

**Keywords:** *Inter-area Bikeway, AHP, Route Selection.*

## I. INTRODUCTION

Road traffic policy of Korea has been developed mostly for automobiles but the automobile-centered policy has caused serious traffic congestion, environmental pollution, and other problems. Under the circumstances, bikes have been spotlighted as an eco-friendly means of transportation to overcome the recent energy scarcity problem. The Korean government enacted Promotion of the Use of Bicycles Act in 1995 and a number of municipal governments have installed bike lanes connecting short sections to promote the use of bikes, but the lanes are not used for everyday-life purpose.

In bike-friendly countries including Germany, Denmark, and France, bike culture has been settled with the increased use of leisure bikes, and accordingly the everyday-life-purpose bike traffic has increased. As for Korea, it is possible to build a network of bike lanes for leisure riding if making good use of the topography centered on the four major rivers including Hangang River and Nakdonggang River, and also bike lanes for exploration of ecological culture across Korea can be built when connecting national highway.

In the case of inter-area bikeway, the route is long and therefore, various alternatives can be reviewed. The best method is to select bike lanes after reviewing all routes, but as they are lanes connecting different areas, the scope of research is huge, which requires high cost and a considerable amount of time. Therefore, it needs to select candidate routes that can connect different areas in the basic planning stage and compare relevant alternatives to select the optimal route. This study aims to propose a methodology of selecting the best route for inter-area bike lanes in the basic planning stage.

## II. BODY

To set up the basic plans for small SOC facilities such as pedestrian walkways and bike lanes, the following procedure has been usually taken: establishing evaluation indicators, calculating weight per indicator by experts, and applying it to the quantified attribute value of the site by using Analytic Hierarchy Process (AHP). This study reviewed the existing methodology and the methodology reflecting site data, simultaneously, and applied the review results for selecting routes.

In this study, the characteristics of leisure bike lanes were reflected to select the routes for inter-area bike lanes but the features of everyday use bike lanes were partially considered, and the following five evaluation indicators were selected: the possibility of an increase in demand for bike, possibility to be connected to public transportation means, investment efficiency, convenience and safety in riding a bike, and connectivity with main attractions.

As for the possibility of an increase in demand for bike, the route was selected to bypass the spot where demand for bike is highly likely to occur. As separate O/D does not exist for travel by bike unlike travel by car, traffic volume cannot be forecasted. Therefore, a population capable of riding a bike is considered.

In terms of investment efficiency, the most cost-effective route was selected with other standards met.

Regarding convenience and safety in riding a bike, uphill path, tunnel section, and proportion of forestland were considered, and routes of which section unfavorable to ride a bike can be bypassed to ensure convenience and safety of bike users and routes that can ensure the right of passing and traffic safety were reviewed.

With regard to connectivity with main attractions, routes that can enhance bike lane network connectivity across the entire connecting with the existing bikeways that are being operated or planned are preferentially reviewed.

Each of the five selection indicators can be a measure of determination with regard to route selection but it is difficult to determine the importance among the indicators. Therefore, the study calculated the weight for each indicator, multiplied the weight by score for each indicator to calculate total score, and decided priority, and for the calculation, the study adopted AHP analysis that measures relative importance among the evaluation indicators and preference of the alternatives with ratio scales and derives quantitative results.

However, the final conclusion through AHP is affected by how a decision-making group is composed. In this study, researchers, road and transportation experts, and bikeway design companies (total 25 persons) were selected as survey subjects and AHP analysis was conducted. Overall average score was derived after excluding scores of the evaluators given the highest score or the lowest score.

### 1) AHP structure and evaluation items

To identify demand for bike on the inter-area bikeway, the number of fourth-or-higher-grade elementary school students (10 years old or older) was surveyed, which can show potential demand for bike coming in and going out of the life zone of major cities. Regarding connection with public transportation, the number of intercity bus terminals, express bus terminals, and train stations were surveyed, which can reveal the section of which accessibility can enhance through connection of bikeway and public transportation nodes. For investment efficiency, 780 million won/km was applied by referring to the Basic Plan of Bikeway on National Highway (2010). The investment efficiency indicator is to select the most cost-effective route with other standards met. For convenience and safety, forestland ratios and other factors were surveyed while for connection with attractions, the number of tourists at the main spots that can enhance connectivity with major attractions. With the above stated evaluation items, AHP hierarchy was composed and survey on the evaluation item content and evaluation criteria was conducted.

