ACCESSIBILITY IN THE URBAN ENVIRONMENT FOR CITIZENS WITH IMPAIRMENTS: USING GIS TO MAP AND MEASURE ACCESSIBILITY IN SWEDISH CITIES

Johan Svensson
Department of Architecture, Chalmers University of Technology, Sweden and
Vectura Consulting, Box 1062, 551 10 Jönköping, Sweden
Johan.Svensson@vectura.se

Abstract

Since the design of our cities tends to constrain people with impairments from performing their daily activities, removing barriers and making public space accessible for everyone is becoming a human rights-issue. Due to an ageing population, the number of impaired citizens is expected to increase substantially over the next 50 years. Hence, there is a current demand on urban planners to find a way to adjust their cities, in order to make them usable for everyone, which will grow stronger as the number of elderly in the society increases over the next few decades. However, to efficiently improve accessibility requires knowledge about the location of obstacles in the urban environment and how these affect accessibility.

Using GIS-models to map and measure accessibility, this study aims at providing new knowledge about the spatial distribution of accessibility and the possibility for impaired persons to travel independently in eight Swedish cities. Furthermore, the study aims at revealing differences in accessibility between different types of neighbourhoods. The study will thus provide new knowledge on how accessibility is affected by the heritage from the different planning principles and guidelines that have influenced the development of the urban environment over the past century

Based on field inventories, detailed digital models of the pedestrian and public transport networks were created for each city, using traditional digitizing methods. Using GIS for network analyses, accessibility was measured by calculating travelling times and distances between home and different destinations, such as grocery stores, bus stops, health care centres, pharmacies or the train station. The method pays attention to the entire travel chain, thus analysing the possibility to reach a destination using a combination of available and usable modes of transport between home and destination.

The results from the study reveal how different types of flaws in the pedestrian network cause interruptions or forces travellers to detours, which restricts accessibility. The results show where it is possible to live and independently perform daily activities as an impaired citizen and also how travelling times and distances vary considerably between impaired and non-impaired citizens. For the mobility impaired, their sensitivity towards long distances and steep slopes turns out to be more restricting to accessibility than spe-

cific details in the physical environment. Accessibility for the vision impaired is restricted mainly due to the insecurity and discomfort caused by a lack of physical separation between pedestrians and bicyclists on a large proportion of the pathways, but also due to problems related to crossing the streets. The results also reveal significant variations between the different types of neighbourhoods within the study area, but also between the different cities included in the study. Residential areas designed according to the principle of complete segregation of pedestrians and motorized vehicles provide the most favourable environment for those with mobility impairments, whereas the town centres provides the least problematic environment for the vision impaired.

In conclusion, the study shows how urban planners, by using GIS-models, can easily enhance their knowledge about how flaws in their cities affect accessibility for impaired citizens. Furthermore, the study shows how planners could easily use these models to simulate potential actions towards improving accessibility. The results from such simulations reveal what effect a certain action would have on accessibility for impaired citizens, thus making it possible to identify and prioritize those actions that would generate the most positive outcome.

Introduction

With the older population growing at a considerably faster rate than that of the world's total population, the young-old balance is shifting throughout the world. Over the next five decades, the number of Europeans aged 80 years or over are projected to almost triple, from 21.8 million in 2008 to 61.4 million in 2060 (Eurostat, 2008). Due to this rapid demographic transition, the number of impaired citizens is expected to increase accordingly. As of today, half the Swedish population older than 80 is defined as mobility impaired to such extent that they need assistance or mechanical aid in terms of a wheelchair, a rollator or a cane, while approximately 15 percent of those older than 80 are visually impaired (Statistics Sweden, 2008).

In the light of this development, it is logical that both researchers and politicians recently have directed more attention towards issues regarding the design of the urban environment and how it tends to constrain people with impairment from socializing. In Sweden, as in several other countries, a growing general awareness about design-related difficulties for people with different forms of functional limitations has been accompanied by changes in the national policies on disability issues. Since the launch of a new political agenda on disability issues nine years ago, Swedish planning regulations have been altered, resulting in increased demand on local authorities to rapidly adjust the design of their cities, in order to make them usable and accessible for everyone. According to the time frame set by the government, this work ought to be concluded by the year 2010 (Swedish Government, 2001).

