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FACULTEIT BEDRIJFSECONOMISCHE WETENSCHAPPEN
master in de mobiliteitswetenschappen

Masterproef
Measuring Walkability in a study area in Flanders

Promotor :
Prof. dr. Davy JANSSENS

Copromotor :
Mevrouw An NEVEN

Maria Van Damme
Proefschrift ingediend tot het behalen van de graad van master in de mobiliteitswetenschappen

Universiteit Hasselt | Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Universiteit Hasselt | Campus Diepenbeek | Agoralaan Gebouw D | BE-3590 Diepenbeek

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Measuring Walkability in a study area in Flanders

School for Transportation Sciences
Master in transportation sciences

Maria Van Damme
Teirlinkstraat 60
9900 Eeklo
0495/37.52.12
maria.vandamme@student.uhasselt.be

Promotor:
Prof. Dr. Davy Janssens

Co-promotor:
Mrs. An Neven

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universiteit hasselt

Maria Van Damme

ABSTRACT

As walking is of relatively great importance in Flanders, indicated by a share of almost 50% of all short distance trips until 1 km as main travel mode, it is important to guarantee a certain level of walk quality, i.e. walkability. This study is an initiative to apply a standardized method of measurement of local walkability in a city in Flanders, i.e. Hasselt, consisting of two statistical sectors: Hasselt Center West (SS2) and Hasselt Center East (SS1). Walkability is approached in two ways: objective, because the quality of walking is of common importance for society and subjective, because pedestrians postulate expectations and needs.

The objective walkability indices, obtained by direct observation, showed a higher score in SS2 with a good walkability, while SS1 has an average score. The perception of the residents and employees within the research area of 20 years or older of the walkability is measured with the abbreviated Neighborhood Environment Walkability Scale. The respondents perceived the walkability in SS1 and SS2 as average to good. The perceptions per subscale showed no significant difference between the two statistical sectors and significant correlations with walkability subscales were only found for one socio-demographic variable, i.e. age. The other socio-demographic variables were only weakly related to the walkability subscores.

It is concluded that the objective and subjective walkability are relatively concordant, as the misperception of the respondents within SS2 is not substantially differing from its objective walkability. The respondents living and/or working in SS1 correctly perceived the walkability in SS1.

INTRODUCTION

Sustainable transportation is part of sustainable development, which is defined by the Organization for Economic Cooperation and Development (OECD) (1987) as the maximization of the development of today's generation's well-being without undermining the future well-being. This is a tridimensional concept, i.e. economic, social and environmental (Zakaria, R. et al., 2013), which can be applied to certain travel modes, hence walking, because they contribute to sustainable transportation.

- Economic: Traveling by foot is, according to the Victoria Transport Policy institute (2011), advantageous because it is a costless travel mode.
- Social: Zakaria, R. et al. (2013) ascertain that walking ensures basic mobility, i.e. the ability to travel, without being restrained by the conditions of certain travel modes, e.g. a train timetable. Basic mobility is a premise to not suffer from transport poverty, in this case within a short distance radius. The Victoria Transport Policy institute (2011) states that walking supports the quality of life.
- Environmental: Travelling by foot is in this sustainable point of view an important travel option, because it is the simple, universal, non-polluting and easily available form of travelling (Coffee, N. et al., 2013).

This shows the common importance of walking for society. Furthermore there are certain expectations and needs postulated by the users of walk facilities, i.e. pedestrians. Kaufmann, C. and Risser, R. (2010) indicate the importance of the perceived needs of pedestrians, because of their direct relation with both the objective and subjective quality of pedestrian movements.

The 'Travel Behaviour Research Flanders' ('Onderzoek VerplaatsingsGedrag Vlaanderen') guarantees since 1995 the systematic data collection concerning mobility in Flanders, but there is no source available that deals with the quality of walking. The last OVG, OVG 4.4, was executed between september 2011 and september 2012 and showed a share of almost 50% of all short distance trips until 1 kilometer for walking as the main travel mode (Mobiel Vlaanderen, 2013). This modal share indicates a relative great importance of walking as a travel mode for short distance trips in Flanders. Because of this large share, it is important to guarantee a certain level of walk quality, also known as walkability. Leslie,

E. et al. (2007) define the walkability of a community as *'the extent to which characteristics of the built environment and land use may or may not be conducive to residents in the area walking for either leisure, exercise or recreation, to access services, or to travel to work'*.

Walkability can be defined on many levels, i.e. micro level (census tracts/blocks & neighborhoods), meso level (cities & regions) and macro level (countries & international). Local quality of walking, i.e. walkability measured on the local level, is defined in the studies of Frank, L. et al. (2005) and Leslie, E. et al. (2007) as the relation between the urban structure and the pedestrian mobility. To encourage people making more trips by foot, it is, according to Leslie, E. et al. (2007), important that the walkability is high enough. The crucial element in this is the built environment.

There are a number of international initiatives, including WALK21-International Charter (2006), International Transport Forum/OECD (s.d.), Sauter (2008), COST 358-PQN Part C (2010), HOTEL (s.d.) and GRIP vzw (2013), undertaken in order to obtain a standard measurement of a local walkability score.

The measuring of walkability can be approached in different ways and thus assessed according to different methodologies. The study of Brownson, R. et al. (2009) provides a critical assessment of the three types of built-environment measures relevant to the study of the walking, that is the objective measures, subjective measures and archival data sets. Subjective measures, i.e. perceived (self-reported) environment measures, appear most often in the form of questionnaires. Objective measures can for example be assessed by using audit tools that observe the street pattern, sidewalk quality, etc.. The archival data sets, i.e. existing data stored in archives, are according to Brownson, R. et al. (2009) often layered and analyzed with GIS. An example of archival data is an indicator of the built environment, net retail floor area, which is not always available on the level of statistical sectors or on the city level. The last type of measures of the built environment is not included in this study because the detailed data collection that is needed to constitute those archival data sets is not executed in the city of Hasselt. The lack of existing archival data sets and the high cost of acquiring these data sets has moved us to only incorporate the distinction between the objective and subjective measures in this study, which is also made in the study of Frank, L. et al. (2005).

Walkability, in its objective perspective, consists of two fundamental aspects that are both related to the built environment: proximity to destinations and connectivity. Proximity is primarily determined by two key land use variables: density, which is the compactness of land use, and land use mix, which is the degree of heterogeneity with which functionally different uses are co-located in space (Leslie, E. et al., 2007). According to Frank, L. and Engelke, P. (2003), land use mix is a measure of the number of different functions that are located in a certain area. Connectivity measures the directness of the path-way between households, shops and places of employment and is based on the design of the street network (Leslie, E. et al., 2007).

The subjective aspect of walkability can be obtained by perceived environment measures. The environment is in this case, according the study of Brownson, R. et al (2009), a combination of the physical (built) environment, social factors and policy influences. (Chrisman, M.S., 2013)

The research from Monteiro de Cambra, P.J. (2012) concerning the pedestrian accessibility and attractiveness mentions that the use of objective measures in combination with user evidence has been a recommended approach as it may provide a richer and more accurate picture of environmental influences. This is why both the objective and subjective aspect of walkability are included in this first research into the quality of walking in a Flemish area. Both the objective walkability score and subjective walkability score, i.e. the perception of the target population of the research area in the context of the quality of walking, and the correspondence between both dimensions are investigated.

PROBLEM STATEMENT

According to the Mobility Report from the Mobiliteitsraad van Vlaanderen (2009), there is still a lot unknown about the walkability on the level of Flanders and lower levels. Both the objective and subjective quality of walking in the cities and villages of Flanders are unexplored. This information is nevertheless necessary for the formulation and implementation of recommendations to improve the local quality of walking, because the pedestrian facilities are mainly provided and maintained at the local level (Vlaamse overheid, 2011). The operation on local level is shown, for instance, by the maintenance of walk facilities and enforcement policy concerning the admitted speed of motorized traffic, accessibility, parking, etc. A concrete example of this is the construction of a sidewalk. Although the provision of pedestrian facilities is situated on the local level, there are no quality checks executed on this level. Another problem concerning the quality of walking is the difficult quantification, which results in the ignorance of the quality of walking (VTPI, 2011).

OBJECTIVES

This study is an initiative to apply a standardized method of measurement of local walkability in a city in Flanders and compare the acquired walkability index with the results of other scientific researches concerning walkability. When this is finished, we will formulate some recommendations to improve the local walkability in case the walkability indices represent low walkability.

Before we focus on our research area, related scientific literature was consulted and outlined in the chapter ‘literature study’. The next step is the more detailed explanation of what is investigated in this study, i.e. the research questions, followed by the methods and execution of both the objective and subjective walkability measurement. The results of the objective and subjective walkability indices and implications of this study are discussed and conclusions are drawn for the city center of Hasselt. At last, some recommendations to improve the local quality of walking, if necessary, and for future research are formulated.

LITERATURE STUDY

Objective walkability

To measure the objective walkability of an area, GIS-based measures are used, which measure the built environment based on existing data sources that have some spatial reference (e.g. address). The indicators measure the two fundamental aspects that are related to the built environment: proximity to destinations and connectivity. These indicators are categorized in:

- Proximity: population density and land-use mix (accessibility, intensity and pattern measures)
- Connectivity: access to recreational facilities (accessibility and intensity measures), street pattern (most common is intersection density) and sidewalk coverage (most common is the ratio of sidewalk length to road length)
- Other: vehicular traffic, crime and other

These built environment measures are more commonly used to assess neighborhood characteristics relevant to walking for transport than for recreation, according to Brownson et al. (2009). Land use mix is an indicator of the equality of floor space among categories of land use, which can be scored in multiple ways (Frank, L. et al., 2005). The most common one of the four diversity measures is entropy scoring, i.e. a measure of equal distribution of walkable land use categories. Entropy scores equal one when land use is maximally mixed or heterogeneous and zero when land use is maximally homogeneous (Brown, B. et al., 2009). When there is a lack of floor area information, the calculation of the entropy scores can be based on land areas instead of building floor areas, according to Frank, L. et al. (2005).

The study from Frank, L. et al. (2006) mentions a mix of 6 land use categories, calculated by the general formula: land use mix= −A/(ln(N)). But according to Reis, R. et al. (2013), the land use mix calculation can be adjusted to another number of land uses, for example five land uses. Both formulas can be found in the appendix.

When the individual indicators are measured, a single composite variable or index can be calculated by combining the individual indicators (primarily for land-use mix, density, and street pattern). (Brownson, R. et al., 2009) This index gives an overall picture of the objective walkability. An overview of objective indicators of walkability, frequently used in scientific studies, is given in the appendix in table 6.

(Frank, L. et al., 2009) calculated a relative walkability score (W) per postal code with the help of 4 parameters: Residential density (D), Density of intersection (I), Land use mix (M) and Net retail area (R). The statistical z-scores of these parameters with average ≈ 0 and SD ≈ 1 are summed up in the following formula: W = Zd + 2*Zi + Zr + Zm.

