CYCLING-FRIENDLY COMMUNITY DESIGNS: COMPARATIVE CASE STUDIES OF CITIES IN GERMANY AND TEXAS, USA

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1 ABSTRACT

Cycling has been increasingly recognized for its various environmental, human health, and economic benefits. Supportive built environments and policies are essential to promote cycling. European countries, such as Germany, Denmark, and the Netherlands, are known for their many exemplary efforts. Cycling levels in these countries are at least 10 times higher than those in the US. While empirical studies have examined various cycling policies and interventions, most of them are individual case studies. Studies comparing the differences between European cities and American cities are limited. This study is designed to use two German cities (Berlin and Bonn) and one American city in Texas (Austin) for comparison, and identify opportunities and challenges in improving cycling environments in Austin. Assessments of multiple evaluation components showed that cycling was much safer and more convenient in German cities than in Austin, due to more supportive bicycle policies and infrastructure/facilities. Both national and city-level bicycle policies existed in German cities, and those policies were geared toward integrating cycling into the overall transportation system, including transit. Austin, on the other hand, only had the city-level policies, and most of its streets are still dominated by automobiles. In terms of the community design, German cities feature mixed land use, high density, and complete cycling networks making cycling highly attractive, contrasting to segregated land use, low density, and discontinuous cycling networks in Austin.

1.1 Keywords

Cycling, urban design, policies, community designs, infrastructure and facilities

2 INTRODUCTION

During the past few decades, the importance of cycling to environment, human health, and economic development has been increasingly recognized in many European countries and in some parts of the United States (US). At the same time, several scholars have conducted empirical studies examining benefits of cycling and exploring ways to promote cycling-friendly environments. Specifically, John Pucher and Ralph Buehler carried out many studies on the contributions of daily cycling to public health (Bassett, Pucher, Buehler, Thompson, & Crouter, 2008; Pucher & Buehler, 2010; Pucher, Buehler, Bassett, & Dannenberg, 2010), ways to make cycling safe and attractive (Pucher & Buehler, 2008a, 2008b, 2009; Pucher & Dijkstra, 2000, 2003), and sustainable transportation in European countries (Buehler & Pucher, 2009; Buehler & Pucher, 2011). Many European cities, such as Amsterdam, Copenhagen, Hamburg, Munich, Berlin, etc., have paid attention to people-oriented developments to create more sustainable and livable communities. A wide range of strategies such as traffic regulation, traffic education, traffic calming, cycling infrastructure, and cycling oriented urban design have been implemented to increase cycling safety (Pucher & Dijkstra, 2000, 2003). Urban designers like Jan Gehl has used social science based research methods (e.g. observations, surveys, mapping) to implement evidence-based strategies to promote people-oriented public spaces (Gehl, 1987, 2010; Matan & Newman, 2012). His work has been widely applied to many cities worldwide especially in European and Australian cities, but also in several American cities including Yew York, Detroit, and Los Angeles. Despite the growing interest and investments in pedestrian and cyclist facilities in the US, especially in large cities such as New York, Washington DC, and Portland, the prevalence of cycling still remains very low compared to many European countries. Cycling infrastructure involving bicycle lanes, trails, and bicycle parking facilities are far from being adequate in the US. Compared to 27% share of trips bicycles make up in the Netherlands, only approximately 1% of trips in the US are by bicycle. Germany and Denmark are both at the high end of the spectrum with 10% and 18% of cycling mode share, respectively (Pucher & Buehler, 2008b).

