Comparison of predicted and actual tranquility levels in Woonerf streets

"An assessment of streetscape greenery and sound levels using a Green View Index and mobile sound measurements"

Colophon

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Abstract

Within the current urbanized modern society, the call for calm and quiet areas seems more pressing than ever. The Woonerf concept is developed in 1960 in the Netherlands and might potentially be such tranquil environment to provide a relief for people to get away from the demands of everyday urban life. On Woonerf streets, through traffic is permitted but discouraged, speed is restricted to a maximum of 15 km/h traffic and pedestrians share the street without segregation. In the past, predictive models have been developed to assess areas based on their sound and visual levels. The urban environment consists of multiple different sound sources and people have different attitudes towards these sources. Because of this complexity, objective sound measurements are examined in combination with the subjective perception of sound through eight perceptual attributes. In this study, sound and visual measurements are evaluated to determine if they are suitable indicators to predict tranquility in Woonerf streets. This will be done by conducting quantitative data measurements in 63 Woonerf streets, supported by data collection by means of a questionnaire, distributes over the cities of Groningen and Leeuwarden, located in the Northern part of the Netherlands. Within the context of Woonerf streets, results show a difference between the prediction of tranquility compared to what people actually perceive. Sound levels are perceived as relatively pleasant and uneventful.

Keywords: *Woonerf concept, Soundscape, Tranquility, Green View Index, Streetscape maintenance*

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Chapter 1. Introduction

1.1 Background

Nearly 4.5 billion people, which is about 57% of the world's population, are now living in urban areas (World bank, 2018a). In the EU, this percentage is even higher, at around 75% of the total population (World bank, 2018b). Approximately 20% of the EU population suffers from unacceptable noise levels and roughly another 20% live in areas where noise levels range between 55-65 decibel (EC, 1996). In residential areas, A-weighted equivalent (LAeq) of 50-55 decibels average (dBA) may result in severe annoyance and noise levels greater than 70-100 dBA may even lead to permanent loss of the ability to perceive sound (WHO 2011). In this highly urbanized continent road traffic noise is becoming a health threat to its population (Bodin, Björk, Ardö and Albin, 2015). Within this increasing urban setting, road traffic noise is considered to be the main source of noise (Ouis, 1999). According to various literature studies, road traffic noise is perceived as one of the most dominant sources for irritation among urban residents (Hedfors, 2003, Raimbault and Dubois, 2005, Yang and Kang, 2005a). Previous work has shown the positive effect of access to quiet urban areas regarding noise reduction (Öhrström, Skånberg, Svensson and Gidlöf-Gunnarsson, 2006). Apart from irritation and annoyance, noise is also seen as a global treat to people's health. This became apparent through broad executed EU policy, where the goal is to alleviate the effects of road traffic noise, which has been one of the objectives the European noise policy aims to achieve (European Directive 2002/49/EC).

To create and protect these quiet urban areas, measures involving greenery, such as shrubs, trees, bushes, and green barriers, have become increasingly popular (Wong et al., 2010). These measures contribute to an urban setting in which noise is being reduced while natural sounds could be amplified (Kang, 2006). Tranquil places are characterized by pleasantness and calmness and are often associated with natural environments. Living in a green and pleasant street might even be considered a top priority for people living in an urban environment (Appleyard, 1980). The majority of people favor natural sounds instead of man-made, and prefer natural environments over man-made environment (Lam, Chau, Marafa and Chan, 2007). While man-made sounds such as road traffic noise are found to be low in natural environments, natural sounds could be strongly present and are often linked with positive feelings (Watts, Khan and Pheasant, 2016).

While the EU recognized the need for an overarching policy in 2002 regarding road traffic noise there were already ideas in the Netherlands on how to deal with urban traffic and quality of living. Originated in 1975, the Dutch Association of Local Authorities (VNG), introduced the Woonerf concept. After it gained legal status the concept has spread across cities and town in the Netherlands and similar concepts have been adopted by other countries abroad. The Woonerf, translated 'living yard' obtained legal status in 1976 and differs from ordinary residential streets on multiple aspects. Woonerf streets incorporate multiple features such as narrow passages, hedges, trees and other forms of vegetation to influence the driving behavior of motorized traffic. Additionally, the speed limit is maximum 15km/h. While other forms of traffic are allowed, the Woonerf central functions are of residence, area for playing and leisure time, providing adequate parking facilities, and as an area to meet (Kraay, 1986).

While speed reduction measures may seem inherent to lower levels of noise, other factors may result in the opposite effect e.g. sudden accelerations of motorized vehicles. Previous research on noise reduction has shown that this will not necessarily lead to higher levels of satisfaction with the perception of sounds (de Ruiter, 2004). When evaluating quiet areas it is important to not only emphasize the objective reality, but also to examine people's perceptions of the acoustic environment (Gozalo and Morillas, 2017).

1.2 Academic relevance

The relationship between greenery and traffic noise has already been extensively studied in various contexts and on multiple spatial scales. This research ranges from the smallest neurophysiological level of the auditory cortex response on tranquil conditions compared to non-tranquil conditions (Hägerhäll et al., 2018), and the small scale, involving various types of greenery and their relationship to noise (Wong et al., 2010; Yang et al., 2011; Van Renterghem, Botteldooren and Verheyen, 2012; Horoshenkov, Khan and Benkreira, 2013; Van Renterghem et al., 2014) and to the larger scale of green space patterns between the urban morphology of different city structures (Margaritis and Kang, 2016). However, in the urban setting, the Woonerf concept combines a unique set of spatial characteristics with legislative policy measures. The relationship between these characteristics and perceived noise levels, as well as the impact on quality of life in these streets, is relatively understudied.

A number of studies have been conducted by using quantitative visual and sound measurements for the development and validation of a Tranquility Rating Prediction Tool (TRAPT). This tool has been further tested by comparing quantitative measurements with reported subjective perceptions of tranquility in urban green spaces (Pheasant, Watts and Horoshenkov, 2010), in urban parks (Watts, Miah and Pheasant, 2013) and by introducing natural scenery and sounds in a healthcare setting (Watts, Khan and Pheasant, 2016). Additionally, TRAPT was used in predicting the tranquility levels between city squares and different scenarios where noise barriers, trees and hedges were introduced (Watts, 2017). The latter shows similarities with features that are also being used within the concept of Woonerf streets. However, only a limited number of scenarios were examined, using simplified urban settings in a simulated environment, with a speed limit of 48km/h and a road width of 8 meters. Therefore, these models do not account for the specific characteristics of woonerf areas, such as the legally mandated speed limit of 15km/h (RVV, 1990) and the specific woonerf design criteria established by the Dutch Ministry of Transport in 1976 (Nalmpantis, Lampou and Naniopoulos, 2017).

While multiple studies have examined the greenness of environments through visual analysis (Yang et al., 2009; Pheasant et al., 2010; Li et al., 2015; Yang et al., 2021), no studies have performed such analysis in a specific season of the year (e.g fall, winter) when vegetation losses its greenery and coupled this to perceived and predicted tranquility levels.

A systematic review by Van den Berg et al. (2015) found that health and mortality are strongly linked to the amount of greenery in residential areas. Furthermore, research has been conducted on the relationship between tranquil green environments and additional health benefits such as lowering stress and alleviation of anxiety (Ulrich, 1981; Ulrich, 1983; Marafa, Tsang, Watts and Yuan, 2018). Moreover, responses from visitors of urban green areas also report a correlation between perceived tranquility of various sites and increased health benefits such as feelings of relaxation and reduced stress (Grahn and Stigsdotter, 2003; Watts et al., 2013, Payne and Bruce, 2019). While previous research has demonstrated that houses with a quiet side and access to greenery have a positive impact on residents' satisfaction and well-being (Öhrström et al., 2006; Gidlöf-Gunnarsson and Öhrström, 2007), the relationship between the quantity of greenery and additional noise mitigation measures on adjacent streets, and residents' actual perceptions of tranquility has not been extensively examined in previous research.

1.3 Societal relevance

The EU estimates the costs associated with road traffic noise to range between 30 and 46 billion euros per year (Den Boer and Schroten, 2007). In western Europe, traffic-generated noise is responsible for reducing disability-free life expectancy by more than one million years annually (WHO, 2011). Noise pollution has been related to a number of negative health effects associated with psychological issues such as stress and anxiety, annoyance and sleep disturbances, cognitive problems regarding memory and concentration, and high cardiovascular risks (Stansfeld and Matheson, 2003; Babisch et al., 2005; Brink, 2011; WHO, 2011; Aluko and Nna, 2015).

Apart from the improved health benefits and potential cost reduction, this research will contribute to a better understanding of which measures are effective in woonerf streets for reducing noise and promoting greenery. This study will examine, in a different urban context, how closely residents' perceptions of tranquility in woonerf streets align with the predicted tranquility levels generated by the TRAPT tool. A more comprehensive TRAPT tool will help future planners in the protection and mapping of urban quit areas. Groups concerned with the spatial design of cities and towns such as municipal urban designers, citizens and leaders in municipal affairs may use aspects of the results to facilitate more tranquil environments for people to live in. Moreover, insights provided by this research can be implemented elsewhere in urban settings to improve tranquility levels of other woonerf areas and residential streets in general. With more in-depth knowledge of individual residents' preferences, urban planners and policy makers can make more informed decisions on how to design streets that are both visually appealing and pleasant to live in.

1.4 Research statement

In light of the information discussed in previous sections, the aim of this research is to investigate the relationship between woonerf features and how this relates to its rated tranquility levels. Therefore, in the city of Groningen 8 neighborhoods consisting of 32 Woonerf streets will be compared with 8 neighborhoods divided into 31 Woonerf streets in the city of Leeuwarden. Quantitative data measurements on the percentage of natural features and the average man-made noise will be gathered. Additionally, questionnaire surveys are delivered to residents of previously mentioned woonerf streets to provide data on perceptive tranquility. Furthermore, this study makes use of the previous discussed TRAPT tool which will determine the predicted tranquility rate. This will be compared to residents' perceptions of tranquility to determine the tool's applicability in woonerf settings. For achieving the aim of this research the following research question is formulated:

To what extent can the tranquility rate of woonerf areas be predicted by its auditory and visual levels?

For provided guidance in answering the main research question the following sub-questions are presented:

1 *What are the perceived tranquility levels between the woonerf areas?*
2 *To what extent are the noise levels affected by the perceptual attributes of the woonerf areas?*
3 *How do the visual levels of greenery/cultural vary between the woonerf areas?*
4 *How does the level of perceived tranquility differ from the predicted tranquility rate within woonerf areas?*
5 *To what extent may active participation in the maintenance of a woonerf greenspaces influence the GVI levels?*

1.5 Structure

This research is structured according to the following chapters. This section provides a summarization of the following chapters. First of all, in chapter two the main concepts will be defined and conceptualized according to the existing literature. In chapter three the data collection methods are presented, as well as the analysis. Subsequently, these results will be displayed in chapter four. In light of these results, conclusions are formed in chapter five. Finally, findings, limitations and recommendations are discussed in chapter six.

Chapter 2. Theoretical Framework

In this chapter, relevant literature and theories are discussed and linked to the research aim. To begin with, the tranquility concept is defined in section 2.1. Subsequently, a reflection of literature is provided in section 2.2 on the relationship between auditory and visual components and predicting tranquility levels. Then, perceived tranquility is discussed on the basis of soundscapes and perceptual attributes. How people experience sound is context dependent. Therefore, the woonerf concept is defined in section 2.4. In conclusion, a visual representation of the relevant concepts is visualized in a conceptual model.

2.1 Defining tranquility

The word tranquility comes from the Latin word ''*tranquillitas*'' meaning quietness, calmness or stillness (Lewis 1891). Within the field of philosophy and psychology, the term tranquility can refer to a feeling of emotion (Berenbaum et al., 2018), be considered as a part of mental well-being (Kaplan and Kaplan, 1989, Soysa et al., 2021), or be seen as a particular mood state (Kriegel, 2019). Tranquility is experienced as a result of satisfaction with the contemporary situation, regardless of one's desire for fulfillment (Berenbaum et al., 2016). Environmental research into the tranquillity construct defined tranquillity as *"how much you think this setting is a quiet, peaceful place, a good place to get away from the demands of everyday life"* (Herzog and Barnes, 1999 p. 173). So, to move away from broad psychological terminology and to comprehend tranquility in urban residential settings, the latter situational definition will be used within this study. However, when describing the feeling of tranquility in relation to the experience of sound, it is often regarded as a construct of two components: pleasantness and calmness, according to the definition of Watts and Pheasant (2015).

2.2 Predicting tranquility

Despite the fact that tranquility is perceived as a subjective matter, many of its perceptive aspects can be related back to the objective reality. Hence, a quantitative assessment of the environment by its visual and auditory level is considered suitable for predicting such differences in perceived tranquility (Pheasant et al., 2008). To identify the central features that affect perceived tranquility Pheasant et al. (2008) have conducted laboratory setting experiments to come up with the initial TRAPT (Tranquility Rating Prediction Tool). This predictive method has been validated in later research in the context of urban parks (Pheasant et al., 2010). Additionally, the TRAPT may be adjusted according to different type of context. This calibrated version of the TRAPT equation offers the possibility to use it for the context of urban green spaces (Watts et al., 2013).

In this equation the TR stands for the predicted tranquility rate ranging from 0-10. The constant from the original TRAPT equation can be changed to account for specific urban context of Woonerf streets. Insights based on the adaptation-level theory (Helson, 1964) suggest, for example, that people living in densely populated urban areas have likely grown accustomed to higher levels of noise and lower levels of greenery. While population density is a relative concept, it is important to note that all the woonerf cases in this study are located in neighborhoods just outside the inner city of Leeuwarden and Groningen, and both cities have roughly 100,000 and 200,000 inhabitants, respectively. Hence, these areas may be considered as densely populated urban areas. It is for this reason that the adjusted constant for urban green areas may be preferred. NCF is the ratio of all the natural and historical visual elements compared to the total visual perception of a human. Lday is the A-weighted Leq (equivalent noise level) within the time period between 7 a.m. and 7 p.m. MF serves as a moderating factor to take into account any negative factors (e.g. graffiti, litter) and positive factors (e.g. the sound of water) that might be present on site (Watts et al., 2009). However, these moderating factors are found be of limited effect, but may result in a maximum of 1 point difference (Watts, 2017). A more in-depth analysis of each factor will be provided in the following sections.

2.2.1 Visual street elements

While non-tranquil spaces are characterized as subjectively fatiguing by sustained attention, tranquil spaces are perceived as restorative environments generated by subjective interest (Kaplan and Kaplan, 1989). Moreover, there is a higher probability for an area to be experienced as tranquil through sensory inputs when natural elements are present. (Hunter et al., 2010). In spite of being a subjective concept, tranquility can be explained by means of quantification regarding the visual elements present in the urban environment. Tranquil environments are related to natural featured landscapes and the absence of man-made factors (Pheasant et al., 2008). When the visual factors of the environment are taken into consideration from an visual objective point of view, tranquility levels were rated higher in natural surroundings compared to urban environments (Herzog and Chernick, 2000). Additionally, Hewlett et al. (2017) state that visual scenes, which are predominantly man-made and dominated by human development, are considered to be non-tranquil environments.

These man-made elements do not include the cultural and contextual elements (e.g. cultural heritage), which are contemplated as aesthetically pleasant. Therefore, cultural and contextual elements are not considered within the group of man-made elements. Instead cultural and contextual elements are weighed similar to the presence of natural elements in an urban environment. Hence, the presence of cultural and contextual elements are equally important compared to natural elements and should also be included to construct the level of tranquility in an urban environment (Watts et al., 2013).

Natural elements within a urban setting can be defined as ‘urban forests’, which includes various different types of vegetation found in cities, as well as trees and shrubs (Yang et al., 2009), or ‘Streetscape greenery’ which *“includes all kinds of vegetation that give the street a green appearance.”* (de Vries et al., 2013 p. 26). While both definitions are comprehensive enough and can be used interchangeably, streetscape greenery will be used when referring to natural elements within the urban context of Woonerf streets.