A recently concluded study has demonstrated how the use of a powerful, yet comparatively straightforward GIS-based method could provide urban planners with the vital data needed in order to make their efforts towards improved accessibility more fruitful (see Svensson, 2009). The method was implemented on seven Swedish cities of varying character and size and the results from these accessibility analyses reveal how the design of the urban environment in general tends to be less constraining for those with mobility impairments, than for those who are severely vision impaired or blind. Furthermore, the results reveal systematic differences in accessibility between the seven towns. Several potential explanatory factors to these differences has been tested and refuted. However, there appears to be a correlation between density and accessibility for those with impairments, as the latter is substantially better in more densely populated towns.

The hypothesis for this forthcoming study is that it is possible to detect similar differences within towns, which would mean that the level of accessibility for those with impairments is determined by where they live in a town. Hence, this study addresses the distribution of accessibility to the supply of service in neighbourhoods of various characteristics within urban areas. The main objective of this study then, is to identify neighbourhood-specific relationships between accessibility and the design of the built environment. The study will thus try to demonstrate how accessibility is affected by the heritage from the different planning principles and guidelines that have influenced the development of the urban environment over the past century.

Mapping and measuring accessibility using network analyses in a GIS

Several previous studies (i.e. Bentzen and Barlow, 1995; Matthews and Vujakovic, 1995 or Sanford et al., 1997) have demonstrated how the imperfect design of the built environment tends to restrict mobility and create insecurity for people with different kinds of functional limitations. This research has contributed with valuable information on how our towns and their transport systems are experienced by citizens with impairments and how certain details in the design of the built environment emerge as obstacles for these citizens. However, in order to understand just how accessibility is affected by the prevailing flaws in the built environment, they must first be located and then put in context.

As flaws in the design could occur on any segment of the pedestrian network, address the primary routes in the pedestrian network only would not be sufficient for a reliable analysis of accessibility. Furthermore, it is important to realize that it is the relative location of the flaws in the urban environment that eventually decides whether a flaw becomes an obstacle and whether it will affect accessibility for just a few or for a large group of impaired citizens. Therefore, a comprehensive field survey of the entire pedestrian network is required, in order to collect all the vital data needed to perform a reliable analysis of accessibility.

In this study, data on the physical environment has been collected by using a specially designed check list, which was developed in co-operation with the Swedish Road Administration's experts on children's traffic safety and accessibility for the impaired respectively (Reneland, 2004). The design of the check list ensures that special attention is directed towards those qualities that affect security and mobility for children, elderly and impaired citizens.

The data collected during the field survey was used to digitize a model of the town's pedestrian network. This digital network contains a detailed set of attributes, with 24 different quality parameters and 102 different parameter values altogether. Each segment of the digital version of the pedestrian network thus contains information about slope, height of kerbstones, type of pavement, width of a sidewalk etc. With these attributes and an assumed basic capacity for defined groups of impaired citizens, e.g. mobility impaired people using a manually propelled wheelchair, it is possible to identify those parts of the pedestrian network that fulfil the defined requirements for usability for a specific group.

In order to be able to analyze accessibility via travel chains including public transport, a model of the town's public transport system is created. The pedestrian network and the public transport system are connected at the bus stops to create a multimodal model that also contains travel times along bus routes, waiting times and changing times at bus stops. Furthermore, demographic data on real estate coordinates, as well as the town's supply of service utilities, i.e. grocery stores, bus stops, health care centres and pharmacies, is added to the model in order to be used as origins and destinations for trips in the forthcoming analyses.

Using the Network Analyst extension to ESRI's software ArcGIS, accessibility is calculated as the possibility to move from each real estate to a selected type of destination, when allowed to use only those parts of the network that are defined as usable for a specific group of impaired citizens. As the method also provides an opportunity for multimodal travels, it is possible to describe accessibility in terms of travel times via travel chains that include travelling with the public transport system.

For each real estate, the program performs an evaluation of whether it is possible to reach the selected type of destination when using those parts of the network that are defined as usable for a specific group of citizens, with regard to their specific capacity and demands on the design of the network. Accessibility is then expressed in terms of distance and travelling time. With demographic data on real estate level it is possible to summarize the amount of people that are able to reach a certain type of destination and to what cost, in terms of travel time and distance. The demographic data also contains information on age and gender. It is thus possible to compare accessibility between different groups, with various demands and capabilities, within the population.

Study area

Digital models of eight Swedish towns of varying size and character have been used to analyse the state of accessibility for impaired citizens in various urban environments. The towns included in the study represent different regions of the country, ranging from

Luleå (65°N) and Umeå (63°N) in the northern part of the country, to Trelleborg (55°N) and Helsingborg (56°N) in the most southern part of the country.