***<AHP evaluation items and criteria>***

| Evaluation items | Evaluation content | Survey items | Remarks |
|---|---|---|---|
| 1. Possibility of an increase in demand for bike | Identify potential demand for the route of each alternative through socio-economic indicator | Population in the route for each alternative | Populations of village, town, and district on the route |
| 2. Possibility to be connected to public transportation means | Identify connection with public transportation by surveying the number of terminals and train stations | The number of intercity bus terminals, express bus terminals, and train stations on the route for each alternative | The number of users of terminals and train stations in county and city on the route |
| 3. Investment efficiency | Identify investment efficiency by calculating approximate project cost for each alternative | Calculate project cost by applying unit work cost for length of each alternative route | Apply 780 million won/km, reference project cost of the Bikeway on National highway, a preceding project |

| | | | |
|---|---|---|---|
| 4. Convenience and safety in riding a bike | Identify convenience and safety through survey of ratios of forestland for each alternative | Tunnel and forestland ratios for each alternative | Tunnels and forestland on the route |
| 5. Connectivity with main attractions | Identify connectivity with attractions through survey of the number of attractions and tourists on the alternative route | The number of tourists on the route for each alternative | The number of tourists of attractions on the route |

**2) AHP analysis results**

Weight on the evaluation item was determined by responses to the pairwise comparison question between evaluation items, and for the pairwise comparison, Thomas Saaty's 9-score scale was adopted. However, relative importance of the possibility of an increase in demand for bike, possibility to be connected to public transportation means, investment efficiency, convenience and safety in riding a bike, and connectivity with main attractions has a great impact on the result, constant sum measurement scale and 100-score scale were adopted, and the analysis results are as follows:

**<*Weight analysis results*>**

| Evaluation items | Possibility of an increase in demand for bike | Possibility to be connected to public transportation means | Investment efficiency | Convenience and safety in riding a bike | Connectivity with main attractions |
|---|---|---|---|---|---|
| Average weight | 0.215 | 0.175 | 0.277 | 0.226 | 0.112 |

We collected data and materials on the selection criteria (the possibility of an increase in demand for bike, possibility to be connected to public transportation means, investment efficiency, convenience and safety in riding a bike, and connectivity with main attractions) for each alternative and standardized to mark. Standardization is a process of unifying scales between the indicators to control the effect as the scales among the indicators are different, and we used unit normal scaling to standardize the evaluation items with the following formula:

$Z_i = \frac{X_i - \overline{X}}{S}$ Where S: standard deviation, $\overline{X}$: mean ---(4-1)

Under the assumption that standardized score follows normal distribution, we converted the scores to normalized scores and multiplied them with the weight per selection indicator to calculate a total value. Normal distribution is one of probability distributions of continuous probability variables and represented in a bell-shaped graph bilaterally symmetrical with the average as the center. Representing how distant the value is from the average in normal distribution by using above-mentioned standardization Z value is probability value in the normal distribution and the result of converting the probability value is normalized score in this study.

Total value = $\sum_i Z_i \cdot W_i$ ---(Formula 4-2)

Where $Z_i$: Standardized score for indicator i for each route, $W_i$: Weight on indicator i for each route

**3) Case Study**

This study set the route connecting Hanggang River and Geumgang River bike lanes as study as basic section of inter-area bikeway. For bikeway connecting the two river areas, three alternatives were selected and features of the alternative routes are as follows:

***<Features of alternative routes>***

| Alternative | Features |
|---|---|
| Alternative 1 | Passing through major cities with a large population, a route with balance between national highway and local road considered |
| Alternative 2 | Shortest-distance route, public transportation (Chungbuk line)-connected route, bike-based city-linked route |
| Alternative 3 | Passing through isolated areas, a route with landscape and view (river, etc.) considered, Songnisan-connected route |

In terms of the five indicators (demand, public transportation, convenience, investment efficiency, and attractions), AHP analysis was conducted for each alternative to select a final route, and quantifiable data were used for the collection of data.

