How can Paratransit Users become attracted to Fixed-Route Bus Services?

A Case Study on Accessibility to Transit in Chapel Hill and Carrboro

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How can Paratransit Users become attracted to Fixed-Route Bus Services?

A Case Study on Accessibility to Transit in Chapel Hill and Carrboro

Bachelorarbeit

Humboldt - Universität zu Berlin
Geographisches Institut

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Executive Summary

This thesis addresses the challenges that individuals with disabilities are facing when using public transportation and that also transit agencies encounter that provide these transportation services. The high cost of special transportation for the disabled and elderly and the increased demand for these services have negative repercussions for both these population groups and the transit agencies. Therefore a solution is recommended that has not been recently highlighted in research studies and shall benefit both parties: The attraction of individuals who use demand-responsive services (or paratransit respectively) to fixed-route transit. A methodology that particularly serves this purpose is elaborated and applied here. The pedestrian and transportation infrastructure is analyzed in terms of accessibility in order to identify the current potential that these users could get attracted to fixed-route transit. To increase this potential in the future, also recommendations for improvement are provided. This methodology has been applied to Chapel Hill and Carrboro, North Carolina, where Chapel Hill Transit (CHT) provides fare-free fixed-route and demand responsive bus services. The analysis of the pedestrian and transportation infrastructure shows that - according to the criteria developed in this study - one quarter of all bus stops in Chapel Hill and Carrboro is currently fully accessible and almost 40% of the bus stops are limitedly accessible. More than one third is not accessible. Inadequate boarding and alighting areas and the absence of pedestrian sidewalks and crosswalks are the most frequently occurring barriers to fixed-route services for individuals with physical impairments. Accordingly, the potential to attract individuals who use paratransit in Chapel Hill and Carrboro is currently low: Only 13% of users currently have full access to fixed-route transit, applying a walking distance of ¼ mile from the user’s residence to the bus stop. In order to get access to fixed-route transit, 21% of the users require improvements of the bus stops and 42% require sidewalk improvements. By improving 29 specific bus stops, 28% of all paratransit users could have access to fixed-route transit in the future, which is an increase of 15%.

In order to actually and successfully attract users with disabilities to fixed-route transit, a combination of different practices needs to be implemented. Hence the improvement of the transportation and pedestrian infrastructure is only one element of an approach that seamlessly integrates all users and services in one transportation system. Consequently, this analysis and the recommended improvements serve to make public transportation more attractive for all possible users.
Acknowledgements

When the decision for my stay at the University of North Carolina at Chapel Hill was made, I wanted to seize the opportunity to do research that is immediately related to the place of this stay and its people. In order to pursue this aspiration I got involved with the Disability Awareness Council of Orange County, NC, the advocacy of the needs and rights of the disabled community in the Chapel Hill region. This involvement was the foundation for the development of a research design, which required extensive and thorough fieldwork along the streets of Chapel Hill and Carrboro.

I would like to thank Prof. Dr. Elmar Kulke and Dr. Peter Dannenberg for being my advisors and supporting this research. I also thank the whole NEURUS team, for giving me the opportunity to stay in Chapel Hill and for the many useful advices.

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<tbody>
<tr>
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<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>APTA</td>
<td>American Public Transit Association</td>
</tr>
<tr>
<td>BTS</td>
<td>Bureau of Transportation Statistics</td>
</tr>
<tr>
<td>CHT</td>
<td>Chapel Hill Transit</td>
</tr>
<tr>
<td>CUTR</td>
<td>Center for Urban Transportation Research</td>
</tr>
<tr>
<td>ECMT</td>
<td>European Conference of Ministers of Transport</td>
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<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
</tr>
<tr>
<td>NCD</td>
<td>National Council on Disability</td>
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<tr>
<td>NOD</td>
<td>National Organization on Disability</td>
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<tr>
<td>NTD</td>
<td>National Transit Database</td>
</tr>
<tr>
<td>SEU</td>
<td>Social Exclusion Unit</td>
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<tr>
<td>TCRP</td>
<td>Transit Cooperative Research Program</td>
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<td>TRB</td>
<td>Transportation Research Board</td>
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<tr>
<td>U.S.</td>
<td>United States of America</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>US DOJ</td>
<td>United States Department of Justice</td>
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<td>US DOT</td>
<td>United States Department of Transportation</td>
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<tr>
<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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1 Introduction

In the U. S. the importance of public transportation for the disabled and elderly populations has been highlighted frequently in the last twenty years. Consequently, public transportation considerably improved all over the country. Agencies provide special transportation services like paratransit\(^1\) for disabled individuals and upgraded vehicles and transportation facilities. The demand for paratransit services heavily increased since the implementation of The Americans with Disabilities Act, forcing transit agencies to search for other possibilities of how transportation can be provided for these population groups most effectively and efficiently. One of these opportunities is the attraction of paratransit users to fixed-route transit. In this study the transportation and pedestrian environment is considered the most essential component of accessible public transportation.\(^2\) In order to pursue the attraction of paratransit users to fixed-route transit particularly the transportation and pedestrian infrastructure need to be upgraded and made accessible for these individuals.

The public transportation system of Chapel Hill and Carrboro - two contiguous municipalities in Orange County, North Carolina with a total population of 68,301\(^3\) - is where this study was conducted. First, the current state of bus stop accessibility of this transit system is analyzed. Then the question of whether or not individuals with disabilities could potentially become attracted to fixed-route transit under this current state of accessibility will be addressed. Finally, recommendations for improving the transportation infrastructure will be given in order to increase the potential to attract disabled individuals to fixed-route transit.

The particular role of transit for individuals with disabilities and elderly people and the improvements that have been realized are highlighted in Chapters 2 and 3. The problems of transit for the disabled and applied solutions are addressed in Chapter 4. The research question with its subquestions and the goals of the research are formulated in Chapter 5. In Chapter 6 the methodology is described and the results are presented. For the purpose of better readability of this thesis, this chapter is structured upon the subquestions of the research, thus methodology and results of each subquestion are presented together. Chapter 7

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1 Paratransit is a special demand-responsive service dedicated for the use by elderly and disabled individuals. For further specifications see Chapter 3.1.

2 In this study the terms “accessibility” and “access” do not refer to the ability to reach desired goods, services, activities and destinations, but to the design of facilities which accommodate individuals with special needs, in this case individuals with disabilities (cp. LITMAN 2010, p. 3).

3 Chapel Hill: 51,519 (TOWN OF CHAPEL HILL 2010b); Carrboro 2000: 16,782 (TOWN OF CARRBORO 2010).
and 8 summarize the results and provide a conclusion. Furthermore the methodology and the results are reviewed in Chapter 9. The thesis is completed with an Outlook in Chapter 10.

2 Relevance of transit for individuals with disabilities

It has always been people with disabilities themselves who insisted on the importance of adequate transportation to assure their mobility. In a recent study conducted in the U.S. twelve percent of people with disabilities state that they cannot get the transportation they need (cp. US DOT 2003, p. 20). Continuous surveys in the 1990s and 2000s reveal that about one third of the disabled population considers inadequate transportation as a problem (cp. NOD/HARRIS INTERACTIVE 2004, p. 18).

The notion that transportation plays a key role for people with disabilities to fully participate in society is nowadays widely acknowledged in the U.S. and in Europe, as well as in other countries. The public transportation sector is often in the focus of scientific research and policy debates. This has been criticised by researchers, who point out that particularly in the U.S. most individuals with disabilities make the majority of their trips in private vehicles (cp. ROSENTHAL 2007, p. 520). This fact is crucial while analyzing mobility behaviour and needs of people with disabilities and it is therefore important to keep this in mind.

Nevertheless, this research is centred on a very specific population group – individuals with disabilities who use paratransit rather than private transportation. Therefore, this paper will not further discuss the significance of private transportation for disabled people, but rather focus on approaches, developments and problems in the public transportation sector.

2.1 Economic self-sufficiency of individuals with disabilities

The relationship between disability and public transportation was already emphasized in the Rehabilitation Act of 1973. At that time the economic self-sufficiency of people with disabilities

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4 Definitions of “Disability” and “Impairment”: The WHO defines “impairment” as a lack of function of a bodily part, whereas “disability” is defined as a physical limitation in performing a specific task in a given society (cp. GOLLEDGE AND STIMSON 1997, p. 490). The ADA defines disability as “a physical or mental impairment that substantially limits one or more major life activities of [an] individual or being regarded as having such an impairment. Major life activities include, but are not limited to, caring for oneself, performing manual tasks, seeing, hearing, eating, sleeping, walking, standing, lifting, bending, speaking, breathing, learning, reading, concentrating, thinking, communicating, and working” (US DOJ 2009, p. 7).

5 The total population with disabilities in the U.S. is 54.4 million people (U.S. resident non-institutionalized population aged 5 years or older), based on the Survey of Income and Program Participation (SIPP) of 2005 (BRault 2008, p. 3).

6 A law enacted in the U.S. which prohibits discrimination on the basis of disability in programs conducted by federal agencies, in programs receiving federal financial assistance, in federal employment, and in the employment practices of federal contractors (cp. US DOJ 2005).
disabilities was in the spotlight. In Section 502 C the newly established *Architectural and Transportation Barriers Compliance Board* was assigned to

1. “determine how and to what extent transportation barriers impede the mobility of handicapped individuals and aged handicapped individuals and consider ways in which travel expenses in connection with transportation to and from work for handicapped individuals can be met or subsidized when such individuals are unable to use mass transit systems or need special equipment in private transportation” (Sec. 502 c1A).

2. “determine what measures are being taken […] to eliminate barriers from public transportation systems (including vehicles used in such systems), and to prevent their incorporation in new or expanded transportation systems” (Sec. 502 c2A) and

3. “prepare plans and proposals for such further actions as may be necessary to the goals of adequate transportation […] for handicapped individuals” (Sec. 502 c3).

After extensive research on the European Continent in the second half of the 1980s, the *European Conference of Ministers of Transportation* (ECMT) also confirms the essentiality of accessible transportation for the economic situation of people with disabilities (cp. ECMT 1991, p. 5). Furthermore in this report the importance of public transportation for other basic activities of everyday life is highlighted: “Without accessible local transport, apparently simple activities such as medical or dental appointments, or household shopping, may have to be planned well in advance and assisted by other people” (ibid.).

### 2.2 Social aspects

Besides economic and health aspects, social participation of people with disabilities has been a focus since the mid-1980s. Surveys conducted in the United States from 1986 to 2004 show that people with disabilities less often socialize with friends, relatives and neighbors and attend religious services less often than people without disabilities. Also disabled people are less likely to eat out in restaurants than those without disability. Although enormous improvements have been realized (see chapter 3.2), this gap between people with and without disabilities is not yet closed (cp. KAYE 1998, p. 3; NOD/HARRIS INTERACTIVE 2004, p.15).

Addressing these observations, debates about the inclusionary and exclusionary effect of public transportation have been held. Generally, people with disabilities are considered as a disadvantaged group in terms of mobility (cp. CASAS 2007, p. 467), and are therefore more
susceptible for social exclusion. In the UK, where researchers and politicians extensively discussed the spatial and mobility component of social exclusion (cp. SEU 2003, p. 4), the social function of public transportation is recognised in the Transport Ten Year Plan of 2000 (cp. DEPARTMENT FOR TRANSPORT 2000, p. 15).

Since the year 2000 many local authorities consider mitigation of social exclusion through improved access to transportation services as a priority (cp. CASS ET AL. 2005, p. 6).

But public transportation not only assures access to locations where people socialize. Solomon points out that a trip by public transportation has a social function by itself: “Public transport can be a way of meeting people, and possibly different kinds of people. […] Buses can be quite a social experience” (SOLOMON 2000, p. 146).

Furthermore, results from several studies on health care suggest that an active social life benefits the health of individuals. A study conducted in 1998 on this topic quotes participants who said that “going out made them ‘feel good’”. The author further states that “this reinforces evidence from previous studies that those who find it easy to get out are more likely to maintain their health (both mental and physical) than those for whom it is difficult to escape from their isolation” (ibid.).

Thanks to the leadership of the UK in questions about the social dimensions of public transportation, this topic has finally been recognised on European Level: In 2004 the ECMT argues that public transportation is a key element in “minimising social exclusion and enhancing social cohesion” (ECMT 2004, p. 11). Shedding light on the social dimension of accessible public transportation, it shall be fundamental “to reduce not only physical, but also psychological barriers – cognitive, information, fear, discrimination“(ibid.).

3 Improvement of public transportation for disabled individuals since the introduction of ADA

In order to develop the research question in this paper, a closer look at the U.S. setting of public transportation for the disabled is necessary. The Americans with Disabilities Act (ADA), which was adopted in 1990 and became effective in 1992, decisively shaped public transportation for the disabled population in the last 20 years. In this chapter these aspects of the law that regard to public transportation will be discussed. Furthermore the impact of the law and realized improvements will be discussed, on a nationwide and local level.

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7 Definition of Social Exclusion. SILVER (2007, p. 15) defines Social Exclusion as “a multidimensional process of progressive social rupture, detaching groups and individuals from social relations and institutions and preventing them from full participation in the normal, normatively prescribed activities of the society in which they live.” For a further discussion of Social Exclusion see also EISENschitz ET AL. 2006.
3.1 The Americans with Disabilities Act (ADA)

The ADA is the successor of the Rehabilitation Act of 1973, but also covers aspects of disabled people’s life that have not been covered by the Rehabilitation Act yet. When passing the ADA in 1990, Congress recognizes that “physical or mental disabilities in no way diminish a person’s right to fully participate in all aspects of society. […] People with disabilities, as a group, occupy an inferior status in our society, and are severely disadvantaged socially, vocationally, economically, and educationally” (US DOJ 2009, p. 4). These disadvantages reveal themselves in various forms of discrimination, particularly “in such critical areas as employment, housing, public accommodations, education, transportation, communication, recreation, institutionalization, health services, voting, and access to public services.” Congress further declared that “the Nation’s proper goals regarding individuals with disabilities are to assure equality of opportunity, full participation, independent living, and economic self-sufficiency for such individuals” (ibid.). The new law shall be a “clear, strong, consistent” and “enforceable” instrument to eliminate discrimination against individuals with disabilities (ibid., p. 5).

