Research Paper

Bicycle System in Severe Cold Cities: A Case Study of Minneapolis, USA

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Abstract

Encouraging bicycle travel is important in reducing carbon emissions and improving the health of all people, but the cold winter climate in austere cities limits people's willingness to travel by bicycle. It is especially important to build a comprehensive bicycle system in the planning for cold regions. The city of Minneapolis is a typical example of a global cold city with a comprehensive bicycle network. In this paper, we use Open Street Map data, POI data, and other open data to explore the planning and construction characteristics of the city in terms of land use, paths, and facilities, using overlay analysis, and kernel density analysis, and spatial connection. It will reveal its systematic construction mechanism in terms of site type, functional diversity, and facility perfection. This study will support the planning of constructing a safe and comfortable bicycle slow-traveling system in severe cold cities.

Keywords

Severe cold cities, bicycle system, open data, Minneapolis

1. Introduction

Cities need to further address the effects of climate change due to traffic congestion, increased air pollution, chronic disease and obesity, and increased greenhouse gas emissions as a result of rapid expansion in motorized transportation and expanding urbanization (Tolley, 1990; Puchera and Buehler, 2012). Urban residents are searching for greener, healthier forms of transportation, and "green transportation modes" (Tolley, 1990) like walking and bicycling are becoming more and more popular. There is mounting evidence that consistent, moderate physical activity improves people's overall health (Frank & Engelke, 2001; Pucher et al., 2010; Oja, Vuori, & Paronen, 1998). Cycling enhances "physical performance, cardiovascular risk factor levels, and postprandial glucose uptake," according to studies (Pucher and Buehler, 2012). Additionally, cycling reduces and relieves anxiety and sadness and improves overall well-being (Pucher and Buehler, 2012). Street environments that are friendly to bikers and pedestrians foster a stronger sense of community and livability and can improve social interaction.

Bicyclists in colder places will encounter extra climate challenges, making cycling a seasonal pastime in colder cities. The usage of bicycles in a transportation system dominated by motor vehicles will confront several challenges. The temperature has been shown to have a significant impact on bicycle riding studies (Bergström and Magnusson, 2003; Flynn et al., 2012; Thomas et al., 2013). Cycling can benefit occasionally from high temperatures (Miranda-Moreno & Nosal, 2011), however, cycling can suffer from low temperatures (Thomas et al., 2009). (Nankervis, 1999; Winters et al., 2007). According to studies, women cyclists may be more sensitive to temperature changes than men (Bergström and Magnusson, 2003; Saneinejad et al., 2012).

Minneapolis is the metropolitan area with the lowest average annual temperature in the continental United States thanks to its cold, dry winters and warm, humid summers. The average temperature in January, the coldest month, can drop as low as -30°C. Bicycle magazine ranked Minneapolis as the second-best U.S. city for bicycling in 2018, making it one of the cities with the highest scores in the nation for cycling. According to the Minneapolis Transportation Action Plan, 2020, more than two-thirds of city residents say they bike to work and to parks frequently or occasionally. Additionally, more than 4% of city residents cycle to school. 98 miles of bike lanes and 101 miles of off-street bikeways and trails are present as of 2019. The city's bicycle infrastructure is more than just a means of transportation; it also plays an important role in Minneapolis' culture.

The purpose of this study is to analyze the bicycle path network system in Minneapolis, USA, and reveal the characteristics of its bicycle paths in terms of land distribution, path function organization, and distribution of supporting facilities. The study will support the planning of constructing a comfortable and convenient bicycle slow travel system in a cold city.

2. Methodology

2.1. Data acquisition

Based on the Arcgis10.6 platform, we import the vector data of bike lanes, land use, and points of interest into the Arcgis10.6 platform for analysis. In this paper, we use OpenStreetMap, open-source data, to obtain information about the city's entire road network, land use, and some points of interest in Minneapolis. We compare this information with a satellite map and correct any incorrect or missing image data. The remaining places of interest and facility information were acquired through the MapIT Minneapolis website, an open data access platform created by the City of Minneapolis. The purpose of this study is to analyze the bicycle path network system in Minneapolis, USA, and reveal the characteristics of its bicycle paths in terms of land distribution, path function organization, and distribution of supporting facilities. The study will support the planning of constructing a comfortable and convenient bicycle slow travel system in a cold city.