2.2.2 Quantification of streetscape greenery

Previous studies have attempted to evaluate streetscape greenery levels based on a qualitative approach. This often referred to the subjective value people gave to a series of images of videos based on a ranking method (Schroeder and Orland, 1994; Tyrväinen et al., 2003). While this qualitative approach provides a valuation of streetscape greenery, results differ across cultural backgrounds and personal characteristics (Aoki, 1999). Contrary to these qualitative methods, urban streetscape greenery may be quantified by other approaches such as field-based surveys (Kardan et al., 2015), or satellite imagery (e.g. Carlson and Ripley, 1997; Leprieur et al., 2000) to objectively quantify large scale areas of vegetation coverage. However, each of these methods come with their own challenges and shortcomings in the urban context. Field-based surveys of big data sets are sensitive to sampling errors and execution on such scale requires major managerial efforts (Dickinson, Zuckerberg, and Bonter, 2010). This limits the possibility to perform periodic assessment and resampling of changes in streetscape greenery over time (Seiferling et al., 2017). Most of the overhead-view measures, such as the normalized difference vegetation index (NVDI), Soil-Adjusted Vegetation Index (SAVI), and Enhanced Vegetation Index (EVI) are based on the red and near-infrared (NIR) reflectance wavelengths of vegetation (Jiang et al., 2008). However, distinct differences in outcome occur when comparing such aerial measurements with greenery levels perceived on a pedestrian level (Lu et al., 2018; Lu, 2019). Furthermore, the overhead greenery visual levels observed by satellite imagery are not equal with the green view percentage as perceived by people on the street level (Li et al., 2015). In other words, vertical visual elements such as vertical greenery or the façade of cultural and contextual buildings are not detectable by satellite imagery. Hence, satellite imagery might be seen as an unsuitable approach to address people's perception of streetscape greenery (Yang et al., 2021).

Various studies have used eye-level assessment of greenery (Pheasant et al., 2010), or Google Street View (GSV) imagery in combination with imagery analyzation tools to determine the percentage of visual streetscape greenery on a pedestrian level (Yang et al., 2009; Li et al., 2015; Yang et al., 2021). In these studies, relevant pixels of photos of streets are calculated and divided by the total amount of pixel to provide a streetscape green ratio of the entire imagery area. This street level approach provides different results in greenery levels compared to imagery taken from above because of the following reasons. First of all, pedestrians view streetscape greenery as 3-dimensional street elements instead of the 2-dimensional overhead view provided by for example satellite imagery (Yang et al., 2009) Figure 1 illustrates how for example a variation in height, when all other aspects remain the same, will result in two different GVI outcomes seen from a pedestrian view. This figure also shows how GVI levels on a street level may vary while GVI levels are qual from an overhead view. This is in line with findings from Anguelov et al. (2010), who argue that street images allow for visual elements to be captured which otherwise might have not been noticed by satellite imagery. Additionally, research of Yang et al. (2009) shows how the placement of for example trees, shrubs and hedges may influence the level of streetscape greenery seen from the pedestrian point of view. This is due to the fact that trees shrubs and hedges placed closer to the viewpoint of a pedestrian will result in a higher greenery perception. Hence, imagery taken on an eye-level resembles the perception of streetscape greenery by people better compared to satellite imagery (Yang et al., 2021) and allows for cultural and contextual elements to be included as well.

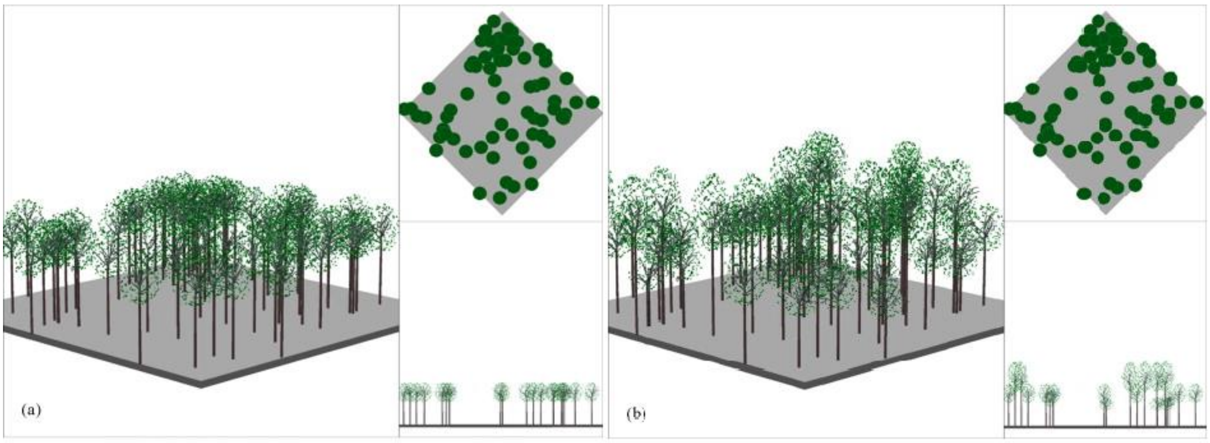

Figure 1. Simplified example of the difference between street level view and overhead view (Yang et al., 2009).

2.2.3 GSV vs manual imagery

While GSV possesses many advantages compared to manual imagery taken on a eye-level in terms of scale, it has several disadvantages. First of all, the GSV imagery database is infrequently adjusted and documented (Yang, 2021). It is evident that streetscape greenery levels fluctuate between the yearly seasons. Because tranquility levels are dependent on the natural elements of the street, fluctuations in greenery levels may lead to a mismatch between the GSV pictures taken and the relevant period of study. A longitudinal study has also shown that a person’s mood is influenced by the seasons throughout the year (Harmatz et al., 2000). Therefore, visual and auditory objective measurements should also be captured in the same period to match the subjective measurements of tranquility. Given these points, manual imagery is considered to be the more suitable approach in predicting the tranquility levels and matching it with the perceived tranquility by the people during fall compared to GSV imagery.

2.2.4 Effect of auditory levels on tranquility

Tranquil spaces offer relief from demands and stress from everyday life. This makes tranquil spaces to be restorative environments which offer various psychological and physiological benefits (Watts, 2017). However, visual elements captured through sight is not the exclusive reason which affect people's response towards urban green space (Grahn and Stigsdotter, 2010). The restorative effect of tranquil spaces can be partially explained by its visual stimuli, but also to some degree by additional auditory factors (Ha and Kim, 2021).

In general terms, sound can be defined as audible acoustic pressure waves which can be detected by a human ear in the form of audible vibrations (Passchier-Vermeer and Passchier, 2000). Noise can be defined as a loud unwanted sound, which is considered to be unpleasant, disruptive and causes inconvenience (Guski et al., 1999; Jarosinska et al., 2018). Sound pressure levels (SPL) are expressed in decibels (dB) and measured in pascal (Pa). To determine whether or not dB levels are within regulative sound limits, A-weighted db (dBA) is frequently used (Sutcliffe et al., 2020). Equivalent sound level parameters such as $L_{A,eq}$, L_{day}, $L_{evening}$, L_{night}, and L_{den}, are commonly used acoustic parameters for objective standardized noise assessment methods (European Directive 2002/49/EC).

Equivalent sound measurements might be a sufficient approach when the situation is well defined and the goal is clear (e.g. regulation of the maximum sound level). However, within the context of urban spaces the sound environment is comprised of various factors and can therefore be seen as far more complex (Rychtáriková and Vermeir, 2013). For example: less noise does not necessarily mean a higher feeling of pleasantness and additional associated health benefits (Yang and Kang 2005a, 2005b; Van Kempen et al. 2014).

Due to the subjective nature concerning sound, it is important to point out the fact that quantitative sound measurements alone, expressed in sound pressure levels (dB), are not adequate enough to determine the quality of sound as perceived by people. Yang and Kang (2005a) have for example found that the sound quality is not automatically improved when sound levels are reduced. Sound level is only one aspect of the acoustic environment and may be perceived as positive or negative despite the associated qualitative measured sound levels (Yang and Kang, 2005a). Relevant factors on how sound is perceived, as well as what meaning people attribute to a particular sound levels and of what elements sound is comprised of should therefore also be included as well (Raimbault and Dubois 2005).

2.3 Perceived tranquility

2.3.1 Classification of sound sources

Regarding the categorization and presence of sounds, various studies have used similar classifications. Brown et al. (2011) divide sound into two groups namely, natural sounds and sound produced by humans. Others include other sound sources as well by adding a third 'other'' category (Kang et al. 2019). While Watts et al. (2013) have used an extended categorization, dividing sound in four categories: natural, mechanical, people, children playing. High level of natural sounds (e.g. bird sounds) are positively associated with the feeling of tranquility while anthropogenic noise (e.g motorized vehicles) are negatively associated with the tranquility construct (Alvarsson et al., 2010; Watts, 2017). Natural sounds are associated with pleasantness, whereas mechanical sounds are perceived as unfavorable and linked with annoyance (Tamura, 2002). Sound from people and children playing are overall regarded as more pleasant or as neutral compared to technological sounds (*Dubois et al., 2006, Nilsson and Berglund, 2006).* Bicycles trips comprise around 25% of total passenger travel movements in the Netherlands (Van der Waard, Immers and Jorritsma, 2013) Hence, bicycle sounds as an additional dominant sound category might also be considered in the Dutch context especially in the context of woonerf streets.

2.3.2 Perceptual attributes associated with the quality of sound

How the sound environment is perceived by people in a particular context could be illustrated by a soundscape (ISO, 2014). Similar to how a landscape represents a perception of the visual environment, a soundscape characterizes how the sound environment is perceived by a person. The urban sound environment is complex (Aletta and Kang, 2018) due to various different sound sources and differences in interpretation and personal preferences. To accommodate for this complexity, soundscape provides a holistic approach centered around the perception of humans within a given context, rather than relying on acoustic environmental measures alone. (ISO, 2014).

The search for international consensus and the necessity for an agreed upon generalization of standards, demanded for a more suitable method how to evaluate soundscapes as perceived by people. This has led to multiple operational assessment tool regarding sound perception within a given environment based on so called descriptors, indicators, and indices. In a literature review of this search for operationalization, Aletta et al. (2016) have identified 'soundscape descriptors' as 'measures of how people perceive the acoustic environment' and 'soundscape indicators' as 'measures used to predict the value of a soundscape descriptor' (p. 66). Soundscape indices are defined as 'single-value scales derived from either indicators or descriptors that allow for comparisons across soundscapes' (Kang et al., 2019 p. 2489).

For the past decade, the International Organization for Standardization (ISO) has been attempting to standardize the operationalization process of soundscape evaluation. This has resulted in the development of the ISO 12913 acoustics soundscape series (ISO 2014, ISO 2018, ISO 2019). This comprehensive method of sound evaluation not only offers a conceptualization of the quality of sound, but also provides options on how to collect the subjective sound experiences perceived by people. In broad terms, ISO/TS 12913-2:2018 offers three different methods of data collection. These options would either entail in-situ questionnaires (Method A or Method B), or ex-situ narrative interviews protocols (Method C) (ISO, 2018). The focus of this study is on Woonerf streets and how environmental sound is perceived by the residents themselves. Therefore, in this study, Method A will be used to determine how the quality of the acoustic environment is experienced. Method A is based on the Swedish Soundscape Quality Protocol (SSQP) developed by (Axelsson et al., 2010) and has been used throughout the years in various environmental sound studies (e.g. Hinalaf and Pérez, 2016; Tarlao, Fernandez and Guastavino, 2016; Nagahata, 2019; Margaritis and van Kann, 2022). The methods described in the ISO/TS 12913-2:2018 were initially developed based on individual or small group sizes (ISO, 2018). Originally, the methods were used for investigating a specific soundscape and a single person's perception. However, soundscape studies have moved to broader soundscapes assessment (e.g. Mitchell et al., 2020) and soundscape studies has shifted from comparison of a single person to comparison between groups of relatively larger sample sizes (e.g Jeon et al., 2018).

Axelsson et al. (2010) perceived affective quality (PAQ) model proposes a two-dimensional measurement system for the affective soundscape quality based on eight adjectives: Pleasant, Exciting, Eventful, Chaotic, Unpleasant, Monotonous, Uneventful, and Calm, (Figure 2), positioned at a 45° angle from one another. These adjectives can be defined as so called 'perceptual attributes', which represent the soundscape as described and experienced by people (Lionello et al., 2021). Tranquility is associated with the two constructs of pleasantness and calmness. When an area is perceived as tranquil, it is expected to be placed within these two factors in the model.

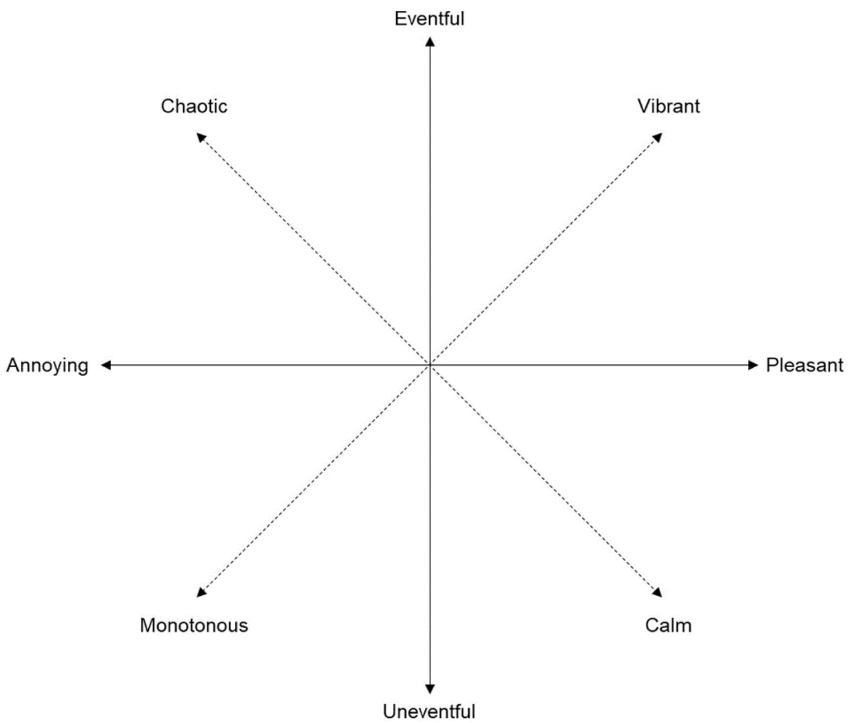

Figure 2. Soundscape based on the eight perceptual attributes (Torresin et al., 2020).

2.4 The Woonerf concept

2.4.1 Origins of the Woonerf concept

Between the late 1960s and early 1970, before the shared space concept became a common approach within urban design, urban planners were already experimenting with this integration principle in the Netherlands. In 1969 in Delft the Netherlands, the concept 'Woonerf' or 'residential yard' was found, which integrated the previously separated roads for pedestrians and cars into one flat surface. The initial idea was to improve the safety of children playing by setting the design of the street to feel like a 'garden'. As a result, cars would have to acknowledge other street users and take their presence into consideration as well.

Criteria according to the Dutch Ministry of Transport in 1976
1. A woonerf must be a primarily residential area.
2. Roads or road networks within a woonerf must only carry vehicular traffic, with an origin or destination within that particular woonerf: through traffic should be excluded.
3. No road within a woonerf should carry a flow of traffic
4. The impression the highway is divided into separate roadway for motor vehicle and a footpath must be avoided. There should be no continuous difference in cross sectional elements along the length of the road.
5. Vertical elements such as plant tubs and shrubs must not restrict visibility.
6. The entrances and exits of woonerven must be so designed that they can be clearly recognized, and it must be obvious to drivers of motor vehicles that these roads are access roads.
7. The boundaries of parts of the highway intended for parking should be clearly marked and as a minimum the corners of the parking space should be marked.
8. There must be adequate parking facilities for residents of a woonerf, although provided that there is surplus car parking capacity available in the immediate vicinity of the woonerf, the supply of parking spaces may be lower than demand.
9. On those parts of the highway intended for use by motor vehicles, features must be introduced which will reduce the speed of all types of vehicle. These features should not be more than 50 meters apart.
10. The features referred to in article 9, should not be located so as to cause vehicles to pass close to housing which fronts directly on to the street.
11. In accordance with the regulations, the features referred to in article 9 should create no danger to traffic passing over them.
12. Adequate street lighting must be provided to ensure that all features, especially those referred to in article 9, are fully visible at night.
13.Areas specially designed as play areas must be clearly identified so they can be readily distinguished form those areas that can be used by vehicles. Where possible play areas should be physically separated from those parts of the high way used by vehicles.
14. The word woonerf must be displayed along with the blue woonerf sign

Table 1. List of woonerf criteria (Hamilton-Baillie, 2001).

