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Assessing area-wide bikeability: A grey analytic network process

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ABSTRACT

This article proposes a bikeability assessment method to evaluate zone-based friendliness to biking within an area. The proposed method is developed as an analytic network process (ANP) that contains grey numbers and multiple assessment criteria. The grey ANP is unique in bikeability literature and overcomes the disadvantages of existing assessment methods in the following ways. (1) The ANP framework can manage the interdependences among criteria and zones, (2) the multiple assessment criteria can consider comprehensive perspectives of bikeability, and (3) the grey numbers measure possible ranges of criteria performances and are good at handling various performances within a zone. The application of the method to the bikeability assessment of zones in Daan District, Taipei City, Taiwan not only verifies the effectiveness of the method but also provides action directions to the local administration in developing bike-friendly environments.

1. Introduction

Biking is a green and active travel mode that consumes minimal energy, produces limited pollution, and accompanies physical activities. Thus, city administrations should increase their efforts in developing bike-friendly environments to encourage travelers to use bikes for short-distance trips within neighborhoods or connecting trips between public transit stations and origins or destinations (Marttens, 2007). In developing improvement plans for biking environments, the initial task is assessing bikeability within areas to identify zones that are hazardous to cycling and improve any shortcoming. The next task is developing improvement plans according to the assessment results. Therefore, zone-based bikeability assessment is critical in developing bike-friendly cities. Zone-based bikeability means general friendliness to bike riding within a zone, which can be a street block, neighborhood, community, or village. The assessment of an individual location or facility only provide fragmentary information about bikeability within a zone and not a general picture of zonal bikeability that considers interdependences among locations and facilities (Birk et al., 2010; Winters et al., 2013).

However, most of the existing bikeability assessment methods in the literature are either location- or facility-based methods. Location-based methods focus on the convenience of a location in reaching destinations by biking. These methods apply various accessibility measures. For example, McNeil (2011) used a cumulative opportunity measure to calculate the destination accessibility score within the 20-min biking area of a location. Lowry et al. (2012) used a gravity-type index to measure the destination accessibility of a location, which was positively related to destinations in other locations and negatively related to travel distances and numeric scores of the bicycle level of service (BLOS) of routes to other locations. By contrast, facility-based methods focus on the suitability of a facility for biking. These methods use multiple criteria to measure the levels of biking comfort and safety along a roadway link or route. The BLOS method, which quantifies the suitability of biking along a specific roadway section (Landis et al., 1997), the *bicycle compatibility index*, which evaluates the capability of a specific roadway to accommodate motorists and bicyclists

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(Harkey et al., 1998), and the *cycling route planner*, which assists cyclists in finding cycling routes that fit their personal preferences (Su et al., 2010), are three typical facility-based methods that consider objective criteria, such as road width, vehicle volume, vehicle speed, and pavement condition. Recently, an increasing number of facility-based methods have been analyzing subjective criteria, that is, bikers' perceptions of biking suitability on multiple attributes along a specific roadway. For example, the Bikeability and Walkability Evaluation Table in Hoedl et al. (2010) considered the attractiveness of biking; the assessment instrument in Horacek et al. (2012) considered safety, path quality, and temperature comfort; the crowdsourcing approach in Krykewycz et al. (2011) evaluated bikeability through local residents' and bicyclists' scoring, and Wahlgren and Schantz (2012) applied the Active Commuting Route Environment Scale to assess bicycle commuters' perceptions of their route environments. The aforementioned methods are good at assessing the bikeability of a location or a roadway but cannot conduct a general assessment of bikeability for a zone.