The cycling levels vary across the regions in the US. As of 2014, the level of cycling to work is only 0.3% in Texas, which is much lower than the national average 0.6%, resulting in higher dependence on automobiles (McKenzie, 2014; US Census Bureau, 2010-2014). Automobile dependency has been shown to be a major contributor to physical inactivity and sedentary lifestyle, which has been linked with many public health problems such as obesity (Jebb & Moore, 1999; Wen, Orr, Millett, & Rissel, 2006). By 2010, Texas was one of 12 states in the US with a prevalence of obesity equal to or greater than 30 (Centers for Disease Control and Prevention, 2011). Lack of physical activity and poor diet lead to obesity which is among the leading causes of death in the US accounting for 400,000 deaths or 16.6% of total deaths in 2000, immediately following tobacco (18.1%) (Mokdad, Marks, Stroup, & Gerberding, 2004). The estimated annual medical cost of obesity in the US could amount to $147 billion in 2008, accounting for approximately 10% of all medical spending (Finkelstein, Trogdon, Cohen, & Dietz, 2009). In addition to walking, cycling is a convenient way to incorporate healthy physical activity into people's daily routine as an efficient travel mode. Compared to the dramatic increase in efforts to promote walking, efforts on cycling promotion have been limited. Significant gaps remain between research and practice on cycling. Even though many empirical studies have indicated the significance of cycling, most practices of urban design focus more on pedestrians and motorized vehicles, sometimes overlooking the potential conflicts between cyclists and pedestrians or vehicles (Forsyth & Krizek, 2011). Moreover, compared to many studies on cycling safety in European cities and in several large cities in the eastern and western regions of the US, studies on cycling in Texas are scarce. Therefore, more studies are needed on cycling-friendly community designs in an effort to promote cycling, which can help counteract the spread of sedentary lifestyles and obesity in Texas and beyond. The purpose of this case study is to explore cycling-supportive strategies used in German cities and compare cycling related policies, community designs, and infrastructure between the selected German and US cities. It aims to draw lessons from German examples and discuss the challenges and potential for their implementation in US cities.

2.1 Benefits of cycling

Cycling, as a healthy and sustainable transportation mode, can bring significant environmental, health, and economic benefits. First of all, cycling generates no air or water pollution and little noise, and it does not consume any non-renewable energy resources; secondly, compared to cars and other motorized transport modes, parking spaces needed for bicycles are quite small; and thirdly, cycling is

much more economical and affordable than motorized transport modes, making it acceptable for and available to everyone including those with limited economic resources (Pucher & Buehler, 2008b, 2010). Besides, cycling is an active transportation mode that can bring significant health benefits. Cardiovascular exercise, as a valuable outcome of cycling, can help restore, maintain, and improve both emotional and physical health (Pucher & Buehler, 2008b). Oja et al. (1991) conducted research about physiological influences of walking and cycling to work, which demonstrated that improved cardiorespiratory and metabolic fitness could be achieved by low-intensity walking and cycling to work at least 3.5 days per week. Huy, Becker, Gomolinsky, Klein, and Thiel (2008) argued that cycling could directly improve older adults' health. Bassett et al. (2008) carried out a study on the effects of walking and cycling on obesity rates in Europe, North America, and Australia, and reported that walking and cycling was negatively associated with obesity. Wen and Rissel (2008) studied relationships between active modes of commuting to work and obesity rates in Australia and revealed "cycling, in particular, had a strong inverse association with being obese" for men (p. 31). Pucher et al. (2010) studied influences of walking and cycling on health, which indicated that self-reported obesity had statistically significantly negative relationships with active travel.

2.2 Cycling trends in Germany and the US

The cycling level in Germany has not been consistently high. Due to the widespread use of private cars, cycling fell dramatically from 1950 to 1975, resulting in increasingly harmful environmental and safety problems. In the mid-1970s, German cities started to establish transportation and urban planning policies to restrict car use by making it more expensive, slower, and less convenient while encouraging environmentally friendly alternatives to cars. Cycling, as one of the most important alternatives, gradually became a popular means of transportation for people's daily routines. Strategies to promote cycling-friendly environments fostered the recovering and thriving culture of cycling in Germany (Pucher & Buehler, 2008b, 2009).

Over the past few decades, the overall cycling level in the US had increased as well because of the realization of its benefits and of the harms of automobile dependence. Cycling to work grew from 0.4% in 1990 to 0.6% in 2014 (City of Austin, 2009; US Census Bureau, 2010-2014), and the bicycle share of total trips rose from 0.6% in 1977 to 1.0% in 2009 (Pucher, Buehler, & Seinen, 2011). When compared to 10% of the bicycle mode share in Germany, bicycle use in the US is still quite low. Cycling rates are unevenly distributed in the US due to the differences in climate, environmental supports for cycling, and socioeconomic characteristics. Cycling levels are commonly higher in the western part of the US and areas near city centers, with the elderly and women cycling far less than young men (Pucher et al., 2011). In contrast, cycling in Germany has become a mainstream mode of transportation for both recreational purposes and practical and daily travel needs to get around cities. Cycling is fairly evenly distributed in Germany across groups with various incomes and genders, but the cycling rate declines slightly with the increase of age (Pucher & Buehler, 2008b).