Since transportation has been labeled a “critical area” where discrimination occurs, much consideration is dedicated to this topic in the ADA statute. Those goals of the ADA regarding transportation services that have relevance in the context of this paper can be summarized as follows:

1. All buses, rail vehicles, or other vehicles newly purchased or remanufactured by a public authority should be readily accessible and usable by individuals with disabilities, including individuals who use wheelchairs (cp. ibid., p. 17f).

2. Public agencies running a fixed-route transportation service should provide a paratransit service for individuals with disabilities, including wheelchair users. The level-of-service must be comparable to the level of the fixed-route service (cp. ibid., p. 18).^8

3. Eligible for this paratransit service are individuals with disabilities who are unable to independently
   a. board, ride, or disembark from any vehicle on the fixed-route system.

^8 The term “comparable level-of-service” means that a) in the case of a fixed-route bus system, paratransit service must be provided to any origin and destination within ½ of a mile on each side of each bus route. The service is either provided as door-to-door or curb-to-curb service. (cp. US DOT 2007a, p. 485), b) hours and days of service are analogue to those of the fixed-route service (cp. ibid., p. 489), c) restrictions and priorities on trip purposes are prohibited. An eligible and subscribed paratransit user cannot be denied a trip, the user is allowed to use the service as often as he or she likes (cp. ibid.).
b. travel to a boarding and disembarking location on the fixed-route system (cp. ibid., p. 18f).  

(4) New transportation facilities should be readily accessible and usable by individuals with disabilities, including wheelchair users (cp. ibid., p. 21f). The same applies to reconstructed facilities. Key rail stations in the system should be made accessible (cp. ibid.).  

Along with the ADA technical standards of accessible transportation vehicles and facilities as well as accessible Public Rights-of-Way (PROW) have been implemented by the Architectural and Transportation Barriers Compliance Board (also U.S. Access Board) and have been continuously enhanced over the last 20 years. These standards will be further discussed in Chapter 6.1.1.

Obligatory regulations and standards that led to improved public transportation services for individuals with disabilities will be discussed in the following chapter.

3.2 Improvement of public transportation through the ADA

In the twenty years since its implementation, the ADA had a strong positive impact on public transportation for individuals with disabilities. The realized improvements of transit services will be discussed on nationwide level – the United States – and on local level – the towns of Chapel Hill and Carrboro. The improvements presented here focus on transportation vehicles and facilities.

3.2.1 Nationwide improvement

As mandated by the ADA, every public transportation authority has implemented a complementary paratransit service and many physical barriers that prevented individuals with disabilities from using transit have been removed. Consequently the National Council on Disability (NCD) states that “the ADA increased overall transportation choices for people with disabilities, and more trips on more mode choices are being provided today than before the law was passed” (NCD 2005, p. 47).

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9 FTA developed three eligibility categories. Category 3 is the one relevant in the context of this research paper: Individuals with disabilities who are prevented to travel to and from a stop or station by an architectural barrier are eligible to use the paratransit service (US DOT 2007a, p. 437).

10 Public Right-of-Way (PROW) as defined by the Public Rights-of-Way Access Advisory Committee (PROWAAC): “The PROW is a complex space serving multiple users and functions. The sidewalk and street crossing network is the basic unit of pedestrian mobility […]. Private, transit, and commercial vehicles vie with pedestrians for right-of-way width. All modes of travel, including motor vehicles, rail transit, and foot traffic share time and space at intersections (PROWAAC 2007, p. 1).
One well documented aspect is the continuous upgrade of the rolling stock and bus fleets. As shown in Figure 1, 36% of the national bus fleet was considered accessible in 1989, thus were ramp- or lift-equipped (cp. Simon 1998, p. 4). In 2006, almost every bus in the United States was accessible (98% = 68,880 buses) (cp. APTA 2008, p. 25; APTA 2009, p. 16; APTA 2010a, p. 16; APTA 2010b, p. 27; US DOT 2007b, p. 57; US DOT 2008, p. 45). Also rail vehicles were improved significantly. While most of the passenger vehicles used for heavy rail systems were already accessible in 1994, around 20 percent of all commuter and light rail vehicles are still inaccessible. This is due to the ADA requirement that, in the case of trains with two or more cars, only one car per train must be accessible (cp. US DOT 2007a, p. 478). In 2009, 90% of all passenger vehicles used by transit authorities in the U.S. were accessible (cp. APTA 2010a, p. 16).

Figure 1: Accessible Passenger Vehicles by Mode. Source: Own figure, according to US DOT (2010), p. 35.

Also in regard to rail stations, the Bureau of Transportation Statistics (BTS) has been reporting significant improvements over the years. 22 percent of rail stations of all types (heavy, light, and commuter) were accessible in 1993 (553 out of 2,452) (cp. NCD 2007, p. 32). In 2008, 63% of all rail stations were accessible (1868 of 2,959 rail stations) (cp. US

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11 Reviewing 14 heavy rail systems, 19 commuter rail systems and 26 light rail systems.
Looking at heavy, commuter and light rail systems, 37 of a 59 systems had no more inaccessible rails stops, in other words, they were fully accessible by 2008.

In contrast to the well-documented upgrade of rail stations, no national database about bus stop improvements is available. Because there is no requirement to make bus stops accessible (unless they are newly constructed or altered), transit authorities do not necessarily monitor the condition of their bus stops.

### 3.2.2 Improvement of public transportation in Chapel Hill and Carrboro

Before addressing the recent upgrade of the system, overall characteristics of transit in Chapel Hill and Carrboro need to be described.

Transit service in Chapel Hill and Carrboro is provided by Chapel Hill Transit (CHT). This public transit authority began operations in Chapel Hill in 1974. In 1977 the service was expanded to Carrboro (cp. TOWN OF CHAPEL HILL 2010a).

Annual transit ridership increased over the decades 1980, 1990 and the early 2000s, but mostly related to a significant population gain. Per capita boardings almost stagnated. Since 2002 the whole transit system – fixed-route and demand-responsive – is fare free, which had a tremendous impact on ridership. Annual unlinked passenger trips more than doubled from 2001 to 2008\(^\text{12}\) (cp. NTD 2001 and NTD 2008; TOWN OF CHAPEL HILL 2007a, p. 80). Also per capita boardings almost doubled between 2000 and 2006 (cp. TOWN OF CHAPEL HILL 2007b, p. 6).

Operating expenses of transit in Chapel Hill and Carrboro are financed by federal assistance (7%), state funds (21%) and local revenues and funds (69%) (cp. NTD 2008).\(^\text{13}\) Capital expenses are completely covered by federal grants.

Chapel Hill Transit is running 31 routes which provide broad transit coverage within the Chapel Hill and Carrboro city limits: According to a survey, 92% of all respondents live within a ¼ mile walk from a bus stop (cp. TOWN OF CHAPEL HILL 2010c, p. 12). Fixed-route Saturday and Sunday services as well as evening and late night services are provided for free, also additional feeder services in areas without regular fixed-route coverage.\(^\text{14}\) Rising ridership and continuous service expansions demonstrate that the fare-free policy is successful.

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\(^\text{12}\) 2001: 3,017,244 annual unlinked passenger trips; 2008: 6,398,761 annual unlinked passenger trips.

\(^\text{13}\) Since Chapel Hill Transit does not charge ticket fares for their service, a partnership consisting of the towns of Chapel Hill and Carrboro as well as the University of North Carolina at Chapel Hill provide financial resources to cover the expenses (UNC: 41% of total, Chapel Hill: 21% of total, Carrboro: 7% of total (TOWN OF CHAPEL HILL 2008, p. 6; KRUEGER AND MURRAY 2008, p. 14)).

\(^\text{14}\) Except for Shared Ride services on evenings and Sundays which are offered around $ 0.75 per trip.
Like every other public transit agency that provides regular fixed-route services, Chapel Hill Transit is required to provide special services for disabled people and to improve their fleet and infrastructure. Already in 1974 CHT implemented an additional demand-responsive service for individuals with disabilities, according to the Rehabilitation Act. This service is also fare-free for eligible users and operates on weekdays and Saturdays.

Around 3000 individuals are currently subscribed to the paratransit service. In 2008, Chapel Hill Transit accessible bus fleet consists of 86 vehicles for fixed-route services and 15 vehicles for demand-responsive services, of which 67 fixed-route buses and all demand-responsive vehicles are lift equipped. The remaining 19 vehicles are ramp equipped low-floor buses (Figure 2). The purchase of the buses in 2007 is part of the agency’s strategy to modernize their fleet. It is projected to acquire another 26 low floor buses between 2008 and 2012 (cp. TOWN OF CHAPEL HILL 2008, p. 8). These vehicles have an important advantage in comparison to standard floor lift equipped buses: Boarding and alighting is more convenient, faster and efficient, particularly for wheelchair users (cp. ibid., p. 36). Furthermore CHT is continuously working on improving comfort for transit riders. Although these improvements are an effort to promote transit itself and are not specifically aimed at individuals with disabilities, they decisively benefit the physically impaired individuals who use public transit.

In 2006, the Passenger Amenities Program was implemented, resulting in better maintenance of existing shelters, repair of damaged shelters and construction of new shelters at bus stops with high numbers of passenger boardings (cp. TOWN OF CHAPEL HILL 2006). Furthermore CHT placed timetable information at 91 bus stops and added real time bus arrival information to four locations (cp. TOWN OF CHAPEL HILL 2008, p. 19).

Town and transit administrations are aware that the pedestrian infrastructure plays a key role in supporting transit. The 2000 Chapel Hill Comprehensive Plan stated that “the Town has
been developed with very few sidewalks and the lack of these sidewalks affects both pedestrian and transit mobility” (TOWN OF CHAPEL HILL 2007a, p. 37). While the downtown and the university campus are sufficiently equipped with sidewalks, many residential areas lack of pedestrian infrastructure. Exceptions are Meadowmont Village and Southern Village, two recently built New Urbanism developments (cp. ibid., p. 40). Thus, one goal of the Comprehensive Plan is to develop a comprehensive pedestrian (and bicycle) network throughout Chapel Hill (cp. TOWN OF CHAPEL HILL 2000, p. 97), leading to the Chapel Hill Bicycle and Pedestrian Action Plan in 2004.

The pedestrian infrastructure has already been significantly expanded since 2002. The focus was mainly on those residential areas that are served by transit but have insufficient pedestrian infrastructure. Between 2002 and 2005 a total of 26.6 miles of new sidewalks where constructed in Chapel Hill and Carrboro, expanding the existing sidewalk system about 20 % to a total of 160 miles in 2005. 75% of new sidewalks were built within ¼ mile of a bus stop (cp. TOWN OF CHAPEL HILL 2007a, p. 41; TOWN OF CARRBORO 2006, p. 35).

In 2005 a sidewalk priority list was issued targeting on 133 sidewalk improvement projects. Almost all of these projects are within the transit area of a ¼ mile.

The Chapel Hill and Carrboro 2035 Long Range Transit Plan projects to further support transit use by Transit Supportive Development (TSD): Beside different land use aspects – mixed use and high density development – the “provision of an attractive, safe and inviting pedestrian environment” is considered a key factor in supporting transit (cp. TOWNS OF CHAPEL HILL AND CARRBORO 2009, p. 9).

4 The challenge of providing transportation for the disabled

Transportation for the disabled – especially transit systems operated by buses in middle-sized cities and in rural and suburban areas - is currently facing two severe challenges:

- The lack of funding for public transportation
- The increasing demand for paratransit

Both challenges will be discussed in this chapter.

4.1 Lack of Funding for public transportation

4.1.1 Funding Overall

The lack of funding has a negative impact on public transportation services and is accountable for many transportation-related problems of individuals with disabilities.
One of these problems is governmental funding. The NCD states: “The transportation difficulties faced by people with disabilities occur in a broad context of inequitable funding” (cp. NCD 2005, p. 19). In order to understand this lack of funding it is necessary to briefly address the historical development of transportation in the United States. After World War II governmental funding on transportation mainly focused on the infrastructure for the automobile, whereas funding for public transportation declined. This development contributed to the fact that the U.S. society has become highly dependent on the automobile (cp. KENWORTHY AND LAUBE 1999, p. 701; PUCHER 2004, p. 223). In the 1980s the value of public transportation was appreciated once again, which led to a renaissance of transit in the U.S.: 21 new rail systems were built between 1985 and 2000 (cp. PUCHER 2000, p. 38). Further modernization of the older systems, mostly in the early 1990s, led to an increase in quality of public transportation (cp. PUCHER 2004, p. 205) and finally to an increase in transit ridership to a level already reached in the 1950s (APTA 2010, p. 10).

Consequently, as Figure 3 shows, governmental expenditures doubled from 1994 to 2007. However, a shift from governmental funding focusing on transit instead of highways cannot be concluded: The graphic also shows that expenditures for the highway infrastructure as well doubled during that period of time. Furthermore the funding shares remained the same: In 2006, subsidies for highways accounted for 60% of the total transportation funds whereas transit subsidies accounted for less than 20% (cp. US DOT 2010, p. 258). These shares are more or less the same as in 1985 (cp. VUCHIC 2005, p. 406).

![Figure 3: Government Expenditures. Source: Own Figure, according to APTA 2010 Public Transportation Fact Book, p. 410, and APTA 2010 Public Transportation Fact Book, Appendix A: Historical Tables, p. 47 and 55.](image-url)
4.1.2 Focus on metropolitan areas

Problems with public transportation for people with disabilities are more critical in rural areas. Recent investments in new rail systems and substantial modernization efforts mainly occurred in larger metropolitan areas, which demonstrates that the national focus of capital investment funding lies on urban mass transportation. Meanwhile the importance of rural public transportation is still neglected by the federal government. The U.S Department of Agriculture reports that only 10 percent of federal funding for public transportation goes to rural areas. The consequence is that rural public transportation services continue to be limited to only 60 percent of rural counties in the U.S., and many authorities only offer a very limited service (cp. USDA 2005, p. 3). This has severe repercussions for individuals with disabilities living in rural areas because special transportation services like paratransit are not mandated by the ADA where no fixed-route system exists. Without access to private transportation, these people are homebound or have to live in institutions.