Another formula for the walkability index was calculated by (Frank, L. et al., 2005) that integrates three variables: net residential density, density of intersection and land use mix. A normalized distribution was taken of each variable (z-score) and then the three variables were combined into an index. This index is weighted based on preliminary analyses of the combined variables to explain the variation in moderate activity levels for this data set, which would be unnecessary in our research. The formula of the walkability index per Metro Area is then: Walkabilityindex W = (6*Z-score of land-use mix) + Z-score of net residential density + Z-score of intersection density.

This study showed a positive relationship between the measures of land-use mix, residential density and intersection density and the number of minutes of moderate physical activity per day. The combined walkability index of these urban form factors was significant and explained additional variation. This study thus supports the hypothesis that community design is significantly associated with moderate levels of physical activity.

The research of (Kerr, J. et al., 2006) in associations with environment and parental concerns of active commuting to school used a walkability index on the census tract level to characterize the environment around each participant's home. Four parameters were included in the calculation of the index: net residential density, retail floor area, intersection density (indicator of street connectivity) and land use mix (with values normalized between 0 and 1, with 0 being single use and 1 indicating an even distribution across the five uses). These four components of the walkability index were normalized for each block group using a Z score. The results showed that both the design of the neighborhoods and parental concerns were significantly associated with children's active commuting to school. The index was calculated using the following equation: Walkability = Z net residential density + Z retail floor area ratio + (2*Z intersection density) + Z land use mix.

The study of (De Meester, F. et al., 2012) calculated a walkability index on the level of a statistical sector using three objective GIS-based measures: residential density, intersection density, and land use mix, which have been consistently related to physical activity. The corresponding values were normalized and z-scores were calculated. The formula is an adapted version of the formula of (Frank, L. et al., 2010) . There were no GIS data were available for the parameter "retail floor area ratio", therefore this parameter was omitted from the formula.

Walkability = (2*z-connectivity) + (z-residential density) + (z-land use mix)

The results of this study showed that gender did not moderate the associations of neighborhood walkability and socioeconomic status (SES) with adolescent physical activity. Only in low-SES neighborhoods, neighborhood walkability was positively associated with physical activity. For active transport to and from school, no association with neighborhood walkability nor with neighborhood SES was found.

All these calculations are sums of weighted z-scores of land-use variables, which results in values that are difficult to compare. (Frank, L. et al., 2005) Frank, L. et al. (2009) suggest to normalize these results to fit a 0 to 1 scale, with 0 being the lowest (lowest walkability/car dependent) and 1 being the highest (most walkable). The walkability index can in this way be divided into quartiles. The other

mentioned walkability studies did not discuss the exact results of the walkability calculation nor the comparison of these results. The research from the Built Environmental and Health Research Group at Colombia University (s.d.) into the association of neighborhood walkability with pedestrian activity among residents of New York City expressed the calculated neighborhood walkability by quintiles.

Another possibility is to divide the walkability scores in deciles, as is mentioned in the study of Cerin, E. et al (2006). Walkability was measured on the neighborhood level, using GIS data on four neighborhood attributes: residential density, street connectivity, land use mix and retail floor area ratio, with higher values of these characteristics indicating more walkable neighborhoods. Within the 16 selected neighborhoods, the walkability indices of 103 census blockgroups were divided in deciles. The top four and bottom four deciles represented high-walkability and low-walkability areas.

After a profound research of the scientific literature, the division in quartiles seems to be a common way of representing the walkability index, as is shown in the studies from (Coffee, N., 2005), (Mayne, D. et al., 2013), (Müller-Riemenschneider, F. et al., 2013) and (Leslie, E. et al., 2005). The master thesis from Coffee, N. (2005) into the construction of an objective walkability index constitutes this index from four measures: dwelling density, intersection density, land use and net retail area. For each measure, the decile score (between 1 and 10) is summed without weighting. The resulting walkability index is further classified into quartiles with the first quartile representing low walkability and the fourth quartile representing high walkability.

Müller-Riemenschneider, F. et al. (2013) agree that previous studies have frequently divided walkability scores into quartiles or quintiles to investigate associations with relevant outcomes as compared to investigations of linear associations with continuous measures. In the observational research from Müller-Riemenschneider, F. et al. (2013) into the neighborhood walkability and cardiometabolic risk factors in australian adults were the participants living in areas with high walkability (highest quartile) compared with those living in less walkable neighborhoods (other three quartiles). This distribution facilitates the comparison of approach and results with other studies of neighborhood walkability.

Leslie, E. et al. (2005)'s study into the perceptions of residents of walkability attributes in objectively different neighbourhoods calculated a walkability index on the level of Census Collection Districts (CCDs), the smallest spatial unit defined by the Australian Bureau of Statistics. The three measures that were included are land use, dwelling density and intersection density. Each of them were classified into deciles to provide a standard score for the three measures, with 1 representing the lowest 10 per cent of CCDs for each measure and 10 representing the top 10 per cent of CCDs for each measure. The walkability score was eventually classified into quartiles, with the 1st and 4th quartiles used to represent the lowest and highest walkability CCDs respectively. This division was also utilized in the conference from Witten, K. et al. (2009) dealing with the correspondence between objective and experiential measures of walkability. The four walkability measures, i.e. intersection density, dwelling density, land use mix and retail floor area ratio, were classified into deciles and recoded into values from 1 (1^{st} decile) to 10 (10th decile). The walkability index for each meshblock was calculated by summing the four 1 to 10 scores, resulting in a possible score from 4 to 40. The main result from this research was that neighborhoods measured as more walkable were also experienced by residents as more walkable.

The study of Duncan et al. (2011) measured the walkability of Metropolitan Areas, which usually comprises multiple neighborhoods or cities, by utilizing the Walk Score, which is an online medium for measuring the walkability of any address in the United States, Canada, and Australia using a patent-pending system. The Walk Score analyzes for each address hundreds of walking routes to nearby facilities. Depending on the distance to the facilities in every category, points are given, with a maximum of points for amenities within a 5 minute walk. To give points to more distant facilities, a decreasing function is used, with no points given after a 30 minute walk. Walk Score thus measures the connectivity, which is one of the two fundamental aspects of walkability, nearby a defined address. Walk Score also measures pedestrian friendliness by analyzing population density and road metrics such as block length and intersection density. The Walk Score uses data sources such as Google, Open Street Map, the U.S. Census, places added by the Walk Score user community, etc. (Walk Score, 2014)

The result of the study of Duncan et al. (2011) was normalized to fit a 0 to 100 scale, with 0 being the lowest (lowest walkability/car dependent) and 100 being the highest (most walkable). This division was determined by Walk Score (2014) and shown in the appendix in table 8.

When using GIS to measure the built environment, some problems can arise. Although many characteristics of the physical environment can be readily measured with GIS, some physical features are not commonly incorporated into GIS databases (e.g. sidewalk width). These physical features can be assessed through direct observation. Another problem is the requirement of specialized expertise and that it can be time-intensive. In some cases, GIS data layers might not be readily accessible for certain geographic regions and can be expensive to acquire. (Duncan et al., 2011) It is in this study impossible to use GIS-based measures as the objective method for the measurement of the physical environment, because there is no standardized measurement of detailed data concerning the physical environment in the city of Hasselt executed and the cost of acquiring this GIS data is high. For this reason, another way to measure the built environment, i.e. direct observation, was chosen in this study.

Direct observation uses audit tools, which allow systematic observation of the physical environment. Audit tools typically require in-person observation for collecting data; by which researchers walk or drive through the research area, while systematically coding characteristics using definitions and a standardized form. The audit tool is usually a paper form containing close-ended questions (e.g., check boxes, Likert scales) and sometimes open-ended questions or comments. Recently audit tools have been developed that use personal digital assistant (PDA) devices, which reduce the time for data entry and the errors in collecting data. The audit tools include measures of land use, streets and traffic, sidewalks, bicycling facilities, public space/amenities, architecture or building characteristics, parking, maintenance and indicators related to safety. (Brownson, R. et al., 2009)

Summary:

Normally, the objective method to measure the physical environment is the use of GIS-based measures, based on existing data sources that have some spatial reference. Another way to measure the built environment is direct observation by using audit tools. The reasons for choosing direct observation over GIS-based measures are the lack of standardized measurement of detailed data concerning the physical environment in the research area and the high cost of acquiring this GIS data. When all the individual physical environment measures are assessed, a single composite objective walkability index is developed by summing the z-scores of the individual indicators (primarily for land-use mix, density, and street pattern).

Subjective walkability

The methods to measure the perception of the environment, i.e. the subjective part of walkability, are telephone interview or self-administered questionnaires (in person or by mail). The most commonly assessed variables involved land use, traffic, aesthetics, and safety from crime at a neighborhood or community level. It is important to develop a questionnaire that is as short as possible, but measures what is needed for the project, because response rates can be negatively affected by long questionnaires. (Brownson, R. et al., 2009)

The most frequently used subjective indicators in literature are listed under here and described in table 7 in the appendix.

- Perceived residential density
- Perceived density of intersections/ street connectivity
- Perceived land use mix/ proximity to nonresidential land uses (land use mix – diversity)
- Perceived net retail area
- Ease of access to nonresidential uses (land use mix – access)/ Perceived walking times to various closest destinations
- Infrastructure for walking and cycling

- Aesthetics
- Traffic safety

When using self-reported data, some caution is needed, because this data is in advance influenced by several socio-demographic factors (Dewulf, B. et al, 2012). Therefore the data set should be corrected by analyzing the data according the crucial socio-demographic factors. This way the sample is a good representation of the target population.

The study from (Brownson, R. et al., 2009) cites the Neighborhood Environment Walkability Scale (NEWS) or the abbreviated version NEWS-A as the tool that is most frequently used on the international scale to assess the perceived characteristics of the environment of which it is assumed that these influence walking and other physical activities. They consist of respectively 98 and 54 items, grouped in 8 multi-item subscales. These subscales measure, according to Leslie, E. et al. (2007), the perception of the two fundamental aspects in relation to the built environment, i.e. proximity to destinations and connectivity and the other relating aspects, e.g. crime. The abbreviated version of NEWS was created in an attempt to provide a more concise and empirically-derived measure of various aspects of the built environment related to walking. (Cerin et al., 2009)

NEWS-A consists of 54 items, grouped in 8 multi-item subscales:

- Perceived residential density
- Proximity to nonresidential land uses (land use mix – diversity)
- Ease of access to nonresidential uses (land use mix – access)
- Street connectivity
- Infrastructure for walking and cycling
- Aesthetics
- Traffic safety
- Safety from crime

Every answer in the multi-item survey matches a score, which are combined in a score on subscale level. All subscales, with the exception of residential density and land use mix – diversity, are rated on a 4-point Likert scale, which ranges from strongly disagree to strongly agree. Residential density items are rated on a 5-point scale, ranging from none to all. Land use mix – diversity is assessed by the perceived walking proximity from home to various types of destinations, with responses ranging from 1- to 5-minute walking distance (coded as 5) to >30-min walking distance (coded as 1). (Cerin et al., 2009)

Summary:

The subjective methods to measure the physical environment are telephone interview or self-administered questionnaires. The most frequently used tool to assess the perceived characteristics of the environment related to walking is the Neighborhood Environment Walkability Scale (NEWS). The abbreviated version NEWS-A was created to provide a more concise and empirically-derived measure. Both surveys consist of 8 multi-item subscales that measure the perception of the two fundamental aspects in relation to the built environment, i.e. proximity to destinations and connectivity and the other relating aspects.