The Dutch Government officially acknowledged the Woonerf concept in 1976 and soon other countries followed the success of the Netherlands as well including Germany (1976), Sweden (1977), Denmark (1977), England (1997), France (1979), Japan (1979), Israel (1981), and Switzerland (1982) (Ben-Joseph, 1995). Each of these countries adopted similar guidelines and traffic regulations. Still, slight differences may exist between countries rules and regulations. The definition and standards is set out in a list of 14 points according to the Dutch Ministry of Transport in 1976, by which a Woonerf must comply (Hamilton-Baillie 2001). A translated list of the Woonerf criteria's is provided in Table 1.

2.4.2 The five principles of a Woonerf design

While the urban design between woonerf streets differs, all woonerf streets are designed according to the following 5 main design principles (Hand, 2007; Collarte, 2012). These principles form the basis of a Woonerf design. By implementation of these principles, an unpredictable environment is created to make drivers more conscious of their surroundings while improving the aesthetics of the street (Appleyard, 1980).

- *The presence of a recognizable gateway*

The entrance of a woonerf should be clearly marked by a distinct gateway. This will let drivers know they are entering a woonerf area. Possible measures that could be taken to emphasize a woonerf gateway are the inclusion of natural features such as trees, narrowing the passage, or an slope (Biddulph, 2012).

- *Incorporation of multifunctional features*

Features should be included which provide a calming and slowing down result of drivers behavior, while improving the attractiveness of the street as well. Features such as trees and hedges give the street an increased green appearance while drivers are forced to drive around them instead of a straight line. Street furniture such as playgrounds, benches and bollards can also be used for traffic calming purposes while simultaneously encouraging the residents to enjoy the street.

- *Removement of the continuous curbs*

All forms of transport share the same street. By eliminating the continuous curbs, drivers are forced to actively be aware of their surroundings. By the absence of continuous curbs, children are encouraged to use the entirety of the street for playing and pedestrians can move without hinder.

- *Meandering of the road*

Instead of only adding features to force drivers to drive more slowly, the design of the street itself is also altered. Instead of a traditional straight line from A to B, a woonerf street uses the curving of the street itself so that, in combination with other features, a driver is limited in sight and speed.

- *Adequate parking facilities*

Instead of a continuous line, parking facilities should be located with intermitted spaces in between. Parking arrangement strategies allow for a combination of provision for parking as well as obstructions for drivers, which functions similarly to the calming function as previously discussed. A schematic bird-eye overview of how a woonerf differs from a conventional road is given in Figure 3. An overview of the 5 principles of a woonerf design is given in Figure 4.

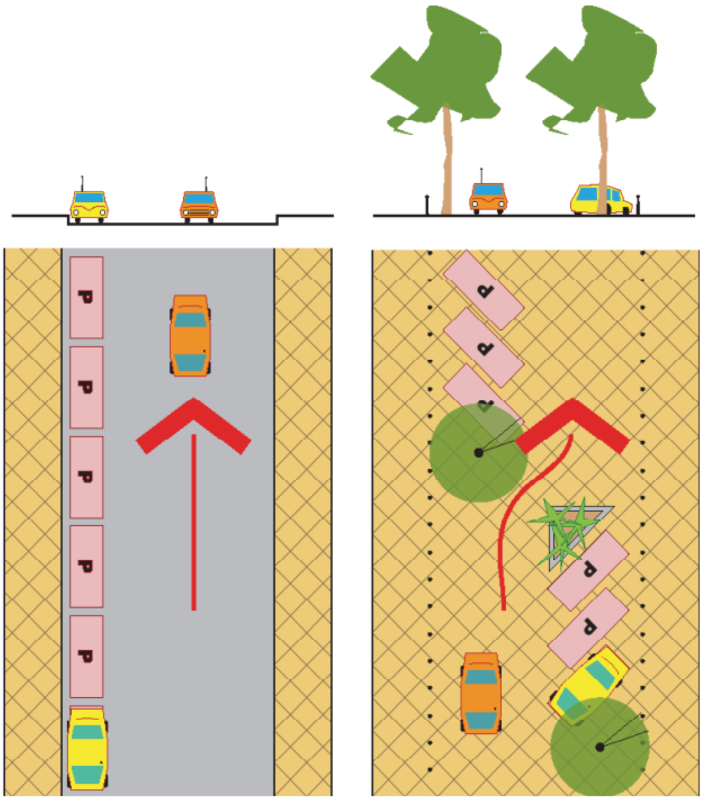

Figure 3. View of a normal street (left) and a woonerf street (right) (Chasan, n.d.).

Figure 4. Five principles of a woonerf design (Appleyard and Cox, 2006).

2.5 Shared space

Throughout history, the main function of streets has shifted from streets which were mainly pedestrian oriented towards streets dominated by automobile vehicles. These two directions can be viewed as two extremes on the spectrum within urban design. According to the classification of traffic and people by Gehl (1987), four distinct classes can be considered within the spectrum, which describe the relationship between cars and pedestrians (see Figure 5). On the one hand, 'automobile-orientated planning' takes the car as central in urban planning, whereas with 'auto-restricted planning', cars in the urban space are as far as possible taken out completely.

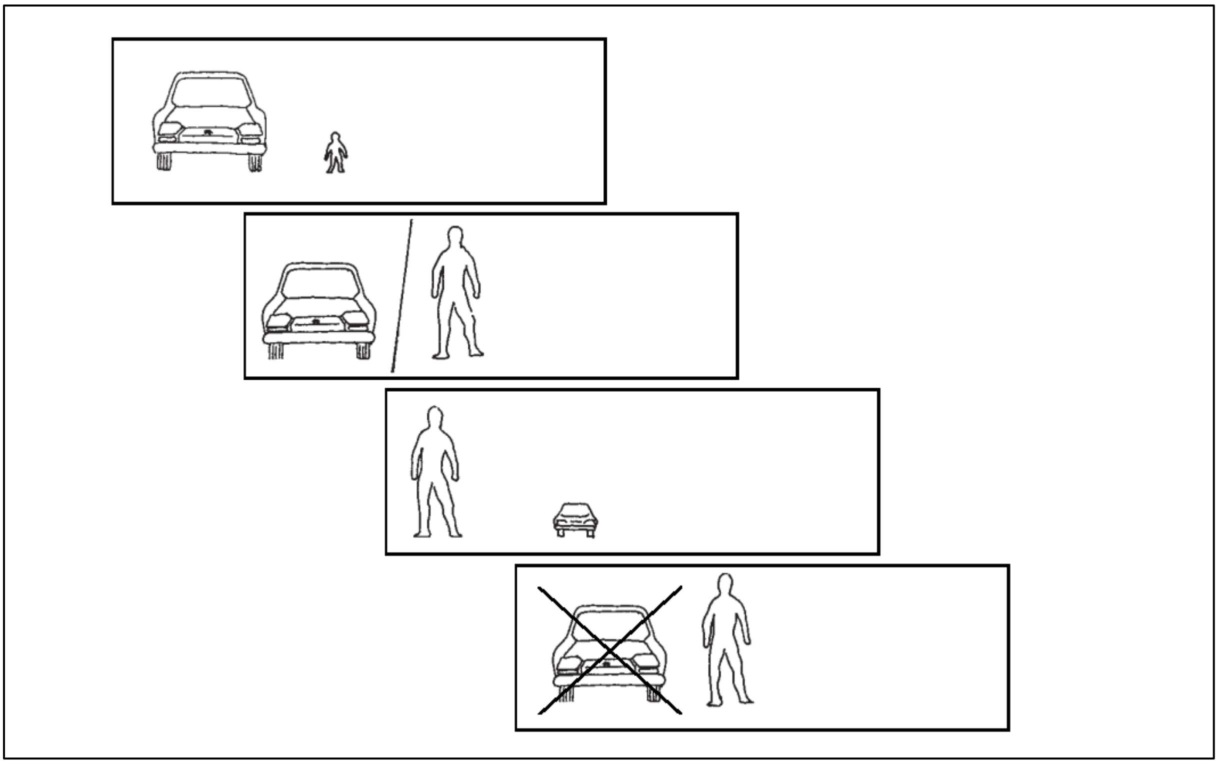

Figure 5. Four classes of relationship between cars and pedestrians (Gehl, 1987).

Nowadays, urban planners attempt to find more of a balance between these two extremes (Moeeni, 2006). This balance can be found in the middle of the spectrum, where two similar, but distinct classes are present. The second class is based on segregation, meaning that each mode of transportation has its own infrastructure. The third class functions according to the notion of integration, where all forms of transport share the same street. In this class, interaction between people, informality, behavior, and norms are central (Hamilton-Baillie, 2005). This integration of different modes of transport and the combination of multiple functions on the street level formed the basis of the 'shared space' concept. Shared space differs from traditional street by its minimalistic design, as most of the traditional street elements have been removed (Gharehbaglou and Khajeh-Saeed, 2018).

2.6 Differences between the Woonerf concept and shared streets

The initial design of the Woonerf concept formed the basic design of the shared streets and used as an example for urban design in many other countries (Ben-Joseph, 1995). The comparison between the characteristics of shared streets according to (Ben-Joseph, 1995) and the characteristics of the Woonerf concept as described by (Kraay, 1986) show the high resemblance between the two concepts (see Table 2).

Characteristics of the Woonerf concept	**Characteristics of shared streets**
It is in an area mainly meant for residence	It is a residential, public space
Sometimes it is a single street or a single square, or a connected area of streets and squares	It can be a single street, a square (or other form), or a combination of connected spaces
Walking and playing are allowed everywhere (that is to say not prohibited)	Walking and playing are allowed everywhere
It is not however the intention that motorized through traffic should use the area	Through traffic is discouraged
There is an intermingling of traffic categories	Paved space is shared by pedestrians and cars, with pedestrians having priority over the entire street
There are no conventional, straight pavements with (raised) kerbs	There are no conventional, straight stretches of pavement with raised curbs and pavement (carriage way) and sidewalk (footway) are not rigidly demarcated
To protect pedestrians and playing children, physical and visual facilities (narrow passages, trees, bollards, varied pavings) are used which induce motorized traffic, especially car drivers, to enter the area at a low speed and continue to drive slowly. There is therefore a firm link between: - the functions of area and street - the presence of speed restrictions - special driver behavior - special rules for driver behavior.	Car speed and movement are restricted by physical barriers, and by deviations, bends, and undulations.
It is an area open to public traffic, to which the traffic regulations apply	
It is mainly paved	
The area is also accessible to motorists and cyclists or mopeds	
Characteristic blue woonerf traffic sign	Its entrances are clearly marked

Table 1. The characteristics of the Woonerf concept as described by (Kraay, 1986) and the shared streets concept according to (Ben-Joseph, 1995).

While the Woonerf and Shared street concept are built around the same integration principles of the shared space concept and are both centered around the notion of behavioral psychology, there are some distinct differences to consider. First of all, the design of shared space is about minimalizing the traditional street elements such as traffic signs (Gharehbaglou and Khajeh-Saeed, 2018). However, the entrance and exit of a woonerf street is indicated by its characteristic blue woonerf traffic sign (see Figure 6).

Within a woonerf area, the public traffic still has to comply to certain traffic rules and regulations. One of the main traffic restrictive measures within a woonerf is the regulation of traffic speeds. Motorized traffic entering a woonerf street has to comply to a maximum speed limit of 'walking pace' under Article 45 of the Dutch traffic regulations (Heydecker and Robertson 2009). After confusion on what this relative concept actually entails, Article 45 was altered. Therefore, in the Dutch context of woonerf streets, a maximum speed limit of 15 km/h is allowed (RVV, 1990).

The Woonerf concept seems like the solution for elimination of traffic issues and the related noise problems related to the speed, amount and activities of traffic movements. To conclude, woonerf streets provide places to be used by the community. While not having the option for a personal backyard, public front yards in a woonerf street offer the availability for residents to socialize, children to play and residents to spend leisure time (Hand, 2007).

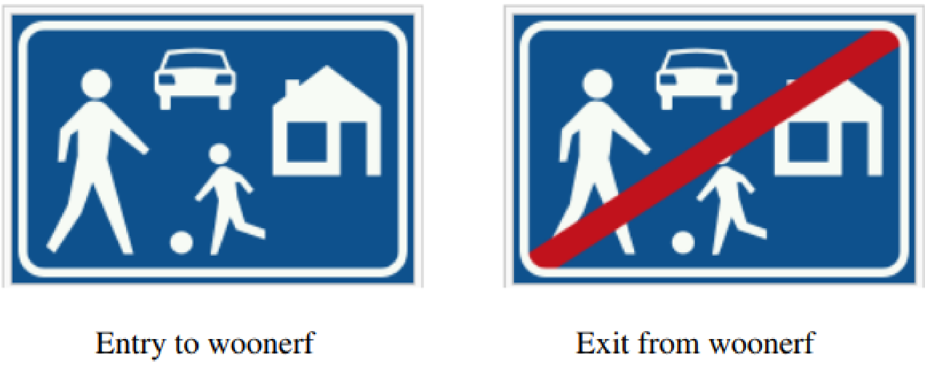

Figure 6. Entrance and exit of a woonerf street (Heydecker and Robertson, 2009).

2.7 Maintenance of urban gardens

Apart from a pleasant living experience, a woonerf street should also provide adequate parking facilities according to the woonerf criteria set up by the Dutch ministry of Transport (Hamilton-Baillie, 2001). This criteria could be an issue and limiting factor with regards to streetscape greenery. Because of limited street space, a decisions has to be made regarding the content of the design. This entails a balance between the provision of adequate parking facilities on the one hand and the use of streetscape greenery on the other.

More people living in cities will not have a private gardens due to increase of urbanization. However, urban public gardens may offer similar experiences (Clayton, 2007). A study in the aesthetic value of urban green space showed that well maintained urban green spaces may add aesthetic value, while neglected urban green spaces may result in a negative opposite effect (Lindemann-Matthies and Brieger, 2016). This is due to the fact that a certain degree of maintenance has a positive appreciative effect, but also lowers the change for vandalism and further neglection.

Adequate maintenance in greenery is mandatory throughout the lifetime of a successful garden. Voluntary participation to maintain a well-developed garden is therefore deemed necessary (Ghose and Pettygrove, 2014). Hence, active neighborhood participation in streetscape greenery developments and maintenance will provide an opportunity to increase green space and aesthetics (Ponizy et al., 2017). However, a study conducted in the United Kingdom showed that one third of the front gardens have no plants, and 25% consist entirely of pavement (Chalmin-Pui et al., 2019). The main reasons provided by people to prefer pavement over greenery were creation for off-road parking and to minimize the maintenance of their garden. Parking facilities should be adequate in the context of woonerf streets and the necessity for off-road parking should therefore not be a major reason for preference of pavement over greenery.

Given the fact that a woonerf is literally translated ''living yard'' and visual green elements are used in the standard woonerf design, gardens and other public green spaces are expected to be present. A front garden is the first section of a building which can be seen, and provides a visual commodity available for public purposes (Chalmin-Pui et al., 2019). Therefore, active participation of maintenance of streetscape greenery could be an indication for higher GVI levels, while a lack in maintenance could result in and opposite negative effect.

2.8 Conceptual model

To represent the relationship between the variables and concepts mentioned in previous sections a conceptual model is provided and displayed in Figure 7. A visual representation shows how active participation in streetscape greenery may influence streetscape greenery. A combination of visual greenery and cultural levels, moderating factors and equivalent sound level are examined to predict tranquility levels. Perceived tranquility is a combination of the equivalent sound level within a street and expected to be mainly a result of a combination of the dominant sound sources. The complexity of sound within the context of urban woonerf street environments is defined by ISO pleasantness and ISO Eventfulness, comprised of eight perceptual attributes. This model shows that even with high equivalent sound levels, a woonerf might still be perceived as pleasant and/or calm.