4.1.3 Funding of ADA

Problems also arise out of a lack of ADA-related funds. Although government expenditures on transit increased overall, ADA regulations do not come along with additional programs to realize cost-intensive improvements like station improvements (cp. ROSEN BLOOM 2007, p. 531). Thus funding of ADA-related capital investments must be accomplished by the general governmental appropriations for transit, which makes the operation and expansion of special services to a major challenge for transit agencies. As ROSEN BLOOM points out, “analysts have noted how difficult it is to set up and maintain effective coordinated programs without continuing financial assistance and leadership – as well as mandate – from regional or state agencies” (ibid., p. 546) and concludes that it is “unlikely […] that […] transit systems will expand their paratransit services beyond the minimum, even as the population of travelers with disabilities climbs, unless additional funding becomes available” (ibid., p. 541).

4.2 Reasons for the high demand of paratransit

The second challenge that transit agencies, as well as the disabled community, are facing is the increased demand for paratransit services. Surprisingly paratransit demand did not

15 Rural population 2000: 59.061 million = 21 % of total population (U.S. CENSUS BUREAU 2010, Table 29).
The definition of “rural area” used in the USDA report is based on the definition of metropolitan and nonmetropolitan areas provided by the Office of Management and Budget (OMB) in 1993: Nonmetropolitan counties are located outside the boundaries of metro areas and have no cities with 50,000 or more residents (cp. USDA 2005, p. 6).
decrease over the years as the fixed-route system became more and more accessible for users with disabilities and many cities report the increase of wheelchair boardings on fixed-route vehicles (cp. WEINER 1998, p. 4).

Paratransit overall has seen a severe increase in ridership, especially since 1991: As shown in Figure 4, 71 million paratransit trips were provided in 1991 and 126 million paratransit trips were provided in 2006 (APTA 2010b, p. 63). This is an increase of 56%. ADA-related paratransit trips increased even more: In comparison to 1991 (14 to 16 million ADA related paratransit trips a year) FTA reported that ADA-related trips tripled until 2001 (46.5 million ADA related paratransit trips) (cp. US DOT 2002, p. 60; KOFFMANN ET AL. 2004b, p. 23). Thus ADA-related trips accounted for 23% of all paratransit trips in 1991 and increased to 44% in 2001. For further paratransit statistics see Appendix A.

![Paratransit Trips in the U.S.](image)

**Figure 4: Paratransit Trips 1984-2006. Source: APTA 2010 Public Transportation Fact Book, Appendix A: Historical Tables, p. 63**

Figure 5 indicates that in Chapel Hill and Carrboro, 66,258 annual paratransit trips were operated in 2006. That is an increase of 72% in regard to 1997 (38,426 annual paratransit trips; cp. TOWN OF CHAPEL HILL 2007b, p. 5). On the national level paratransit trips increased by 27% in the same time period (cp. APTA 2010a, p. 10). **Accordingly, the percentage increase in paratransit ridership in Chapel Hill and Carrboro is more than two times higher than the national increase in this period.**
The demand for paratransit is increasing due to several reasons that will be discussed in this chapter. On the one hand, the demographic change and the growth of the disabled population contribute to the increasing demand. On the other hand, inadequate transportation and pedestrian infrastructure prevent individuals with disabilities from riding fixed-route transit. Consequently, these individuals rely on special transportation services like paratransit. Furthermore, particular eligibility practices increase the demand for paratransit.

### 4.2.1 The demographic change and the growth of the disabled population

The population of the elderly and disabled is on the rise in the United States which possibly contributes to the increased demand for paratransit. (cp. KOFFMANN ET AL. 2007, p. 35) According to the Administration on Aging, the proportion of individuals with the age 65 and over will increase from 12.8% in 2008 to 19.3% in 2030 (cp. U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES 2009, p. 5). As shown in Figure 7, the number of elderly individuals over 65 is projected to be 88.5 million in 2050 (cp. THE FEDERAL INTERAGENCY FORUM ON AGING-RELATED STATISTICS 2010, p. 72).
Along with the aging of society the number of individuals with disabilities is rising. As shown in Figure 8, in 2005 more than 54 million individuals with disabilities were counted (cp. BRAULT 2008, p. 3). This could also mean that the need for transportation services of these population groups could further increase.

The increased life expectancy may also contribute to the continued rise of demand for paratransit: “Analysts project that many elderly will outlive their ability to drive by 7 to 10 years” (KOEFFMANN ET AL. 2007, p. 36).
4.2.2 Inadequate transportation facilities

Many fixed-route bus systems are still inadequate for the use of individuals with disabilities and therefore paratransit is the only option available. The following problems of fixed-route services further increase paratransit demand:

- Transit stations or stops are inadequate for the use by the disabled (cp. EASTER SEALS 2006a, p. 52):
  - No stable boarding/alighting areas,
  - missing connection from stops to sidewalks (see Figure 8),
  - missing security/safety components like shelters, lighting and police call boxes and
  - signage and information missing or not usable by individuals with hearing and visual impairments.

- Temporary inhibited access to transportation vehicles due to malfunctioning lifts or ramps (cp. ibid., p. 30 and 50),

- Insufficient training of fixed-route bus drivers regarding conduct towards transit users with disabilities (cp. ibid., p. 36),

- No stop announcements on transit vehicles (cp. ibid., p. 26 and 50) and

- No transit stop in the vicinity of the user’s trip origin or destination (cp. ibid., p. 50).

4.2.3 Inadequate pedestrian infrastructure

Besides the problems regarding transportation facilities, often the pedestrian infrastructure is inadequate for the use by disabled individuals. The NCD (2005, p. 121) states that:

- Sidewalks and crosswalks are often not available or not accessible,

- Sidewalks are often too narrow or in bad condition or temporary obstructed (see Figure 9 and Figure 10),

- Curb cuts and tactile warning pads are absent and

- Audible signals on pedestrian lights rarely exist.

The NCD emphasizes the importance of the pedestrian...
infrastructure for transit use: “Almost every trip involves a pedestrian component, whether it is walking several blocks on the sidewalk or simply crossing the street” and “if public rights-of-way are not accessible, then people with disabilities are unable to connect to other forms of transportation such as buses or trains. An accessible pedestrian environment permits people with disabilities, especially those who do not drive, to remain independent and more involved in the community” (NCD 2005, p. 121). The ADA has not yet consistently addressed the problem of inaccessible or unavailable pedestrian infrastructure. Thus it might occur that even in the case both the transportation facilities and vehicles are accessible, access for individuals with disabilities is not guaranteed.

Indeed, since 2006 the ADA standards require recently built or altered transportation facilities to have at least one accessible path to sidewalks, parking spaces and the entrance to the building this transit stop or station serves (cp. U.S. ACCESS BOARD 2004, p. 23). But since the ADA does not embrace regulations for existing facilities and public rights-of-way, there is no requirement to make existing sidewalks, crosswalks and other elements of the pedestrian infrastructure accessible. Although the U.S. Access Board issued guidelines for the design of accessible public rights-of-way\textsuperscript{16}, these guidelines have not become mandatory yet.

4.2.4 Reasons related with eligibility practices

Inadequacies in fixed-route transit systems prevent physically capable individuals from using these systems. As the fixed-route system and pedestrian infrastructure become accessible over the years, these individuals are enabled to use the service. Nevertheless several reasons exist why this transition does not always happen in practice:

➢ Some users have ridden paratransit since the 1970s and 1980s. The Rehabilitation Act mandated agencies to provide either accessible fixed-route transit or paratransit for users with disabilities, but not both (cp. NCD 2005, p. 50). Many transit agencies decided to provide only paratransit to these users. Thus, the fixed-route system remained inaccessible. As a result, individuals with disabilities became accustomed to the convenience of this service and continued to do ride paratransit. The NCD points

out that it is difficult for individuals with disabilities to switch to fixed-route transit. Because many of them have no experience in navigating fixed-route transit. The high demand for paratransit is partially a consequence of fear towards fixed-route transit (cp. NCD 2007, p. 50).

- Another problem is that some agencies only provide two eligibility choices: Full eligibility or no eligibility at all. A survey conducted by the Center for Urban Transportation Research (CUTR) at the University of South Florida reveals that 28% of the respondent agencies\(^{17}\) do not provide trip-by-trip eligibility (cp. SAPPER ET AL. 2009, p. 32). This eligibility configuration prevents individuals from using fixed-route transit for some trips because of the fear of losing their paratransit eligibility status (cp. NCD 2007, p. 51).

- Some transit agencies seldom review their eligibility process or the eligibility status of the persons subscribed to the service. Although the most common review period is three years, some transit agencies wait up to five years to review the eligibility certification of paratransit users (cp. SAPPER ET AL. 2009, p. 29). As a consequence, individuals are still using paratransit despite their improved ability to use the fixed-route system.

- Transit agencies allow paratransit riders to continue using paratransit despite they became ineligible due to improvement of the facilities. The before mentioned survey indicates that half of the respondent transit agencies allow former eligible ADA riders to continue using the paratransit service after improvements have been made (cp. ibid., p. 33).

4.3 Summary: Consequences of the lack of funding and the high demand for paratransit

Financial limitations and the increase in paratransit demand caused by a variety of reasons has negative consequences for both the transit agencies and individuals with disabilities.

Since the demand of paratransit trips has risen dramatically, transit agencies are increasingly burdened with the high costs for this service. Although paratransit ridership was only 1.8% of the whole transit ridership in 2008, paratransit comprised 13% of transit operating costs (cp. APTA 2010a, p. 10 and 21). The operating cost per trip for paratransit service is about $22.14; for all other modes, the operating cost per trip is $2.75 (cp. CHIA 2008, p. 3), which

\(^{17}\) 39 respondents, 28% =11 transit agencies.
means that a paratransit trip exceeds the cost for a usual transit trip more than eight times. Consequently, transit agencies are struggling with capacity limitations which have repercussions on their service quality. Some agencies are no longer able to satisfactorily serve the disabled community. The NCD criticizes the unreliability of many paratransit services, referring to individuals with disabilities who reported delays and neglect of paratransit trips, long durations of trips, long waiting times on the telephone when reserving trips and overstrained transit staff (cp. NCD 2005, p. 48).

4.4 Approaching the problems: Reducing paratransit trips and promoting fixed-route transit

Most transit agencies in the U.S. are aware of these problems and try to take action. Yet, there is no simple solution because the situation is complex and delicate: The ADA mandates that agencies may not deny transportation to individuals with disabilities. Furthermore, agencies do not want to lose the confidence of the disabled and elderly population. Thus, the challenge is that mobility of the still growing population of the disabled and elderly must be assured, and at the same time operations expenditures must be reduced. Consequently, transit agencies have implemented practices to promote fixed-route transit to individuals with disabilities and elderly people in order to reduce the demand for paratransit trips. The following are emerging practices:

- Trip-by-trip eligibility determination (cp. SAPPER ET AL. 2009, p. 12),
- Travel training for disabled and elderly people. CUTR indicates that in 2009, 73 % of the respondent transit agencies provided fixed-route travel training to their paratransit users (cp. ibid.),
- Charge of supplemental fares for service beyond the ¾ mile corridor of fixed-routes (cp. ibid.),
- Offering of free or reduced fares for fixed-route services to persons determined to be ADA paratransit eligible. 61% of transit agencies provided free or subsidized passes to paratransit passengers for the use of fixed-route transit in 2009 (cp. ibid.),
- A variety of integrated and flexible services like paratransit feeder services (cp. BURKHARDT ET AL. 2002, p. 19; WEINER 2008, p. 5), community buses or circulators, demand-responsive connectors and route/point deviation (cp. KOFFMANN ET AL. 2004a, p. 5f; WEINER 2008, p. 5),
- Improvement of the pedestrian and transportation infrastructure (cp. BALOG 1997, p. 6.1-32; SAPPER ET AL. 2009, p. 37)
5  Objective of the study

5.1 Deduction of the research question: Focus on accessibility of transportation and pedestrian facilities

In order to encourage individuals with disabilities to use fixed-route transit, a combination of all practices mentioned needs to be implemented. Each of these measures contributes to the consolidation of a fixed-route transit system; recently, agencies have turned to the analysis of their complete fixed-route infrastructure and the impact of accessibility improvement where physical barriers currently prevent individuals from using the system. The vast majority (81%) of transit agencies reporting to the CUTR state that they are making efforts to improve accessibility to fixed-route bus stops (cp. Sapper et al. 2009, p. 37). The same tendency is shown in Table 1, although the percentages differ: 58% of survey respondents in this study claim to improve accessibility to transit stops. 41% of the respondents are realizing path improvements. The figure also reveals that the commitment to stop accessibility improvement differs between small and larger agencies (cp. Chia 2008, p. 16).

<table>
<thead>
<tr>
<th>Policy/Practice</th>
<th>Overall</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Very Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Accessibility</td>
<td>81%</td>
<td>19%</td>
<td>75%</td>
<td>25%</td>
<td>88%</td>
</tr>
<tr>
<td>Design Guidelines for Improved Accessibility</td>
<td>57%</td>
<td>43%</td>
<td>50%</td>
<td>50%</td>
<td>65%</td>
</tr>
<tr>
<td>Stations, Paths, Facilities</td>
<td>55%</td>
<td>45%</td>
<td>50%</td>
<td>50%</td>
<td>65%</td>
</tr>
<tr>
<td>Stop Accessibility</td>
<td>58%</td>
<td>42%</td>
<td>50%</td>
<td>50%</td>
<td>59%</td>
</tr>
<tr>
<td>Path Accessibility</td>
<td>41%</td>
<td>59%</td>
<td>42%</td>
<td>58%</td>
<td>35%</td>
</tr>
<tr>
<td>Public Information</td>
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<td>25%</td>
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<td>33%</td>
<td>88%</td>
</tr>
<tr>
<td>Station/Stop Visual and Audio Communications</td>
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<td>47%</td>
</tr>
<tr>
<td>Other Fixed-Route Improvements</td>
<td>36%</td>
<td>64%</td>
<td>35%</td>
<td>65%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Table 1: Agencies’ Practices of Improvements for Riders with Disabilities. Source: Chia 2008, p. 16.