Overview objective and subjective walkability

Most of these measures, both objective and subjective, are considered to be first generation measures, which are currently the only available and scientific measures (Brownson, R. et al., 2009). Until now, there has been little undertaken to investigate walkability in Flanders. The only research that could be found, relating to walkability, is the study of De Meester, F. et al. (2012) which investigates whether neighborhood walkability and neighborhood socioeconomic status (SES) are associated with

physical activity among Belgian adolescents and whether the association between neighborhood walkability and physical activity is moderated by neighborhood SES and gender. Neighborhood walkability is the same concept as walkability, but on a more detailed level, that is the neighborhood. This research relates walkability with the health of the target population and thus uses another method to measure these suggested associations. The neighborhood walkability was measured, in accordance with previous cited sources, for each statistical sector using three objective GIS-based measures: residential density, intersection density and land use mix, all combined in a walkability index per statistical sector. The physical activity was objectively assessed using accelerometers and self-reported by using the Flemish Physical Activity Questionnaire (FPAQ), the Flemish version of the IPAQ. The demographic variables, i.e. gender, age, nationality and SES, were self-reported. The conclusions that were drawn in this study showed that neighborhood walkability was only positively related to physical activity among adolescent boys and girls living in low-SES neighborhoods.

As a summary of the literature review, an overview of the most frequently used walkability indicators, both objective and subjective and per component, is given in the following table.

TABLE 1 Overview Most Frequently Used Indicators of Walkability

Component	**Objective**		**Subjective**	
	Indicator	**References**	**Indicator**	**References**
Proximity to destinations				
Population density	Population density	(Duncan et al., 2011)		
	Residential density	(Reis, R. et al., 2013) (Frank, L. et al., 2005) (Frank, L. et al., 2009) (Dewulf, B. et al, 2012) (Duncan et al., 2011) (Müller-Riemenschneider, F. et al., 2013) (Cerin, E. et al., 2006)	Perceived residential density	(Cerin et al., 2009)
Land use mix	Land use mix	(Reis, R. et al., 2013) (Frank, L. et al., 2005) (Frank, L. et al., 2009) (Dewulf, B. et al, 2012) (Duncan et al., 2011) (Müller-Riemenschneider, F. et al., 2013) (Cerin, E. et al., 2006)	Perceived land use mix	(Cerin et al., 2009)
	Net retail floor area	(Frank, L. et al., 2009) (Dewulf, B. et al, 2012) (Cerin, E. et al., 2006)	Perceived net retail floor area	(Cerin et al., 2009)
Connectivity				

Intersection density	Intersection density	(Reis, R. et al., 2013) (Frank, L. et al., 2005) (Frank, L. et al., 2009) (Dewulf, B. et al, 2012) (Duncan et al., 2011) (Müller-Riemenschneider, F. et al., 2013) (Cerin, E. et al., 2006)	Perceived intersection density	(Cerin et al., 2009)
	Highway density	(Duncan et al., 2011)		
Accessibility	Median pedestrian route directness (median of the ratio of distance between one point and another via the street network and straight-line distance between two points) route)	(Duncan et al., 2011)	Perceived walking times to various closest destinations	(Dewulf, B. et al, 2012)
Other				
Infrastructure for walking	Count of cul de sacs (based on nodes associated with only one street segment)	(Duncan et al., 2011)	Perception of infrastructure for walking	(Cerin et al., 2009)
Traffic safety	Average speed limit	(Duncan et al., 2011)	Perceived traffic safety	(Cerin et al., 2009)

RESEARCH QUESTIONS

As in the rest of the paper, the division between objective and subjective walkability is persisted:

- The objective part of the study examines the current score of the walkability index in the research area.
- The subjective part of the study investigates how the target population within the research area, i.e. the frequent users of the pedestrian facilities in the research area, perceive or think about the area in the context of the quality of walking.
- The final research question investigates to which extent the objective and subjective dimension of the walkability in the research area correspond. If both dimensions are not approximately compatible, the question arises which recommendations should be formulated to improve the correspondence and to bring the objective and subjective walkability to a higher quality level, if necessary.

METHOD

Design

This study demonstrates how a standardized method of the measurement of both the objective and subjective component of walkability can be applied in Flanders on the local level (i.e. neighborhood level). Our research area is located in Hasselt, a city in the region of Flanders, Belgium with an area of

102.20 km², 73.807 residents and thus a population density of 721,9 residents per km² (FOD Economie, AD Statistiek en Economische informatie, 2011).

The 'small ring' ('kleine ring') is chosen as our neighborhood of interest, as most of the researches in walkability are on the neighborhood level. The 'Spatial Composition plan Hasselt' ('Ruimtelijk Structuurplan Hasselt'), by Technum (2009) mentioned that the concentration of cultural inheritance in the area of the 'small ring' is very high, with approximately 57 preserved buildings within an area of 0.216km². We assume in accordance with Technum (2009) that this high concentration of cultural inheritance is one amongst other indications of the importance of avoiding polluting travel modes in the city center. The center function of the area within the 'small ring' shows that it is important within this area to encourage the use of more sustainable travel modes, like walking.

The area of the 'small ring' is approximately 0,324km² big and contains 2.546 inhabitants (Gemeente Hasselt, 2011). We assumed that the 'small ring' acts both as a physical and psychological barrier for walking, because of its flow function for motorized traffic around the city center.

In similarity with the research of Dewulf, B. et al. (2012), Cerin et al. (2009) and Reis, R. et al. (2013), a statistical sector within the neighborhood was chosen as research area. A statistical sector is the smallest territorial base unit for what socio-economic statistics are computed (Nationaal Geografisch Instituut, 2013). Because the area within the small ring consists of two statistical sectors, i.e. SS1 Hasselt center East and SS2 Hasselt center West, both sectors are included in this study. This is shown in figure 1 in the appendix.

Participants

The target group of this study is, in accordance with the related works of (Reis, R. et al., 2013) (Frank, L. et al., 2009) (Dewulf, B. et al, 2012) in foreign countries, a number of randomly sampled adult residents per selected neighborhood or statistical sector. Overall, the participants in the related walkability studies were between 20 and 65 years old. The statistical sector Hasselt center East, also called SS1, contains in total 1.068 inhabitants of which 88 were younger than or 19 years old and 980 were older than 20 in 2011, according to (Gemeente Hasselt, 2011). The statistical sector Hasselt center West, also called SS2, contained in 2011 1.478 inhabitants of which 148 were younger than or 19 years old and 1.330 were older than 19. Only the inhabitants older than 19 years old were considered in this study, so the target group consists of 2.310 inhabitants. Although children and adolescents also use the pedestrian facilities in both statistical sectors, they are not included in the target population because they travel less often autonomous by foot than adults and their ability to perceive the research area concerning walking is not yet fully developed. Therefore, only persons older than 19 were included in this study. Residents older than 65 years old were not included the related walkability studies, but in this study they are, because of the relative large share of the elderly in the city of Hasselt in comparison with other cities in Flanders. Approximately 20% of all residents in Hasselt are 65+ years old, while the average share of the elderly in Flemish cities is around 16%. (Algemene Directie Statistiek en Economische Informatie (ADSEI) van de FOD Economie, 2012)

The center of Hasselt also consists of numerous shops, offices and horeca, which is the reason the target group is extended to all the employees and 20+ inhabitants in the SS1 and SS2 in Hasselt. The involvement of the employees was not found in related scientific work, because those research areas mainly consist of residential area, but we consider it as an added value for the research. We developed the hypothesis that employees spend a lot of time on and in the environment of their work location, so they must have a certain perception of the walkability of that environment.

So the requisite for persons to participate in this study is:

- to have an age of 20 years or older
- to be a resident of or employee in statistical sector 1 or 2

Procedure & materials/data/tools

Objective Walkability

Because of the distinction between the objective and subjective quality of walking, the research is divided in an objective and subjective approach. The first task is to constitute an objective indicators matrix, based on previous research on walkability. The objective quality of walking in the statistical sectors 1 and 2 in Hasselt is calculated by an overall walkability index, constituted by a number of relevant indicators. In a large share of the cited related literature, a four-attribute walkability index is used, consisting of residential density, density of intersections, land use mix and net retail area. But Mayne, D. et al. (2013) postulate that the use of this four-attribute index is often limited by the availability of retail floor space data. The application of three-attribute indexes may allow then greater use of walkability indexes in research, but research on the comparability of associations between three and four-attribute indexes and domain-relevant outcomes is required. (Mayne, D. et al., 2013) In this case, there was no data on the retail floor space available for the statistical sectors SS1 and SS2. We decided to not include this attribute in the walkability index, because of its difficult measurement.

Subjective Walkability

Although the NEWS survey is most frequently used in previous walkability research, in this case the abbreviated version NEWS-A sample survey was chosen as the basis for the subjective part of this study, because we expect a higher response rate from the target population if the survey is of a shorter length. The use of NEWS-A, rather than the NEWS survey, is recommended by Cerin, E. et al. (2006) whenever participant burden is a significant concern.

Some additions were made to this survey, containing the addition of a number of essential socio-demographic questions, the translation of the survey in Dutch and the development of an online version of the survey using Qualtrics, because this way more participants can be reached. The target population was informed about this survey through numerous communication channels that is by personal distribution of 1400 informational letters to randomly sampled employees and residents, a reference in the digital newsletter of the local authorities to the residents, a reference on the websites of Okra and Seniorennet and on the Facebookpage of the local authorities.

To estimate the minimum sample size the population size of the research area, the desired confidence level, the margin and the probability of errors are considered. (Alles over Marktonderzoek, 2014) In this case, the population consists of both all the residents of 20 years old or older and all the employees in SS1 and SS2. The size of the target population is unknown, because of the lack of detail in the statistics of Hasselt. The number of employees is only measured on city level, not on statistical sector level, which means that no estimation of the share of employees can be deducted from the share on city level.