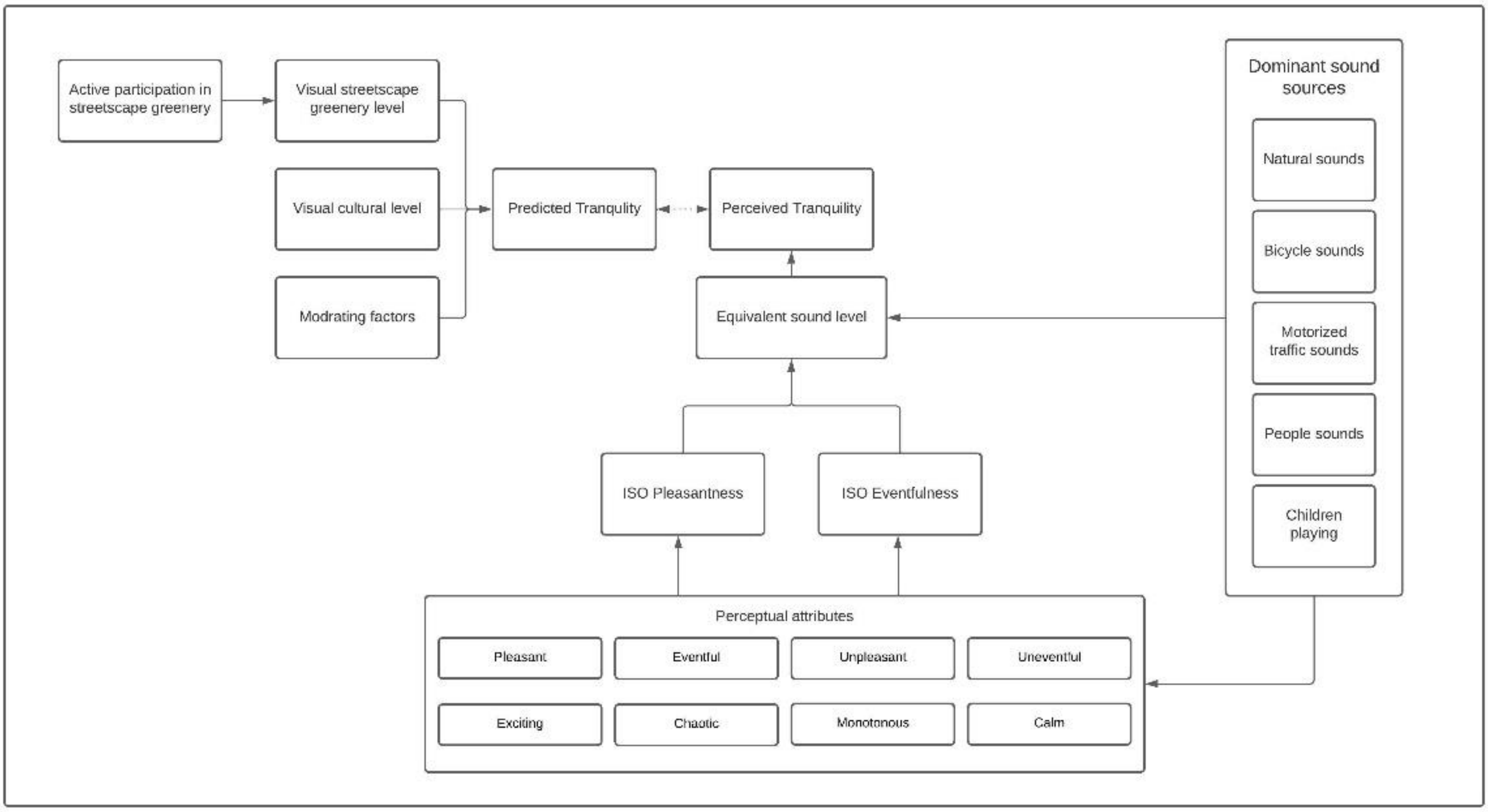

Figure 7. Conceptual model (Author, 2022).

Chapter 3. Methodology

This methodology chapter describes the methods and procedures used to conduct visual and sound measurements, as well as calculations to analyze the collected data. First, the research design is briefly introduced, followed by an introduction of the area under study. Next, the case selection process is explained and a visual representation of the study area is provided in section 3.2. Then, various data collection methods are described, followed by the calculations used in this study for data conversion and analysis purposes. To conclude, ethical considerations are discussed in section 3.5.

3.1 Research design

The methods used to answer the research sub-question can be divided into two data collection sections. For the TRAPT tool, a combination of SPL measurements and manual photographic imagery is used. This method allows for an objective representation of the physical environment to determine the predicted tranquility level in a given context. However, to accommodate for the complexity of the subjective nature of soundscape as perceived by people, an additional questionnaire method is used to examine if the predicted tranquility levels are corresponding to the actual perceived tranquility levels. For the soundscape, residents of woonerf streets were asked to fill in a questionnaire according based on the Method A of ISO/TS 12913-2-2018. Personal characteristics may also be of influence on the assessment of a soundscape (Yang and Kang, 2005). Differences between cases may provide further understanding of contextual factors influencing tranquility levels. Therefore, the questionnaire is comprised of additional questions to provide demographic and educational data on the resident living in the woonerf streets.

3.1.1 Study area

This study focuses on the cities Groningen and Leeuwarden, both located in the northern part of the Netherlands. The city of Groningen is located in the municipality Groningen, in the northern part of the Netherlands. The municipality Groningen, which is centered around the city of Groningen, has a size of 185,6 km^2. It is one of the most densely populated areas in the northern part of the Netherlands. In 2022, about 235.000 inhabitants were living in Groningen, equivalent to a population density of 1266/km^2 (CBS, 2022). The city of Leeuwarden is located in the province of Friesland, adjacent to the province of Groningen. The size of the municipality of Leeuwarden is 237,7 km^2 with a population of 126.000 and an population density of 528/km^2 (CBS, 2022). See also Figure 8.

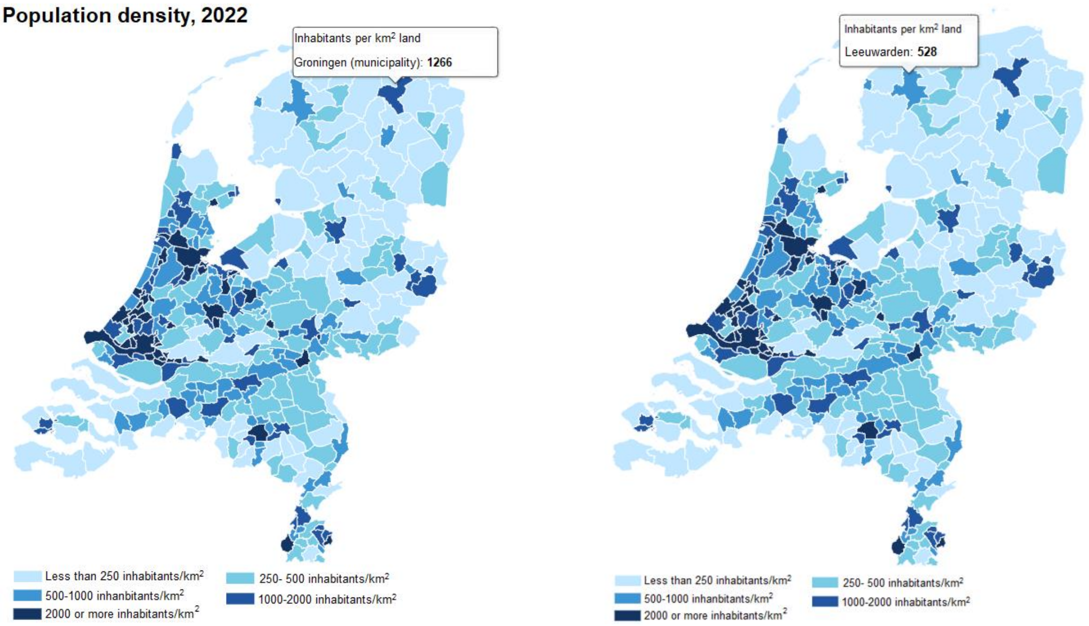

Figure 8. City location of Groningen (left) and Leeuwarden (right) in the Netherlands (CBS, 2022).

3.2 Case selection

In total, 63 woonerf streets are selected. 32 streets were located over eight neighborhoods around the inner-city of Groningen. In Leeuwarden, 31 streets were selected, also located in eight different neighborhoods and in similar locations around the inner city. A visual representation of the case selection within the cities of Groningen and Leeuwarden is displayed in Figure 9 and 10. A list of all woonerf streets selected in the cities of Groningen and Leeuwarden can be found in Appendix B. The approach for the case selection combines already known knowledge on characteristics specifically related to woonerf streets and the use of Overpass turbo, a web based tool for the OpenStreetMap (OSM) database. With Overpass turbo, it is possible to run an Application Programming Interface (API) query to select an overview of nodes and ways according to predefined criteria. As the focus of this study is on residential woonerf streets and the maximum allowed speed in woonerf streets in the Netherlands is 15km/h, a query is formulated according to the following criteria in the search for potential woonerf streets: *"highway= living street''* and *"maxspeed=15"* (see appendix A).

As already mentioned in section 2.6, the characteristic blue woonerf sign indicates the beginning and end of a woonerf street. However, in some cases the end of a woonerf street is indicated by the start of a 30km/h zone sign, which signals the end of the 15km/h woonerf street (see Figure 11) (RVV, 1990; SWOV, 2018). So, to verify if a street is indeed a woonerf street, Google Street View (GSV) is used to analyze if the characteristic blue woonerf sign is present at the entrance and if a blue woonerf sign with a red line across, or the start of a 30km/h zone sign is present, which marks the end of a woonerf street.

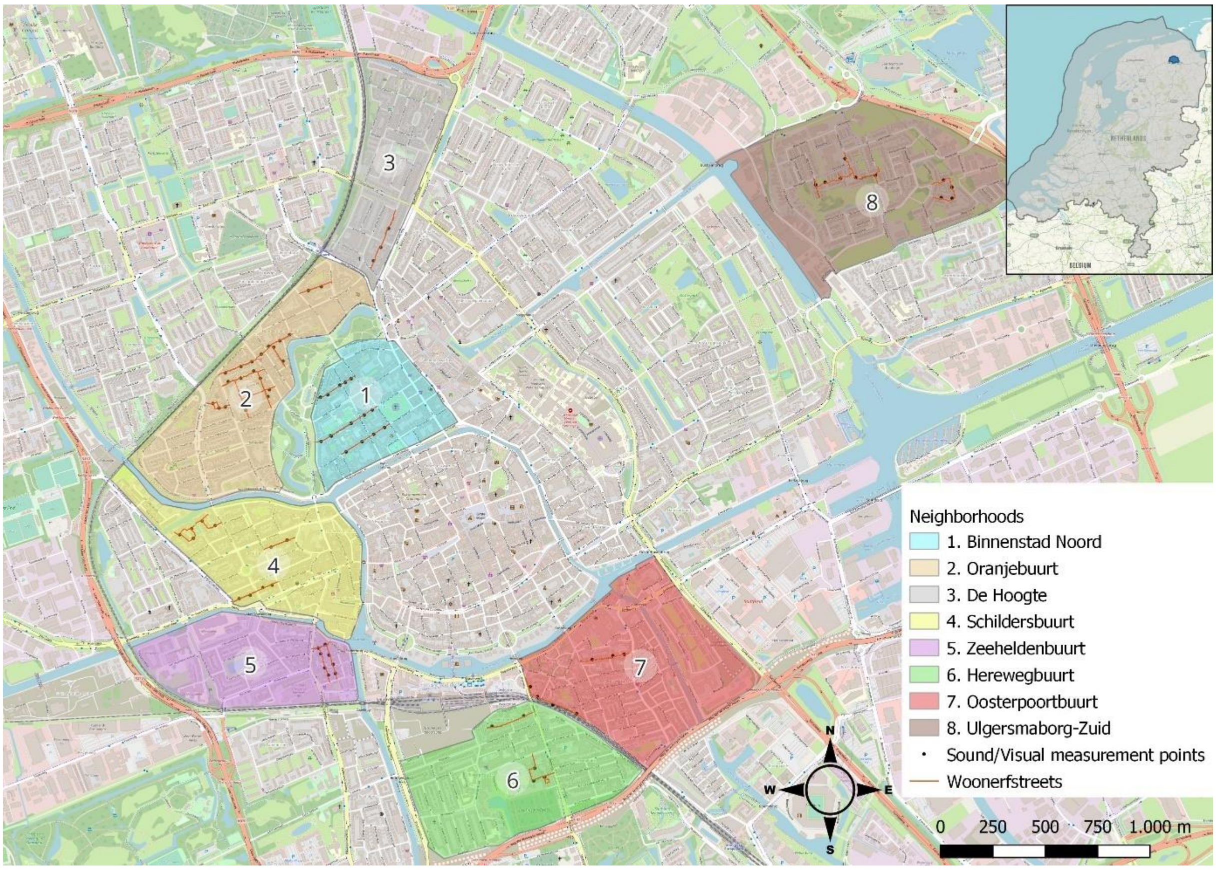

Figure 9. Visual representation of 32 woonerf streets selected in the city of Groningen.

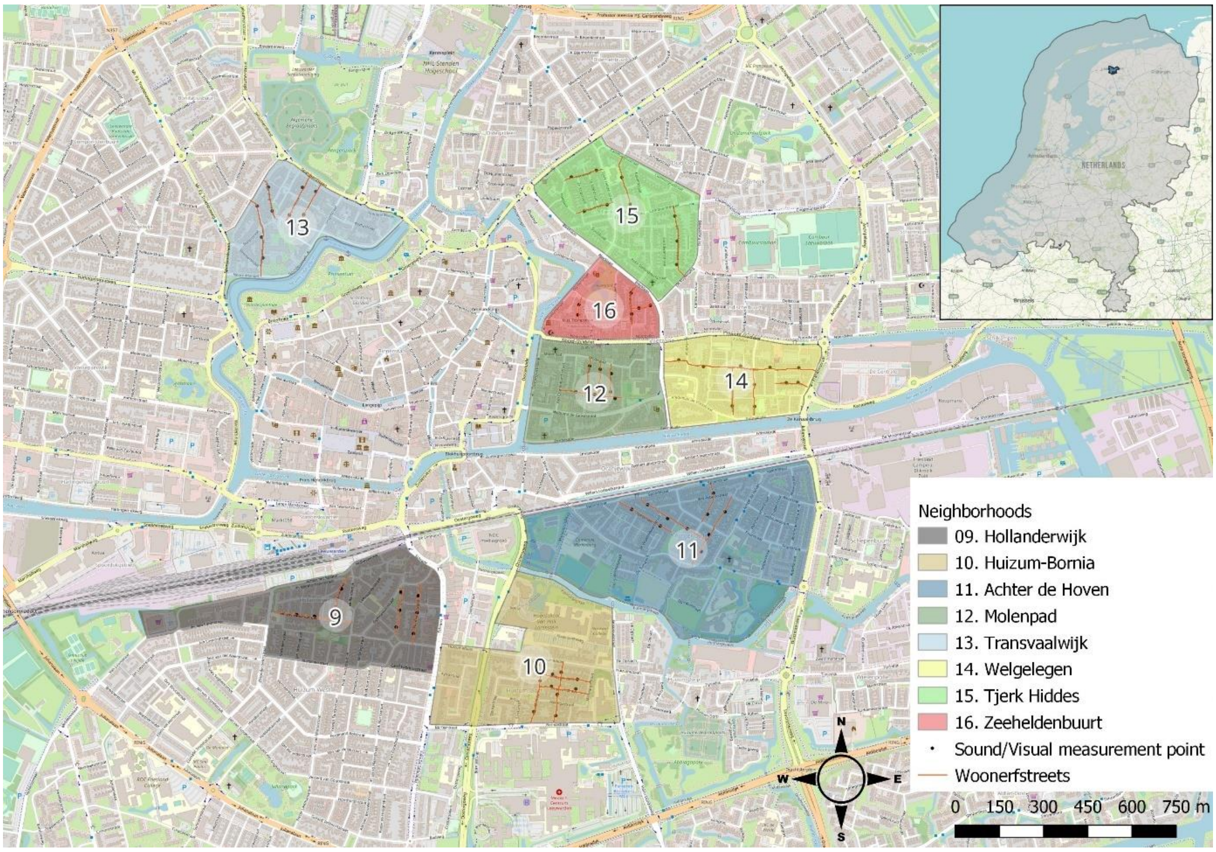

Figure 10. Visual representation of 31 woonerf streets selected in the city of Leeuwarden.