Despite the obvious merit, agencies have only sparsely taken this systematic approach to addressing the accessibility of existing bus stops. A study conducted by the Transportation Research Board in 1997 states: “Well-established, quantitative methods for documenting the need for new transit facilities […] are regularly used by transit systems. In contrast, there are no established quantitative methods for documenting the need to enhance overall bus stop
accessibility” (Balog 1997, p. 93). In TCRP Synthesis 74 a survey of transit agencies’ practices has been conducted. But the authors of the study admit that there is a lack of research regarding the policies, methods and practices that are suitable to increase bus stop accessibility (cp. Chia 2008, p. 29).

As the author is student of a discipline with focus on spatial problems, the accessibility of transportation and pedestrian facilities will be in the focus of this paper. The assumption is that barrier-free transportation facilities and an extensive and accessible pedestrian infrastructure are the most critical prerequisites to make fixed-route transit an option for specific population groups such as individuals with disabilities and the elderly.

5.2 The research question

In Chapel Hill and Carrboro – like in many cities – barriers still exist at bus stations and stops as well as in the pedestrian infrastructure. Whereas the current condition and extent of the sidewalk system is already well documented, both in Chapel Hill and Carrboro, the condition of bus stations and stops has not been comprehensively recorded in an inventory. Furthermore the current state of accessibility to fixed-route transit for individuals with disabilities and the potential of attracting paratransit users to fixed-route services has not yet been identified. This lack of knowledge will be systematically filled in, in order to give recommendations for future improvement. The focus of the research question is on individuals with a lack of physical mobility and with vision and hearing impairments, but the recommendations for improvement are generally aimed on all individuals with different kinds of impairments (e.g. cognitive impairments or mental challenges). Nevertheless, the special needs of individuals with these impairments are not specifically addressed in this study.

The question “How can paratransit users become attracted to fixed-route bus services?” is divided into three consecutive questions, each one based on the findings of the previous one:

- What is the current state of access to transit?
- What is the current potential to attract paratransit users to fixed-route services?
- Which improvements are necessary to increase this potential in the future and which improvements are the most urgent and/or the most likely to be effective?

5.3 Goals of the study

This research focuses specifically on public transportation in Chapel Hill and Carrboro, North Carolina. The aims of the research are as follows:
Improving access to fixed-route transit shall provide an option for those individuals with disabilities who want to travel independently without being dependent on additional assistance or trip reservations in advance. Fixed-route transit could also appeal to individuals who consider themselves stigmatized or excluded by the usage of separated transportation services. All these users may find accessible and attractive fixed-route transit more adequate for their needs.

Due to the attraction of users to fixed-route transit, the capacities of special transportation services shall be rededicated to those users whose only mobility option is paratransit. Consequently, these users can be served more efficiently and reliably in the future.

This research shall follow the current efforts of transit agencies to reduce paratransit demand by analyzing and improving their fixed-route transportation system. This will provide a possibility for Chapel Hill Transit to decrease the financial burden and improve the quality of their service.

This study shall fill the research gap regarding accessibility to bus transit by providing a systematic approach to analyze and improve accessibility to fixed-route transit.

6 Methodology and Results

This chapter is structured along the three research subquestions presented in Chapter 5. These act as self-contained segments of the study, but are also based on the findings of the previous subquestion. In order to assure proper readability, the methodology and results of each subquestion are presented one after another. The results of all subquestions are summarized in Chapter 7. As an introduction to each of the subquestions, indicators are identified. These will make the question measurable for the analysis. Following the discussion on indicators, the procedure of the analysis is described in detail. Finally the results are presented.

6.1 Current state of access to transit in Chapel Hill and Carrboro

In order to ascertain the current state of access to transit, it is necessary to define how an accessible bus stop environment should look. For consistency, both the bus stop and its environment were surveyed when conducting a bus stop inventory.

6.1.1 Operationalization of the subquestion: Defining an accessible bus stop environment

Part of accessible transit is having accessible transportation facilities and an accessible pedestrian infrastructure adjacent to the transportation facilities. In order to identify the
current state of access to transit, the elements of an accessible transportation and pedestrian infrastructure need to be defined. The assumption is that several features of the pedestrian infrastructure, like sidewalks and crosswalks, along with stations, stops and vehicles, are involved in a complete trip from the origin to a final destination. All of these elements need to be equally accessible in order to form a complete chain. In the case that one of these elements is not readily usable by an individual with a disability, the chain is interrupted and access to transportation and the person’s destination is hindered.

In addition to the ADA minimum standards and guidelines two already existing checklists have been consulted in order to define an accessible bus stop environment. The first one is part of a comprehensive tool aiming on access to transit by closely analyzing the configuration and condition of a bus stop and the immediate pedestrian environment. It has been developed by Easter Seals, a non-profit organization focused on supporting the disabled. Easter Seals has a dedicated program for transit accessibility for individuals with disabilities called “Project ACTION”. This program is funded by the Federal Transit Administration (FTA) of the U.S. Department of Transportation. As stated on the Project ACTION website (projectaction.easterseals.com), the goal of the program is “to increase mobility for people with disabilities under the ADA and beyond”. The intention of Project ACTION is to follow the ADA guidelines and standards on one hand, securing access to transit for mobility impaired people; and on the other hand to provide a toolkit to create best practices of accessible design in order to increase quality of public transportation overall (cp. EASTER SEALS 2006a, p. 13).

The second checklist is an instrument that is specifically designed to audit the pedestrian infrastructure, developed by Kelly Clifton and Andréa Livi, University of Maryland, and Daniel A. Rodríguez, University of North Carolina (see Appendix B for the full audit).

Elements of these checklists have been selected to prepare an instrument intended to identify more than 40 characteristics of a bus stop and its pedestrian environment (see Appendix C). These characteristics have been aggregated into component groups in terms of the three objectives: accessibility, convenience and safety.

6.1.1.1 Accessibility

The accessibility component focuses on the availability and condition of sidewalks, crosswalks and stable surfaces at the bus stop, thus providing information about the status of accessibility to surrounding trip generators. Sidewalks, crosswalks and other stable surfaces linked to each other form a path that connects the bus stop with trip origins or destinations.
Without an appropriate adjacent pedestrian infrastructure the bus stop is not considered accessible in this study. To consider a bus stop fully accessible, the following five key elements need to be available and each one needs to be fully accessible for itself:

1. **The bus stop boarding and alighting area.**

   In order to be considered accessible the boarding and alighting area must be designed according to the ADA guidelines (cp. U.S. ACCESS BOARD 2004, p. 252f):
   - Area must be at least 5 feet x 8 feet,
   - The area’s surface must be stable made from: concrete, cobble stone or asphalt (see Figure 11),
   - Area may not be uneven or have a significant slope,
   - Area may not be obstructed (for example by encroaching trees or election campaign signs).

2. **Adjacent Sidewalk.** In order to be considered accessible a sidewalk must meet the following specifications (cp. EASTER SEALS 2006b, p. 5):
   - The sidewalk’s surface must be stable,
   - The sidewalk must be at least three feet wide for the use of a wheelchair,
   - The sidewalk must be at least in a fair condition with only minor root uplifting, cracks and breaks. Severe breaks and root uplifting on the sidewalk may be hazardous for pedestrians, especially for individuals with visual impairments and wheelchair users,
   - The capacity of the sidewalk may not be derogated by encroaching trees, bushes or temporary barriers such as waste bins and
   - The sidewalk may not be interrupted by a steep or graveled entrance way to a property (see Figure 12).
3. A **connection** consisting of stable material must be available **between the bus stop boarding/alighting area, the adjacent sidewalk and shelters or benches if available** (cp. U.S. ACCESS BOARD 2004, p. 252).

4. The **sidewalk must connect** to at least one of the bus stop’s **trip generators** (e.g. residential complex, grocery store) or to the **next street intersection** (cp. ibid, p. 23).

5. The **sidewalk must connect to an accessible crosswalk** (cp. EASTER SEALS 2006b, p. 5). A crosswalk is considered minimally accessible when:
   - The sidewalks on both sides of the streets or on all four corners of the intersection have curb cuts and
   - the crosswalk is visible on the street (e.g. through painting or signs, see Figure 13).

![Figure 13: Accessible Crosswalk](source: Own Picture)

**Figure 14: Key Elements of an accessible Bus Stop Environment**

Source: U.S. ACCESS BOARD 2004, p. 253, modified by author
In the case that all five key elements of an accessible bus stop described above are available and meet the specifications, an uninterrupted chain is provided for the transit user to get from the trip origin to the bus stop or from the bus stop to the final trip destination. Thus, the bus stop is considered fully accessible. If any of these elements are absent or not in the required condition, the transit user cannot conveniently reach or leave the bus stop. Consequently, the bus stop cannot be considered accessible.

6.1.1.2 Safety
The safety component reveals the safety and security level of a bus stop for the transit user in general and the user with mobility impairments in particular. Again, the complete chain between boarding or alighting the bus to and from the trip origin and destination is considered. Consequently, safety considerations at the bus stop like lighting and the availability of a phone or police call box as well as safety aspects of crosswalk amenities are taken into account (see Appendix D for full list of safety elements).

6.1.1.3 Convenience
Finally, the convenience component covers aspects that additionally disburden transit use for individuals with disabilities. The component includes availability of shelters, benches, trash cans and other amenities; existence and condition of signs, schedules, maps and real-time information; usability of shelters and information for individuals with different kinds of impairments and the cleanliness of the bus stop area (see Appendix D for full list of convenience elements).

6.1.2 Conducting the field work and processing the analysis: The bus stop inventory
Chapel Hill Transit operates 26 weekday bus routes, eight weekend routes and three (so called) “Safe-Ride” routes. These bus routes serve 636 bus stops within the Chapel Hill and Carrboro city limits, and eleven stops in Chatham County and Hillsborough, the latter of which have not been taken into account in this analysis. The 636 bus stops were surveyed within two months in Fall 2009. A paper-pencil instrument was used to record the observations (see Appendix C): One sheet to determine the standard elements of every bus stop and one sheet to record characteristics of bus stops with further amenities (shelters, benches, etc.). A picture was taken of each bus stop and the time and date of its inspection was recorded. The inspection of a single bus stop ranged from two to eight minutes. The fieldwork was conducted by bicycle, which required appropriate weather conditions and was carried out primarily in morning and evening hours. In order not to disturb operations, the
highly frequented bus stops in downtown Chapel Hill and Carrboro and on the university campus were inspected on Sundays.

The collected data was then processed in Microsoft Excel and SPSS. A bus stop rating was created based on a points rationing scheme (see Appendix D). Every bus stop was allocated a specific number of points for the number and quality of its amenities. Because this study mainly focuses on accessibility and usability for individuals with disabilities, the accessibility component is the decisive component in this rating: Accessibility aspects are weighted two and a half times higher than safety and convenience aspects.

**Accessibility Status:** Five points are awarded for the availability of each of the five key elements described above and are considered the foundation of an accessible bus stop. Additional to the availability of these elements in general, points are awarded if the key elements fully meet the specified requirements. In the case that all five key elements of an accessible bus stop are available and entirely meet the specifications, the maximum number of points is awarded, which totals 42. If one specification of a key element is not fulfilled, the number of points totals 39. In both cases, the bus stop is considered to have a “fully accessible” status. In case one or two of the key elements are completely missing or up to three specifications are not fulfilled, the point total ranges from 31 to 37. The bus stop is considered to have the status of “limited accessibility”. In the case that more than two of the key elements are not available or more than 3 specifications are not fulfilled, the bus stop is considered “not accessible” and the number of awarded points totals below 31.

**Safety and Convenience Status:** The Safety and Convenience Status is determined for every bus stop with full or limited accessibility. It is dependent on the equipment of the respective bus stops with elements like shelters, benches and lighting. The maximum number of points for safety and convenience totals 30. It is important to note that the Convenience and Safety Statuses depend on the Accessibility Status: For the bus stops in the respective category of accessibility, the average number of convenience and safety points is calculated. Thus, two categories of convenience and safety are formed: One category of bus stops with a status above average and one with a status below average in their respective accessibility categories. The Accessibility Status and the Convenience and Safety Statuses combine to form a rating ranging from 5 to 1.
Table 2: Accessibility, Convenience and Safety Status

<table>
<thead>
<tr>
<th>Accessibility Status</th>
<th>Accessibility Score</th>
<th>Convenience and Safety Status</th>
<th>Convenience and Safety Status (CCS)</th>
<th>Average CSS of this category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully accessible</td>
<td>39-42</td>
<td>Above average in this category</td>
<td>12 and higher</td>
<td>11.70</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Below average in this category</td>
<td>0-11</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Limited accessibility</td>
<td>31-37</td>
<td>Above average in this category</td>
<td>11 and higher</td>
<td>10.13</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Below average in this category</td>
<td>0-10</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Not accessible</td>
<td>below 31</td>
<td>Not determined</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

6.1.3 Results

6.1.3.1 Overall bus stop accessibility

The results of the bus stop inventory, following the criteria developed in this study, are shown in Figure 12. 24% of all bus stops are currently fully accessible in Chapel Hill and Carrboro. Less than half of the fully accessible bus stops (10% of total) have a Status of Convenience and Safety that is above average for bus stops in this category. These bus stops can be considered best practice examples. Accordingly, a slight majority of the bus stops in this category (13.4% of all bus stops) have a Convenience and Safety Status below average. Almost 40% of all bus stops are currently limitedly accessible, whereby up to two key elements of a fully accessible bus stop are not available. In this category, around one third of the bus stops (14.5% of the total) have a superior Convenience and Safety Status (measured in relation to the average in this category), and almost two third have a status below the average in this category (25% of all bus stops). 37.4% of all bus stops are currently inaccessible, which means that more than two key elements of a fully accessible bus stop are missing. The Convenience and safety Status has not been analyzed separately for these bus stops.