The desired confidence level in most scientific studies equals 95%, so this level was chosen for this study. This confidence level corresponds to a Z-score, a constant value, that is 1.96 in this case. The margin and probability of errors have to be determined, because every research based on a sample results in deviations in comparison with reality. The margin of error, also called the confidence interval, determines how much higher or lower than the population mean you are willing to let your sample mean fall. The logical consequence of a confidence level of 95% is a margin of error, a p-value, of 5%. The probability of errors, also called the standard of deviation, shows how much variance is expected in the responses. The safest option is to use a variance of 0.5 when the survey is not administered yet. (Smith, 2013)

Once all these variables are known, except for the population size, following equation can be used to calculate the necessary sample size (Smith, 2013):

$$\text{Necessary Sample Size} = (\text{Z-score})^2 * \text{StdDev}*(1-\text{StdDev}) / (\text{margin of error})^2$$
$$= ((1.96)^2 \times .5(.5)) / (.05)^2 = .9604 / .0025 = 384.16$$

So it can be concluded that there are 385 respondents needed in this research to achieve reliable results. If we calculate the minimum sample size with the assumption of a population size of 2.310

persons, which are all the residents in SS1 and SS2 of 20 years or older, a confidence level of 95% and a confidence interval of 5%, this results in a sample size of 330 respondents or more.

Data-analysis

Objective Walkability

The walkability index is calculated by summing the z-scores of the individual indicators residential density, density of intersections and land use mix. Z-scores indicate how much an individual score deviates from the mean and whether a score lies within the normal distribution. Scores that are not found in the interval (–1.645;1.645) have a probability lower than 5% (Lund, A. & Lund, M., 2013). The calculation of z-scores is easily done with IBM SPSS Statistics 22. Table 2 gives a detailed overview of the assessment of the objective indicators and calculation of the objective walkability index per statistical sector.

TABLE 2 Calculation Objective Indicators and Walkability Index

Objective indicators	Calculation	Measurement scale	Score SS1	Score SS2	Source/procedure
Residential density	Ratio of residential units and number of residential units/km² of residential land A residential dwelling unit means a single-family residence where one or more persons maintain a household, including a manufactured home. (The State Decoded, 2012)	Quantity/km²	730 households /0.12km² = **6083 hh/km²**	852 households /0.096km² = **8875 hh/km²**	Because there was no data available concerning the number of residential units on the detailed level of statistical sectors in Hasselt, the number of households was chosen as a substitute. (Provincie Limburg, 2013) The area within the 'small ring' was calculated by: Area of a circle = $1/4 \pi d^2 = ¼\ \pi\ (524m)^2 = 0.216km^2$ Boundary between both SS is the chord of a circle segment, i.e. SS1: area SS1= 0.12km² area SS2 = area circle - area SS1 = 0.096km²
Density of intersections	Number of intersections in SS1 and SS2 True intersections consist of 3 or more legs (Kerr, J. et al., 2006)	Quantity/km²	40/0.12km² = **333/km²**	37/0.096km² = **385/km²**	We counted the number of intersection per statistical sector by observing a map of the city center of Hasselt (Google, 2013)

Land use mix	Equality of floor space among 5 categories of land use (Reis, R. et al., 2013)	%	0.9195/1.6094
			= 0.5713
			= **57%**
				0.9178/1.6094
				= 0.5703
				=**57%**
					The calculation of the land use mix is an adjusted version of the general formula in the study from Frank, L. et al. (2006) of a mix of 6 land use categories: land use mix= −A/(ln(N)). This calculation is adjusted to another number of land uses, what changes the value of N, in this case for five land uses. Because the land use was measured by observing the number of buildings per land use instead of measuring areas per land use, the value of a differs from the original formula.
					
					Adjusted formula: Land use mix= −A/(ln(N)) with
					
					• A=(b1/a)*ln(b1/a) + (b2/a)*ln(b2/a) + (b3/a)*ln(b3/a) + (b4/a)*ln(b4/a) + (b5/a)*ln(b5/a)
					• a = total number of buildings for all land uses in the research area (instead of total square feet of land for all land uses)
					• b1-b6 measure buildings of land use (instead of areas of land use) for:
					  ○ b1= residential
					  ○ b2= commercial
					  ○ b3= recreational
					  ○ b4= educational/cultural
					  ○ b5= other
					• N= number of land uses with buildings>0 (instead of area > 0)

Residential land use	Ratio of area within SS1 and SS2 assigned to residential use and total area within SS1 and SS2	%	146/553 = 26,4%	232/643 = 36,1%	A map from the area within the ‘small ring’ in Hasselt (Google, 2013) was printed as the worksheet for the observation of the land uses. Then we walked through each street within the ‘small ring’ and marked for every building its land use category on the map (worksheet). This worksheet is shown in the appendix in figure 3. When this was finished, we summed up all the buildings for each land use per statistical sector and divided this number by the total number of buildings within the statistical sector.
Commercial land use	Ratio of area within SS1 and SS2 assigned to commercial use	%	360/553 = 65,1%	362/643 = 56,3%	Observation & (Google, 2013) e.g. bakery, clothes shop, restaurant

	and total area within SS1 and SS2				
Recreational land use	Ratio of area within SS1 and SS2 assigned to recreational use and total area within SS1 and SS2	%	10/553 = 1,8%	2/643 = 0,3%	Observation & (Google, 2013) e.g. fitness, orchestra, sports team
Educational/ cultural land use	Ratio of area within SS1 and SS2 assigned to educational/cultural use and total area within SS1 and SS2	%	8/553 = 1,4%	3/643 = 0,4%	Observation & (Google, 2013) e.g. university, high school, theatre
Other land use	Ratio of area within SS1 and SS2 assigned to other use and total area within SS1 and SS2	%	29/553 = 5,2%	44/643 = 6,8%	Observation & (Google, 2013) e.g. hospital, local services, register, shelter
Net retail area	Ratio of retail shop floor-area in SS1 and SS2 and total retail parcel area area in SS1 and SS2, with a higher value indicating less parcel space allocated to car parking at retail sites	Quantity/km²	/	/	This data was not available for both statistical sectors.
Population density	Number of residents in SS1 and SS2	Quantity/km²	1.068/0.12km² = **8900/km²**	1.478/0.096km² = **15396/km²**	(Gemeente Hasselt, 2011)
Average speed limit	Ratio of the sum of speed limits in SS1 and SS2 and number of different speed limits in SS1 and SS2	km/h	maximum speed of 30km/h	maximum speed of 30km/h	(Stad Hasselt, 2003)
Total walkability index W	Sum of statistical Z-scores of 4 parameters: Residential density (D), Density of intersection (I), Land use mix (M) and Net retail area (R). W= Zd +Zr+Zm+ (2*Zi)	Without unit (per postal code) (per neighborhood = census unit)	n/a	n/a	(Frank, L. et al., 2009) (Kerr, J. et al., 2006) (Badland, H.M. et al., 2009)
	Sum of statistical Z-scores of 3 parameters: Residential density (D), Density of intersection (I) and Land use mix (M). W= (6*Zm) + Zd + Zi	Without unit (per Metro Area)	(6*0.79) + (-0.7071) + (-0.7071) = 3.3258	(6*0.79) + (0.7071) + (0.7071) = 6.1542	(Frank, L. et al., 2005)

	Sum of statistical Z-scores of 3 parameters: Residential density (D), Density of intersection (I) and Land use mix (M). W = (2*Zi) + Zd + Zm	Without unit (per statistical sector)	(2*(-0.7071)) + (-0.7071) + 0.79 = -1.3313	(2*(0.7071)) + (0.7071) + 0.79 = 2.9113	(De Meester, F. et al., 2012) (Mayne, D. et al., 2013)

Subjective Walkability

The NEWS-A survey was completed by 288 respondents, which is a too little sample size to have a confidence level of 95%. Only 157 respondents of the 288 are meeting the inclusion criteria for this survey, i.e. being resident and/or employee within the area of the ‘small ring’ in Hasselt.

Every answer in the multi-item survey matches a score, which is in most of the cases according to the rule: a higher score denotes a higher walkability. The scoring procedures are listed by (Dr. James Sallis - Measures to Download, s.d.) and these combine the individual scores per answer in a score on subscale level, of which there are 8. After the online NEWS-A survey in Dutch was completed by 288 respondents, it was deactivated to analyze the results. First, every value per question was recoded from words to numbers, according to the scoring procedure from Dr. James Sallis. Then the score for all the respondents per subscale was calculated. Because self-reported data is influenced by several socio-demographic factors, the data set is to a limited extent corrected by calculating the scores per subscale according as gender, age and resident/employee. This way the sample is a relatively good representation of the target population, although the results can not be generalized for all the residents and employees older than 20 years old within the ‘small ring’ in Hasselt.

RESULTS

Objective Walkability

The results in table 2 show that statistical sector 2, i.e. Hasselt Center West, overall has a higher score than SS1, except for the variable land use mix. The equality of floor space among 5 categories of land use, i.e. land use mix, is exactly the same for both statistical sectors, which is remarkable, taking into account the smaller area of SS2. Two variations of calculating the objective walkability index are utilized, but both sum up the z-scores of the individual indicators. Although the calculation of z-scores is much more meaningful when there is an abundance of comparable items available, it is the only way to calculate the objective walkability index.

Walkability indices can have negative values, for example in the study from Frank, L. et al. (2005) the walkability index had values ranging from –14.66 to 30.53. The summation proposed by Frank, L. et al. (2005) had a positive value for SS1, while the summation proposed by De Meester, F. et al. (2012) and Mayne, D. et al. (2013) resulted in a negative value for SS1, which can be interpreted as an average objective walkability score for Hasselt center East. Statistical sector 2 had the highest walkability score and both the calculated walkability values were positive, so we interpret this as an average to good objective walkability score for Hasselt center West. The two ways of summation both show a higher walkability score for SS2, so it can be concluded that the objective walkability is higher in Hasselt Center West.

Subjective walkability

Descriptive Statistics

Descriptive statistics are presented in table 3 for demographics. The distribution of the discrete variable residence and/or work location within the 'small ring' shows some remarkable percentages. 1/4th of the complete sample claims to work on a location within the small ring, 22% to reside within the small ring and approximately 7% claims to both work en live within the small ring. But 37% does not work nor lives within the research area, which means that the sample size shrinks with 106 persons to be meaningful. At last, there were 25 missing values for this crucial variable, which represents 8.7%. The sample size, only consisting of respondents that comply with the inclusion criteria, comprises 157 respondents. The data show that there is no equal distribution of males and females in the sample. Around 40.8% of the valid participants are male, while 59.2% consists of females. The continuous variable age was structured in categories of 20 years. The largest share of the participants, 45.9%, has an age between 20 and 39 years old.

A more detailed distribution was made within the small ring, i.e. the distribution between SS1 Hasselt center East and SS2 Hasselt center West. 15.3% of all the participants lives in SS1 while 21% lives in SS2. 14 % of all the participants works in SS1 while 29.3% works in SS2. 3.2% both works and lives in SS1 and 4.46% both works and lives in SS2.The last possible combinations are working in one statistical sector and living in another. 1.3% lives in SS1, but works in SS2 and 3.2% of all participants works in SS1, but lives in SS2. The remaining 8% indicated to work and/or live within the ‘small ring’, without specifying their residence and/or work location. It can be concluded that the largest share of the participants is found in statistical sector 2, Hasselt Center West.