2.3 Factors related/contributed to cycling

Based on the cycling trends during the past decades, significant differences can be observed between the US and Germany. The fact that cycling in the US is a less accessible and attractive transportation mode is primarily attributed to the neglect of cycling safety and cycling supportive facilities. In Germany, a diverse range of policies such as traffic regulations and related programs, community design solutions, and supportive infrastructure and facilities have been implemented to make cycling safer and more popular (Pucher & Buehler, 2008b; Pucher et al., 2011).

German governments have played an essential role in planning policies and interventions to create cycling-friendly environments and to fund cycling infrastructure and facilities. Since at least the 1970s, local governments in Germany have been funding and implementing cycling related policies, programs, and plans that are tailored based on the local contexts and needs. More recently, since approximately the 1980s, federal/central governments have been providing research supports, design guidelines, model projects and funding for cycling (Pucher & Buehler, 2008b). The German National Cycling Plans were first proposed in 2002 and updated in 2012 to promote cycling safety by specifying relevant goals and strategies/measures, which included restrictions and regulations on the use of motor vehicles and an increased supply of facilities for cycling including cycling lanes, cycling crossings at intersections, and bicycle parking spaces (Federal Ministry of Transport, 2012).

The roles of urban design including overall community design and detailed design of bicycle supportive infrastructure and facilities are of equal importance. Efficient and comprehensive design solutions can make the cycling experience more pleasant and fun, as well as safer. Compared to comprehensive, integrated, and coordinated cycling route systems covering in both rural and urban areas in Germany, cycling supportive infrastructure and facilities are far from adequate and efficient in the US with incomplete and disconnected systems in most communities (Pucher & Dijkstra, 2000).

3 METHODS

This case study aims to compare cycling-friendly environments between two German cities (Berlin and Bonn) and one American city in Texas (Austin), and is carried out in two major phases. Lessons from German best practices are summarized as guidelines, strategies, and implications for promoting cycling environments in Texas. The first phase focuses on each of the three target study areas – policies, community designs, and infrastructure/facilities – in greater detail to discuss how they contribute to promoting cycling. In this phase, assessments of each study area were made based on relevant information from the previous studies and policy documents from local and federal governments. Further, casual direct observations from the visits were used to further confirm the actual features implemented in the study communities. To guide the evaluation of the community design component, six dimensions of urban design including functional, morphological, perceptual, social, visual, and temporal dimensions are further explored to take the experience of cycling from the cyclist's viewpoint into the discussion of urban design requirements/preferences (Forsyth & Krizek, 2011). The second phase contains a more detailed evaluation of community design and cycling supportive infrastructure and facilities within a 1,200 meter by 1,200 meter (0.75 mile by 0.75 mile) area covering part of a university campus and the surroundings in each of the three cities. This particular study location was selected to ensure some comparability across the three cities with widely varying environmental characteristics. The presence of a major university was a common feature of all three cities. This size of area was selected to ensure feasibility of the direct field observation and to reflect on a 5-minute cycling distance. The selected areas are located around the main buildings of the major university located in each of the three study cities, including Humboldt University of Berlin and University of Bonn in Germany, and University of Texas at Austin in the US.

4 FINDINGS

4.1 Policies

A variety of policies, including both nationwide and citywide policies on a broad range of issues related to land use, transportation, urban development, environment, housing, parking, and taxation, have been implemented in Germany to facilitate safe and convenient cycling. Nationwide or statewide policies and design guidelines regarding cycling are not available in the US. Therefore, this study discussing cycling policies in the US city is based on the city level, while discussions on the cycling policies in Germany involve both national and city levels.

The city of Austin has the best overall cycling environment and the highest level of cycling to work in Texas with 1.4% in 2014, which is much higher than the national average (City of Austin, 2009; US Census Bureau, 2010-2014). Austin is the leading city in Texas in taking actions to promote sustainable transportation including cycling. Cycling has become increasingly important in people's daily life in Austin. The Austin Bicycle Plans including a series of cycling related polices have been adopted and updated periodically since 1972 to achieve the vision of making Austin one of the best cycling friendly communities in the US. Promoting cycling environments guided by the city's Bicycle Plans makes Austin a valuable example for other cities in Texas to follow. By comparing cycling related policies and design guidelines in Austin with those in German cities, potentials and challenges of promoting cycling in Austin as well as in other Texas communities can be better identified.