It is important to note here that in Chapel Hill and Carrboro only a few facilities exist for vision impaired persons. Only major bus stops and stations are announced by the Talking Bus system inside and outside the bus. Furthermore some bus stops are equipped with tactile warning pads at the boarding/alighting area. Only four crosswalks close to bus stops are

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Talking Bus® is an automatic voice announcement system installed on buses of Chapel Hill Transit. Bus stops and direction of the bus are announced inside and outside the bus.
equipped with audible pedestrian signals. Although these aspects were considered in the bus stop inventory, the focus of this study is not specifically on visually-impaired persons (see Chapter 8). Thus, even bus stops that are termed as “fully accessible” in this study may not be fully accessible for this group of individuals.

Looking at the spatial distribution of accessible and inaccessible bus stops, it becomes evident that in both downtown areas of Chapel Hill and Carrboro as well as on university campus the bus stops are mostly well equipped. In residential areas, also in those areas close to downtown Chapel Hill, many inaccessible bus stops exist. For an overview of all bus stops in Chapel Hill and Carrboro see Appendix F.

6.1.3.2 Analysis of dominant inadequacies of bus stops

As shown in Figure 14, of the most pervasive accessibility issue for bus stops are problems with the boarding and alighting area. These problems affect almost three quarters of all bus stops and mainly arise from three circumstances. The first is the surface of the area. Half of the problems related to the boarding and alighting area are caused by inappropriate surfaces such as grass, gravel or dirt (see Figure 16). These surfaces are not adequate for the use of wheelchairs and should be replaced by concrete slabs or cobble stones. The second problem is the size of the area. Many boarding and alighting areas do not have the appropriate dimension.
of 5x8 feet. The third problem is in most cases related to topographical conditions. The boarding area slopes up or down, e.g. the area is in a ditch.

The second-most occurring inadequacy is the lack of appropriate pedestrian crossings. Close to 70% of all bus stops have no accessible pedestrian crossing or crossing amenities nearby.

Another prevailing issue is a set of problems related to sidewalks. 45% of all bus stops have inadequate pedestrian facilities or a complete lack of sidewalks. Almost one third of all bus stops are not connected to a sidewalk. This fact accounts for two thirds of all sidewalk related problems. The remaining third of these sidewalk problems regard sidewalks that are not readily usable by individuals with disabilities. These difficulties affect 21% of the 440 existing sidewalks and are described in detail as follows:

- The minimum width of the sidewalk is less than 3 feet (18 cases),
- The sidewalk does not connect to the boarding/alighting area (19 cases),
- The sidewalk is in hazardous condition (12 cases),
- Other sidewalk related problem, e.g. gravel on sidewalk originating from access roads to properties (42 cases).

![Figure 16: Inaccessible Boarding/Alighting Area. Source: Own Picture](image)

![Figure 17: Prevailing Inadequacies of Bus Stops](image)
6.2 Current potential to attract paratransit users to fixed-route services

In this chapter the current potential to attract paratransit users to fixed-route services will be identified. The subquestion is operationalized by determining each user’s level of access to transit, called “Accessibility Levels” in this study. Then the procedure of the analysis in ArcGIS is described and the results are presented.

6.2.1 Operationalization of the subquestion: Accessibility Levels

After the current state of accessibility to transit has been determined, the current potential to attract paratransit users to fixed-route transit needs to be identified. Paratransit users who may potentially become attracted to fixed-route transit are determined via Accessibility Levels, based on the following criteria:

- Availability of a fully accessible bus stop in vicinity of the paratransit user’s residence,
- Availability of paved driveways and sidewalks,
- Distance from the paratransit user’s residence to a fully accessible bus stop along the network of paved driveways and sidewalks.

Thereupon three Accessibility Levels are determined. Every paratransit user is assigned to one of these levels, which provide information about the current degree of potentiality that the paratransit user becomes attracted to fixed-route transit. These levels are defined as follows:

1. **Level 1 Accessibility: Paratransit users whose residence is not within ¼ mile linear distance of any bus stop**, whether accessible or not (see Figure 18). Considering the current configuration of the fixed-route bus network there is no potential to attract these paratransit users to fixed-route transit. Even in the case that an accessible pedestrian infrastructure in the vicinity of the paratransit user’s residence exists, the actual walking distance along the sidewalk

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19 The attraction of paratransit users is labeled as “potential”, because on order to attract paratransit users to fixed route services (a) a combination of different practices presented in Chapter 4.4. needs to be applied and (b) this analysis excludes several factors which have influence on transportation for individuals with disabilities (see Chapter 9.)
network remains prohibitive at ¼ mile or longer. Consequently the residence is not within transit coverage. In order to have these users within the coverage area the bus routes of the current fixed-route network need to be enhanced or modified. However, the configuration of the current bus route network is not in the focus of this study and recommendations for alteration will not be proposed. Accordingly, paratransit users with this Accessibility Level will be excluded from the further analysis.

(2) Level 2 Accessibility: Paratransit users who have their residence within a ¼ mile linear distance of a bus stop and also within a ¼ mile actual walking distance from a fully accessible bus stop (see Figure 19).

A sidewalk or other stable path is provided along the entirety of the route from the residence to the bus stop and vice versa. A paved driveway or other stable path connects the residential building with the sidewalk. When all of these prerequisites are met, these paratransit users have full accessibility to fixed-route transit.

As defined in Chapter 6.1.1 an appropriate sidewalk is considered a requirement to establish access to transit. Right-of-way that is dedicated to motorized traffic is strictly not considered for the use by pedestrians even in the case that the street is little travelled on by motorized vehicles. Several circumstances might imply a danger for pedestrians: Speed of vehicles, complex topographical settings, shading, etc. The assumption that these circumstances might bear a danger applies to individuals with disabilities to an even larger extent. The only exceptions from this assumption are paved driveways and parking lots. Unpaved driveways may not have a stable surface and therefore may not be usable by persons with disabilities, especially wheelchair users.

Figure 19: Level 2 Accessibility

20 ¼ or a ½ mile are the walking distances frequently applied, especially in Transit Oriented Development (TOD) projects (cp. Cervero et al. 2004, p. 140). The ¼ mile distance is applied here, although for users with different kinds of physical or mental impairments an even shorter distance could be applied.

21 Unpaved driveways may not have a stable surface and therefore may not be usable by persons with disabilities, especially wheelchair users.
One has to bear in mind that a fully accessible bus stop might not be the closest stop to the user’s residence. There might be a closer bus stop that is not fully accessible. In order to determine the current potential to attract paratransit users to fixed-route buses only the fully accessible bus stops are taken into account. Limitedly accessible and inaccessible bus stops situated closer to the user’s residence are addressed when identifying recommendations for improvement.

(3) **Level 3 Accessibility:** Paratransit users whose residences are within a $\frac{1}{4}$ mile linear distance of a bus stop, thus are within the transit coverage. Nevertheless these users have currently no access to fixed-route transit. This is the case if one of the following circumstances applies (see Figure 20):

- The individual’s residence has no connection to the sidewalk system, which includes the case that the only connection is an unpaved parking lot or driveway.
- There is no sidewalk at all or no continuous sidewalk leading to any bus stop.
- There is a bus stop within a $\frac{1}{4}$ mile walking distance, but this bus stop is inaccessible or only limitedly accessible.
- A continuous path from the user’s residence to a fully accessible bus stop does exist and vice versa, but the walking distance is more than $\frac{1}{4}$ mile, whereas the stop within $\frac{1}{4}$ of a mile does not feature a continuous path to the user’s residence.

The potential to attract paratransit users whose access to bus stops falls into Level 3 Accessibility is currently limited.

**The group of users with Level 3 Accessibility is the group this study actually focuses on.** Through bus stop improvements and/or improvements in the pedestrian infrastructure the Accessibility Level of users in this group could switch to Level 2 Accessibility and consequently the potential to attract these users to fixed-route transit would increase significantly. Hence the final goal of this analysis is to suggest improvements in order to increase the percentage of paratransit users with Level 2 Accessibility.
6.2.2 Processing the analysis: Network Analysis in ArcGIS.

In order to identify the Accessibility Levels of paratransit users a Network Analysis is conducted using ArcGIS Network Analyst extension. This analysis is described here and is also graphically represented in Appendix E.

The analysis makes use of the following available data:

- Sidewalk inventory of Chapel Hill and Carrboro conducted by the respective municipalities, available as shape files,
- Inventory of all paved driveways and parking lots in Chapel Hill and Carrboro,
- The Chapel Hill Transit fixed-route bus network including all bus routes and stops,
- Current street network of Chapel Hill and Carrboro,
- All postal addresses in Carrboro and Chapel Hill as Address Points in geographic coordinates,
- Residential addresses of all currently subscribed paratransit users. These addresses are geo-coded but are not available as Address Points.

The bus stop rating from the inventory is joined to the attribute table of the bus stop layer via the bus stop ID. The paratransit users’ addresses are joined to the Address Points.

First step in the analysis is the conversion of all polygon features into line features – driveways, parking lots and sidewalks shape files of Chapel Hill. This conversion is due to requirements of the network analysis: the network creating process requires line features. After this conversion, the features are screened for topology errors (dangles, overlaps, pseudonodes) and the network consisting of paved driveways, paved parking lots and sidewalks is created and built. On this network the shortest path from every paratransit user’s residence to the closest bus stop is identified using the Network Analyst. The “Closest Facility” tool is the most suitable to solve this problem: The residences of the paratransit users are determined as “incidents” and the bus stops as “facilities”. In the first run of the analysis every bus stop is a “facility” without consideration of accessibility and rating of the bus stop.

Before running the actual network analysis, paratransit users who have no bus stop within a ¼ mile radius of their home are identified using the Proximity Analyst and assigned the group of users with Level 1 Accessibility.

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22 This ID was assigned to every bus stop on the system by Chapel Hill Transit.
Next, the network analysis is executed which delivers the following intermediate results: (1) The residences that are connected to a stop by an accessible route and those that are not, and (2) if the home is connected to a sidewalk, the routes and distances of each paratransit user’s residence to nearest the bus stop is calculated. Based on these first results two further steps are undertaken:

The attributes table of “routes” is joined to the table of “incidents” via the Incident ID and the Object ID. By selecting the “incidents” without a route to a bus stop, the paratransit users who do not have access to a bus stop are determined. These paratransit users are part of the group with Level 3 Accessibility. Then, from the attribute table of “routes” the routes are selected which lead to a bus stop with Accessibility Status “fully accessible” (Rating 4 or 5). Furthermore, from this selection, the routes that are shorter than ¼ mile are selected. This step delivers one part of users with Level 2 Accessibility. The remaining users with a route longer than ¼ mile to the closest bus stop are users with Level 3 Accessibility.

Although their closest bus stop is fully accessible, these paratransit users are not within the current transit coverage. Without changing the current configuration of the bus network these users will not gain access to fixed-route transit. Consequently, these users are not in the focus of this study and will not be considered in the subsequent analysis. The next step based on the network analysis is to deal with the paratransit users whose closest bus stop has the Accessibility Status “limited accessibility” or “not accessible” (Rating 1, 2 or 3). Although, for these users, the closest bus stop is not accessible, they might have a fully accessible bus stop in their vicinity, which is just slightly farther away than the closest. In order to identify these users with an “alternative route”, first the routes which lead to a bus stop with the Rating 1, 2 or 3 are selected from the attribute table of “routes”. This selection identifies the users whose closest bus stop is limitedly accessible or inaccessible. These users are embraced in the second network analysis: They serve as input for the Closest Facility layer “incidents”. As “facilities” serve only the fully accessible bus stops with Rating 4 and 5 this time,23 the result is the output of alternative routes, which do not lead to the closest bus stop but to an accessible one.

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23 It is essential for the subsequent analysis steps that the Incident ID and the Facility ID of the second network analysis correspond to the Incident ID and Facility ID of the first network analysis, otherwise the attribute tables cannot be successfully joined.
The subsequent analysis steps are the following:

(1) It is possible that paratransit users have no alternative route due to discontinuities in the sidewalk system. This part of users needs to be identified. In order to do this, the table of “routes” from the first network analysis is joined to the table of the resulting routes of the second network analysis. Consequently, in this table, every paratransit user is assigned to one route which leads to a not sufficiently accessible bus stop and to an alternative route if available. The users without alternative routes are selected. They are part of the group of Level 3 Accessibility users. In these cases the original route to an inaccessible or not fully accessible bus stop is considered again: the routes with distances up to ¼ mile are selected. The corresponding users will be in the focus of the further bus stop improvement recommendations. The users with routes longer than ¼ mile will not be considered anymore.24

(2) The attribute table of “routes” from the second network analysis is used to determine those paratransit users who have an alternative route less than ¼ mile to a fully accessible bus stop by selecting these routes. The second run of the network analysis indicates that although the accessible bus stop is not the closest one, these users currently have full access to fixed-route transit and are the second group of users with Level 2 Accessibility.

In order to identify users with inadequate alternative access, the “routes” longer than ¼ mile are selected. The check for an alternative access to fixed-route transit has not been successful for them. Thus, in order to improve access to transit for these users the only way is to improve the bus stops which are closest to the users’ residences. Therefore, the original routes to the bus stops with Rating 1, 2 or 3 are considered again – as it was done before – and the walking distance of ¼ mile is finally applied. The procedure is the following: The attribute table of “routes” from the first network analysis is joined to the selected alternative routes with distances longer than ¼ mile from the second network analysis via the “Incident ID”. The result is that every alternative route longer than ¼ mile is assigned to its original shorter route to an

24 The original routes, which are longer than ¼ mile, could have already been excluded before determining alternative routes. Nevertheless, the walking distance is addressed at the end of this and the following step in order to apply different walking distances. In doing so, it can be tested whether and to what extent the results are sensitive to different walking distances (see Chapter 7.5).
inaccessible bus stop. Eventually those original routes are selected – and the corresponding paratransit users with it – which are shorter than ¼ mile. These users are part of the Level 3 Accessibility group and will be part of the further bus stop improvement analysis. As before, the users with routes longer than ¼ mile will not be in the further focus of this research.