TOWN	Helsingborg	Umeå	Luleå	Falun	Trelleborg	Alingsås	Nynäshamn	Säffle
Urban population	86 872	70 844	57 560	35 950	24 848	22 232	13 294	9 222
Popultation Density (population/hectare)	23,0	19,8	15,0	13,4	22,7	20,0	20,9	12,4
Pedestrian network (km)	758	608	430	270	202	200	101	114
Network Density (Metres of pathways/pop.)	8,7	8,6	7,5	7,5	8,1	9,0	7,7	12,3

Table 1. Study area statistics.

User groups

In this study, accessibility for those who are severely vision impaired or blind refers to those who are unable to use visual references in the outdoor environment and thus are dependent upon tactile and audible references for orientation. Analyses of accessibility for those who are mobility impaired refer to two different categories. The first category includes those who are able to walk with the assistance of a stick or crutches and thus find it difficult to walk on uneven, soft or slippery surfaces and on slopes, in stairs or over longer distances. The second category contains those who uses a manually propelled wheelchair or a rollator and thus find it difficult or impossible to move on uneven, soft or slippery surfaces, over longer distances, or on slopes or pathways with cross-slopes, while stairs and high kerbstones form impassable obstacles.

Usable environment

As functional limitations and individual capacity vary due to type and level of functional limitation, sensitivity towards different kinds of flaws in the pedestrian network vary accordingly. An analysis of the qualities of the pedestrian network in the seven towns reveals that a significantly smaller proportion of the pedestrian network meets the demand from the severely vision impaired or blind citizens.

A more thorough analysis of the qualities of the pedestrian network indicates that few street crossings are designed to provide a safe crossing for those who are blind or severely vision impaired. In this study, all under- or overpasses are considered as a safe crossing for a severely vision impaired or blind person, provided that the design of the pathway and its possible stairs makes it usable. Street crossings at roundabouts must be signalized or an over- or underpass to be usable. At streets with low traffic flow, painted and sign-posted street crossings are considered usable if the kerbstone towards the street is perpendicular and at least four centimetres high. At streets with more than two lanes to pass or at streets with higher flows of traffic, the street crossing must, in addition, be signalized with sound and lights to be considered usable.

As a consequence, it becomes very difficult or hazardous for blind people to walk from one residential block to another, in order to reach a selected destination. The remaining usable parts of the network form a pattern of islands, where the vision impaired would become isolated until someone assisted them across the street.