Compared to Germany, cycling related policies in Austin are still far from being adequate, especially for those regarding the restrictions of car use. Car use in Germany is much less convenient and far more expensive because of high taxes, high parking prices, limited parking spaces, etc. Table 1 summarizes a list of cycling related policies to compare specific strategies and measures in German cities and Austin, in terms of (a) land use and housing, (b) transportation, (c) parking, (d) taxation, and (e) traffic law.

Table 1. Cycling related policies in German cities and Austin, Texas.

Categories	Specific strategies	
	German cities	Austin
Land use and housing policies	• Limitation of new developments beyond already built-up areas • Mixed use developments to make short distance trips by bicycle or on foot available	• Low density land use (major destinations are not within a 5-minute biking distance)
Transportation policies	• Traffic education and training • Complete street: multi-modal transportation to integrate the bicycle system with transit • Traffic regulations (e.g. restrictions on the use of motor vehicles, limited car access to neighborhoods, etc.) • Speed limitations of motor vehicles (e.g. 30 kilometers/hour [19 miles/hour] or less in residential neighborhoods, 7 kilometers/hour [4 miles/hour] in home zones, etc.) through traffic calming, home zones, car-free zones, deliberately narrowed roadways, etc. • Shared bike bus lane to promote bike use while limit car use • Well maintained and separate circulation systems for cyclists versus motorists • Priority traffic signals and crossing intersection improvements for cyclists	• Traffic education, cycling training, and cycling promotion (e.g. cycling to school, cycling to work, etc.) • Complete street: multi-modal transportation to integrate the bicycle system with transit (underway) • Little restrictions on car use with complete road networks for cars • Speed limitations of motor vehicles (e.g. 48 kilometers/hour [30 miles/hour] or less in residential neighborhoods, 32 kilometers/hour [20 miles/hour] or less in school zone, etc.) through signage, traffic calming, etc. • Incomplete and discontinuous cycling networks (limited bicycle lanes and crossings)
Parking policies	• Limited car parking spaces in cities • Large supply of bike parking facilities throughout cities • State-of-the-art bicycle parking facilities at train stations • Strict time limit for parking or residents-only parking in urban neighborhoods • High parking prices in city centers (e.g. €1-4/hour in Berlin city center)	• Large supply of parking spaces for motor vehicles including ground parking lots and parking garages that are convenient and user-friendly throughout the city • Available parking hours based on specific locations • Low parking prices (e.g. $1/hour for metered parking and free during some time)
Taxation policies	• High taxes/fees on private car ownership and use including high gas price • More than €1,500 to obtain a driver's license for fees and strict training requirements	• Much lower taxes/fees on private car ownership and use including lower gas price compared to Germany • Less than $50 to obtain a driver's license
Traffic laws	• Cyclists' rights enforced by polices and courts including special protection for children and elderly cyclists • Motorists assumed legally to take charge of almost all crashes with cyclists	• Same rights and responsibilities as motorists

Sources. City of Austin (2009); Pucher and Buehler (2008b), p.512 & 522

4.2 Community designs

Overall land use patterns and arrangements of cycling path networks are the two major factors that influence cycling levels. Cycling levels are higher in communities with more diverse land uses, higher density, and greater connectivity of street and cycling path networks, than communities with segregated

land uses, low density, and poor connectivity (Saelens, Sallis, & Frank, 2003). Among the keys to the high level of cycling in Germany are the mixed-use developments and complete and continuous cycling networks for cities/towns/neighborhoods.

Even though the cycling level in Austin has increased greatly through a series of cycling policies and promotional programs during the past years, overall land use patterns and bikeway networks still make Austin cycling-unfriendly. Major destinations are too far for bicyclists because of segregated land use patterns and lower density developments. City street networks are designed for motorists, and incomplete cycling networks make cycling less convenient and more dangerous. Table 2 compares community design features related to cycling in Austin with those in German cities based on the six dimensions of urban design.

Table 2. Community designs for cycling in German cities and Austin, Texas.