The analysis in ArcGIS is completed with the output of all relevant attribute tables as dbf-files. The further analysis will be conducted in SPSS.

### 6.2.3 Results

1789 of 2351 addresses of paratransit users within the city limits of Chapel Hill and Carrboro could be correctly identified. The remaining addresses where either outside the Chapel Hill and Carrboro limits – thus in unincorporated parts of Orange County – or were erroneous.

#### Level 1 Accessibility:

**245 users (14% of total) are not within a ¼ mile radius of fixed-route transit,** thus are considered not within transit coverage. With the current configuration of the fixed-route system, the current walking distance to a bus stop is too long – especially taking a physical or mental impairment into account. These users will continue to rely on special services like paratransit or feeder buses.

Accordingly 1544 paratransit users (86% of total) are covered by fixed-route transit.

#### Level 2 Accessibility:

**228 users (12.7% of total) currently have full access to fixed-route transit.** These users can be further specified:

- For 201 users the closest bus stop in vicinity of their residence is a fully accessible one, but only **for 117 users the route to the closest bus stop is shorter than ¼ mile.**
- Of those users whose closest bus stop is an inaccessible one, 429 have access to a fully accessible bus stop via alternative routes. But only **111 users have an alternative route shorter than a ¼ mile.**

#### Level 3 Accessibility:

**1316 paratransit users (74% of total) have currently Level 3 Accessibility,** thus have no access to fixed route transit. This group of users can be further specified:

- 759 users (42% of total) do not have a route to a bus stop due to problems in the pedestrian infrastructure.
For 84 users (4.7% of total) the closest bus stop is a fully accessible one, but the route to and from the residence to the bus stop is longer than ¼ mile.

584 users’ closest bus stop is an inaccessible one. Of these, 155 users (8.66% of total) have no alternative route to a fully accessible bus stop.

Of those 429 users with an alternative route, 318 have an alternative route longer than ¼ mile (17.77%).

The improvement recommendations focused on in the next chapter concentrate on 1138 of the 1316 users with Level 3 Accessibility:

- All 759 users with problems in the pedestrians infrastructure need sidewalk additions or improvements,
- Users who need improvement to the inaccessible bus stops to gain access to the fixed-route system. The focus is on 379 users which meet all three of the following criteria:
  - The closest bus stop is not accessible,
  - User has no adequate alternative route to an accessible bus stop,
  - The route to the closest (but not accessible) stop is shorter than ¼ mile.

178 users who do not meet these criteria are excluded from the further bus stop improvement analysis.

<table>
<thead>
<tr>
<th>Number of users with Level 3 Accessibility</th>
<th>Accessibility problem</th>
<th>Improvement Recommendation</th>
<th>No improvement Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>759 users (42% )</td>
<td>Absent or inadequate pedestrian infrastructure</td>
<td>Sidewalk improvements for all 759 users</td>
<td></td>
</tr>
<tr>
<td>84 users (4.7% of total)</td>
<td>Route to accessible bus stop longer than ¼ mile</td>
<td>All 84 users</td>
<td></td>
</tr>
<tr>
<td>155 users (8.66%)</td>
<td>Closest bus stop not accessible and no alternative route</td>
<td>Bus stop improvements for 139 users whose route to closest inaccessible bus stop is shorter than ¼ mile</td>
<td>16 users whose route to closest not accessible bus stop is longer than ¼ mile</td>
</tr>
<tr>
<td>318 users (17.77%)</td>
<td>Closest bus stop not accessible and alternative route longer than ¼ mile</td>
<td>Bus stop improvements for 240 users whose route to closest inaccessible bus stop is shorter than ¼ mile</td>
<td>78 users whose route to closest not accessible bus stop is longer than ¼ mile</td>
</tr>
<tr>
<td>1316 users</td>
<td>1138 users</td>
<td>178 users</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Users with Level 3 Accessibility
6.3 Improvement recommendations

In this chapter bus stop improvements are recommended. First, the subquestion is operationalized via “Target Groups”. Then the analysis is processed in SPSS. At the end of this chapter the bus stops are presented for which improvements are recommended.

6.3.1 Operationalization of subquestion: Target Groups

As already addressed in Chapter 6.2.1, the users with Level 3 Accessibility are the users who need improvements of the transportation and pedestrian infrastructure to gain access to transit.

In order to determine what kind of improvement needs to be applied, these users with Level 3 Accessibility are divided into two “Target Groups”:

(1) Target Group TG1:

This Target Group embraces **paratransit users with Level 3 Accessibility whose residences are connected to the pedestrian infrastructure but none of the stops in walking distance is accessible**. To attract these users to fixed-route bus services, recommendations for improvement need to concentrate on the bus stop environment. In order to identify the bus stops that need improvement a shift of perspective is necessary: Instead of focusing on the paratransit users’ residences, the bus stops that are currently inaccessible or only provide limited access are now in the focus. For every bus stop with this status those paratransit users will be identified and counted who reside within a ¼ mile walking distance of this bus stop. Eventually a ranking of bus stops will evolve from this procedure. The ranking is according to the number of paratransit users dwelling in proximity to the corresponding bus stop. This ranking herewith reveals the bus stop improvement priority: The bus stop with the most users residing within a ¼ mile should be improved first. In order to specifically focus on the most urgent improvements, only the bus stops with five and more residences nearby are taken into consideration for the improvement recommendations.

The improvement focus on bus stops with several users in the vicinity is a cost and feasibility consideration. Ideally every single bus stop, which is not yet readily accessible, should be made usable for individuals with disabilities. But such major capital investment is not feasible, and also not yet required by the ADA. Consequently, the limited funds available must be exerted deliberately in locations and geographical areas where a high number of paratransit users can be addressed in order
to most effectively and cost efficiently enhance overall accessibility to the bus system and increase the potential to attract paratransit users to fixed-route transit.

(2) Target Group TG2:

This Target Group embraces paratransit users with Level 3 Accessibility whose residences are currently not connected to the sidewalk infrastructure. Although these users might have a bus stop located in their vicinity, they have no access to the bus stop due to the lack of a continuous sidewalk. Consequently, in order to attract these users to fixed-route services, suggestions for improvements need to focus on the pedestrian infrastructure.

There are many different approaches how to assess sidewalk enhancements and improvements from the perspective of transit accessibility. One might look on paratransit users who reside in immediate proximity to bus stops but are not connected to the sidewalk system. These users could have access to transit if only little sidewalk extensions were realized.

It is also possible to have a closer look on specific spatial units. The downtown areas of Chapel Hill and Carrboro as well the university campus are relatively well equipped with wide and appealing sidewalks. In residential neighbourhoods which were designed according to New Urbanism principles like Meadowmont and Southern Village, also much consideration has been given to pedestrian needs. Barriers to pedestrian activity are more likely encountered at commercial centres designed for access by car. And despite the recent sidewalk improvements in both towns there are still many neighbourhoods and apartment complexes in Chapel Hill and Carrboro that completely lack sidewalks, impeding safe access to transit for individuals with disabilities and for all people.

It is difficult to operationalize the question how and where sidewalk extensions and upgrades are not only necessary but also feasible. Improvement of the pedestrian infrastructure cannot only be addressed from the perspective of transit accessibility, but must embrace a variety of different needs and urgencies. These cannot be discussed within the limited framework of this paper, thus specific sidewalk improvement recommendations are not presented in this study.

6.3.2 Processing the Analysis in SPSS

The process of determining the users who need bus stop improvements has already been described and conducted in Chapter 6.2.2. The next step is to identify those inaccessible and
limitedly accessible bus stops with five or more paratransit users within ¼ mile walking distance. For this purpose the users with Level 3 Accessibility who have not been excluded yet and their corresponding routes are processed in SPSS. The attribute table exported from ArcGIS shows the Facility ID of the bus stops with the Rating 1, 2 and 3. A frequency analysis of the Facility IDs is performed. The result is that the Facility IDs of the bus stops with five or more paratransit users’ residences within walking distance of a ¼ mile are displayed. The Facility ID of each bus stop can easily be translated into the original Bus Stop ID. The bus stop with the highest number of paratransit users in its vicinity is the bus stop on top of the priority list.

6.3.3 Results

The Network Analysis conducted in Chapter 6.2.2 reveals that there are 379 paratransit users (21% of all users) with Level 3 Accessibility who have not yet access to fixed-route transit, but could gain access through bus stop improvements. As defined above these users are represented in Target Group 1 and therewith are in the focus of improvement recommendations. Now those currently inaccessible bus stops are identified which have five or more paratransit users of TG 1 living in its vicinity. The result is that **29 bus stops have five or more users living within a ¼ mile walking distance.** By improving all of the 29 recommended bus stops, a total of **265 paratransit users within walking distance of these bus stops gain access to fixed-route transit, which is 70% of all users in Target Group 1 that could gain access to transit. This increases the percentage of those with full access by 15%, and thus doubles the number of users with full access.**

This result seems rather remarkable at first. But having a look at the spatial distribution of these 29 bus stops, it is not surprising that some of the stops are next to elderly homes or large housing complexes where a considerable number of paratransit users reside in relatively high spatial concentration. In one of these cases 32 users reside within walking distance of one bus stop, followed by several stops with 10-20 users in the catchment area.

The fact that these users did not yet have adequate access to fixed route transit might be traced back to a circumstance that has been alluded briefly before: Particularly some of the older apartment complexes in Chapel Hill and Carrboro are intentionally designed for the access by car. Although many of these complexes have been modernized, they sometimes continue to lack of contemporary facilities to accommodate pedestrians and transit. It is apparent at this point that these bus stops in close vicinity to apartment complexes are the ones which most
urgently need an upgrade. At the same time these upgrades are most effective in regard to the aspired attraction of paratransit users to fixed route transit.

Taking a closer look at the deficiencies of these bus stops, 28 of the 29 bus stops have limited accessibility, half with a superior Convenience and Safety Status (Rating 3) and half with a status below average (Rating 2). Only one bus stop is inaccessible.

Due to the fact that (almost) all of these 29 bus stops are limitedly accessible, there are either one or two key elements of a fully accessible bus stop not available. At 27 of 29 bus stops insufficiencies regarding the crossing facilities for pedestrians exist. At 22 of these 27 bus stops the amenities are not sufficient to be considered accessible because of the following reasons: curb cuts only exist on one side of the street or on two corners of the intersection (5 cases), only curb cuts are available (8), only curb cuts and tactile warning pads are available (2), and curb cut is only at one side of the street and traffic signal available (1). In the remaining 5 cases no amenities exist at all.

At 19 of these bus stops – solely or additionally to the pedestrian crossing issues – problems with the boarding and alighting area exist: 18 areas are uneven due to the partial coverage with grass and one area is sloping up. Five of the bus stops have sidewalk-related deficiencies. Summarizing the analyzed deficiencies it turns out that it takes only minor improvements to make the identified bus stops fully accessible for individuals with disabilities. In most cases accessible pedestrian crossings need to be implemented along with stable boarding and alighting areas at bus stops. This seems very feasible considering the positive effect for many individuals with disabilities potentially intending to use fixed route transit at these bus stops.

The remaining 6% of bus stops need further, more extensive improvement.

7 Summary of results

In this chapter the results of the three subquestions will be summarized and visualized. Furthermore, in order to assess the impact of the walking distance on the analysis, the sensitivity of this parameter will be tested using a 1/8 mile walking distance. The conclusion

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25 See Chapter 6.1.1: As an “accessible crosswalk” is considered a crosswalk with the following minimum requirements: curb cuts on both sides of the street or on all corners respectively and a visible crosswalk.
addresses the need to better coordinate all services provided by an agency and to further integrate special transportation into traditional fixed-route services.

**Bus Stop Accessibility:**

Applying the criteria developed in this study only one quarter of all bus stops is currently fully accessible, whereas more than one third is inaccessible. The absence of adequate pedestrian crossings at more than two thirds and the non-availability of sidewalks at almost one third of all bus stops discourage all individuals, but particularly those who are disabled because of different kinds of physical and mental impairments, from using public transportation.

**Current potential to attract paratransit users to fixed-route transit:**

Figure 23 shows the potential as it is today: 86% of all paratransit users are within transit coverage, 13% have Level 2 Accessibility and full access to transit and 73% have Level 3 Accessibility, thus currently no access to transit. 14% of users are not within coverage, thus have Level 1 Accessibility and are not in the focus of this analysis.

**Improvement Recommendations:**

Recommendations for improvement are related to those users who are in the group with Level 3 Accessibility. These recommendations include sidewalk improvements for users in Target Group 2 (42% of total) and improvements of the bus stop environment for users in Target Group 1 (21% of total, see Figure 24). For 10% of users in Target Group 1 access cannot be achieved either through bus stop or sidewalk improvements. The potential to attract these users to fixed-route transit cannot be increased under the current route configuration of the fixed-route bus system.
Result after improvement of 29 bus stops:

After the improvement of 29 bus stops a total of 28% of all paratransit users have access to transit, which doubles the number of user who potentially can be attracted to fixed-route services (see Figure 25). Six percent of users could gain access through further bus stop improvements.

Recommendations for those users who need sidewalk improvements have not been given in this study, further research is required.

Sensitivity of the results for different walking distances:

In this research the walking distance of a ¼ mile is applied, which decides whether an individual with disability has access to fixed-route transit or not. Although this parameter is typically used to assess the catchment area of transit, it is highly debatable whether it can be applied to individuals with physical impairments. Therefore the network analysis has been processed to that effect that the walking distance acts as a variable. Thus, in this particular case, the walking distance of a ¼ mile can be substituted by a different parameter, for instance an 1/8 mile.