Given that the majority of Minneapolis neighborhoods have sizes between 150 and 250 meters, 200 meters around each path is thought to be an appropriate walking distance when analyzing the characteristics of the surrounding land distribution of the off-street bikeways. By using the bikeway network as a reference point, a 200 m buffer zone was created and using the overlay analysis approach, the buffer zone was overlaid with each site type to assess and determine the distribution indicators' characterization status for each site type. Nine different land kinds, including commercial, water, residential, green, industrial, cultural, mixed, and transportation land, will be used to study the land distribution indices.

2.2. Study Object

To ensure the convenience and security of riding, the City of Minneapolis, USA, implemented the *Protected Bikeway Update to the Minneapolis Bicycle Master Plan*. On-Street bikeways, which can increase bicycle user safety to some extent, physically separate bikers from motorized traffic by placing features including curbs, medians, movable bollards, crash barriers, and curbs. While this is going on, Off-street bikeways prioritize pedestrians and bicyclists since they are farther from motorized traffic and have picturesque surroundings that encourage urban inhabitants to ride on them.

The distribution of bikeways in Minneapolis is depicted in Figure 1. It reveals that the majority of bikeways are located in the downtown area and close to the lake and that they extend from the downtown area to the residential area and connect with the water system to form a comprehensive bikeway network. and the Midtown Greenway to connect to the city's core, as well as the Cedar Lake Trail, the Hiawatha LRT Trail, and others. This study focuses on the examination of off-street bikeways-related indicators to expose the systematic construction mechanism of the bicycle system in terms of land type, functional variety, and facility completeness and thus to analyze the planning and construction regulations.

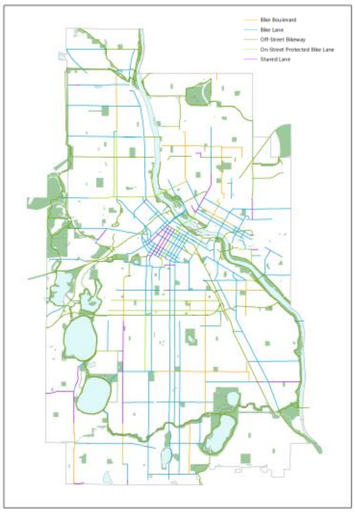


Figure 1. Distribution of bikeways in Minneapolis.

Source: the authors.

Figure 2. Distribution of off-street bikeways.

Source: the authors.

Trails that are not connected to any road are referred to as off-street bicycle networks. Similarly, off-street facilities that improve accessibility to places with aesthetic value are referred to as off-street cycling networks (Gobster, 1995), The trails are frequently found in parks or rural locations away from major cities. Off-street bikeways are useful as a recreational and exercise tool since 24% of bikers use them for commuting, 19% for running errands, and 82% for exercise. These off-street bike lanes are also available 24/7, safer for cyclists, and quickly plowed after a winter snowstorm.

Off-street bikeways can both increase comfort for all users (especially households) and improve safety along major county roads in suburban and rural areas by allowing complete separation from motorized traffic and reducing intersections with roadways. Off-street bikeways are located along roadways, sometimes outside the street right-of-way, frequently along abandoned or active railroad corridors, waterways, or parks. The Minneapolis Grand Rounds, the Midtown Greenway, the Hiawatha LRT Trail, and the Minneapolis Diagonal Trail are a few of the more noteworthy examples (Figure 3).