Dimensions	Specific approaches	
	German cities	Austin
Functional	• Complete cycling systems/networks	• Incomplete cycling systems/networks with gaps and barriers
Morphological	• Appropriate land use to make major destinations close enough for cycling (shorter distance than auto-oriented developments while longer distance than pedestrian oriented developments)	• Segregated land use and low-density developments appropriate for automobile transportation (major destinations often not within a cycling distance)
Perceptual	• Clear and logical hierarchies with easy wayfinding for cycling network	• Unclear hierarchies of cycling networks that increase uncertain and unsafe feelings of cycling
Social	• Various destinations for different social groups of cyclists conveniently connected by cycling lanes	• Uneven distribution of cycling rates across different socioeconomic groups due to inconvenient and disconnected cycling networks
Visual	• Legible and attractive medium scale environments that can be optimally experienced at cyclists' speed	• Large scale environments that are not attractive for cyclists
Temporal	• Potential change of cycling networks over time	• No information/data available

Note. Adapted from " Urban Design: Is there a Distinctive View from the Bicycle?" by A. Forsyth & K. Krizek, 2011, *Journal of Urban Design*, 16(4), p.538

4.3 Infrastructure and facilities

According to Pucher and Buehler (2008b), cycling supportive infrastructure and facilities in Germany expanded greatly from the mid-1970s to the mid-1990s, including an increase of bikeway network from 12,911 kilometers (8,023 miles) in 1976 to 31,236 kilometers (19,409 miles) in 1996. In 2004, Berlin had a total of 1,140 kilometers (708 miles) of bikeway network, including "860 kilometers of completely separate bike paths, 60 kilometers of bike lanes on streets, 50 kilometers of bike lanes on sidewalks, 100 kilometers of mixed-use pedestrian-bike paths, and 70 kilometers of combined bus-bike lanes on streets" (Pucher & Buehler, 2008b, p. 511). By 2015, Bonn had a total of 300 kilometers (186 miles) of bikeways (City of Bonn, 2015). The overall length of cycling facilities in Austin had almost doubled from 778 miles in 1998 to 1451 miles in 2008, with small portions that were separate bicycle lanes (City of Austin, 2009). Compared to 860 kilometers (534 miles) of completely separate bike paths in Berlin in 2004, only 211 kilometers (131 miles) of separate bicycle lanes were available in Austin in 2008 (City of Austin, 2009).

Currently, German cities have a comprehensive package of cycling facilities, including separate and shared cycling lanes, clear signage and signals, convenient and sufficient bicycle parking, appropriate lighting, advanced stop lines (bike boxes) and cycling crossings at intersections, etc. The four main types of cycling lanes depending on specific locations or needs of cyclists include: (1) completely separate circulation systems for cyclists versus motorized modes and pedestrians; (2) shared cycling

lanes with motorized modes; (3) shared cycling lanes with pedestrians; and (4) shared cycling lanes with both motorized modes and pedestrians. Various types of bicycle parking are widely available in Germany, including both formal parking with racks at different scales and informal parking (e.g. street posts, poles, trees, etc.). Detailed designs are also essential to promote cycling-friendly environments. Detailed environmental features, such as signage, paving patterns, curb ramps, marked cycling crossings, and other artful cycling facilities, can improve safe, legible, and visually interesting built environments that are optimal when experienced at a speed of cyclists (Forsyth & Krizek, 2011). In contrast with German cities that have even distributions of cycling infrastructure and facilities, environmental supports for cycling in Austin is concentrated in city centers and areas around the universities. Table 3 shows a comparison between cycling infrastructure/facilities in Germany cities and Austin following the six dimensions of urban design.

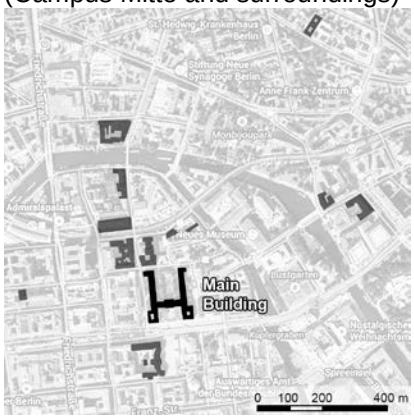
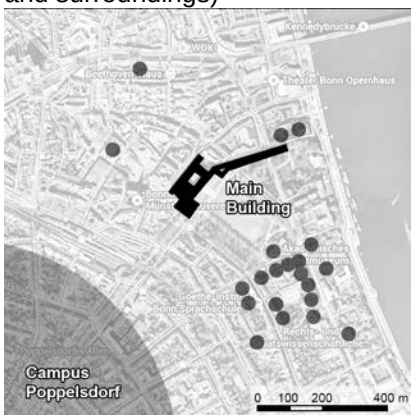
Table 3. Cycling supportive infrastructure and facilities in German cities and Austin, Texas.