Figure 11. End of a woonerf by either the blue woonerf sign (left) or the start of a 30km/h zone (right) (RVV, 1990; SWOV, 2018).

3.3 Data collection

In this study, multiple data collection methods are used. For predicting the tranquility rate according to the TRAPT tool, spot reading of the A-weighted sound pressure level and panorama photos on the same location were taken to determine the NCF and Lday.

For the locations of the spot readings the following three criteria were used:

1) Locations should not be too close to the beginning and ending of the woonerf, as the sight of other adjacent streets should be minimized.

2) For the same reason, locations where the main woonerf street meets an adjacent street are excluded as well.

3) When after visual inspection no more visual aspects of the previous measurement are in sight (e.g curve of the road), a new visual measurement can be taken.

Additionally, field research was performed by the large scale distribution of questionnaires focused on quantitative data collection represented based on Likert scales in combination with several open questions. These open ended questions were included to provided additional information and contextual depth to the woonerf streets and to allow for possible design/policy recommendation after data analysis.

3.3.1 Data collection period

Within the time period of 8:00 a.m. and 11:00 a.m. sound and visual data measurements were collected between the 1st until the 30th of November 2022. The days selected for data collection were not planned in advance, but rather on the day itself. Precipitation or high winds will greatly influence the sound measurements, resulting in potential errors. Therefore, only with a Beaufort wind force of 2 or less and no precipitation of any kind (e.g. rain, mist, snow), data was be collected. Questionnaires were distributed within the same period as when the sound and visual data collection took place.

3.3.2 Spot based sound measurements

For the sound measurements a mobile device (SM-G973) was positioned on a universal tripod (Studio ME) at a 1.5 m height. This height is comparable to the average ear height of an adult in an upright standing position (Anon, 2017a). The tripod was placed in such a way that traffic or other forms of activities are not hindered in the process of sound data collection. The NoiseCapture mobile app is used (Version 1.2.22.2 dec. 2021 r.a134a55) to collect the SPL data (Leq, LA10, LA50, and LA90). NoiseCapture is a mobile app exclusively on Android to measure environmental noise, developed by the Environmental Acoustic Laboratory (Ifsttar) and the DECIDE team of the Lab-STICC (CNRS). Each sound measurement will last one minute. Before the data collection started, manual calibration was performed with a reference device in the NoiseCapture app. The mobile device was manually calibrated in accordance with a calibrated reference device (Voltcraft SL-451) at 95 dB. Sound measurements were attached as attributes to a spatial layer. For this step, the LocusGIS app was used. LocusGIS allows for data to be attached to specific coordinates and is stored in a shapefile. This shapefile is later used for further analyzes in a Geographical Information System (QGIS).

3.3.3 Spot based visual measurements

For the visual measurements the same mobile device (SM-G973) was positioned on a universal tripod (Studio ME) at the same height as the average ear height perpendicular to the street's surface. At the same location of each sound measurement, a visual measurement is also performed. The only difference is that the tripod is placed in the middle of the road to perform visual measurements. At each location, four pictures were taken at 0°, 90°, 180°, 270°. Each time going clockwise, starting with the house side of the street. The mobile device is capable of a field of view (fov) in the horizontal direction of 77°, allowing for a panoramic 360° view without any overlap of imagery. The vertical fov of a standard camera lens is ±20° and compatible with studies related to a person's eye fov (Anon, 2017b). Coordinates of the visual measurement locations are automatically stored and allocated to corresponding pictures.

3.3.4 Questionnaires

Approximately 3100 questionnaires leaflets were distributed to all the residents living in the 63 woonerf streets. For the development of the questionnaire the map-based survey tool Maptionnaire was used. After a short introduction of the research topic, residents were able to access the questionnaire by the use of a QR-code of by filling in a URL link. A translated version is also added, allowing non-native Dutch speakers to participate in the questionnaire as well (see Appendix C). It was not possible for the participants to proceed to the next page of the questionnaire if a question was not answered.

Questions regarding the subjective perception of a soundscape followed the Method A described in the ISO/TS 12913-2:2018. Eight perceptual attributes were evaluated based on a 5-point Likert scale ranging from 1, “strongly disagree” to 5, “strongly agree”. Three questions regarding the tranquility, importance of tranquility, and maintenance of streetscape greenery were based on a 10 point Likert scale with “1” always being the lowest value and “10” representing the highest. The questionnaire is also comprised of categorical questions related to the dominance of sound sources (e.g motorized sound and children playing) and the visual elements (Natural/Cultural vs Man-made), a ranking question about the presence of characteristic street elements typically found within a woonerf is also included in the questionnaire based on (Kraay, 1986; Ben-Joseph, 1995). Two open-ended questions are also added to address the potential reasoning of residents to choose for living in a woonerf street and for future recommendations relevant for urban designers and policy makers.

3.4 Data analysis

After the finalization of the data retrieval period, the data was transformed into datasets suitable for data mapping in QGIS and statistical analysis in SPSS. For the visual analysis Adobe Photoshop was used.

3.4.1 Sound data analysis

In total 155 one minute noise measurements were used to measure the L_{A10}. These measurement are used as a representation value for $L_{A10,18h}$ for the various woonerf street locations between 7 a.m. and 7 p.m. Because there was no detailed hourly and/or period traffic data available, Method 3 of Abbott and Nelson (2002) is used to convert the L_{A10} data into L_{day} for non-motorways roads by the following equation:

$$L_{day} = 0.95 \times L_{A10,18h} + 1.44\, dB \qquad (1)$$

Questions covering the eight perceptual attributes regarding the perception of sound in woonerf streets were analyzed by the use of corresponding Likert values as distances. These values were transformed into X,Y coordinates on a scatterplot between -1 and +1 by equations (2) and (3) provided in ISO12913:3-2019.

$$ISO\ Pleasantness = \begin{bmatrix} (pleasant - annoying) \\ + \cos 45° \times (calm - chaotic) \\ + \cos 45° \times (vibrant - monotonous) \end{bmatrix} \times \frac{1}{(4 + \sqrt{32})} \qquad (2)$$

$$ISO\ Eventfullness = \begin{bmatrix} (eventful - uneventful) \\ + \cos 45° \times (chaotic - calm) \\ + \cos 45° \times (vibrant - monotonous) \end{bmatrix} \times \frac{1}{(4 + \sqrt{32})} \qquad (3)$$

3.4.2 Visual analysis

In the 63 woonerf streets a total of 620 pictures were taken. The Green View Index was calculated based on the equation of Yang et al. (2009). This formula uses the total green pixel area of four pictures divided by the total amount of pixels (see equation (4). $Area_{g\_i}$ is the total amount of green pixels in the *ith direction (north, east, south, west°).* $Area_{t\_i}$ is the total amount of pixels of the same four pictures.

$$Green\ View = \frac{\sum_{i=1}^{4} Area_{g\_i}}{\sum_{i=1}^{4} Area_{t\_i}} \times 100\% \qquad (4)$$

The NCF value uses a similar formula but also includes the contextual visual elements and excludes the visible sky area. This formula been used to calculate NCF values in many studies (e.g. Watts and Bauer 2021) by the following equation:

$$NCF = \frac{\sum_{\theta}^{6} \frac{An\theta\ \times 100}{(At\theta)}}{6} \qquad (5)$$

where $An\theta$ represents the amount of green and contextual pixels, and $At\theta$ is the total amount of pixels minus the sky. Six images cover the 360° horizontal surroundings pedestrians can see. Instead of six pictures, four pictures were taken in this study in the 0°, 90°, 180°, 270° direction. For the GVI and the NCF values, visible skies were excluded. Contextual pixels of visible cultural heritage buildings are also relevant and should be added to the amount of green pixels. To investigate whether or not cultural heritage buildings are present in a particular woonerf street, The Cultural Heritage Agency of the Netherlands (RCE) is consulted. The RCE is a government organization concerned with the protection and conservation of the national heritage in The Netherlands. For each woonerf street, the cultural heritage register formed by the RCE is examined to see if cultural heritage buildings are indeed present in that particular woonerf street. The modified calculation formulas for GVI and NCF used in this study are as follows:

$$Green\ View = \frac{\sum_{i=1}^{4} Area_{g\_i}}{\sum_{i=1}^{4} Area_{t_i} - Area_{s_i}} \times 100\% \qquad (6)$$

$$NCF = \frac{\sum_{i=1}^{4} Area_{g\_i} + Area_{c\_i}}{\sum_{i=1}^{4} Area_{t_i} - Area_{s_i}} \times 100\% \qquad (7)$$

In these formulas $Area_{c\_i}$ is the number of contextual pixels and $Area_{s_i}$ the number of sky pixels. ImageJ version 1.53t 24 and Adobe Photoshop version 24.1 were both used on a pilot case to examine if both programs provided the same NCF value. The four pictures taken at each point are laid in a square for efficiency purposes. Both programs showed similar results (16% and 17% respectively). Consequently, it was decided to analyze the complete imagery dataset by using Adobe Photoshop, as this was considered to be the more convenient program for larger samples. Through Adobe Photoshop image analyzation tools, manually extraction of pixel areas required for equations (6) and (7) was performed. Figure 12 shows the pixel extraction process for a randomly taken data point with no cultural buildings present. A full list of all the analyzed data point is provided in Appendix D.

Figure 12. Example of the pixel analysis for a randomly taken picture. Four pictures laid together form the total panoramic view (left). Exclusion of sky pixels (center) and the streetscape greenery (right).

3.4.3 Mapping technique regarding sound and visual measurements in QGIS

The collected visual data was put in an excel sheet to perform calculations according to equations (6 and 7). This method allowed for the data to be converted into the desired outcome for all the visual spot based measurements at once. After calculations were completed, the NCF outcomes are placed in the same spatial layer of the initial sound data measurements, which was documented in the LocusGIS application. With this method, all the converted visual data can be placed in QGIS and be allocated to the corresponding streets at which the initial data was collected. Finally, Inverse Distance Weighted (IDW) interpolation is conducted for visual and sound data. Interpolation techniques have been used in the past to represent sound levels (Can et al., 2014) and emphasize the added value of interpolation for illustrative purposes (Margaritis and Kang, 2017). As the data points are spread around the cities of Groningen and Leeuwarden, a 25 meter buffer is set around the woonerf streets and used via the clip raster to mask layer tool. This is deemed necessary because otherwise levels at the middle of the spectrum would fade into the background of the base layer.

3.4.4 Tranquility calculations

For calculation of the predicted tranquility, the adjusted equation for urban green spaces given by Watts et al. (2013) is used. This equation is as follows:

$$TR = 10.55 + 0.041 \times NCF - 0.146 \times L_{day} + MF \quad (8)$$

In this equation the TR stands for the predicted tranquility rate ranging from 0-10. The number 10.55 is an adjusted constant from the original TRAPT equation, derived from insights based on the adaptionlevel theory (Helson, 1964). This theory implies that people living in densely urban populated areas have likely grown accustomed to higher levels of noise and lower levels of greenery. NCF is the ratio of all the natural and historical visual elements compared to the total visual perception of a human. Lday is the A-weighted Leq (equivalent noise level), within the time period between 7 a.m. to 7 p.m. MF servers as a moderating factor to take into account any negative factors (e.g. graffiti, litter) and positive factors (e.g. the sound of water) which might be present on site (Watts et al., 2009). However, these moderating factors are found be of limited effect, but may result in a maximum of 1 point difference (Watts, 2017). For simplification, moderating factors are therefore not taken into account in this study. Equation (8) was put into an excel spreadsheet to calculate the predicted tranquility for all woonerf streets.

3.4.5 Statistical analysis

472 responses from residents living in woonerf streets were collected through a questionnaire in the cities of Groningen (314) and Leeuwarden (158). Before statistical analysis took place, respondents with no submitted end time were excluded from the dataset. Respondents were required to answer each question before proceeding to the next one. After exclusion of unsubmitted responses, a completely filled in dataset of N = 410 formed the basis for further statistical analysis. Sound and visual measurements were added as additional variables, as well as the predicted tranquility rate levels derived from equation (8).

Descriptive statistics was used to compare categories and to provide a visual representation of single variables. Bar charts were primarily used as they were deemed the most effective option for presenting information on frequencies and categories across multiple woonerf streets or neighborhoods. A comparison of questionnaire data with the measured data on sound, GVI and predicted tranquility was performed through a series of statistical tests. When $N \geq 30$, normal distribution is assumed according to Central Limit Theorem. However, the assumption for normality and equal variances was checked, even if the sample size is large enough according to the Central Limit Theorem to be considered normally distributed. To check for normality, Shapiro-Wilk normality tests are performed in combination with a visual interpretation of Histograms, Stem-and-Leaf plots and Q-Q Plots. For samples with $N < 30$, Shapiro-Wilk tests are also used in combination with a visual inspection of Stem-and-leaf and boxplots to examine whether or not samples are normally distributed. When this was not the case, nonparametric Wilcoxon signed rank test were used for paired measurements. When more than two categories were compared, an Independent-Samples Kruskal-Wallis Test was performed. An overview of data documentation and analysis is given for each (sub) question in Table 3.

	Specific information	Moment of retrieval	Method of data Retrieval	Method of Documentation	Method of Analysis
Main Research Question	Tranquility levels by auditory and visual levels	December-January 2022	Comparative case study	Combined of the sub questions	Derived from answering sub questions
Sub Question 1	Perceived tranquility levels	November 2022	Questionnaire	Mapptionnaire	SPSS
Sub Question 2	Noise levels by perceptual attributes	November 2022	Questionnaire NoiseCapture	Mapptionnaire LocusGIS	QGIS
Sub Question 3	Visual greenery/cultural levels	November 2022	Questionnaire Camera	Mapptionnaire Excel	QGIS
Sub Question 4	Difference between predicted and perceived tranquility levels	November 2022	Questionnaire NoiseCapture Camera	Mapptionnaire Excel	SPSS QGIS
Sub Question 5	Influence of active participation of maintenance on visual greenery levels	November 2022	Questionnaire Camera	Mapptionnaire	SPSS

Table 3. Overview of data analysis and collection methods.

3.5 Ethical considerations

Residents who participated in the questionnaire remained fully anonymous. Participants were stored by a “Respondent ID” of a randomized string consisting of 12 digits and letters. Participants were noticed of this full anonymity in the introduction of the questionnaire. It was not possible to refuse any questions before proceeding to the next one. In the introduction part before the start of the questionnaire, participants were informed of the possibility to stop the questionnaire at any time. All the data gathered is saved only on the database used for data collection and on a personal computer database. This database is only accessible by the researcher himself. The data gathered will be kept confidential at all times and will not be shared with third parties. In one of the questions, participants are asked to fill in their street of residents. Therefore, a link can be made between the data provided by an anonymous resident and a specific street. However, this question is deemed necessary for further comparative research of the variables relevant in this study.

Chapter 4. Results

In this chapter results will be presented from the analyzes mentioned in chapter 3. The following chapter is structured according to the sub-questions stated in chapter 1 in order to answer the main research question: ''*To what extent can the tranquility rate of woonerf areas be predicted by its auditory and visual levels?*''.

4.1 Comparison of perceived tranquility between the woonerf areas

In the questionnaire respondents were asked to rate the tranquility of their street by choosing a number between 0 and 10, where 0 is considered ''least tranquil'' and 10 is ''most tranquil''. To prevent potential outliers to be of dominant influence on the average tranquility rating, only the neighborhoods with a response rate of ≥ 20 were selected (see Table 4). The lowest average perceived tranquility rate was measured in De Hoogte (5.60) and the highest in the Transvaalwijk (7.80). Between Groningen and Leeuwarden minimal differences can be observed in the perceived tranquility rate with scores of 6.68 and 6.78 respectively. All neighborhoods, except for the Transvaalwijk, show a high level of variance. The histogram in Figure 13 displays a moderate left-skewed distribution (-0.910) of the perceived tranquility frequency.