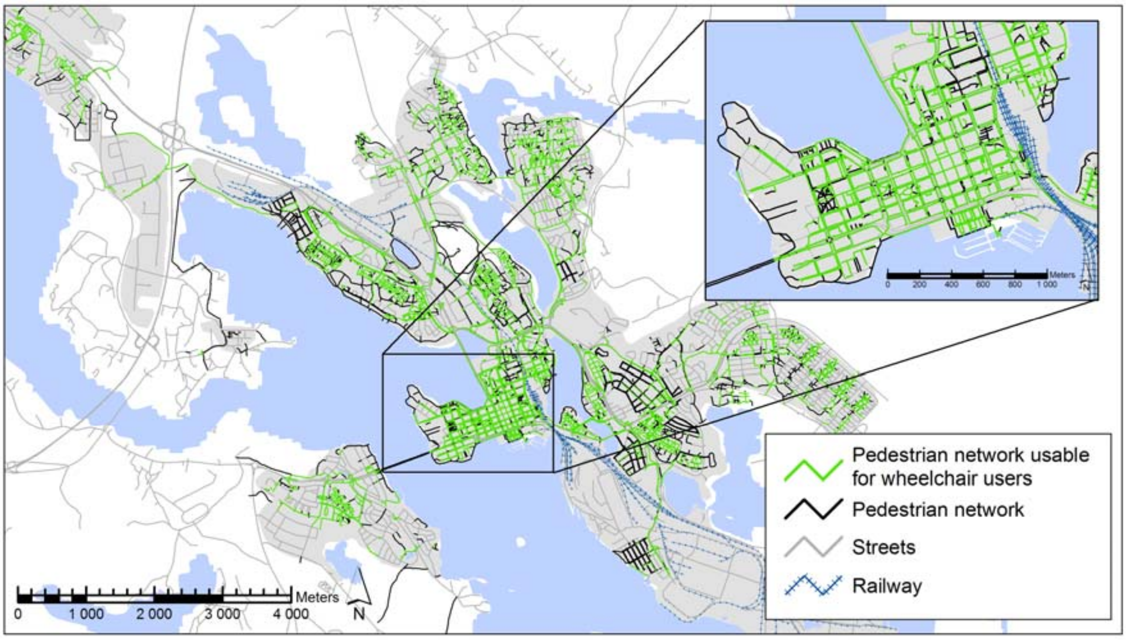

Figure 2. Pedestrian network usable for wheelchair users in Luleå

TOWN	**Helsingborg**	**Umeå**	**Luleå**	**Falun**	**Trelleborg**	**Alingsås**	**Nynäshamn**	**Säffle**
Part (%) of network usable for mobility impaired using cane/crutches.	55,7	76,8	61,9	53,6	65,1	54,5	66,6	45,8
Part (%) of network usable for mobility impaired using wheelchair/rollator.	55,3	76,5	61,4	53,0	64,8	54,1	53,1	45,6
Part (%) of network usable for severely vision impaired.	41,1	52,6	36,1	34,5	51,2	31,4	39,4	27,3

Table 2. Pedestrian network usable for the various user groups

Variations in accessibility due to type of functional limitation

Only a small proportion of the population is able to reach destinations such as health care centres, pharmacies and bank offices by foot, if they are allowed to use only those parts of the pedestrian network usable for impaired citizens. This is mainly due to the prevailing patterns of location, with few service units located far apart, and less due to the design of the built environment (Svensson, 2009). Consequently, most impaired citizens need motorized transport to reach various service utilities around town. For those that don’t drive, accessibility to a bus stop and the ability to travel with the public transport is a key to an independent lifestyle.

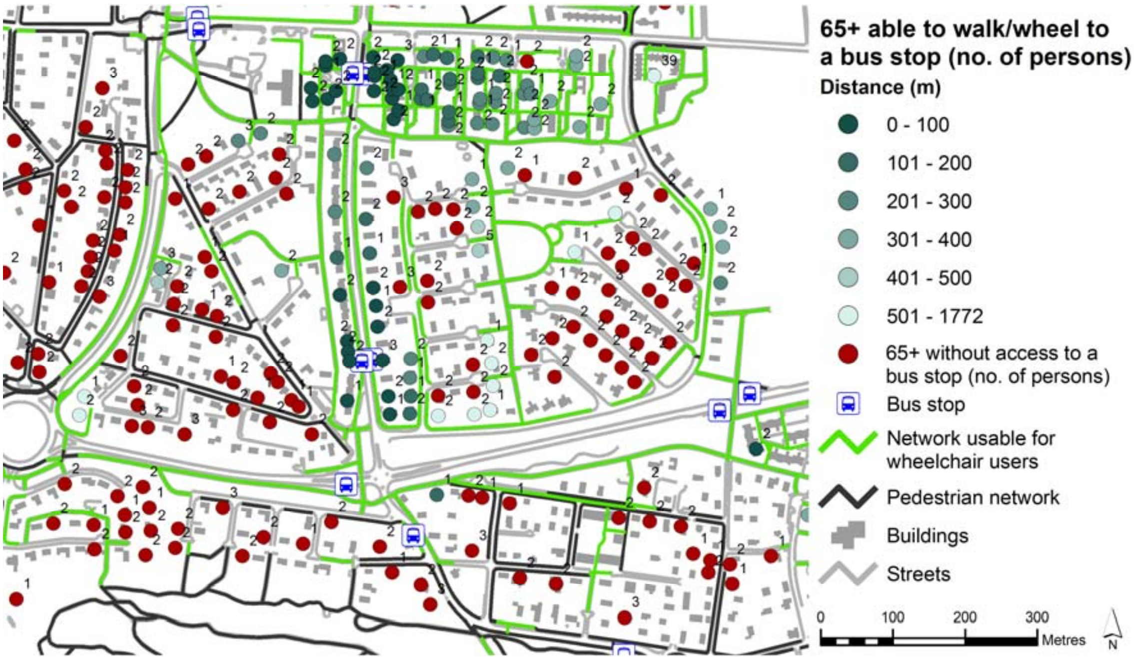

Figure 3. Accessibility to a bus stop for those older than 65 when using a network that is usable for wheelchair users. Eastern Helsingborg.