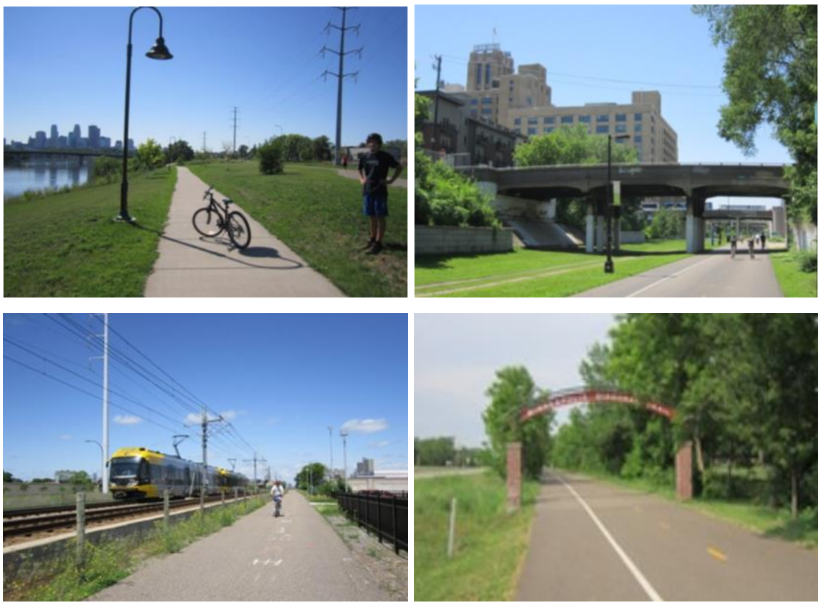


Figure 3 Famous off-street bikeways in Minneapolis. Source: Hennepin County-Metro Bike Trails Guide.

The design must consider bikers, be 6-10 feet wide (Figure 4), be able to follow a natural or picturesque course, and offer extra amenities like benches for the leisure users it draws. Off-street bikeways design provides the advantage of separating bicyclists and pedestrians from motor vehicles, preventing cars from driving and parking within the building, and solving door-opening issues when cars are parked.

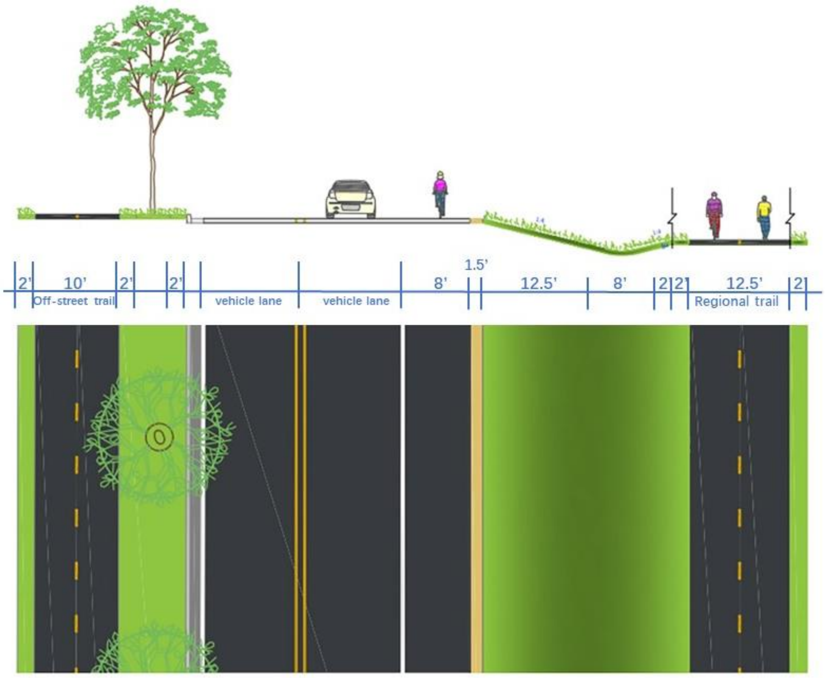


Figure 4 Off-Street Bikeways cross-sectional design. Source: Hennepin County 2040 Bicycle Transportation Plan.

3. Results

3.1. Land Use Distribution Characteristics of Off-Street Bikeways

The distribution density of the top three types of land in the off-street bikeways is found to be residential land (20.94%), green land (14.04%), and water land (10.76%). This finding suggests that these three types of land are more appealing to users; see Figure 5 for more information. It can be said that the recreational bicycle road network for urban residents is situated adjacent to the residents' homes as well as parks, green spaces, and water regions, which are land-use types with lovely and pleasant scenery. In addition to increasing the comfort and accessibility of residents' cycling, connecting the city's primary landscape resources would also fully utilize the resources of the urban landscape and satisfy the spatial need of urban inhabitants for leisure and recreation.