Dimensions	Specific approaches	
	German cities	Austin
Functional	• Safe, convenient and well maintained cycling lanes and parking spaces • Appropriately signed and well-lit cycling and parking spaces to maximize cycling safety	• Disconnected bikeway network for the whole city • Partially well maintained cycling lanes • Limited parking spaces for bicycles • Plenty of unsigned bikeways
Morphological	• Design goals concerning openness or enclosure maintained by cycling lanes or bicycle parking • Spaces defined at the scale of cyclists regarding height and speed	• Limited spaces defined at the scale of cyclists regarding height and speed (most spaces defined and maintained at the scale of motorists)
Perceptual	• Clearly perceived built elements/details for cyclists as well as pedestrians and/or motorists • Cycling lanes with safe and attractive views for cyclists • Pleasant landscape conditions (e.g. well-grown street trees, well-maintained cycling lanes with very gentle slopes, etc.) that make cycling more comfortable	• Lack of built elements/details and signage for cyclists • Narrow and unsafe cycling lanes in most area • Poor landscape conditions (e.g. lack of street trees, poorly maintained cycling lanes with moderate to steep slopes, etc.) that make cycling less comfortable
Social	• Some travel lanes that are wide enough for cyclists to ride side by side • Availability for groups of cyclists to temporarily park and interact	• Limited spaces for groups of cyclists to temporarily park and interact
Visual	• A balance of diversity to create legible, efficient and attractive visual cues (e.g. signage, marked cycling crossings, etc.) rather than visual clutter for cyclists	• Limited and unclear cycling visual cues (e.g. signage, marked cycling crossings, etc.) that lack diversity and clarify
Temporal	• Potential change and maintenance of supportive facilities over time (e.g. more parking spaces for bicycles, added cycling lanes, etc.) • Availability of snow removal during the winter season • Clear visibility of built elements/details during different seasons • Potential renewal of signage, paving patterns and colors, etc. over time	• No information/data available

Note. Adapted from " Urban Design: Is there a Distinctive View from the Bicycle?" by A. Forsyth & K. Krizek, 2011, *Journal of Urban Design*, 16(4), p.538

4.4 Cycling environments around the university campuses

According to the aerial maps of the 1,200 meter by 1,200 meter (0.75 mile by 0.75 mile) study areas in Figure 1, the most significant difference between the universities in German cities and Austin is that there is no clear boundary for the university campuses in Germany. University buildings are scattered throughout the cities without a clear campus boundary and are mostly located near the city centers in Germany. A mix of university buildings with other land uses such as commercial, residential, and recreational makes major destinations within an easy biking distance from the university campuses in Germany. Table 4 shows a more detailed comparison of cycling environments regarding the two study areas of community designs and infrastructure/facilities among the three selected university communities. Cycling environments are consistently safe and convenient throughout the areas within and outside the universities in Germany, while cycling infrastructure/facilities are much more complete within the University of Texas in Austin compared to the surroundings. Figure 2-4 displays a photographic inventory of cycling infrastructure/facilities located within the three university campuses and in the surroundings, including cycling lanes, cycling crossings, and bicycle parking.

Humboldt University of Berlin (Campus Mitte and surroundings)	University of Bonn (main building and surroundings)	University of Texas at Austin (west campus and surroundings)
		

Note. All the main buildings are marked in black. For the Humboldt University of Berlin (left), the rest of the university buildings are marked in gray. For the University of Bonn (middle), buildings around the main building are roughly marked in gray dots, and the Campus Poppelsdorf is roughly marked in gray. For the University of Texas at Austin (right), the campus is marked in gray.

Figure 1. Aerial maps of the 1,200 meter by 1,200 meter (0.75 mile by 0.75 mile) study areas (2015). Diagram by the authors.

Table 4. Cycling environments around the university campuses in German cities and Austin, Texas.