TABLE 3 Sample Characteristics (N=157)

	Mean or %		SD	Range	Mean or % SS1	Mean or % SS2
Gender	Female: Male:	59.2% 40.8%	n/a	n/a	60.4% 39.6%	60.7% 39.3%
Age (in years)	45.46		16.419	20-84	45.6	45.36
Residence and/or work location within the 'small ring'	Residence: Work location: Both:	40.8% 45.9% 13.4%	n/a	n/a	49.1% 39.6% 11.3%	38.2% 52.8% 9%
Education	Primary education: Special needs education: High school (technical/vocational): High school (general): Higher non-academic education: Higher academic education: Other:	1.3% 0.6% 17.2% 15.9% 40.1% 24.2% 0.6%	n/a	n/a	0% 0% 18.9% 22.6% 34% 22.6% 1.9%	2.2% 0% 15.7% 12.4% 43.8% 25.8% 0%
Family members	(including participant)	2.35	1,106	1-5	2.30	2.38
Marital status	Unmarried: Married: Cohabiting: In relationship (not cohabiting): Divorced: Widow/widower: Other:	19.7% 44.6% 20.4% 6.4% 7.0% 0.6% 0.6%	n/a	n/a	30.2% 37.7% 18.9% 3.8% 9.4% 0% 0%	13.5% 49.4% 22.5% 7.9% 4.5% 1.1% 1.1%
Profession	Laborer: Servant (executive position): Servant (not an executive position): Retired: Liberal profession: Self-employed: Civil servant: Student/pupil: Housewife/houseman: Disabled (>1year): Other:	4.5% 12.7% 33.1% 15.3% 0.6% 9.6% 14.0% 3.8% 1.3% 1.9% 2.5%	n/a	n/a	7.5% 9.4% 34% 17% 0% 7.5% 11.3% 7.5% 3.8% 0% 1.9%	2.2% 14.6% 33.7% 14.6% 1.1% 11.2% 14.6% 1.1% 0% 3.4% 3.4%

Abbreviations: n/a, not applicable, SD, standard deviation.

The first test to execute on the walkability subscales is the distribution test, i.e. the normality test. This is a crucial criterion before executing T- and F-tests on variables, because the use of these tests hinges on the assumption of normality of underlying distributions of the variables. (Gupta, V., 1999). So it is important to decide whether to execute parametric tests when the distribution is normal or non-parametric tests if not. This is tested using the one sample Kolmogorov-Smirnov method, a non-parametric test, based upon the Z distribution. (Gupta, V., 1999) The crucial criterion in this test is the significance value, which is provided by SPSS. The standard criterion that is used for significance is the hypothesis that the distribution is normal can be rejected at the 95% level of confidence. So if the significance value is lower than 0.05, the variables are distributed normally. The results show that all the subscales are distributed normally, i.e. have a significance value lower than 0.05, except for land use mix – diversity (residence) and land use mix – diversity (work location), which have a value of respectively 0.200 and 0.148. For both subscales, non-parametric tests are then used.

Descriptive analysis walkability subscales

The next step is the descriptive analysis of the walkability subscales of the NEWS-A survey. Because the related literature showed that it is a common way of representing the walkability index and thus the objective walkability score is divided in quartiles, the subjective walkability score will also be presented in quartiles. Every walkability subscale has a score on the scale of 0 to 4, so each quartile has ranges from zero to one. The first quartile (0-1) represents low walkability, the second (1-2) and third (2-3) quartiles average walkability and the fourth quartile (3-4) represents high walkability. All the subscale scores are summarized in table 4.

Not one subscore is found in the first quartile, i.e. low walkability, which means that the respondents perceive the walkability in SS1 and SS2 as average to high. The subscales with the lowest appreciation in this sample are the residential density, traffic hazards and hilliness. It is remarkable how the score per subscale for both the statistical sectors is found in the same quartile. It thus seems that the subscale scores for both statistical sectors are approximately equal and that the difference between SS1 and SS2 concerning the subjective walkability is marginal. To test per subscale whether there is a significant difference between the statistical sectors SS1 and SS2, the differences between two means are tested. In this case the same variable, i.e. walkability subscale, has been measured in two independent groups, i.e. statistical sectors, and we want to know whether the difference between group means is statistically significant. This is done by the non-parametrical test of Mann-Whitney for the subscale land use mix – diversity and the parametrical two sample t-test for all the other subscales.

Before executing the two sample t-test, some assumptions have to be met, according to Ohio University, College of Arts and Sciences (s.d.):

- The data are continuous
- The data follow the normal probability distribution, which is in this study already tested
- The variances of the two populations are equal
- The two samples are independent
- Both samples are simple random samples from their respective populations

All these assumptions are met, except for the equal variances of the two populations. Before the significance per subscale is checked, the type of two-sample t-test, i.e. for equal or for unequal variances, to use is determined. This is done by the "Levene's Test for Equality of Variances", a test of the homogeneity of variance assumption, i.e. homoscedasticity, for a variable calculated for two or more groups. A high value for F and a P-value lower than 0.05 indicate that the variances are heterogeneous which violates a key assumption of the t-test. (Wielkiewicz, R.M., 2000)

The results of the Levene's Test show that the subscales residential density, land use mix – access and lack of parking have heterogeneous variances, also called unequal variances. The significant difference between both statistical sectors has to be searched in the t-test for Equality of Means under the category ‘equal variances not assumed’, an alternative way of computing the t-test that accounts for

heterogeneous variances. The other normally distributed subscales are found to have homogenous variances, which are equal variances. For these subscales, the difference between S1 and SS2 is found in the t-test for Equality of Means under the category 'equal variances assumed'.

All the values of the significance of the t-test for Equality of Means are higher than 0.05, which means that there is no statistically significant difference between SS1 and SS2 for the walkability subscales. Only the subscale residential density has a significance value close to 0.05. An overview of the test values is given in table 4.

The Mann-Whitney test is used as the alternative for the independent t-test for the subscale land use mix – diversity, because its distribution is not normal, a requisite for the t-test. The significance values are higher than 0.05, so there is no statistically significant difference between SS1 and SS2 for the walkability subscale land use mix – diversity.

The walkability subscales land use mix – diversity and land use mix – access both have three values for the significance test, unlike the other subscales. This is because of their further distribution in the NEWS-A survey into the categories residents, employees and both. This distribution was done because the questions in both land use mix subscales focused on the concrete home or work location, unlike the questions from the other subscales, which were more abstractedly described.

TABLE 4 Scores Subscales NEWS-A Survey

Subscale	**Meaning**	**SS1 Mean (range) + SD**	**Quartile**	**SS2 Mean (range) + SD**	**Quartile**	**Significance T-test for Equality of Means**
Residential density	score ↑ walkability ↑	1.44 (0.00 – 3.13) ± 0.74	2nd	1.68 (0.00 – 3.14) ± 0.51	2nd	0.05 T
Land use mix – diversity	score ↑ walkability↓	1.88 (1.1 – 2.99) ± 0.59	3rd	1.91 (1.19 – 3.29) ± 0.60	3rd	0.15 M-W 0.57 0.92
Land use mix – access	score ↑ walkability ↑	3.71 (2.67 – 4.00) ± 0.46	4th	3.95 (3.33 – 4.00) ± 0.10	4th	0.30 T 0.95 0.33
Street connectivity	score ↑ walkability ↑	3.37 (1.50 – 4.00) ± 0.65	4th	3.22 (1.50 – 4.00) ± 0.74	4th	0.08 T
Infrastructure and safety for walking	score ↑ walkability ↑	2.76 (1.33 – 3.67) ± 0.53	3rd	2.66 (1.50 – 4.00) ± 0.55	3rd	0.25 T
Aesthetics	score ↑ walkability ↑	2.87 (1.50 – 4.00) ± 0.58	3rd	2.81 (1.00 – 4.00) ± 0.59	3rd	0.32 T
Traffic hazards	score ↑ walkability↓	2.63 (1.67 – 4.00) ± 0.53	2nd	2.69 (1.67 – 3.67) ± 0.47	2nd	0.59 T
Crime	score ↑ walkability↓	1.77 (0.00 – 3.67) ± 0.93	3rd	1.77 (0.00 – 3.67) ± 0.89	3rd	0.46 T
Lack of parking	score ↑ walkability ↑	3.47 (0.00 – 4.00) ± 0.77	4th	3.41 (0.00 – 4.00) ± 1.11	4th	0.98 T
Lack of dead-end streets	score ↑ walkability ↑	3.07 (0.00 – 4.00) ± 1.26	4th	3.11 (0.00 – 4.00) ± 1.34	4th	0.75 T
Hilliness	score ↑ walkability↓	2.44 (1.00 – 4.00) ± 0.85	2nd	2.08 (0.00 – 4.00) ± 1.18	2nd	0.86 T
Physical barriers	score ↑ walkability↓	1.40 (0.00 – 4.00) ± 0.82	3rd	1.42 (0.00 – 4.00) ± 0.89	3rd	0.08 T

Abbreviations: ↑, increasing, ↑, decreasing, SD, standard deviation, T, T-test, M-W, Mann-Whitney test.

Correlations

The next, more detailed, item that is interesting to investigate is the correlations of the walkability subscales with the socio-demographic variables per statistical sector. The socio-demographic variables that are included are gender, age, resident and/or employee within the statistical sector, current profession, highest education level, marital status and number of family members. It is important to realize that correlations can not be generated with nominal data, so the variables gender, resident and/or employee within the statistical sector, current profession, highest education level and marital status have to be analyzed with the Chi square, which only shows whether the variables are related, but won't give a correlation. As the Chi square only shows whether there is a relation, but not the size of its effect, the Cramer's V is calculated in SPSS22 to give an indication of the association between two variables as a percentage of their maximum possible variation. The value of V lies between zero and one, with one meaning a perfect relationship and zero meaning a statistical independence.

The correlations for the walkability subscales that are normally distributed are tested with the parametric Pearson test. The use of the Pearson correlation requires that the variables are approximately normally distributed, the variables are continuous, the outliers are removed and that the data is homoscedastic (Lund, A. & Lund, M., 2013). The socio-demographic variables that are ordinal, i.e. age and number of family members, can thus be analyzed for correlations with the walkability subscales. The value of the Pearson correlation coefficient lies between -1 and 1; which means there is a linear relation between both variables. A value of zero means that there is no linear relation, but there may be another, e.g. quadratic, relationship.

The correlations for the walkability subscale land use mix – diversity with the socio-demographic variables is tested with the non-parametric Spearman's rho test. This test is used because land use mix – diversity is not normally distributed, which is a requisite for conducting the Pearson's correlation.

The same rule for both the Pearson and Spearman test count: A minus one indicates a perfect negative correlation, while a plus one indicates a perfect positive correlation. A correlation of zero means there is no relationship between the two variables. The sign of the correlation indicates the direction of association between both variables.

The correlation coefficients are given in table 5, with a bold font indicating a significant relationship on the 95% confidence level. We first consider the significant correlations, which can only be found for the variables age and number of family members.