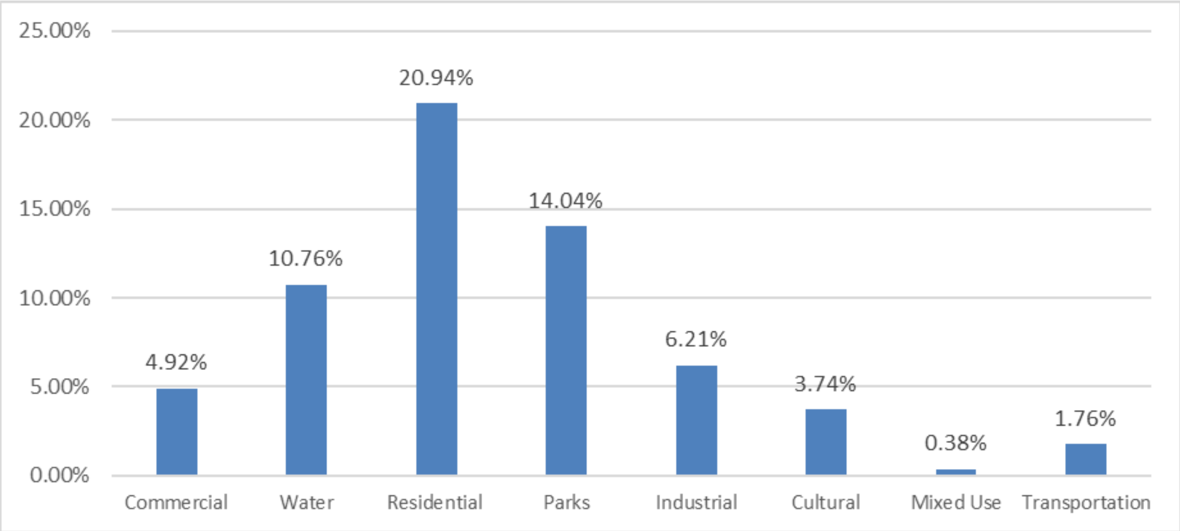
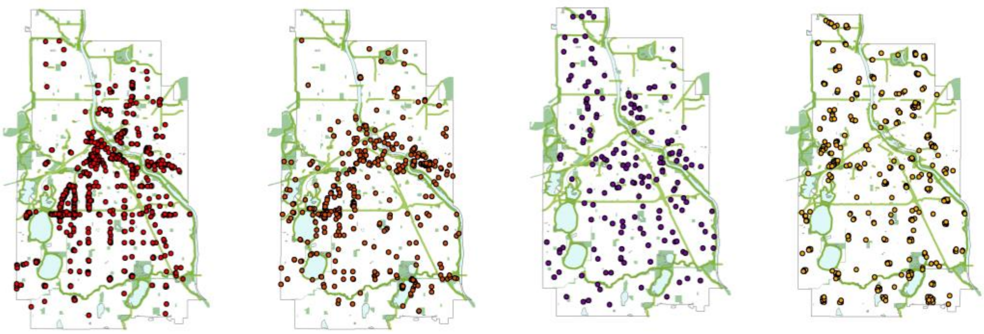


Figure 5 Density of land distribution by type. Source: the authors.

3.2. Functional Organization Characteristics of Off-Street Bikeways

The geographic data and attribute data relevant to the study were filtered out through appropriate pre-processing after the acquisition of the urban road and interest point data. The distribution density of various functional facilities along the cycling path was calculated using buffer analysis and spatial connection analysis based on the spatial statistics method of the arcgis10.6 platform. Seven categories were used to categorize the information on places of interest and facilities: places for eating, shopping, and entertainment; places for public services; places for education; places for cultural attractions; places for sports; and places for bus stops and light rail stations (Figure 6).



a. Dining, shopping, and entertainment facilities b. Public service facilities c. Educational facilities d. Sports facilities

e. Cultural facilities and attractions f. Bus stops g. Light rail stops

Figure 6 POI facility points classification and distribution. Source: the authors.