***<Final analysis results>***

| Division | | | Alternative 1 | Alternative 2 | Alternative 3 |
|---|---|---|---|---|---|
| Features | | | 1) Passing through major cities (with high demand)<br>2) Route with balance between national highway and local road | 1) Shortest-distance route<br>2) Lowest project cost<br>3) Public transportation (Chungbuk line)-connected route<br>4) Bike-based city-linked route | 1) Passing through isolated areas<br>2) Route with landscape and view (river, etc.) considered<br>3) Songnisan-connected theme route<br>4) Longest-distance route |
| Length (km) | | | 74.5 | 62.8 | 119.0 |
| Quantitative evaluation | 1) Population (person) | | 1,082,520 | 1,055,231 | 454,984 |
| | | Z score | 0.62 | 0.54 | -1.15 |
| | | Normalization | 88.95 | 88.13 | 65.36 |
| | | Weight (AHP) | 0.215 | 0.215 | 0.215 |
| | | Score | 19.12 | 18.95 | 14.05 |
| | 2) No of tourists (person) | | 14,287,041 | 13,607,057 | 12,813,692 |
| | | Z score | 0.97 | 0.05 | -1.02 |
| | | Normalization | 92.73 | 80.78 | 66.72 |
| | | Weight (AHP) | 0.112 | 0.112 | 0.112 |
| | | Score | 10.39 | 9.05 | 7.47 |
| | 3) Ratio of forestland (%) | | 277.5 | 269.5 | 249.2 |
| | | Z score | -0.83 | -0.28 | 1.11 |
| | | Normalization | 68.81 | 75.69 | 94.19 |
| | | Weight (AHP) | 0.226 | 0.226 | 0.226 |
| | | Score | 15.55 | 17.11 | 21.29 |
| | 4) Public transportation users | | 7,795,912 | 8,027,888 | 6,081,014 |
| | | Z score | 0.46 | 0.68 | -1.15 |
| | | Normalization | 87.07 | 89.66 | 65.42 |
| | | Weight (AHP) | 0.175 | 0.175 | 0.175 |
| | | Score | 15.24 | 15.69 | 11.45 |

| | | | | | |
|---|---|---|---|---|---|
| 5) Project cost (100 million won) | | Project cost | 581.1 | 489.84 | 928.2 |
| | | Z score | 0.37 | 0.76 | -1.13 |
| | | Normalization | 85.61 | 90.51 | 65.59 |
| | | Weight (AHP) | 0.175 | 0.175 | 0.175 |
| | | Score | 14.98 | 15.84 | 11.48 |
| Total score | | | 75.28 | 76.63 | 65.74 |
| Selected alternative | | | - | ◎ | - |

## III. CONCLUSION

This study selected evaluation indicators for the basic design stage of the selection of routes for inter-area bike lanes and suggested a relevant methodology, and applied the methodology for evaluation in a case study. To select the evaluation indicators, the characteristics of leisure bikes were considered. The five evaluation indicators include the possibility of an increase in demand for bike, possibility to be connected to public transportation means, investment efficiency, convenience and safety in riding a bike, and connectivity with main attractions. To identify relative importance among the evaluation indicators, the study adopted AHP analysis which measures the importance among the indicators and preference of the alternatives with ratio scales and derives quantitative results. In addition, for comparison between surveyed materials, normal distribution was standardized under the assumption that standardized score follows normal distribution and each weight was applied. As a result, Alternative 1 was selected and it is deemed not affected by the size of population or the number of tourists as its length is short. The methodology of evaluating route selection for inter-area bike lanes in this study proposed detailed evaluation criteria for the selection of routes for leisure bike lanes, which have yet to be established, and is expected to help policymakers to make better decisions.

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