Neighborhood	Mean	N	Variance	Minimum	Maximum
1. Binnenstad Noord	6,25	24	3,065	2	9
2. Oranjebuurt	6,95	88	3,653	1	10
3. De Hoogte	5,60	20	5,411	2	9
4. Schildersbuurt	6,96	52	2,273	3	10
5. Zeeheldenbuurt	6,90	20	2,095	3	9
6. Herewegbuurt	6,76	21	2,790	3	10
7. Oosterpoortbuurt	6,21	28	5,286	1	10
8. Ulgersmaborg- Zuid	6,62	21	5,148	2	10
Groningen	**6,68**	**274**	**3,641**	**1**	**10**
09. Hollanderwijk	7,25	20	3,461	3	10
10. Huizum-Bornia	6,19	21	2,862	2	9
11. Achter de Hoven	6,00	22	3,810	2	9
12. Molenpad	6,76	21	4,190	3	10
13. Transvaalwijk	7,80	20	,695	6	10
Leeuwarden	**6,78**	**104**	**3,358**	**2**	**10**
Total	**6,70**	**378**	**3,557**	**1**	**10**

Table 4. Average perceived tranquility rating between 13 neighborhoods in Groningen and Leeuwarden with N ≥ 20.

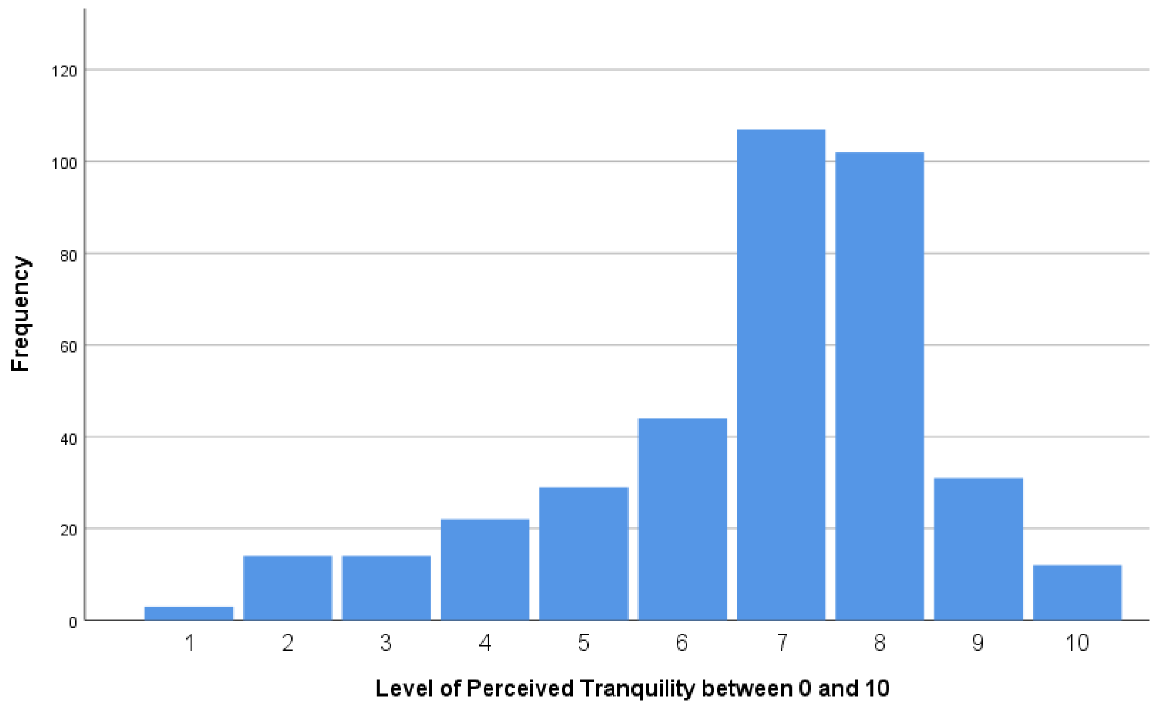

Figure 13. Distribution of how residents in Groningen and Leeuwarden perceive Tranquility levels in their woonerf street.

Before conducting any statistical tests to compare the perceived tranquility between woonerf areas in Groningen and Leeuwarden, a Shapiro-Wilk normality test is performed in combination with a visual inspection of histograms, stem-and-leaf plots and Q-Q Plots. According to the Shapiro-Wilk test, five neighborhoods show a non-significant result of $p > 0.05$ and can therefore be considered normally distributed (1, 10, 11, 12) (see Appendix E). To check for equal variances across the groups, a Levene's test is performed. A p value < 0.05 indicates the variances to be not equal. Because the sample size per neighborhood is $N \geq 20$, an one-way ANOVA test may still be performed according to the Central Limit Theorem. When the sample size of each group is not similar, a significant difference may be detected while this is not the case (type I error). Considering neighborhood 2 and 4 are relatively large compared to the rest, a one-way Welch ANOVA test is used to adjust for the unequal sample sizes. Furthermore, complementary to the ANOVA, a nonparametric Independent-Samples Kruskal Wallis test is carried out, as assumptions of normally distribution and equal variances are not met.

The Welch ANOVA test shows a p value < 0.01. This indicates a significant difference of perceived tranquility between the thirteen woonerf neighborhoods in Groningen and Leeuwarden. As the variances across groups are not equal, a Games-Howell post-hoc test was performed. A significant difference of perceived tranquility ($p < 0.05$) can be observed at neighborhood 13 (Transvaalwijk) compared to neighborhoods 1, 3, 10, 11 (Binnenstad Noord, De Hoogte, Huizem-Bornia, Achter de Hoven). Analysis of the additional Independent-Samples Kruskal Wallis test also shows a p-value < 0.01 indicating a significant difference of perceived tranquility between the neighborhoods in Groningen and Leeuwarden.

Multiple additional statistical tests were performed to analyze for differences between perceived tranquility for other categories as well. An Independent-Samples Kruskal Wallis test was performed to analyze the average perceived tranquility levels across the educational background. Here, a nonparametric test is preferred, as the sample size of category 'primary education' = 2 within the total sample. The test shows a non-significant difference ($p > 0.05$). Therefore, the null hypothesis for equal perceived average tranquility across categories of educational background should be retained. When the primary education category is excluded, a Welch ANOVA test indicates that there is no significant difference as well ($p > 0.05$). As the group sample sizes for age is $N \geq 30$, but groups size across categories are unequal, a Welch ANOVA test is performed across the categories of age. The p-value < 0.001 indicates that perceived tranquility is not equal across different age groups. A Levene's test indicates that the variances are equal ($p > 0.05$). Therefore, a Tukey HDS post-hoc test is performed. This test shows that there is a significant difference of perceived tranquility between the age group 55 – 65 and the younger age groups of < 25 years, 25 – 35 years and 36 – 45 years.

Frequency bar charts of the educational background and the age groups between neighborhoods is given in Figure 14 and 15. Almost all the neighborhoods have a relatively young demographic, with most residents being under 35 years old. In the Transvaalwijk the age groups 56-65 and > 65 are overly present. A high percentage of residents have an educational background on the level of a Bachelor's or Master's degree. The category 'primary school' as the highest form of education is only present in Ulgersmaborg-Zuid and only accounts for 5% of the neighborhoods total.

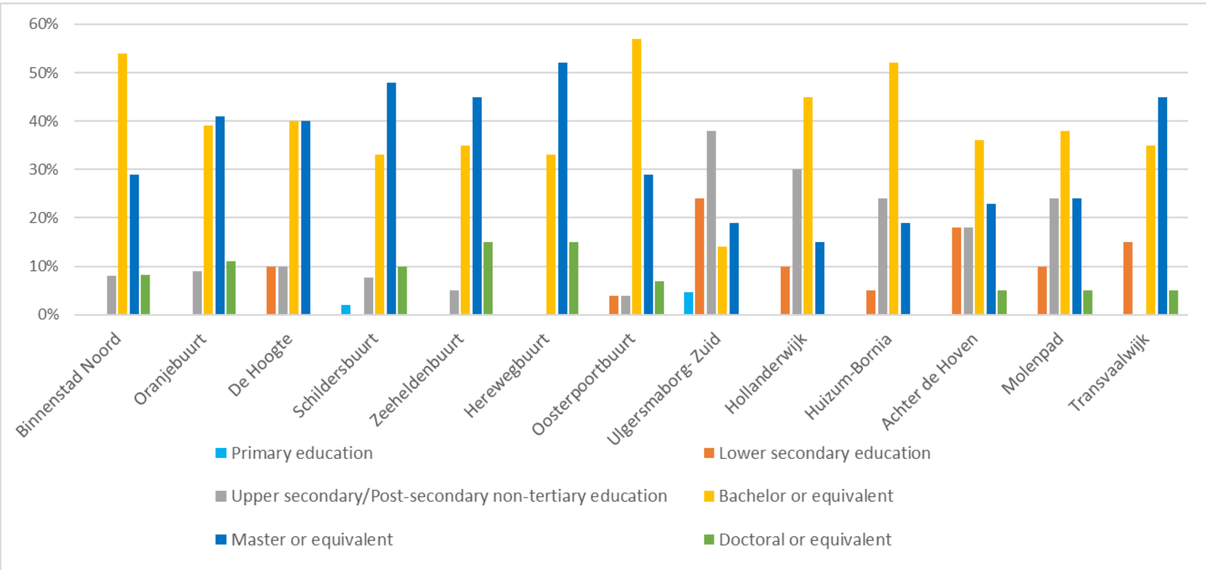

Figure 14. Educational background between neighborhoods in Groningen and Leeuwarden with N ≥ 20.

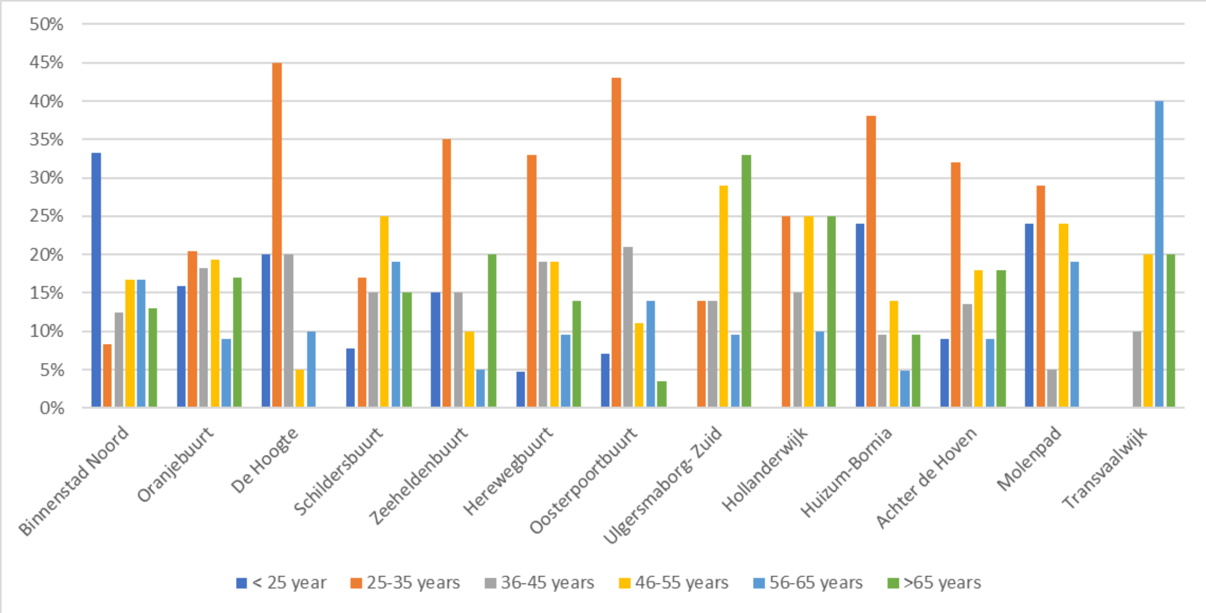

Figure 15. Differences in age groups between neighborhoods in Groningen and Leeuwarden with N ≥ 20.

4.2 The link between noise levels and the eight perceptual attributes

A questionnaire is used to determine which sound sources residents perceive as most dominant. Five sound categories (Natural, Bicycle, Motorized traffic, People, Children playing) were chosen as the most relevant sounds within the context of woonerf streets. Figure 16 shows the frequency of the reported most dominant sound source by residents of woonerf streets in percentage of the 13 neighborhoods in Groningen and Leeuwarden.

Multiple observations can be made from this figure. First of all, residents perceive motorized traffic and people sounds as most dominant, while natural, bicycle, and children playing sounds are perceived as less dominant. This is true for all neighborhoods except for Ulgersmaborg-Zuid. In this neighborhood the sound of children playing is perceived as most dominant compared to the other sound sources. Also, with regard to natural sounds, 20% of the respondents perceive natural sound as the most dominant sound source in two neighborhoods (i.e. Schilderbuurt and Ulgersmaborg-Zuid). In contrast, no residents in the neighborhoods of De Hoogte and Achter de Hoven perceive natural sounds as the most dominant sound in their streets.

Additionally, residents of woonerf streets generally perceive bicycle sounds as less dominant compared to all other sound sources. Residents of Binnenstad-Noord and De Hoogte rate bicycle sounds more often as the most dominant sound source compared to the other neighborhoods. When comparing the neighborhoods of Groningen and Leeuwarden, a distinct difference in overall perception of bicycle sounds can be observed. Even though residents generally rate bicycle sounds as less dominant compared to other sound sources, they are perceive as more dominant in the city of Groningen than in Leeuwarden.

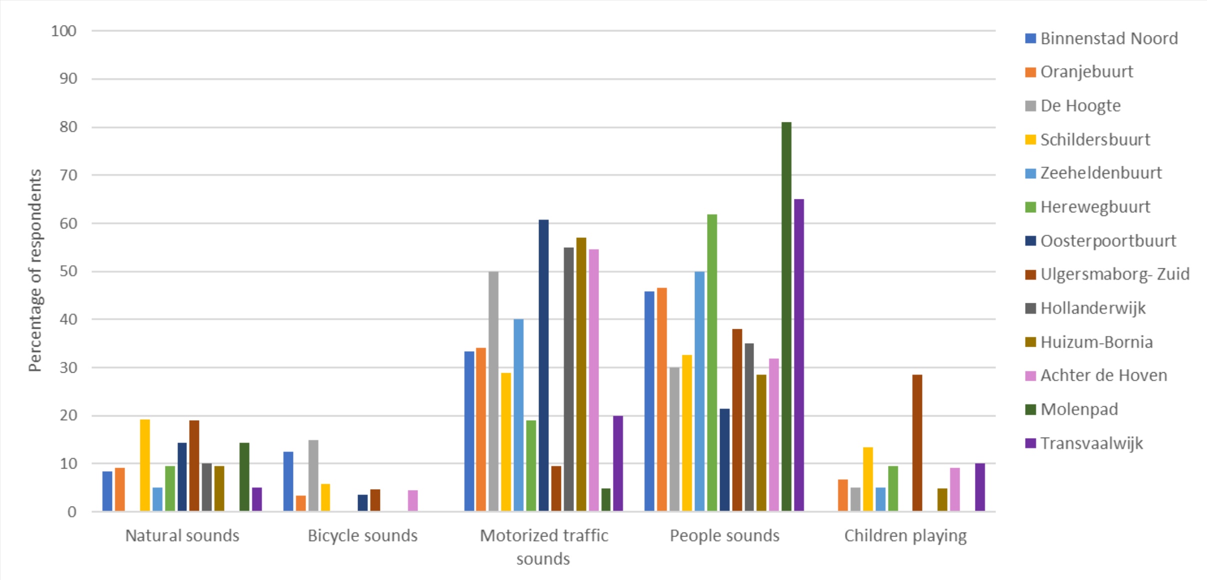

Figure 16. Most dominant sound source perceived by residents of neighborhoods in Groningen and Leeuwarden with N ≥ 20.

Figure 17 presents a bidimensional circumplex model that displays the eight perceptual attributes previously mentioned in opposing directions from each other. Using the ISO-based Coordinates formula (see equation 2, 3), X,Y-coordinates are calculated for the ISO Pleasantness and ISO Eventfulness axes, respectively. These coordinates determine the locations of the 13 neighborhoods in the Soundscape Scatter Plot.

Given these coordinate points, the following noticeable aspects can be distinguished. First of all, concerning the Pleasantness axis, almost all neighborhoods (12 out of 13) are located within the range of 0.2 and 0.6. The Transvaalwijk shows the highest score of 0.59 whereas De Hoogte is just outside the range (0.17) and ranks the lowest of all neighborhoods with regard to Pleasantness. The fact that the lowest end is still on the side of the positive axis shows that residents perception of sound show little resemblance with the feeling of annoyance and is rated as relatively pleasant.