In SS1, both lack of parking and lack of dead-end streets seem to have a positive correlation with age, which means that when the age increases, the perception of both the lack of parking and lack of dead-end streets increases. This statistical sector also shows a negative correlation with the subscale physical barriers. In SS2, age is positively correlated with the perception of crime. There also seems to be a correlation between the subscale land use mix – diversity and the variable age, which is positive for the residents and employees within SS2, but a negative correlation for the respondents that are both resident and employee within SS2. In both statistical sectors, the number of family members is not correlated with the perception of the walkability.

The significant relations per subscale are shown with a bold font in table 5 for the variables gender, resident and/or employee within the statistical sector, current profession, highest education level and marital status. The correlations with the walkability subscores for these variables is unknown, we only know that they are related. The values of Cramer's V for the significant relations lie between 0.3 and 0.5, which means that the strength of these relations is quite weak. Not one significant relation is perfectly related or statistically independent.

TABLE 5 Correlations walkability Subscales & Socio-demographic Variables

SS1								
Walkability subscales	**Gender (C)**	**Age**	**Resident and/or employee (C)**	**Current profession (C)**	**Highest education level (C)**	**Marital status (C)**	**Number of family members**	**N**
Residential density	0.971	-0.27 P	0.923	0.922	0.978	0.938	0.04 P	49
Land use mix – diversity Residents: Employees: Both:	 1.00 1.00 0.877	S -0.20 -0.20 -0.24	n/a	 1.00 1.00 0.769	 1.00 1.00 0.742	 1.00 1.00 0.809	S -0.10 -0.10 -0.06	 4 4 41
Land use mix – access Residents: Employees: Both:	 0.707 0.707 0.315	S -0.58 -0.58 0.19	n/a	 1.00 1.00 0.989	 0.791 0.791 0.254	 0.577 0.577 0.388	P 0.74 0.74 0.11	 4 4 41
Street connectivity	0.245	0.16 P	0.387	**0.506**	**0.444**	0.319	-0.77 P	44
Infrastructure and safety for walking	0.562	-0.10 P	0.501	0.531	0.533	0.470	-0.07 P	43
Aesthetics	0.508	-0.19 P	0.457	0.532	0.471	0.419	0.13 P	43
Traffic hazards	0.313	0.26 P	0.483	**0.504**	0.333	0.419	-0.12 P	43
Crime	0.587	-0.20 P	0.517	**0.583**	0.485	0.521	-0.06 P	43
Lack of parking	0.234	**0.32** P	**0.389**	0.455	0.288	**0.477**	0.05 P	43
Lack of dead-end streets	0.237	**0.48** P	0.342	0.440	0.313	**0.411**	0.13 P	43
Hilliness	**0.434**	0.30 P	0.321	0.523	0.272	0.318	-0.25 P	43
Physical barriers	**0.487**	**-0.31** P	0.364	0.475	**0.404**	0.345	-0.22 P	43
SS2								
Walkability subscales	**Gender (C)**	**Age**	**Resident and/or employee (C)**	**Current profession (C)**	**Highest education level (C)**	**Marital status (C)**	**Number of family members**	**N**
Residential density	0.828	-0.09 P	0.828	0.788	0.834	0.844	0.01 P	88
Land use mix – diversity Residents: Employees: Both:	 1.00 1.00 0.748	S **0.85** **0.85** **-0.29**	n/a	 1.00 1.00 0.724	 1.00 1.00 0.655	 1.00 1.00 0.757	S 0.46 0.46 -0.14	 7 7 76
Land use mix – access		P	n/a				P	

Residents: Employees: Both:	/ / 0.228	/ / 0.12		/ / 0.506	/ / 0.218	/ / 0.242	/ / 0.09	7 7 76
Street connectivity	0.290	0.16 P	0.239	0.363	0.170	**0.365**	-0.02 P	83
Infrastructure and safety for walking	0.442	-0.05 P	0.444	0.449	**0.543**	0.439	-0.05 P	81
Aesthetics	0.370	0.22 P	0.287	0.401	**0.451**	0.338	-0.19 P	80
Traffic hazards	0.242	0.06 P	0.303	0.325	0.233	0.255	-0.10 P	80
Crime	0.307	**0.32** P	0.391	0.355	0.339	**0.438**	0.07 P	79
Lack of parking	0.317	-0.03 P	0.146	0.299	**0.349**	0.243	0.08 P	79
Lack of dead-end streets	0.289	0.09 P	0.208	0.301	0.208	0.291	0.16 P	79
Hilliness	1.71	0.38 P	0.287	0.329	0.273	0.250	0.10 P	79
Physical barriers	**0.364**	-0.00 P	0.224	0.334	**0.322**	0.201	0.07 P	79

Abbreviations: (C), Chi square test, P, Pearson test, S, Spearman's rho test

Regressions

Another analysis that can be executed, is the regressions analysis, an investigation of the presence of a predictive association and whether this is a positive or negative effect (Gupta, V., 1999). This can only be done with the correlations between the walkability subscales and the socio-demographic variables that have been shown significant. In this study, only the variable age showed to be correlated to some walkability subscales, i.e. in SS1 positively correlated with lack of parking and lack of dead-end streets and negatively correlated with the subscale physical barriers, in SS2 positively correlated with the perception of crime and correlated with the subscale land use mix – diversity. Regressions are not investigated in this research, because of the low number of significant correlations and low number of respondents that meet the inclusion criteria and thus the possible causal relations would only be relevant to a very limited target population, which would make the generalization of the results of the regression analysis impossible.

DISCUSSION

The walkability indices show that the objective walkability is higher in Hasselt Center West, SS2, but the variable land use mix seems to have the exact same score in both statistical sectors, i.e. 57%. This equal distribution of land uses is remarkable, because the statistical sectors differ in spatial area. Although SS2 has a smaller area, i.e. 0.096km², in comparison with SS1, i.e. 0.12km², the equality of buildings among 5 categories of land use is the same. This result goes against the expectation that a wider area would have a more equal distribution than a smaller area, although the difference in areas is relatively low in this case.

It is hard to compare the objective walkability scores with those in other scientific articles, because the walkability indices depend among other things on the number of indicators that are included and the number of comparable research areas. The inclusion of more objective walkability indicators then results in a bigger range from the indices, because more z-scores are summed. The number of comparable research areas influences the value of the z-scores by increasing its accuracy when the number of research areas increases. So this study, with only two research areas, has a limited accuracy of the z-scores of the objective walkability indices.

The results of the conducted NEWS-A survey show that not one walkability subscale was perceived as low walkable, so the overall perception of the research area is an average to good walkability. The walkability subscales residential density, traffic hazards and hilliness scored average, but the other subscales scored well. The perceptions for each subscale did not significantly differ between Hasselt Center West and Hasselt Center East, which is not surprising. The built environment features of these statistical sectors are very similar, as they both are located in urban settings. This however does not mean that the objective quality of walking is the same for both sectors.

The lack of an overall subjective walkability index hindered the comparison between the objective and subjective walkability in both statistical sectors. This correspondence thus was determined by comparing the meaning of the objective walkability index with the most frequent quartiles of the subjective walkability subscores. The respondents within SS2 did not perceive this sector in total concordance with its objective walkability score. They slightly underestimated the walkability in SS2, while the walkability within SS1 was perceived correctly by the respondents in SS1 as average.

The only significant correlations that were found, are between the socio-demographic variable age and a number of perceived walkability subscales. There were no significant correlations found for the variable number of family members. The other socio-demographic variables are nominal, so no correlations can be found for this type of data. It is obvious that the number of significant correlations in this research is very limited, which probably can be explained by the small number of respondents and the relatively small research area. This low number of correlations is in contrast with our expectations as previous walkability studies showed numerous significant correlations between socio-demographic variables and walkability scores.

The significant relations of the variables gender, resident and/or employee within the statistical sector, current profession, highest education level and marital status with the walkability subscales per

statistical sector are found to have a weak strength. This is contrary to our expectations. We would, for instance, expect that a resident would have another perception of residential density than an employee.

In this study, the subjective dimension of walkability does not deviate substantially from the objective dimension. But since these analyses are based on a small number of respondents, these results cannot be generalized.

As the objective walkability is of sufficient quality, no recommendations are formulated for policy to improve walkability. It would however be interesting for the city of Hasselt to use this good walkability as an added value by promoting the city center as a walkable area. This can boost the image of the city by profiling itself as "the city for pedestrians". To do this, it is important to maintain this level of walkability within the 'small ring'. It can thus be interesting to execute a systematic objective walkability check on a regular basis, in accordance with this study.

IMPLICATIONS

This study has some implications for research, practice and policy. To ensure and maintain the local walkability, it is of crucial importance to understand the aspects of the built environment that facilitate or constrain walking. By linking the objective walkability index to land use and research, planning and policy strategies aimed at ensuring the local walkability, the city of Hasselt has the potential to take the walkability of the city center to a higher level. Such an inclusive approach of policy has a bigger impact than isolated interventions.

This approach should be pursued in the acquisition of GIS-data. Although Geographic Information Systems data have the potential to be a useful walkability surveillance tool, that potential is currently unrealized. But, as previously mentioned, the acquisition of such built environment data is expensive and time consuming, so it can be beneficial to set a cooperation between different departments of the city of Hasselt, e.g. population, economy and transportation. This cooperation ideally leads to the continuous collection of built environment variables that are crucial for measuring walkability.

This study only examined urban settings, as the research area is located in a city center. Suburban and rural settings, which are expected to have different built environment conditions, would probably present different issues for walkability.

CONCLUSIONS

While in the past numerous studies have investigated the walkability of neighborhoods in different countries, this study is the first to examine the walkability in a research area within Flanders, i.e. the 'small ring' in Hasselt. The objective walkability showed to be higher in Hasselt Center West, SS2, with a good walkability, while SS1 has an average quality of walking. As the walkability in both statistical sectors is sufficient, no recommendations are needed.

The respondents perceive the walkability in SS1 and SS2 as average to high with no significant difference of the perceptions per subscale between the two statistical sectors. So the participating residents and employees within statistical sector 2 of 20 years and older misperceive the objectively assessed good walkability while the respondents living and/or working in SS1 correctly perceive the walkability. This deviation from the real quality of walking is not substantial. Significant correlations with walkability subscales of the NEWS-A were only found for one socio-demographic variable, i.e. age, while in previous walkability researches the share of significant correlations was higher. The other socio-demographic variables were only weakly related to the walkability sub scores.

LIMITATIONS AND FUTURE RESEARCH

A major limitation of this study is the lack of GIS data for the city of Hasselt. Although obtaining GIS data can be time-consuming and expensive, it is the most common way to objectively measure the built environment. The local government was contacted, but responded that no measurement of GIS data on the census level has been conducted in Hasselt and thus no detailed built-environment data is available. It was in this study impossible to acquire GIS-based measures, for example the retail floor area ratio, because the time to execute this study is limited and the cost of acquiring GIS data is high, while the budget of this study is non-existent. This complicated and extended the duration of the data collection.