	German cities	Austin
Community designs	• University buildings are scattered in the cities without a clear boundary between the universities and the surrounding communities. • Highly irregular city blocks and street patterns and orientations assist bicyclist and pedestrian movements through distinguishable visual cues and landmarks, while obstruct vehicle movements. • Mixed land use and high-density city development make major destinations easily reachable within a biking distance. • Safe, convenient and complete cycling networks are ramified all over the cities.	• Most university buildings are concentrated in a clearly delineated university district (less mixed land use compared to the universities in Germany). • More regular city blocks and grid street patterns facilitate movements of vehicles. • Segregated land use and low-density city development make major destinations within a driving distance rather than biking/walking distance. • Incomplete and discontinuous cycling networks make cycling unsafe and inconvenient all over the city.
Infrastructure and facilities	• A mixed level of cycling lanes including completely separate cycling lanes and shared cycling lanes with vehicles or/and pedestrians are provided as appropriate. • Bicycle parking spaces for both informal and formal facilities are available along streets, in major entrances, in courtyards, etc. • Bike boxes and marked cycling crossings at intersections increase cycling safety and promote bicyclist movements. • Marked cycling tracks, distinct paving patterns for cycling, and curb ramps improve cycling environments. • Cycling facilities such as bicycle racks are combined with artful designs to help create interesting and attractive built environments. • Well-lit cycling and parking spaces enhance cycling safety at night. • Pleasant landscape conditions (e.g. well-grown street trees, well-maintained cycling lanes with very gentle slopes, etc.) make cycling more comfortable.	• Cycling related infrastructure and facilities are much more sufficient within the university than the surroundings, especially for bicycle parking spaces (unevenly distributed cycling infrastructure and facilities throughout Austin compared to even and wide distribution of cycling infrastructure and facilities in the German cities). • A mixed level of cycling lanes including completely separate cycling lanes and shared cycling lanes with vehicles or/and pedestrians are partially provided. • Bicycling parking spaces are largely supplied throughout the campus while limited cycling parking spaces are provided for the surroundings. • Lack of bike boxes and marked cycling crossings at the intersections make cycling unsafe and unattractive. • Cycling lanes are poorly and partially marked. • Austin B-cycle stations (automatic bicycle rentals) are located throughout the Austin city center. • Poor landscape conditions (e.g. lack of street trees, poorly maintained cycling lanes with moderate to steep slopes, etc.) make cycling less comfortable.

Berlin	Bonn	Austin
		
Separate cycling lane	Separate cycling lane	Separate cycling lane
		
Separate cycling lane	Separate cycling lane	Separate cycling lane
		
Shared cycling lane with pedestrians	Shared cycling lane with vehicles	Shared cycling lane with vehicles

Figure 2. Cycling lanes in German cities and Austin, Texas. Photos by the authors.

Berlin	Bonn	Austin
		
Marked cycling crossing	Marked cycling crossing	Shared cycling crossing with pedestrians
		
Intersection with spatial textured pavers	Bike box at intersection	Bike box at intersection

Figure 3. Cycling crossings at intersections in German cities and Austin, Texas. Photos by the authors.

Berlin	Bonn	Austin
		
Bicycle parking near back entrance of building	Bicycle parking in the plaza	Bicycle parking on the street to restrict vehicles
		
Bicycle racks with artistic details	Bicycle parking near main building entrance	B-cycle station

Figure 4. Bicycle parking in German cities and Austin, Texas. Photos by the authors.

5 CONCLUSIONS

The lower level of cycling in Austin compared to German cities is attributed to insufficient governmental policies and interventions, inadequate cycling facilities/environments, and the widespread automobile dependent lifestyles and culture. Table 5 summarizes major differences between German cities and Austin in terms of policies, community designs, and infrastructure and facilities. Drawing from the lessons learned from the German cities, important strategies that Austin may explore to promote cycling include: (a) comprehensive cycling system and improved cycling environments with more pleasant landscape conditions, (b) cycling related education and promotional programs/events, (c) restrictions on car use, and (d) promotion of cyclists' rights.

Table 5. Summary of major variations in cycling environments between German cities and Austin, Texas.