Limited studies have developed zone-based bikeability assessment methods. Winters et al. (2013) proposed a method to identify zones that are more and less conducive to cycling. The method of Winters adopted five assessment criteria, including accessibility and suitability of a zone for biking, and a mapping procedure of a geographic information system that creates a weighted sum score of criterion performances that represent the level of bikeability in a zone. A similar method was suggested in the cycle zone analysis of Birk et al. (2010). The two aforementioned studies initiated pioneer methods of zone-based bikeability assessment. However, their proposed methods have three disadvantages that require improvement. First, the interdependence among criteria and zones are ignored. The interdependences among criteria are critical in zone-based assessment, but existing methods consider criteria to be independent of one another. For example, among the five criteria used by Winters et al. (2013), the bicycle route density could be related to the connectivity of bicycle-friendly streets in a zone; however, the method uses a weighted sum of criterion scores to represent the bikeability level in a zone, implying an assumption that the criteria are independent of one another. The aforementioned disadvantages are also shared by most current location- and facility-based methods. Furthermore, not only the evaluated zone but also its neighboring zones should be considered in assessing bikeability because biking travels are usually conducted across zones and network connectivity is a significant concern of bikers (Lowry et al., 2012). However, existing zone-based methods ignore the interdependence among zones and assess each zone independently.

Second, the researchers disregard the comprehensive criteria for bikeability assessment. Winters et al. (2013) applied five criteria that denoted facility suitability, namely, bicycle route density, bicycle route separation, connectivity of bicycle-friendly streets, environmental amenity (topography), and destination accessibility (destination density). Birk et al. (2010) used seven criteria that represented facility suitability, namely, bikeway quality, road network density, bike network density, permeability/barrier, connected node ratio, environmental amenity (average road segment slope), and destination accessibility (distance to commercial establishments). Existing zone-based methods evidently value the issue of the suitability of a facility more than that of an amenity and accessibility. In addition to topography, numerous amenity attributes, such as greening, air quality, lighting, and traffic condition, are related to bikeability but disregarded by existing methods. For destination accessibility, Winters et al. (2013) ignored roadway networks, whereas Birk et al. (2010) considered incomplete destinations (commercial destinations only). Third, variety within zones is neglected. A zone contains multiple locations and facilities with different attributes; thus, bikeability within a zone should not be homogeneous. Moreover, providing complete information about bikeability in a zone requires not only average values but also value variety. However, existing zone-based methods cannot handle various criterion performances within a zone.

Therefore, this research develops a new method called area-wide bikeability assessment model (ABAM) to overcome the aforementioned disadvantages. The proposed method is developed as an analytic network process (ANP) to manage interdependences among criteria and zones. The ANP is a multiple-criteria assessment method that ranks alternatives (zones in this research) according to a framework with interdependent criteria and alternatives. Grey numbers are used in ANP to reflect and handle diverse performances within a zone. A grey number denotes the possible values of a criterion performance in a range rather than the exact value. The assessment criteria used in the method are determined through literature reviews and stakeholder interviews to ensure their comprehensiveness in representing bikeability. The validity and applicability of method are verified through community bikeability assessments in Daan District, Taipei City, Taiwan. The rest of this paper is organized as follows. The second section explains the assessment criteria and modeling concepts. The third section presents the model formulation. The fourth section illustrates the model application in Daan District. Finally, the fifth section draws conclusions and raises recommendations for future applications.

2. Assessment criteria

Previous studies assessed bikeability from different perspectives. For example, McNeil (2011) and Lowry et al. (2012) emphasized destinations accessible by biking. Winters et al. (2013) considered the attributes of built environment that influence biking. Wahlgren and Schantz (2012) focused on bikers' perceptions of biking environments. The considerations of previous studies can be synthesized into four perspectives, namely, facility suitability relating to performances of facilities that can influence comfort, safety, or biking convenience (e.g., bikeway width); environmental amenity relating to physical and built environments that can be related to biking (e.g., slope); destination accessibility relating to destinations accessible by biking (e.g., the gravity-type index mentioned in the previous section), and regime friendliness relating to policies, laws, governance means, and social supports that are related to biking friendliness. The present study develops assessment criteria on the basis of the first three perspectives and assumes regime friendliness of biking within cities to be identical among zones. The assumption is valid in the context of Taipei because the city is the basic unit of governance in Taiwan and in charge of determining and implementing bike-related policies over the city. However, if a city can implement different regime friendliness for biking among zones, then the fourth perspective should be considered in developing assessment criteria.

Table 1 lists the assessment criteria adopted in this research. These criteria are determined in two steps. Initially, this study