1) Functional Diversity

From the perspective of bicycle system construction, the seven types of functional variation in the study region were examined and visually expressed (Figure 7). The average value of functional diversity around off-street bikeways was found to be higher when compared to the functional diversity within the city limits (Table 1). In the area covered by off-street bikeways (Figure 8), the percentage of neighborhoods with functional diversity above 1.10 was 66.8%, and the areas covered by bikeways with high functional diversity were primarily concentrated in park green areas and near water areas. The functional diversity of off-street bikeways is still larger even if the pathways are shorter because the mixed functional diversity around the paths is unaffected by path length. There is a spatial association between functional variety and bikeway density, and generally speaking, neighborhoods with more functional diversity have more bikeways.

This demonstrates that there is a considerable need for bicycle system links and interconnections to establish networks in communities with a high functional variety. A portion of the safety of cyclists is thought to be increased by the separation from motor vehicles, and the growth of functional businesses around the bicycle system will also contribute to an increase in the frequency of use of nearby parks and bodies of water as well as drive the development of commercial facilities, luring more urban residents to stop here. Thus, to enhance the number of public amenities besides the bicycle lanes and draw in traffic, planning for the development of a cold-land urban bicycle system should be linked with the research of regional functional diversity indicators.

Table 1 Functional diversity of urban areas compared to off-street bikeways functional diversity

Functional diversity	Minimum	Maximum	Mean Standard	Deviation
Functional Diversity in the City	0	1.70	1.06	0.40
Path functional diversity	0	1.70	1.13	0.39

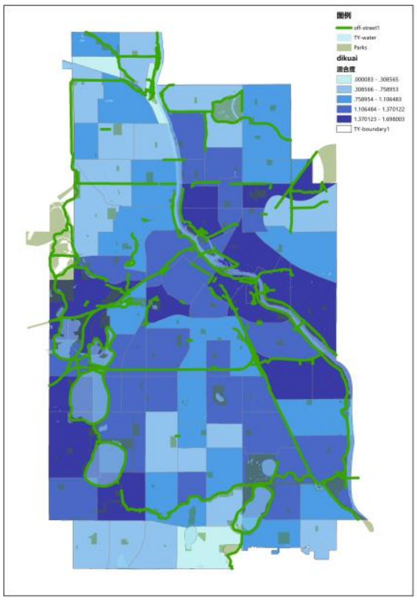


Figure 7. Functional diversity of the urban area.

Source: the authors.

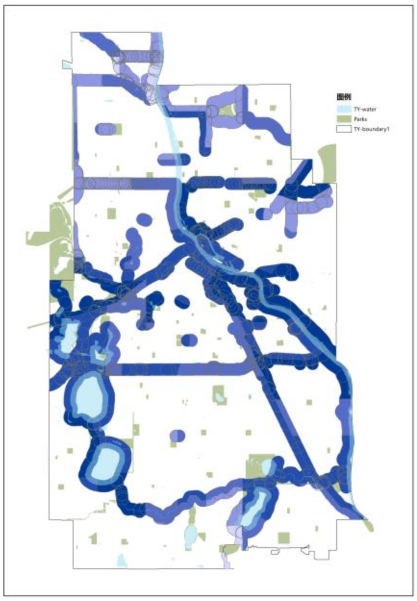


Figure 8. Functional diversity around the path.

Source: the authors.

2) The density of functional facilities distribution

Each functional distribution density index is defined to measure the functional organization properties of each path. The length of each path must be elicited in the first stage, and the number of different facilities that are located within the buffer zone must be counted in the second. According to the actual situation, two different buffer distances were established. The first buffer zone is located 50 meters from the bicycle path and is used to count the bus stops and light rail stations on either side of the path as well as public life service facilities, educational facilities, dining, shopping, and entertainment facilities. The region 200 meters from the bicycle route, which is used to tally the number of cultural amenities, attractions, and sports facilities on both sides of the path, is the second type of buffer zone.