	German cities	Austin
Policies	• Complete street: multi-modal transportation to integrate the bicycle system with transit • High level of speed limitation (e.g. 30 kilometers/hour [19 miles/hour] or less in residential neighborhoods) • Strict time limit for parking or residents-only parking in urban neighborhoods • High parking prices • Cyclists' rights more strongly enforced than the motorists' rights	• Complete street: multi-modal transportation to integrate the bicycle system with transit (underway) • Low level of speed limitation (e.g. 48 kilometers/hour [30 miles/hour] or less in residential neighborhoods) • Little time limit for parking • Low parking prices • Same rights and responsibilities as motorists
Community designs	• Mixed land use • High-density development • Complete and continuous cycling network • Clear hierarchies of cycling networks • Legible and attractive large scale environments at cyclists' speed	• Segregated land use • Low-density development • Incomplete and discontinuous cycling network • Unclear hierarchies of cycling networks • Unattractive large scale environments at cyclists' speed
Infrastructure and facilities	• High maintenance • Limited vehicle parking spaces • Large supply of bike parking facilities throughout the city • Legible, efficient and attractive visual cues/details (e.g. marked crossings at intersections) • Pleasant landscape conditions (e.g. well-grown street trees) for more comfortable cycling	• Low maintenance • Large supply of vehicle parking spaces throughout the city • Limited bike parking facilities except for city center and university areas • Lack of visual cues/details (e.g. unmarked crossings at intersections) • Poor landscape conditions (e.g. lack of street trees) for less comfortable cycling

6 DISCUSSIONS

6.1 Challenges for Texas cities

Even though there is an urgent need for promoting cycling environments in Austin as well as in many other cities in Texas and beyond, challenges regarding existing city layouts and infrastructure, landscape conditions, climate and topographic conditions, and traditional lifestyles and culture make cycling related strategies difficult to be implemented in American communities. Current city zoning and land use patterns in Texas cities follow motor-oriented urban design/plan solutions, making automobiles necessary for people to get around in cities. Automobile dependent lifestyles and culture are widely accepted, which leads citizens in Texas to view cars as the only or most convenient way to make their daily trips. Most existing streets in Texas cities are designed for vehicles, without adequate accommodation of bicyclists. Cycling related infrastructure and facilities (e.g. cycling lanes, cycling crossings, signage, etc.) are poorly maintained without timely repairs due to limited budget from governments. Building facades and

streetscape are often boring without sufficient visual interests or wayfinding guidance for cyclists. The high temperature and humidity in many months of the year and topographic changes with moderate to steep slopes in some Texas cities make cycling even less feasible or attractive. Poor landscape conditions with limited supplies of street trees and/or overhead structures make cycling in hot weather far from being comfortable.

6.2 Cycling-friendly community design principles for Texas cities

Due to the challenges mentioned above, promoting cycling in Texas cities is a long-term process that needs support from governments, urban designers/planners, and other related professionals. Governmental policies and interventions should emphasize the importance of cycling and provide measures and funding to promote the cycling environment, improve the cycling experience, and encourage bicycle use. Cyclist-friendly urban design approaches are needed to take cycling experiences more seriously during the policy decision-making processes. The following cycling-friendly community design principles may be considered to encourage cycling in Austin and other Texas cities:

1) Create complete cycling systems with sufficient supplies of cycling lanes, cycling crossings, bicycle parking, signage, and other cycling supportive facilities and details;
2) Encourage complete streets with efficient multi-modal transport systems to incorporate bicycle with transit;
3) Encourage cycling related programs (e.g. tree planting program) that support cooler cycling environment;
4) Ensure timely repairs supported by related policies to maintain cycling supportive infrastructure and facilities;
5) Promote landscape conditions (e.g. well-grown street trees) for better and more comfortable cycling environment;
6) Provide policies and interventions to restrict private vehicle use while encourage public transportation and cycling; and
7) Promote diverse and mixed land uses and high-density developments with better connectivity of street and cycling path networks.

This is a case study and has several limitations. First, the study communities in Germany and in Texas are selected for the feasibility of carrying out the study given the ability to visit the cities and collect the necessary data. While the 1200m by 1200m site selected for the detailed analyses were selected to ensure some comparability, it is possible that additional/different findings could be extracted if other or more areas were used in the assessments. Second, due to the limited data availability, some of the discussions were made based on the personal observations of the authors and subject to different interpretations. Third, another related limitation is the reliance on the use of primarily qualitative methods. Future work utilizing more objective data and additional sites/communities or analysis dimensions can further contribute to understanding cycling environments that are appropriate for promoting cycling in different countries, communities and/or populations.

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