There is only one way of calculating the objective walkability score that is found and used in scientific articles concerning walkability which is summing up the z-cores of the individual indicators. In this research only two walkability scores are compared, i.e. SS1 and SS2, what decreases the meaning of z-scores, which are scores that indicate how much an individual score deviates from the mean. It would be interesting in the future to extend this research by including a lot more statistical sectors in Hasselt for comparison, so the mean would be composed by more than 2 values.

The subjective part of the study is limited by the use of a convenience sample, which means that the participants are persons that are willing to complete the survey. So the participants are not a correct representation of the population within the ‘small ring’ in Hasselt. With a minimum sample size of 330 respondents for a confidence level of 95% and an actual sample size of 157 respondents, the response rate from the target population was lower than expected, although the abbreviated version of the NEWS-survey was used to avoid participant burden, because a higher response rate from the target population is expected if the survey is of a shorter length. The consequences of this lower sample size are the less reliable reflection of the population mean and thus a decrease in the accuracy of estimates, which results in less valid and reliable conclusions. This could partially be solved by obliging respondents to answer the question whether their residence and/or work location is situated within the 'small ring' in Hasselt. In this research 8.7% of the respondents did not answer this question and 37% indicated to not work nor live within the research area, which made the sample size reduce with approximately 46%.

This study focuses on built-environment design on the neighborhood (statistical sector) level as a predictor of the quality of walking, but other factors, according to Bagley, M. & Mokhtarian, P. (2002), can also be important, for instance noise, pollution, weather, topography and personal preferences.

As is suggested by Brownson, R. et al. (2009), further research into the first generation measures is needed. This research should focus on the improvement of the technical quality, the understanding of the relevance for different populations and the value of these first generation measures for science. Another possibility is the use of these measures on a more detailed level, for instance the individual residence level. Many of the measures that constitute the current walkability index can be applied at the individual residence level.

It is recommended to ensure the application of similar definitions and data for computing the values of objective walkability measures, leading to a higher inter-rater reliability in future walkability studies. To attain this, a detailed documentation of the computations of the measures should be composed to ensure replication of the measuring methods.

The investigation of physical activity can be an additional value for this research as it is hypothesized that the building environment is significantly associated with moderate levels of physical activity. The study from Frank, L. et al. (2005) supported this hypothesis by showing a positive relationship between the measures of land-use mix, residential density and intersection density and the number of minutes of moderate physical activity per day.

To improve the accuracy of the subjective walkability measures, it can be useful to incorporate the time that respondents have lived and/or worked in the research area. This presumes the hypothesis that people become more aware of the closest facilities of a particular type the longer they work and/or live within a certain area. This variable was not yet included in the survey because the idea arose after the survey was distributed.

Another improvement that can be made to the subjective walkability measures is the distribution from questions per subscale into the categories resident, employee and both resident and employee. In this research, both the subscales land use mix – diversity and land use mix – access were further distributed in the NEWS-A survey into these categories, because the questions focused on the concrete home or work location. Although the questions of the other walkability subscales are not as detailed as the land use mix subscales, this distribution can possibly explain these subjective walkability sub scores.

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APPENDICES

Calculation Land Use Mix

According to Frank, L. et al. (2006): Land use mix= −A/(ln(N)) where area =

- A=(b1/a)*ln(b1/a) + (b2/a)*ln(b2/a) + (b3/a)*ln(b3/a) + (b4/a)*ln(b4/a) + (b5/a)*ln(b5/a) + (b6/a)*ln(b6/a)
- a = total square feet of land for all six land uses present in buffer
- b1-b6 measure areas of land use for:
    - b1= single-family residential
    - b2= multifamily residential
    - b3= retail
    - b4= office
    - b5= education
    - b6= entertainment
- N= number of six land uses with area > 0

According to Reis, R. et al. (2013): Land-use mix= (-1) * [(square footage of commercial / total square footage of commercial residential, and office) ln (square footage of commercial / total square footage of commercial, residential, and office)+ (square footage of office / total square footage of commercial residential, and office) ln (square footage of office / total square footage of commercial residential, and office) + (square footage of residential / total square footage of commercial, residential, and office) ln (square footage of residential / total square footage of commercial, residential,and office)] / ln (n3); where n3=0 through 3 depending on the number of different land uses present.

TABLE 6 Objective Indicators In Related Studies

Research	Research area	Target group	Objective indicators	Method	Calculation	Result	References
Walkability and Physical Activity Findings from Curitiba, Brazil	32 census tracts selected to vary in income and walkability	697 randomly sampled inhabitants of selected neighbourhoods (18-65 years)	▪ Residential density *Number of residential units per residential acre* ▪ Density of intersections *Number of intersections/km²* ▪ Land use mix *Evenness of distribution of square footage of land use*	GIS-software	▪ Ratio of residential units and area within every tract assigned to residential use ▪ Density of intersections within every tract ▪ As division of land use in 5 categories: residential, commercial, recreation, educational/ cultural and others	Walkability index in every tract	(Reis, R. et al., 2013)
Objectively measured walkability and active transport and weight-related outcomes in adults	urban and suburban neighbourhoods	n/a	▪ Residential density ▪ Density of intersections ▪ Land use mix	n/a	n/a	n/a	**Invalid source specified.**
Linking objectively measured physical activity with objectively measured urban form	Metro Areas in Atlanta	357 adults: (20-70 years, household annual income <$45,000/>$54,000)	▪ Residential density ▪ Density of intersections ▪ Land use mix	GIS-software	▪ Count of households/acres of land in residential use ▪ / ▪ Evenness of distribution of square footage of residential, commercial, and office development	Combined walkability index	(Frank, L. et al., 2005)
Correlates of Non-Concordance between Perceived and Objective Measures of Walkability	High walkable neighborhoods	2650 adult residents (19-65 years) with discordant perceptions with objective	▪ Residential density ▪ Density of intersections ▪ Land use mix ▪ Net retail area	GIS-software	/	/	**Invalid source specified.**

		neighborhood attributes					
Healthy Neighborhoods: Walkability and Air Pollution	Metro Vancouver in southwest British Columbia, Canada per postal code	Inhabitants of the postal codes areas	▪ Residential density ▪ Density of intersection ▪ Land use mix ▪ Net retail area	GIS-software	▪ Number of dwelling units per square kilometer of residential land ▪ Number of intersections/ km² ▪ Evenness (i.e., equality) of floor space among categories of land use ▪ Retail shop floor-area divided by retail land area	Relative unitless walkability score for each postal code	(Frank, L. et al., 2009)
Correspondence between objective and perceived walking times to urban destinations: Influence of physical activity, neighbourhood walkability and socio-demographics	24 neighbourhoods in Ghent, Belgium. Each neighbourhood containing 1 to 5 adjacent statistical sectors	50 adults (age 25-66) randomly selected per neighbourhood	▪ Residential density ▪ Density of intersection ▪ Land use mix	GIS-software	/	/	(Dewulf, B. et al, 2012)

Validation of Walk Score for Estimating Neighborhood Walkability: An Analysis of four US Metropolitan Areas	addresses from four geographically diverse US metropolitan areas with several street network buffer distances (*i.e.*, 400, 800, and 1,600meters)	733 participating children (5-11 years) and their families in the YMCA-Harvard After School Food and Fitness Project, an obesity prevention intervention	▪ total retail walking destinations/ km² ▪ total service walking destinations/ km² ▪ total cultural/educational walking destinations/ km² ▪ parks/ km² ▪ median pedestrian route directness ▪ intersection density ▪ count of cul de sacs (based on nodes associated with only one street segment) ▪ average speed limit ▪ highway density ▪ residential density ▪ population density + distance to various categories of amenities (e.g., schools, stores, parks and libraries)	GIS-software + Walk Score	▪ total retail walking destinations/ km² ▪ total service walking destinations/ km² ▪ total cultural/educational walking destinations/ km² ▪ parks/ km² ▪ median of the ratio of distance between one point and another via the street network and straight-line distance between the two points (value →1 = more direct route) ▪ number of street intersection/ km² ▪ count of cul de sacs ▪ miles/h ▪ % area that is highway traveled right of way ▪ US census block group occupied housing units/ km² ▪ US census block group total population/km² + Calculating the linear distances to the closes facilities, then combining these scores by equally weighting and summing of walkability scores	Walkability index + Walk Score of 0 to 100	(Duncan et al., 2011)

Neighborhood walkability and cardiometabolic risk factors in australian adults: an observational study	Two road network neighborhood buffers (i.e. service areas). A neighborhood buffer of 1,600 m and a neighborhood buffer of 800 m, reflecting the more immediate neighborhood environment.	5,970 adult residents of the Perth metropolitan area, in Western Australia, participating in the Western Australian Health and Wellbeing Surveillance System (HWSS) survey between 2003 and 2006, and consenting to data linkage.	▪ residential density ▪ street connectivity ▪ land use mix	GIS-software	▪ Ratio of number of residential dwellings to residential area in ▪ Ratio of count of three or more way intersections to area in km² ▪ (calculated using an entropy formula adapted from that originally used by Frank et al. (2005), which incorporates the proportion of area covered by each land use type by the summed area for all land use types of interest divided by the number of land use classes)	Walkability index	(Müller-Riemenschneider, F. et al., 2013)
Neighborhood Environment Walkability Scale: Validity and Development of a Short Form	103 census blocks within 16 selected neighborhoods	1,286 adults aged 20–65, all of whom were residents of private dwellings in King County, WA	▪ residential density ▪ street connectivity ▪ land use mix ▪ retail floor area ratio	GIS-software	▪ number of residential units per acre ▪ number of intersections per square kilometer ▪ evenness of distribution of building floor area of residential, retail, entertainment, office, and institutional development ▪ ratio of retail building floor area to land area	Walkability index	(Cerin, E. et al., 2006)

TABLE 7 Subjective Indicators in Related Studies

Research	Research area	Target group	Subjective indicators	Method	Calculation	Result	References
Correspondence between objective and perceived walking times to urban destinations: Influence of physical activity, neighbourhood walkability and socio-demographics	24 neighborhoods in Ghent, Belgium. Each neighborhood containing 1 to 5 adjacent statistical sectors	50 adults (age 25-66) randomly selected per neighborhood → 1,164 respondents	Perceived walking times to various closest destinations *Accessability of different facilities*	NEWS (Neighbourhood Environmental Walkability Scale)	Counts of the response options		(Dewulf, B. et al, 2012)
Correlates of Non-Concordance between Perceived and Objective Measures of Walkability	High walkable neighborhoods	2650 adult residents (19-65 years) with discordant perceptions with objective neighborhood attributes	▪ Perceived residential density ▪ Perceived density of intersections ▪ Perceived land use mix ▪ Perceived net retail area	NEWS	/	/	**Invalid source specified.**
Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A)	16 selected neighborhoods (116 census blockgroups) in the Baltimore, MD–Washington, DC regio	Sample of 912 adults within selected blockgroups	▪ Perceived residential density ▪ Proximity to nonresidential land uses (land use mix – diversity) ▪ ease of access to nonresidential uses (land use mix – access) ▪ street connectivity ▪ infrastructure for walking and cycling ▪ aesthetics ▪ traffic safety ▪ safety from crime	NEWS			(Cerin et al., 2009)