Applying the 1/8 mile distance instead of a ¼ mile, the results change significantly: Only 4% of paratransit users have currently full access to fixed-route transit instead of 13%. 23% of users are within transit coverage but do not have a chance to get access to transit (compared to 10%). Together with the 14% not within transit coverage (which have not changed), 37% of all users have no access to fixed route transit (see Figure 26). 17% of paratransit users could gain access through bus stops improvements compared to 21% applying a ¼ mile. It might be surprising that this percentage does not significantly change. But it is a consequence of the fact that the group of users, who have no alternative route to a fully accessible bus stop, grows when the critical walking distance is 1/8 mile and partially compensates the users who cannot get access to transit now, because their walking distance is longer than 1/8 mile.

![Figure 24: Future Potential to attract paratransit users: After improvement of 29 Bus Stops. Source: Own figure.](image)
The subsequent analysis discloses that only 16 bus stops have five or more paratransit users living in walking distance of 1/8 mile compared to 29. By improving these bus stops, 184 of 304 users in Target Group 1 could gain access to fixed-route transit, this is 10% of all users. Together with the 4% who had access before the improvements, 14% of all paratransit would finally have access to fixed route transit.

8 Conclusion

Chapel Hill Transit as well as the town administrations of Chapel Hill and Carrboro have undertaken serious efforts to improve access to transit by upgrading bus stops and improving the pedestrian infrastructure. Local authorities are about to continue this process: In 2010 several pedestrian islands have been implemented on Martin Luther King Jr. Boulevard, formerly a hazardous barrier for every individual – whether impaired or not – trying to cross the street.

Nevertheless, this study has proved that there is still a lot to do. The current potential to attract paratransit users to fixed route services is very low, only a small percentage of 13% has full

Figure 25: Future Potential to attract paratransit users: After improvement of 16 Bus Stops and 1/8 mile walking distance applied. Source: Own figure.

Figure 26: Martin Luther King Jr. Boulevard near Chapel Hill Town Hall in 2009. In 2010, four Pedestrian Crosswalks and Refuge Islands were installed on this street. Source: Own picture.
access to it. Furthermore, this percentage can be assessed considerably lower, considering that the appliance of the ¼ mile walking distance is highly debatable and probably needs to be replaced by a shorter distance. This analysis has successfully demonstrated that – beside the condition of bus stops – the lack of sidewalks is crucial.

On the other hand, fairly little effort is needed to significantly increase the potential to attract paratransit users in the future. By improving only 29 of the bus stops – often in the vicinity of homes for the elderly or apartment complexes – the number of paratransit users who currently have access to fixed-route transit would double. Contrary to this, the improvement of the sidewalk infrastructure is much more complicated and depends on many different parameters. The figures indicate that a quarter of all paratransit users do not have access to fixed-route transit even after improvements have been undertaken. Almost half of all users are depended on substantial further improvements of the pedestrian and transportation infrastructure. Without drastic modification and extension of the current fixed-route transit system these users will not have access to fixed-route transit in the future. They continue to rely on special services like paratransit. Consequently the aspiration of attracting paratransit users to fixed-route transit only affects a small part of the disabled community and thus can only diminish the use of paratransit, but cannot replace paratransit itself.

In order to effectively provide adequate transit services for users in remote areas, paratransit services should be integrated into and coordinated with fixed-route transit. The most promising forms of integrated services are feeder buses, which have been recently highlighted by the Transportation Research Board. Cities all over the U.S. have installed feeder buses to complement their fixed-route services (cp. KOFFMANN ET AL. 2004a, p. 5f; WEINER 2008, p. 7). So did Chapel Hill Transit where this service is open to all users and provides transportation services to and from neighborhoods with poor access to fixed-route transit. Some agencies even offer feeder services that pick up and release the passenger at the curb in front of their house. This is especially suitable for disabled users who actually could use transit without further assistance but are prevented in doing so by inaccessible sidewalks and bus stops.

9 Review of methodology and further concerns

The method used can be considered successful to assess accessibility of paratransit users in Chapel Hill and Carrboro. The key difficulties encountered in this process are described here.
Analysis in ArcGIS

The network analysis as the crucial part of this study could be successfully conducted using the data collected in the bus stop inventory and supplied by Chapel Hill Transit. Nevertheless, several difficulties entailed the analysis to be complex and time-consuming:

- Assigning of provided addresses to Address Points in order to determine the exact location of the paratransit users’ residences.
- Two separated infrastructure data sets (streets, sidewalks etc.) for Chapel Hill and Carrboro with varying accuracy. Also different feature geometries of the same object caused problems: In case of the sidewalk data, Carrboro sidewalks where provided as line feature class and Chapel Hill sidewalks as polygon feature class.

Although the method is applicable for this kind of research question, the approach turned out to have several weaknesses:

- No differentiation between the paratransit users’ impairments in this analysis. This aspect should be considered in order to provide adequate facilities for users with all kinds of impairments.
- The bus stop inventory mainly focuses on the needs of people with physical impairments, because not many facilities for visually impaired individuals do exist (exceptions are the Talking Bus, tactile warning pads and audible crossing signals).
- No consideration of paratransit users’ trip purposes and trip destinations.
- Frequencies and headways of fixed-route bus service at bus stops have not been taken into account.
- The fact that many transit trips need a transfer, in case of Chapel Hill and Carrboro to another bus line of CHT or another agency, has not been considered adequately.
- No considerations of topographical conditions have been taken into account, which is an important factor in Chapel Hill and Carrboro.
- No analysis of cooperation and communication processes between different stakeholders involved in the matter (e.g. disability organizations, the different transit agencies and the town administrations).

In conclusion it can be stated that this analysis followed a highly generalized approach, which selected a few key variables to determine the overall system’s Level of Accessibility. The limitations listed above, indicate why this broad study cannot pinpoint the precise impact of the improvements. However, this study has successfully identified where route impediments are concentrated and how many people would be impacted by infrastructure improvements.
10 Outlook: Towards more attractive public transportation

Although this analysis specifically focuses on the improvement of transit for individuals with disabilities and elderly persons, these improvements should be considered as investment in the future of transit in general.

A more positive perception of transit could be created by realizing improvements that address a wide spectrum of the population regardless of disability and age. Barrier-free pedestrian infrastructure with wide and intact sidewalks, audible pedestrian signals at crosswalks and sidewalk lighting makes walking attractive to everyone; Similarly, accessible transportation facilities, equipped with elements like shelters, benches, police call boxes, schedules and/or real time information etc. enhance safety and convenience and increase the overall quality of transit services. This is especially the case for users who are temporarily impaired due to injuries or diseases. Also persons who carry heavy baggage or groceries or travel with small children and strollers etc. can be considered “temporarily impaired”.

However, it is not the scope of the ADA to make transit an attractive option for all possible users of transit. Rather, it is a civil rights law which secures the basic needs for individuals with disabilities. In order to address the future development of transit in the U.S., the aim should be to create best practices and not minimum requirements. Thus the improvement efforts need to go beyond the ADA. On the one hand aspects of urban form and land use, mobility behavior and lifestyles, amongst many others, need to be integrated in improvement considerations. On the other hand a more inclusive design approach is necessary, an approach that “is intended to create environments that are more usable by all people, including people with disabilities” (EASTER SEALS 2006a, p. 13).

Universal Design is such an approach, which combines many different perspectives of design (“accessible design”, ”barrier-free design”, “inclusive design” etc.) and forms a new school of thought. “Universal Design is a philosophy that […] professes to be a broader paradigm of design that celebrates diversity and is inclusive of all users regardless of age or ability” (AUDIRAC 2008, p. 4). This new paradigm not only gives consideration to the growing number of disabled individuals but also to the aging of society. “The universal design concept considers those changes that are experienced by everyone as they grow from infancy to old age” (THE CENTER FOR UNIVERSAL DESIGN 2000, p. 4). Consequently, Universal Design does not address a specific group of vulnerable population like the ADA does, but places disability, aging and temporary impairment “within the context of normal expectations of the human condition” (ibid.).
Although it is evident that accessible transit benefits to all transit users, including those who are facing temporary impairments, the Universal Design perspective is not yet broadly adopted. Since the implementation of the ADA, the need of accessible public transportation was always related to specific population groups such as the elderly and disabled. Consequently, when pedestrian and transportation infrastructure are remodeled or constructed in the future, the entirety of transit users should be addressed to the maximum extent possible. Improving the pedestrian infrastructure and transportation facilities under the Universal Design perspective is a long-term investment contributing to a promising future of transit in the U.S. Thus, the purpose of making public rights-of-way and fixed-route transit fully accessible should be supported by adequate funding. This most likely would solve many of the problems transit agencies as well as individuals with disabilities are currently facing.
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Appendices

Appendix A: Paratransit Statistics 1984-2008

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P = Preliminary.
(a) Data not continuous for data noted, see Methodology, Page iv.
See Glossary following Tables for complete definitions.

Table 4: Paratransit Statistics 1984-2008 (Source: APTA 2010b, p. 63)
Appendix B: Pedestrian Environment Data Scan (PEDS) Tool

![PEDS Table]

**Figure 27:** Pedestrian Environment Data Scan (PEDS) Tool. Source: Clifton et al. (2004)
## Appendix C: Instrument of the Bus Stop Inventory

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Table 5: Instrument of the Bus stop Inventory, Part 1: Common features of a bus stop
<table>
<thead>
<tr>
<th><strong>Bus Stop No.</strong></th>
<th></th>
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<tbody>
<tr>
<td>C25a shelter</td>
<td>Orientation shelter</td>
</tr>
<tr>
<td>C25b</td>
<td>Shelter belongs to?</td>
</tr>
<tr>
<td>C25c</td>
<td>Width</td>
</tr>
<tr>
<td>C25d</td>
<td>Height</td>
</tr>
<tr>
<td>C25e</td>
<td>Depth</td>
</tr>
<tr>
<td>C25f</td>
<td>Wheelchair maneuver?</td>
</tr>
<tr>
<td>C25g</td>
<td>Wheelchair fit?</td>
</tr>
<tr>
<td>C25h</td>
<td>Distance shelter-curb?</td>
</tr>
<tr>
<td>C25i</td>
<td>Damages shelter</td>
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<tr>
<td>C25j</td>
<td>Condition shelter</td>
</tr>
<tr>
<td>C26a seating</td>
<td>Type of seating?</td>
</tr>
<tr>
<td>C26b</td>
<td>Problems seating?</td>
</tr>
<tr>
<td>C26c</td>
<td>Condition seating</td>
</tr>
<tr>
<td>C27a Trash</td>
<td>Type of installation</td>
</tr>
<tr>
<td>C27b</td>
<td>Trash problems</td>
</tr>
<tr>
<td>C28a News Box</td>
<td>NB barrier on sidewalk?</td>
</tr>
<tr>
<td>NB</td>
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<tr>
<td>C28b</td>
<td>NB barrier to access bus?</td>
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<tr>
<td>C28c</td>
<td>NB chained to pole etc?</td>
</tr>
<tr>
<td>C28d</td>
<td>NB blocking schedule?</td>
</tr>
<tr>
<td>D35a Lighting</td>
<td>Type of lighting</td>
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<tr>
<td>D36a Pay Phone</td>
<td>Reach of wheelchair use?</td>
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<tr>
<td>D36b</td>
<td>Police call box?</td>
</tr>
<tr>
<td>D37a Landscape</td>
<td>Problems</td>
</tr>
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Table 6: Instrument of the Bus stop Inventory, Part 2: Enhanced features of a bus stop
Explanations:

<table>
<thead>
<tr>
<th>A2</th>
<th>Other shelter?</th>
<th>T=tree</th>
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<tbody>
<tr>
<td>A4</td>
<td>Position to intersect/jun</td>
<td>NS=nearside, FS=farside, MB=midblock, NN=not near an intersection, FP=freeway bus pad</td>
</tr>
<tr>
<td>A3</td>
<td>Purpose of stop</td>
<td>Boarding=B, Alighting=A, Boarding &amp; Alighting=BA, Kiss and Ride=KR, Transfer=T, Park and Ride=PR</td>
</tr>
<tr>
<td>A7</td>
<td>Property description</td>
<td>Apartment Building=A, Industrial Site/Building=I, Park=P, School=S, Day Care=DC, Library=L, Park and Ride=PR, Supermarket=SM, Government Building=G, Mall/Shopping Center=M, Place of Worship=W, Transit Center/Station=T, Hospital=H, Nursing Home=N, Residence townhouse =RT, residence detached=RD, vacant lot=V, Human Service Agency=HS, Office Building=O, Retail Store=R, Other=SPEC</td>
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<tr>
<td>B8</td>
<td>Landing area</td>
<td>min 5 ft wide, 8 ft deep</td>
</tr>
<tr>
<td>B9</td>
<td>LA pos to curb/street</td>
<td>below street level=B, Shoulder=S, on grass strip=GS, partially sidewalk and grass strip= SS, sidewalk=SW, Bus bulb=BB, Off-road/no sidewalk=O, Other=spec</td>
</tr>
<tr>
<td>B10</td>
<td>Material of LA</td>
<td>Asphalt=A, Dirt=D, Gravel=G, Concrete=C, Grass=GS, Paver=P, Other=SPEC</td>
</tr>
<tr>
<td>B11</td>
<td>LA problems</td>
<td>Uneven=U, Slopes up from the street=SU, slopes down from the stree=SD, Ditch=D requires stepping over drain inlet=I, Other=SPEC</td>
</tr>
<tr>
<td>B11a</td>
<td>LA accessible?</td>
<td>Not accessible=NA, Minimally accessible=MA, accessible=A</td>
</tr>
<tr>
<td>B13</td>
<td>Trip Generator</td>
<td>Primary trip generators for passengers at this stop. Apartments large building/complex=AL, Apartments small buildings=AS, Townhomes=T, Detached homes=RD, Day care &amp; pre-school=DC, Gas station=GS, Government Building=G, Hospital &amp; Clinic=H, Hotel=HO, Human Service Agency=HS, Library=L, Major Shopping=MS, Neighborhood Shopping=NS, Nursing Home &amp; assisted living=N, Office building=O, Park and ride=PR, place of worship=W, Restaurant or Cafe=R, School elementary/middle=SE, School High=SH, School College/University=U, Senior Center=SC, Transfer to other routes &amp; transit center=T, Retail=RT, other=SPEC</td>
</tr>
<tr>
<td>B14</td>
<td>Sidewalk width</td>
<td>no sidewalk=N, Dirt track=DT, less than 3=3-, 3-5=3-5, 5 or greater=5+</td>
</tr>
<tr>
<td>B15</td>
<td>SW barrier/ probs in block</td>
<td>access road to property steep =ARS, access road to property graveled=ARG, crossing of side street hindered=CH</td>
</tr>
<tr>
<td>B18</td>
<td>Sidewalk condition</td>
<td>1=hazardous-large breaks, cracks, root uplifting, someone could get hurt from normal or use of a wheelchair would be difficult; 2=in poor shape though not hazardous - very rough, some root uplifting, cracks, breaks; 3=fair - minor root uplifting, minor cracks or breaks; 4=good - not perfect but no immediate repair; 5=cosmetically excellent, new</td>
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<td>B20</td>
<td>SW connects?</td>
<td>trip generator=TG, Nearest Intersection=IS, nearest junction/side street=NJ</td>
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<tr>
<td>B21</td>
<td>Street cross to other side</td>
<td>Crosswalk on Nearest intersection=NI, crosswalk on nearest junction with side street= NJ, midblock crosswalk=MBW</td>
</tr>
<tr>
<td>B22</td>
<td>Amenities @ crossing</td>
<td>Curb cuts all corners/both sides=CCA, Curb cuts some corners/one side=CCS, Visible crosswalk=CV, Pedestrian crossing Signal=PS, Audible Crosswalk Signal=AS, Accessible Pedestrian Signal=APS, Traffic Light=TL, Crossing Guard Assistance=GA, Tactile Warning strip on curb cut=TW, Other=SPEC</td>
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<tr>
<td>B24</td>
<td>Connect other transit</td>
<td>Triangle Transit=TTA, Orange County Transit=OCT, Other=SPEC</td>
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<td>Column</td>
<td>Description</td>
<td>Details</td>
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<td>D29</td>
<td>Location on street</td>
<td>in travel lane=TL, Bus lane=BL, paved shoulder=PS, in right turn only lane=RT, unpaved shoulder=US, off street=OS, No parking portion of street parking lane=NP, Bike Lane=BK, Travel Lane/Bike Lane=TL/BK, other=SPEC</td>
</tr>
<tr>
<td>D30</td>
<td>No parking indication</td>
<td>One no parking sign=1S, 2 or more no parking signs=2S, Bus only sign=BO, painted curb=PC, painted street=PS</td>
</tr>
<tr>
<td>D31</td>
<td>Traffic cont NI?</td>
<td>Traffic Signals=TS, Flashing Lights=FL, Stop/Yield Sign=Y, none=N, Other=SPEC</td>
</tr>
<tr>
<td>D34</td>
<td>Traffic hazards</td>
<td>Bus stop is just over the crest of a hill=CR, bust stop just after a curve=CU, near railroad crossing at grade=RC, passengers hidden from view of approaching bus=HD, stopped bus straddles crosswalk=SC, bus stop just before crosswalk=BC, High speed traffic=HST, No crosswalk=N, other=SPEC</td>
</tr>
<tr>
<td>E38</td>
<td>Sign: bus route indicated?</td>
<td>N=no, Wrong=wrong indicated</td>
</tr>
<tr>
<td>E39</td>
<td>Sign: How installed?</td>
<td>on ist own pole=OP, on building=OB, on utility pole=UP, on shelter=OS, other=SPEC</td>
</tr>
<tr>
<td>E40</td>
<td>Sign: problems</td>
<td>Sign in poor condition=SPC, Pole in poor condition=PPC, Sign position hazardous to pedestrians=PH, Sign not permanently mounted=NM, lighting on sign is poor=LP, other=SPEC</td>
</tr>
<tr>
<td>E42</td>
<td>Schedule: how installed?</td>
<td>on ist own pole=OP, on building=OB, on utility pole=UP, on shelter=OS, on pole under bus stop sign=US, in a shelter=IS, other=SPEC</td>
</tr>
<tr>
<td>C25a</td>
<td>Shelter Orientation</td>
<td>Facing towards the street=FS, Facing oncoming traffic=FT, Facing away from street=FA</td>
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<tr>
<td>C25b</td>
<td>Shelter belongs to?</td>
<td>Own agency=OA, shared stop=SS</td>
</tr>
<tr>
<td>C25i</td>
<td>Damages to shelter</td>
<td>Broken panels=BP, Graffiti=GR, Holes in the roof=HR, Missing panels=MP, Other=SPEC</td>
</tr>
<tr>
<td>C25j</td>
<td>Condition Shelter</td>
<td>1=hazardous - broken glass, unstable; 2=in poor shape though not hazardous; 3=fair - needs repainting, glass panels need thorough cleaning, protruding but not hazardous bolts; 4=good - not perfect but no immediate repair need; 5=cosmetically excellent, new</td>
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<tr>
<td>C26a</td>
<td>Type of seating?</td>
<td>Bench inside shelter=BS, Freestanding Bench=FB, Fold down bench=FDB, leaning bench=LB, other=SPEC</td>
</tr>
<tr>
<td>C26b</td>
<td>Problems seating</td>
<td>Broken pieces=BP, needs painting=NP, Graffiti=GR, not securely installed=NSI, other=SPEC</td>
</tr>
<tr>
<td>C26c</td>
<td>Condition seating</td>
<td>1=hazardous, someone could get hurt from normal use; 2=in poor shape though not hazardous; 3=fair - needs repainting, needs cosmetic attention; 4=good - not perfect but no immediate repair need; 5=Cosmetically excellent, new</td>
</tr>
<tr>
<td>C27a</td>
<td>Type of installation</td>
<td>attached to shelter=AS, free standing=FS, garbage bag=GB, Bolted to sidewalk=BS, other=SPEC</td>
</tr>
<tr>
<td>C27b</td>
<td>Trash problems</td>
<td>Trash can full=TF, bus stop littered=BSL, grocery carts=GC, Trash can not securely installed=NSI, adjacent property littered=APL, Trash can barrier on path to bus stop=BR, other=SPEC</td>
</tr>
<tr>
<td>D35a</td>
<td>Type of lighting</td>
<td>Street light=STL, Shelter light=SHL, outside light on adjacent building=AB, other=SPEC</td>
</tr>
<tr>
<td>D37a</td>
<td>Problems landscaping</td>
<td>Trees/bushes encroaching on the landing area=TLA, Trees bushes encroaching on the sidewalk=TS, Tree branches hit bus=TB, Other=SPEC</td>
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Table 7: Explanations to Instrument
## Appendix D: Points Rationing Scheme

### Accessibility

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<thead>
<tr>
<th>Points Rationing Scheme</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boarding/Alighting Area</td>
<td>Not offroad, stable surfaces: Sidewalk or Landing Pad. Materials: Concrete, cobble tone, asphalt</td>
</tr>
<tr>
<td></td>
<td>No obstacles for Wheelchair Users</td>
</tr>
<tr>
<td></td>
<td>No Landing Area problem (sloping down, sloping up, otherwise uneven)</td>
</tr>
<tr>
<td>Sidewalk</td>
<td>Sidewalk available</td>
</tr>
<tr>
<td></td>
<td>Narrowest width not less than 3 feet</td>
</tr>
<tr>
<td></td>
<td>No sidewalk problems (Encroaching trees, gravel on access roads)</td>
</tr>
<tr>
<td></td>
<td>Condition not worse than 3</td>
</tr>
<tr>
<td>Landing Area connects to sidewalk</td>
<td>5</td>
</tr>
<tr>
<td>Sidewalk connects to Trip Generator or Nearest Intersection</td>
<td>5</td>
</tr>
<tr>
<td>Street crossing opportunity</td>
<td>Available and visible on the street and equipped with curb cuts on all corners of intersection/ both sides of the street</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
</tr>
</tbody>
</table>

### Convenience

<table>
<thead>
<tr>
<th>Points Rationing Scheme</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelter available</td>
<td>2</td>
</tr>
<tr>
<td>Seating available</td>
<td>2</td>
</tr>
<tr>
<td>Trash Can available</td>
<td>2</td>
</tr>
<tr>
<td>Wheelchair fits in Shelter</td>
<td>1</td>
</tr>
<tr>
<td>Wheelchair can maneuver into shelter</td>
<td>1</td>
</tr>
<tr>
<td>Condition of shelter 4 or 5, no other problems</td>
<td>1</td>
</tr>
<tr>
<td>Condition of Seating 4 or 5, no other problems</td>
<td>1</td>
</tr>
<tr>
<td>No problems with encroaching trees or bushes on sidewalk</td>
<td>1</td>
</tr>
<tr>
<td>Bus Stop Sign available and in good condition</td>
<td>1</td>
</tr>
<tr>
<td>Bus route indicated on sign</td>
<td>1</td>
</tr>
<tr>
<td>Sidewalk width 5 feet and wider</td>
<td>1</td>
</tr>
<tr>
<td>Sidewalk condition is 5</td>
<td>1</td>
</tr>
<tr>
<td>Route/Schedule/Map available</td>
<td>1</td>
</tr>
<tr>
<td>Real-Time Information available</td>
<td>1</td>
</tr>
<tr>
<td>Route/Schedule/Map in wheelchair height</td>
<td>1</td>
</tr>
<tr>
<td>Real-Time Information in wheelchair height</td>
<td>1</td>
</tr>
<tr>
<td>Amenities at crossing: curb cuts + visible crosswalk + 2 further amenities (tactile warning pad or pedestrian signal traffic signal or audible signal)</td>
<td>1</td>
</tr>
<tr>
<td>Connection to other transit</td>
<td>1</td>
</tr>
<tr>
<td>Tree shading or other shelter</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22</strong></td>
</tr>
</tbody>
</table>

### Safety

<table>
<thead>
<tr>
<th>Points Rationing Scheme</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting available</td>
<td>2</td>
</tr>
<tr>
<td>No traffic hazards (no high volumes of traffic etc.)</td>
<td>1</td>
</tr>
<tr>
<td>Phone or police call box available</td>
<td>1</td>
</tr>
<tr>
<td>Bus stop location on street: Bus bay or bus lane</td>
<td>1</td>
</tr>
<tr>
<td>Traffic control at nearest intersection: Yield sign, traffic signal</td>
<td>1</td>
</tr>
<tr>
<td>Gras strip buffer between road and sidewalk</td>
<td>1</td>
</tr>
<tr>
<td>“No parking” indication available</td>
<td>1</td>
</tr>
<tr>
<td>Not more than 3 traffic lanes</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

Table 8: Points Rationing Scheme
Appendix E: Network Analysis in ArcGIS

Input Data:
- Address Points
- < join > Addresses of Paratransit Users
- Street Network
- Bus Stops
- < join > Bus Stop Rating
- Bus Lines
- Paved Driveways and Parking Lots
- Sidewalks

Sidewalks, Paved Driveways and Parking Lots

Polygon to Line
- All features are Line Features

Create Topology
- Validating Topology
- Fix Topology Errors

No more topology errors

Create New Network Dataset
- Build Network

Network of Sidewalks, Paved Driveways and Parking Lots

First Network Analysis:
- Network Analyst, New Closest Facility
- Incidents Feature Layer: Address Points of Paratransit Users
- Facilities Feature Layer: Bus Stops + Rating

1. Residencies connected to pedestrian infrastructure
2. Routes + distances to/from residency to/from bus stops

- a. Select routes with Rating of Facilities
  (=Bus Stops) 4 and 5

- b. Second Network Analysis:
  Network Analyst, New Closest Facility
  Incidents Feature Layer: Address Points of users with routes to Bus Stops
  with Rating 1, 2, and 3
  Facility Feature Layer: Bus stops with Rating 4 and 5

Users with Level 1 Accessibility

Select distances of Alternative routes < 1/4 mile

Users with Level 2 Accessibility (part)

Select distances of Alternative routes > 1/4 mile

Users with Level 2 Accessibility (part)

Select distances < 1/4 mile and > 1/4 mile

Users with inadequate Alternative Route:
- Users with Level 3 Accessibility (part)
- a. Users with Alternative Routes > 1/4 mile
  < join via IncidentID >
  Routes of First Network Analysis
- b. Select distances of First Network Analysis
  < 1/4 mile and > 1/4 mile

1. Route Distance < 1/4 mile:
   Bus Stop Improvement Recommendation
2. Route Distance > 1/4 mile:
   No Bus Stop Improvement Recommendation

Users with no Alternative Route:
- Users with Level 3 Accessibility (part)

Residencies not connected to pedestrian infrastructure:
- Users with Level 3 Accessibility (part)

Proximity Toolset:
- Point Distance: Bus Stops to Users' Residencies

Legend:
- Yellow = Procedure in ArcGIS
- Blue = Intermediate Result

Figure 28: Network Analysis in ArcGIS
Appendix F: Bus Stop Accessibility in Chapel Hill and Carrboro

Map 1: Bus Stop Accessibility in Downtown Chapel Hill and on the UNC Campus

Legend:
- green circle = Fully Accessible
- orange circle = Limitedly Accessible
- red circle = Not Accessible
- yellow line = Bus Line
Bus Stop Accessibility in Chapel Hill and Carrboro

Legend:
- Green = Fully Accessible
- Orange = Limitedly Accessible
- Red = Not Accessible
- Yellow = Bus Line

Map 2: Bus Stop Accessibility in Chapel Hill and Carrboro
Erklärung

Ich erkläre, dass ich die vorliegende Arbeit selbstständig und nur unter Verwendung der angegebenen Literatur und Hilfsmittel angefertigt habe. Die aus fremden Quellen direkt oder indirekt übernommenen Inhalte sind als solche kenntlich gemacht.

Berlin, 29. Oktober 2010

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Tobias Kuttler