Cultural amenities and attractions, bus stops, and sports facilities all rank among the top three in terms of density, indicating that off-street bikeways have a greater distribution of all three categories of facilities.

Table 2 Descriptive statistics of the distribution density of each functional facility in off-street bikeways

Name of facilities (pcs/km)	Minimum	Maximum	Mean Standard	Deviation
Public service facilities	0	117.18	3.41	13.12
Educational facilities	0	110.73	0.88	8.80
Dining, shopping, and entertainment facilities	0	110.60	1.89	8.07
Cultural facilities and attractions	0	190.94	5.00	18.01
Sports facilities	0	236.97	6.62	25.73
Bus stops	0	417.55	9.68	35.28
Light rail stops	0	45.20	0.25	2.68

3.3. Bicycle Infrastructure Characteristics of Off-Street Bikeways

The three different types of bicycle service facilities in the study area were subjected to a kernel density analysis, and the clustering characteristics of these facilities were displayed within a 1000m buffer zone, to assess whether the bicycle system infrastructure can address the "last mile" issue and satisfy urban residents' demand to use and park bicycles (Figure 9). Zooming in on the nodes (Figure 10) reveals that these two major roads contain a significant number of motor vehicle parking lots and bus stops, with Hennepin Avenue South having the most motor vehicle parking lots and bus stops. It can be seen that the bicycle parking points are primarily situated near the Mississippi River and on the two main roads of East Lake Street and Hennepin Avenue South on both sides of the Midtown Greenway. Additionally, there are two bus stops that are connected to the bridge entrance on either side of Hennepin Avenue South, making it simple to store bicycles and transfer to public transportation. Since bicycles are used more frequently in these areas, where there are many commercial establishments, public services, and cultural facilities, bicycle infrastructure is also more widely dispersed and primarily concentrated in the downtown, University of Minnesota, and Midtown Greenway neighborhoods.

To meet the demand for bicycle parking as well as to make daily life and public transportation interchanges easier and more convenient, it can be seen that the bicycle rental and parking facility points are not located along bicycle lanes but rather are integrated with public transportation, locations with high pedestrian traffic, such as city centers, university areas, and distinctive paths used frequently by the public. This creates a comprehensive network system. Comparatively, bicycle parking spaces are more influenced by public transportation infrastructure. To address the issue of the public transit interchange, bicycle parking spaces are distributed along with bus stops, motor vehicle parking lots, bus yards, and upper bridge entrances.

a. Bicycle parking points b. Bicycle rental points c. Bicycle racks

Figure 9 Heat map of bicycle infrastructure distribution. Source: the authors.

a. Hennepin Avenue South b. East Lake Street

Figure 10 Enlarged view of bicycle parking nodes. Source: Google map.

4. Conclusion

The Minneapolis cycling system's performance demonstrates that building bicycle infrastructure in places with cold climates can also have a high use rate and that urban residents view bicycles as a form of recreation. The characteristics and laws governing the planning and development of the bicycle system in cold cities are obtained by evaluating the characteristics of the land distribution, functional organization, and infrastructure of the Minneapolis cycling system.

To meet the daily transportation requirements of urban residents and to enhance regional bicycle transportation links, we can think about constructing bicycle paths around parks and water areas with rich landscape resources, as well as around residential areas, which will increase convenience and accessibility. Concerning functional organization, it has been determined through the analysis of functional diversity and density of different functions that the majority of the functions with a diversity of 1.10 or more are located close to parks and water areas and that the bus stops, cultural facilities and attractions, and sports facilities have the highest densities of all the functions. The density of each function should be taken into account, and bicycle roads should be built more densely in areas with high functional diversity, as well as near cultural and sporting venues with aesthetic value. Additionally, public service facilities should be set up to improve the comfort of bicyclists, promote the development of the surrounding area, and draw in foot traffic. The position of bicycle racks and parking stations should be chosen within an acceptable buffer zone, and thorough attention should be given to the surrounding land use and public transportation to create a seamless transportation network and further address the "last mile" issue.

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