The shortage of usable pathways and sidewalks, as illustrated in Table 2 above, is of course a major obstacle for citizens with vision impairments. It is thus logical that their accessibility to the various service utilities is at a significantly lower level, than the level of accessibility for those who are mobility impaired. As shown in the example beneath, only a fraction of the population is able to reach a bus stop from their home, if they are allowed to use only those parts of the network that are defined as usable for severely vision impaired or blind citizens.

TOWN	**Helsingborg**	**Umeå**	**Luleå**	**Falun**	**Trelleborg**	**Alingsås**	**Nynäshamn**	**Säffle**
Part (%) of pop. with access to bus stop using paths usable for mobility impaired using **cane/crutches**.	49,4	48,8	20,5	16,2	46,1	34,3	37,0	19,3
Part (%) of pop. with access to bus stop using paths usable for mobility impaired using **wheelchair/rollator**.	46,7	46,4	17,5	15,6	42,6	32,0	31,9	19,0
Part (%) of pop. with access to bus stop using paths usable for **severely vision impaired**.	16,9	15,6	5,3	9,2	17,4	5,5	12,2	7,7

Table 3. Accessibility to a bus stop via usable parts of the pedestrian network

However, for many of those with mobility impairments, lack of stamina, balance and muscular power decreases their ability to transport themselves over longer distances, even where the physical infrastructure provides them with such an opportunity (Månsson, 2002). Hence, the observed differences in accessibility between the vision and mobility impaired decrease when one takes into account the restricted ability for mobility impaired citizens to walk longer distances.

Variations in accessibility between various neighbourhood types

Accessibility for those with impairments tends to be significantly better in cities of higher density (Svensson, 2009). This correlation between density and accessibility is, however, not as straightforward when separate neighbourhoods are studied. Residential areas, both those with apartment buildings and those with single family houses, designed according to the principle of complete segregation of pedestrians and motorized vehicles provide the most favourable environment for those with mobility impairments.

Figure 4. Areas planned according to the principle of complete segregation of pedestrians and motorized vehicles. (Photos used with permission from Blom Sweden AB)

However, in traffic separated neighbourhoods, the public transport is generally located in the outskirts of the area, resulting in comparatively few people living close to a bus stop. Hence, when assuming a limited individual range of 300 metres for those who are mobility impaired, accessibility to the public transport is at a slightly lower level in traffic separated areas, than in the city centres and in areas with low rise apartment areas, primarily built during the period from 1930 trough the 1950's and supplied by a grid road network. The latter types of neighbourhoods also provide the least problematic environment for the severely vision impaired.

The difficulties for the severely vision impaired in areas designed according to the principle of complete segregation of pedestrians and motorized vehicles relate to the need to separate pedestrians from bicyclists, while shared pathways are most common in those areas. In neighbourhoods with single family houses that are served by a grid network or similar, accessibility is poor for all groups of impaired citizens. This is partly due to few people living close to a bus stop in these areas, but also due to missing links in the networks.

Figure 5. City centre area (Helsingborg, upper left); Area with low rise apartments (Umeå, upper right); Sparse (Falun, lower left); Dense (Helsingborg, lower right) areas with single family houses (Photos used with permission from Blom Sweden AB).

Conclusion

The design of the built environment tends to constrain those with functional limitations from socializing, getting to work, to visit the dentist etc. These problems have been emphasised by several previous studies and this study brings further evidence to this case. More importantly though, this study provides new knowledge about the occurrence of different types of flaws in the design of the built environment and how these flaws affect accessibility for citizens with impairments. The study confirms that the design of our cities tends to be less constraining for those with mobility impairments, than for severely vision impaired or blind citizens. Consequently, accessibility to the town's supply of goods and services vary significantly due to type and grade of functional limitation.

Furthermore, the study shows how accessibility varies, not only due to type of functional limitation, but also due to where one lives, with significant variations in accessibility between different neighbourhood types. However, even in those areas where accessibility is comparatively good, most impaired citizens need motorized transport of some sort to gain access to destinations other than bus stops or, to some extent, grocery stores. In the case of Sweden, this stresses the importance of providing accessibility to and making the public transport system usable for people with impairments.

In addition to the new knowledge on accessibility for impaired citizens in Sweden, the study also demonstrates how geographic information systems, GIS, could be used in the planning process, in order to gain vital information about the need for improvement in the built environment. The study shows how urban planners, by using GIS-models and network analyses, can rather easily enhance their knowledge about how certain flaws in their cities affect accessibility for impaired citizens. This knowledge is essential in enabling a more straightforward road towards adjusting our cities, in order to make them usable for everyone.

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