In terms of Eventfulness, all neighborhoods have neutral to low scores. More specifically, the vast majority of neighborhoods (11 out of 13) are positioned between 0 and -0.2 on the Eventfulness axis. Only the Oosterpoortbuurt and the Transvaalwijk are just outside this range, with scores of 0.04 and -0.25 respectively.

When considering the two axes altogether, the Transvaalwijk scores relatively high on the Pleasantness axis and low on the Eventfulness axis. Hence, this neighborhood shows the highest resemblance with associated feelings of calmness. Given these results, a clustered area can also be observed in Figure 17. Regarding the eight perceptual attributes of noise, high similarities occur between the different woonerf neighborhoods. It is also worth noting that the extreme values found on the Pleasantness axis correspond to the outer values of the average perceived tranquility in Table 4, previously mentioned.

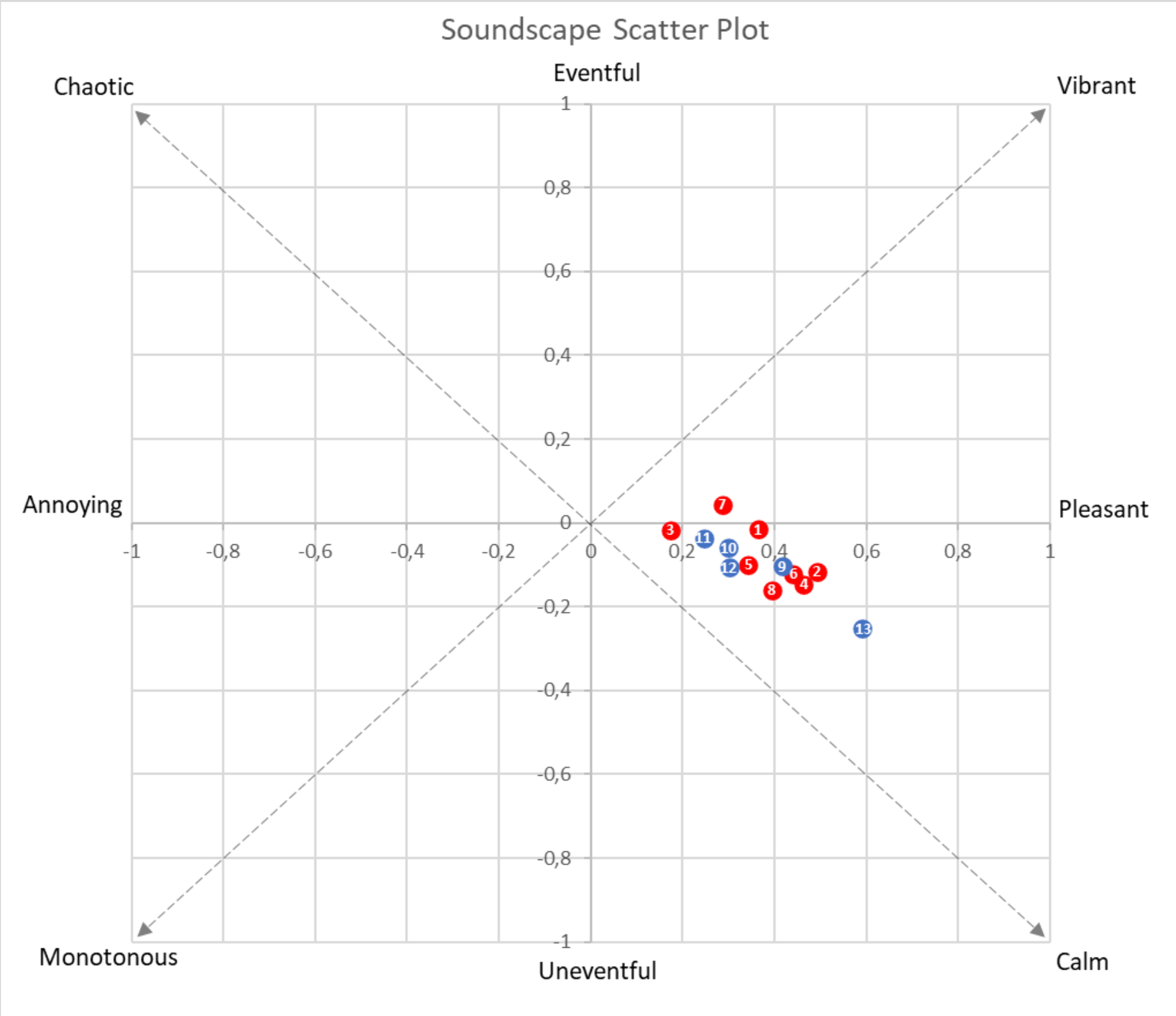

Figure 17. Bidimensional circumplex model of the eight perceptual attributes laid in opposing directions from one another, based on ISO 12913-3. Blue and red points represent the neighborhoods located in Groningen and Leeuwarden respectively. The numbers correspond to specific neighborhoods previously mentioned in Table 4.

The Leq (dB) is measured at multiple points within the woonerf streets. Interpolation of these data points result in two sound maps of Groningen and Leeuwarden, which is shown in Figure 18 and 19. Equivalent sound levels range from minimum of 39 dB and maximum 62 dB. In Groningen, Street 29 is located close to a public school which might explain the relatively high sound levels. The other red colored spots are located near major roads and/or the railway station. In Leeuwarden, street appear to be in general closer to the lower end of the spectrum. Street 35 and 36 are located close to the railway station. However, Street 34 and 33 are positioned within the same radius. While these difference cannot be explained at the hand of the larger urban context, other influences are discussed in Chapter 6.

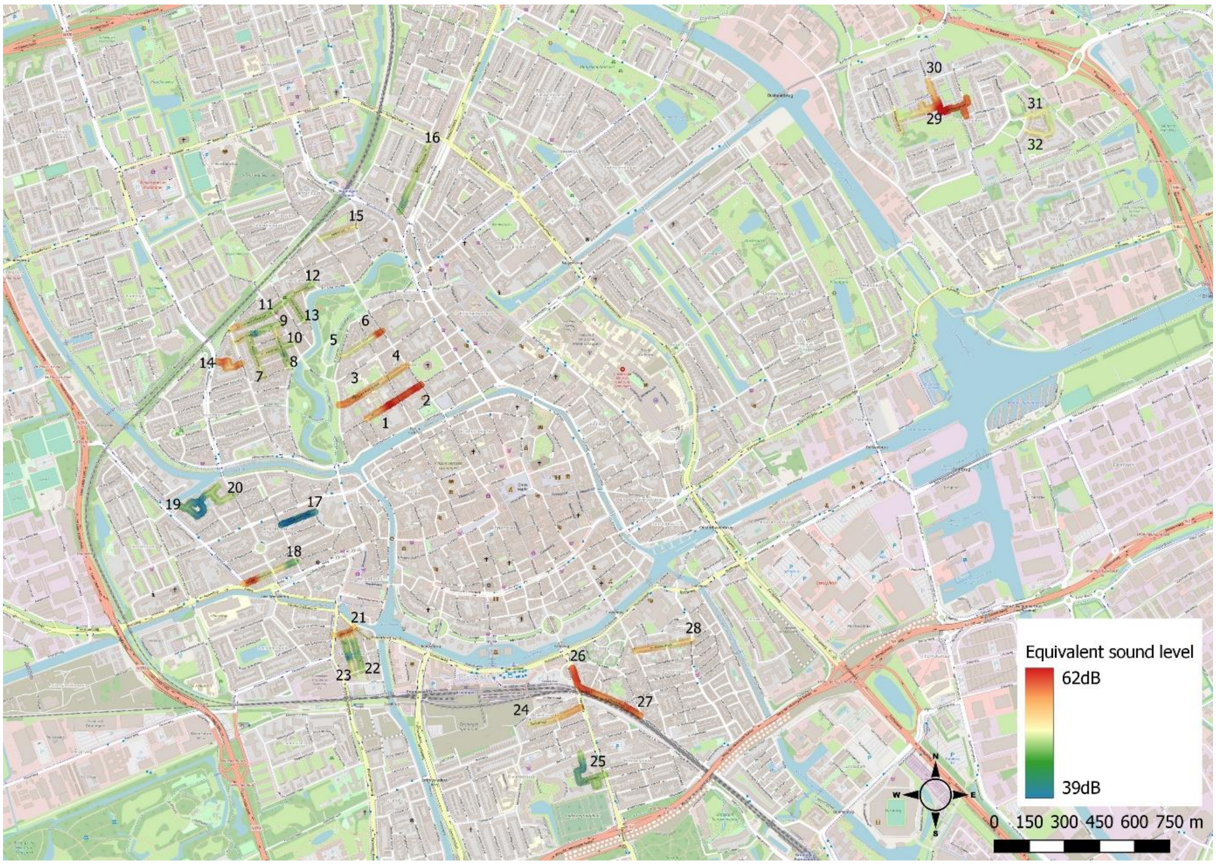

Figure 18. Sound map of 32 woonerf streets in the city of Groningen.

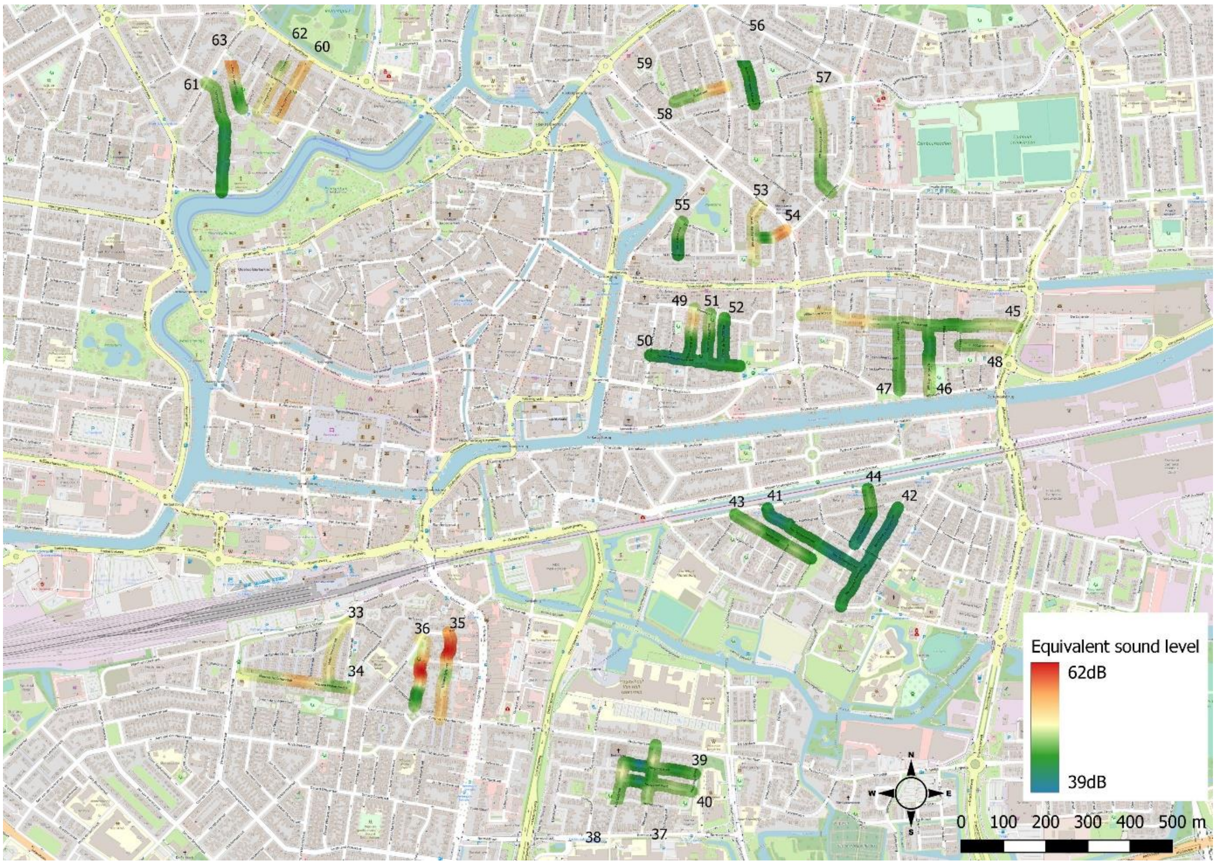

Figure 19. Sound map of 31 woonerf streets in the city of Leeuwarden.

The bar chart in Figure 20 shows the average Lday (converted using equation 1) on a neighborhood level. As previously mentioned, even though Oosterpoortbuurt and Binnenstad Noord score in absolute numbers still very low on eventfulness, relatively they are the highest of all neighborhoods. These neighborhoods also report the highest average Lday decibel levels compared to the rest. The majority of neighborhoods (11 out of 13) score below the 55 dB. This can be considered within the normal sound level range of a residential area. The average sound Lday shows no exceptional outliers and is according to the cluster found in Figure 17 considering the Eventfulness axis. Based on the data of the sound levels and the perceptual attributes, even lower overall sound levels (dB < 40) are required for a street to be perceived as uneventful.

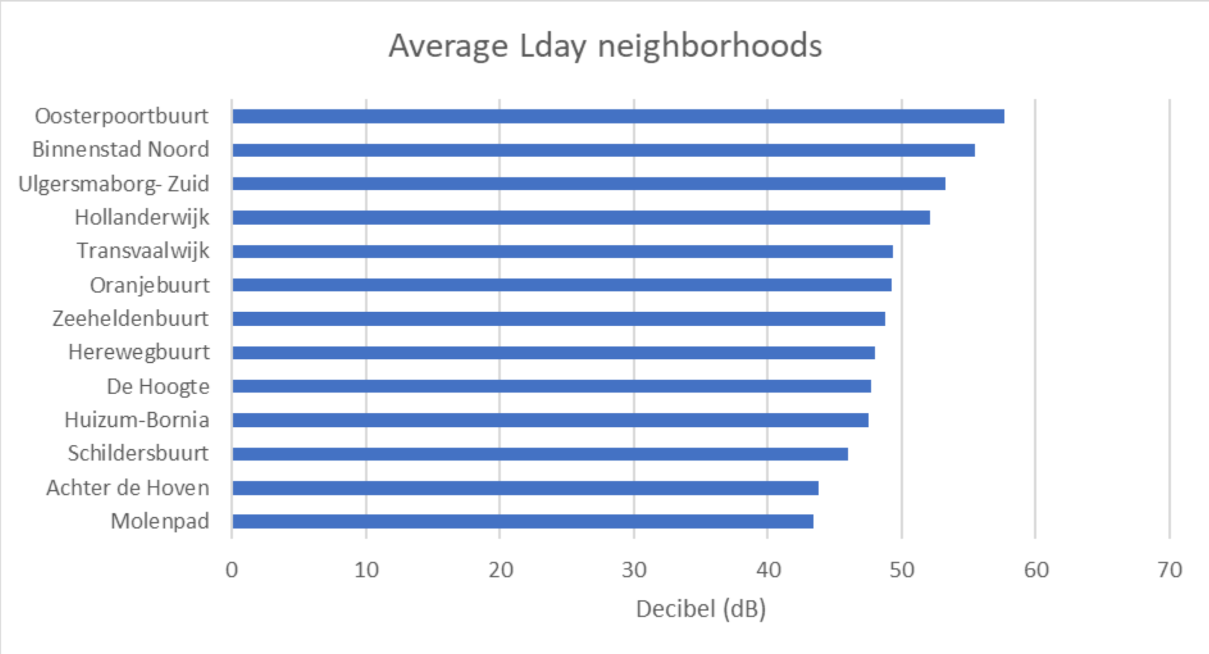

Figure 20 Bar chart of average Lday.

4.3 Variation of NCF levels between the woonerf areas

The pixel extraction approach discussed earlier is used to calculate the GVI percentage. GVI and Cultural percentage form the two constituent parts of the NCF percentage of woonerf streets in Groningen and Leeuwarden. Interpolated visual maps showing these results are presented in Figure 21 and 22. The numbers are according to the street numbers mentioned in Appendix B and represent the 63 street names of the woonerf streets selected in Groningen and Leeuwarden.