Developing a framework for assessment of the environmental determinants of walking and cycling	Local neighborhoods in Australia	31 experts to represent the perspectives of urban planning/local government (n=20), transport (n=3), public health (n=1) and pedestrian, cycling and disability advocacy groups (n=5)	▪ Availability and accessibility of competitive transport alternatives and infrastructure (e.g., transit, sidewalks, bike lanes) ▪ Availability of local government and highway funds for sidewalks and bike lanes ▪ Frequency of nonmotorized transportation (variation by trip purpose and/or trip distance) ▪ Presence of integration between residential and commercial land uses in dense population areas ▪ Presence of protective social factors and absence of social disorder ▪ Presence of attractions and comforts as well as absence of physical disorder ▪ Availability and accessibility of facilities or natural features for activity ▪ Availability of local government funds	Telephone interviews and self-administered methods (in person or by mail)	Aggregation of individual responses to identify patterns in design and neighborhood features	/	(Pikora, T. et al., 2003)

			for parks and recreation facilities ▪ Presence of community-wide campaigns to increase active living				

TABLE 8 Walk Score Scale (Walk Score, 2014)

Walk Score®	**Description**
90–100	Walker's Paradise: Daily errands do not require a car.
70–89	Very Walkable: Most errands can be accomplished on foot.
50–69	Somewhat Walkable: Some errands can be accomplished on foot.
25–49	Car-Dependent: Most errands require a car.
0–24	Car-Dependent: Almost all errands require a car.

FIGURE 1 Research area in Hasselt (Google, 2013).

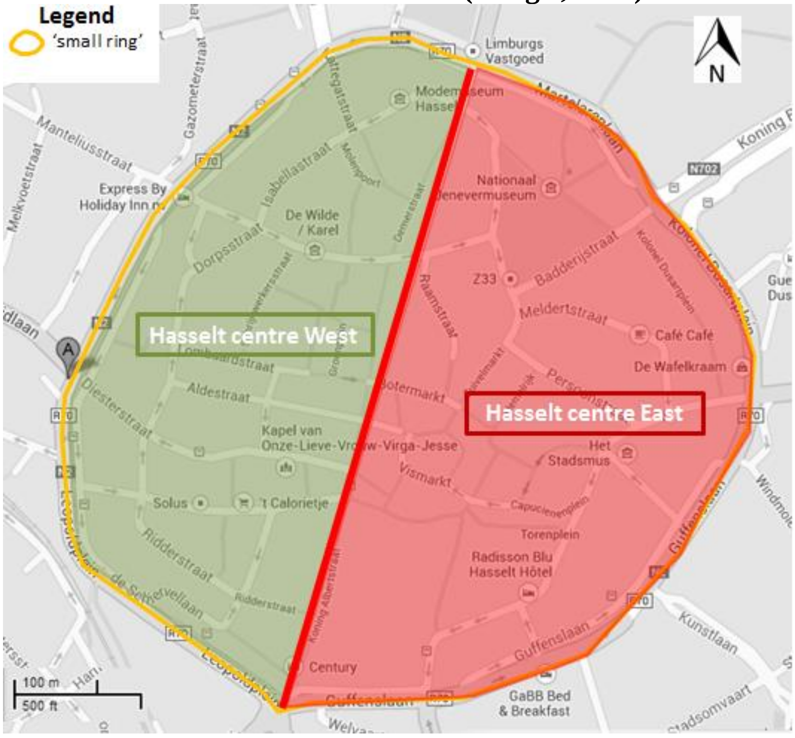


FIGURE 2 Research area situated in Limburg (Provincie Limburg, s.d.)**.**

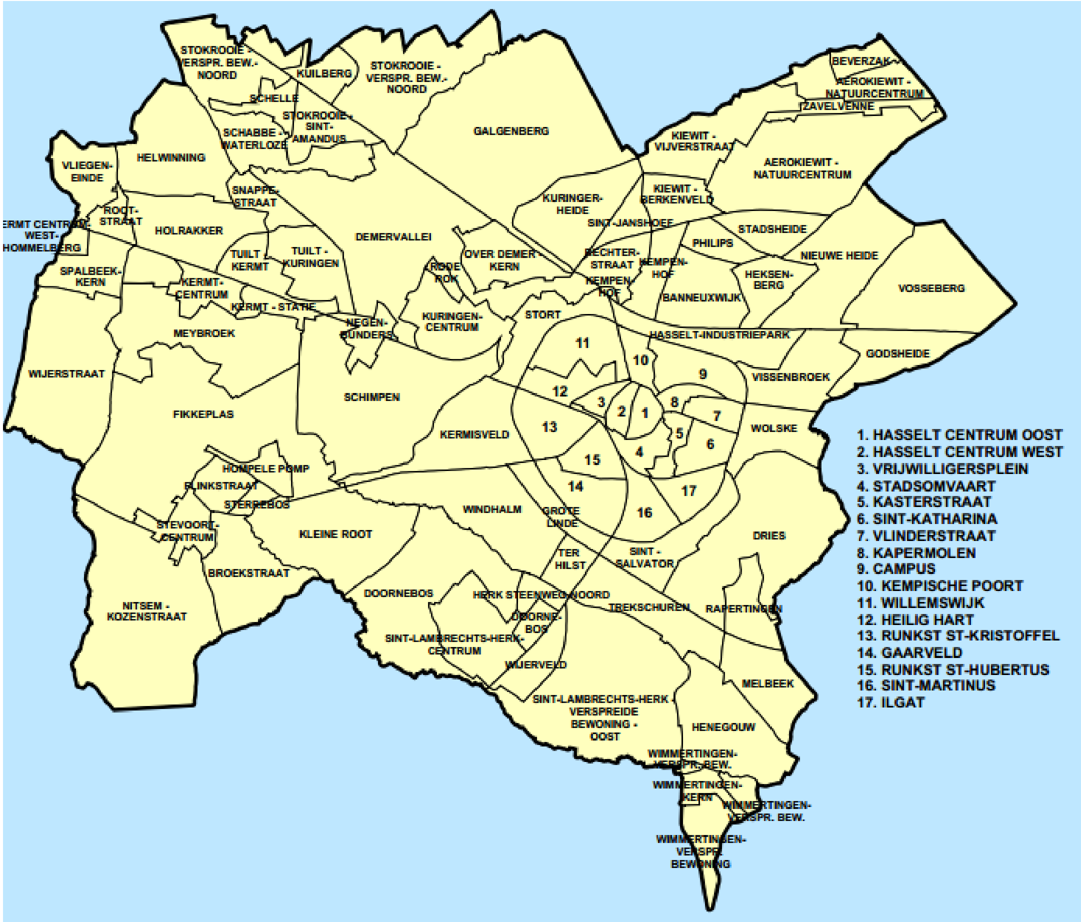
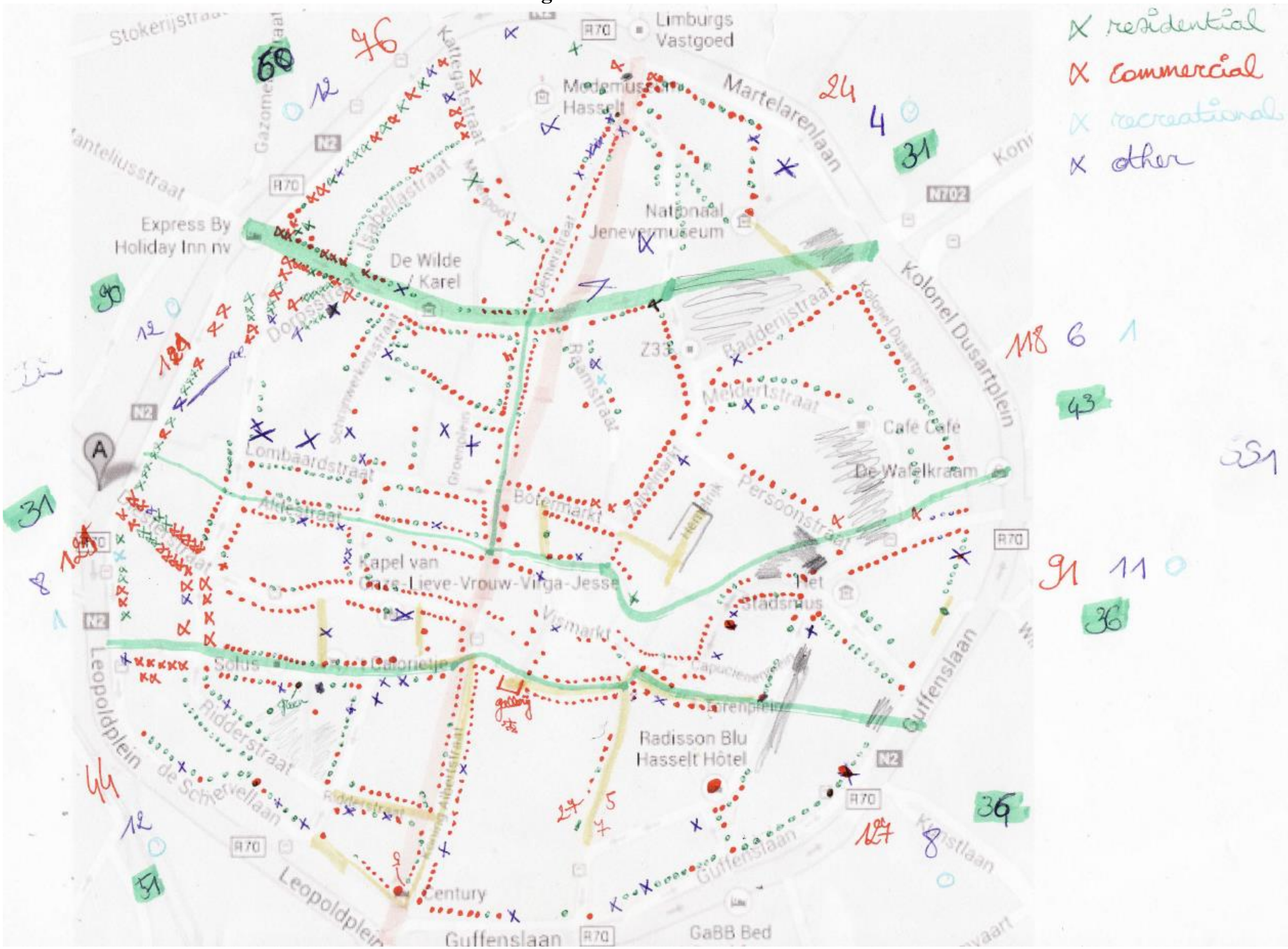


FIGURE 3 Observation land use mix within 'small ring'.



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Datum: **3/06/2014**