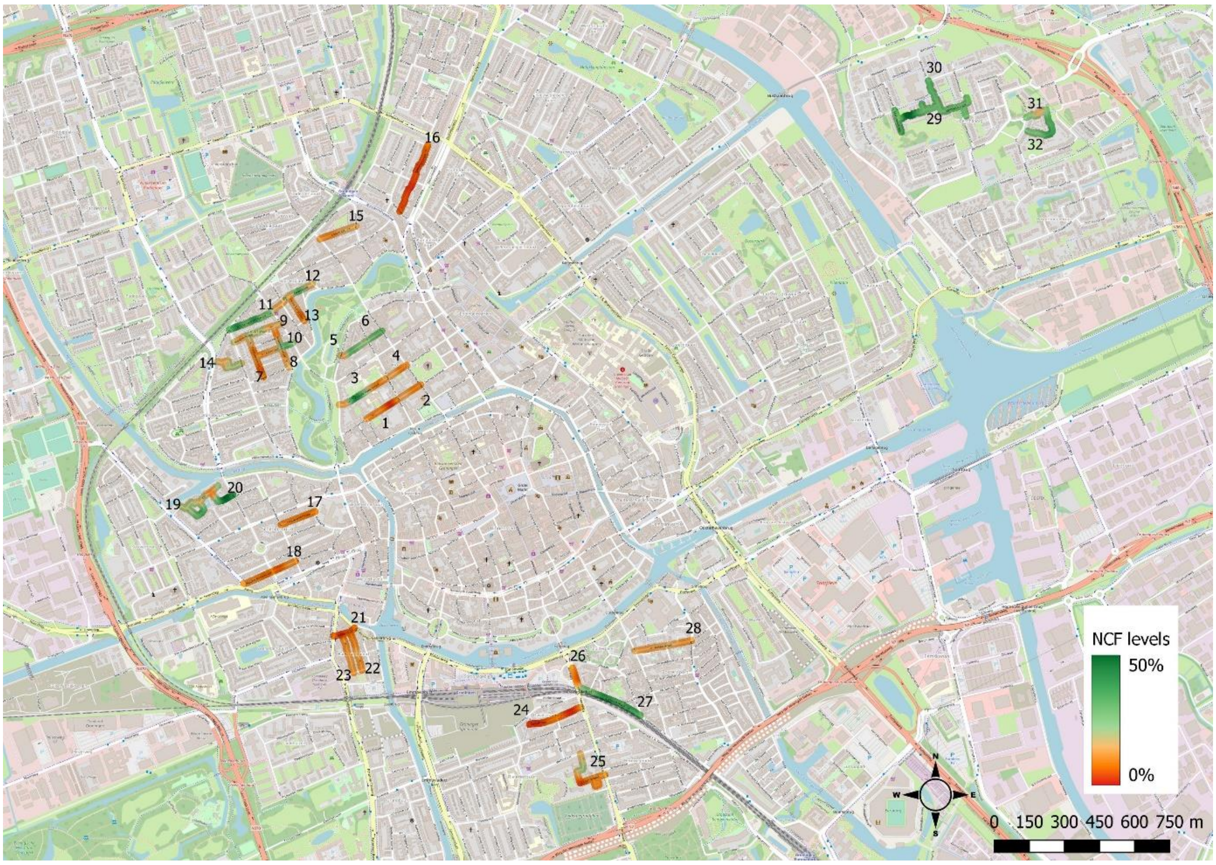

Figure 21. NCF percentage in Groningen.

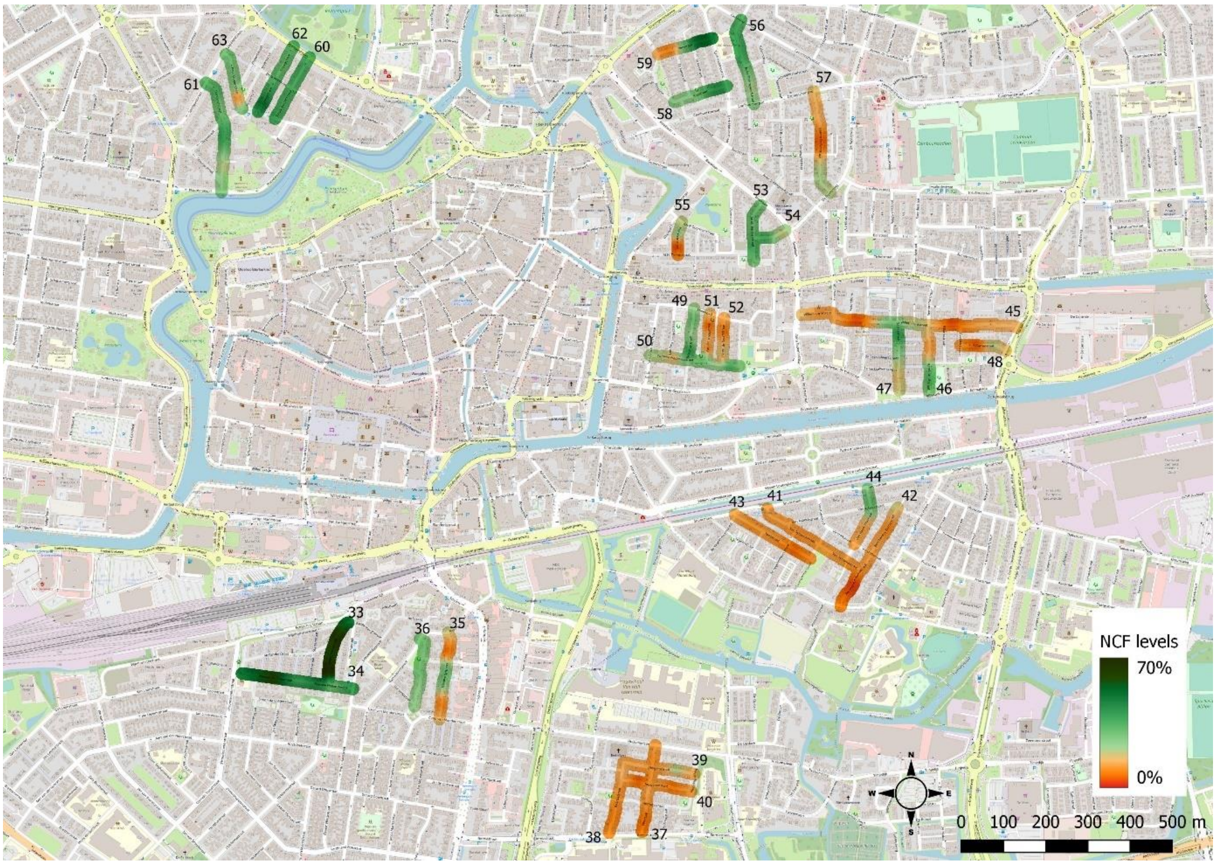

Figure 22. NCF percentage in Leeuwarden.

Figure 23 provides an illustration of how GVI levels differ between woonerf streets. Each square consists of four pictures taken in the 0°, 90°, 180°, 270° direction and represent the visual perception of residents on a street level at a random data measurement point. This figure compares the three highest and lowest scoring streets to illustrate how variations in GVI levels can affect the overall appearance of a woonerf street.

2% **3%** **3%**

41% **36%** **36%**

Figure 23. Visual representation of GVI levels on a pedestrian view. Upper row: 24. Davidstraat (left), 21. Eelderstraat (center), 16. Bedumerstraat (right). Bottom row: 62. Cronjéstraat (left), 27. Lodewijkstraat (center), 60. Schalk Burgerstraat (right)

For the NCF percentage, cultural buildings should be included as well. In Groningen, street 11 scores the highest NCF score (38%) and street 24 the lowest (2%). In Leeuwarden, street 33 scores the highest (67%) and street 40 has the lowest score (6%). Both of these highest scoring streets share a relatively high percentage of cultural percentage. This high percentage of cultural visuality is due to the fact of the location of the street within the larger urban area. Street 33 and street 34 are both located in a complete block of residential houses which are considered to be cultural heritage.

There are six streets (11, 20, 27, 29, 30, 32) in Groningen that score above 30% NCF. In Leeuwarden nine streets (33, 34, 49, 53, 58, 59, 60, 61, 62) score above this value. When comparing Groningen to Leeuwarden this equals to roughly 19% and 29% of the total streets being above 30% NCF respectively. When comparing the city of Groningen to Leeuwarden regarding the total average visual levels of greenery/cultural levels, a 4% difference can be observed (18%-22%).

To analyze how the NCF percentage on a neighborhood scale, woonerf streets are combined according to the list of neighborhoods mentioned in Table 4. Note that only neighborhoods with at least 20 respondents are included in this analysis. These results are displayed in Figure 24.

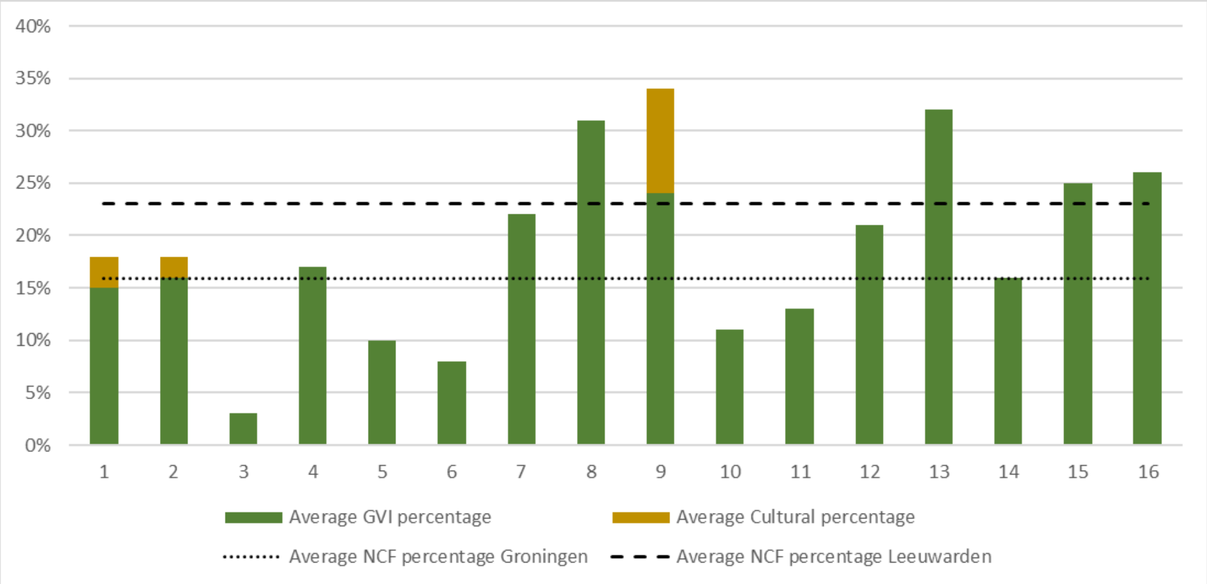

Figure 24. Average NCF percentage of neighborhoods in Groningen and Leeuwarden

It can be observed that neighborhood 3 (De Hoogte) is valued the lowest (3%), and neighborhood 9 (Hollanderwijk) scores the highest NCF percentage (34%). When aggregation of streets occurs, cultural visual levels are relatively less influential considering street 11, which previously ranked highest in Groningen, is now ranked average around 18% on a neighborhood level.

Distinguishing between *Natural/Cultural elements* and *Man-made elements* (without including cultural) when selecting the lowest scoring neighborhood 3 (De Hoogte) shows similar results. When asked what visual elements resident found to be attracting their attention the most in their streets, a clear difference can be observed between these categories when comparing the total average and De Hoogte (see Figure 25).

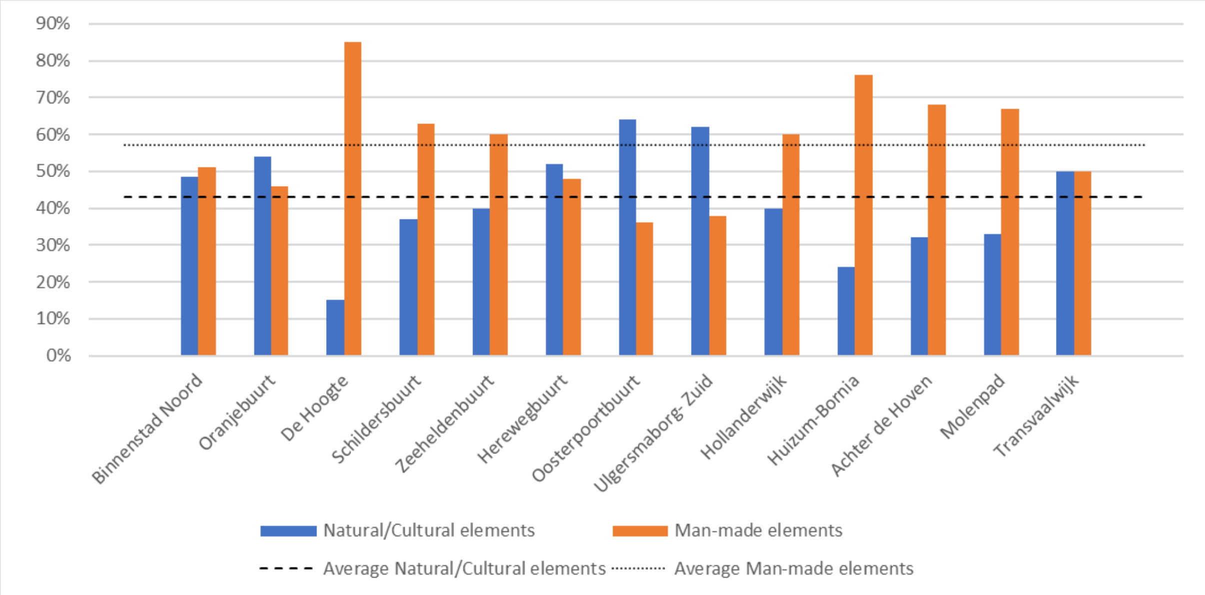

Figure 25. Visual dominance of Natural/cultural elements vs Man-made elements according to the residents of neighborhoods in Groningen and Leeuwarden with N ≥ 20.

A difference between the visual levels of greenery/cultural of woonerf streets can be observed. Woonerf streets NCF visual levels range from 2% at the lowest end to 67% at the highest. Apart from the present of greenery in a woonerf street, cultural buildings seem to have a determining role as well considering the NCF percentage of woonerf areas. When only regarding GVI levels, streets considered to be average at first are ranked at the top end when cultural buildings are also taken into consideration. When present, cultural buildings have a considerable impact on a street NCF levels.

4.4 Comparison of perceived and predicted tranquility rate at multiple spatial levels

Multiple paired sample t-tests were performed to compare the predicted tranquility rate with the tranquility as perceived by the residents living in the woonerf streets. A comparison is made of the average tranquility levels between woonerf streets, as well as within woonerf streets in neighborhoods with more than 20 respondents within Groningen and Leeuwarden. The following section is organized in descending order, starting with a comparison on the larger city wide scale towards the smaller scale, examining specific samples on a street level within specific neighborhoods.

4.4.1 Comparison of the average perceived predicted tranquility at the street level

A paired sample t-test is conducted to compare the average predicted tranquility with the average perceived tranquility levels within all woonerf areas combined for the cities of Groningen and Leeuwarden. These results are displayed in Appendix E. The results of the t-test indicate a statistically significant difference in means ($p < 0.001$). On average, perceived tranquility levels were 2.31 points higher than predicted tranquility levels (95% CI [1.97, 2,65]). The average predicted and perceived tranquility of 62 streets are used to form a linear regression model (see Figure 26). A non-significant, weak and positive correlation is found ($r = 0.224$, $p > 0.05$) on a street level between the perceived tranquility levels by the residents of woonerf streets and the predicted tranquility levels according to the TRAPT tool. A large variation is shown between the perceived and predicted values ($R^2 = 0.050$) between the woonerf streets of Groningen and Leeuwarden combined. The regression line starts at 5.23 points at x = 0 which results in the line not starting at (0,0) but rather at (0, 5.24) at the origin. This means that even when no tranquility is predicted, a 5.24 point tranquility level is still perceived.

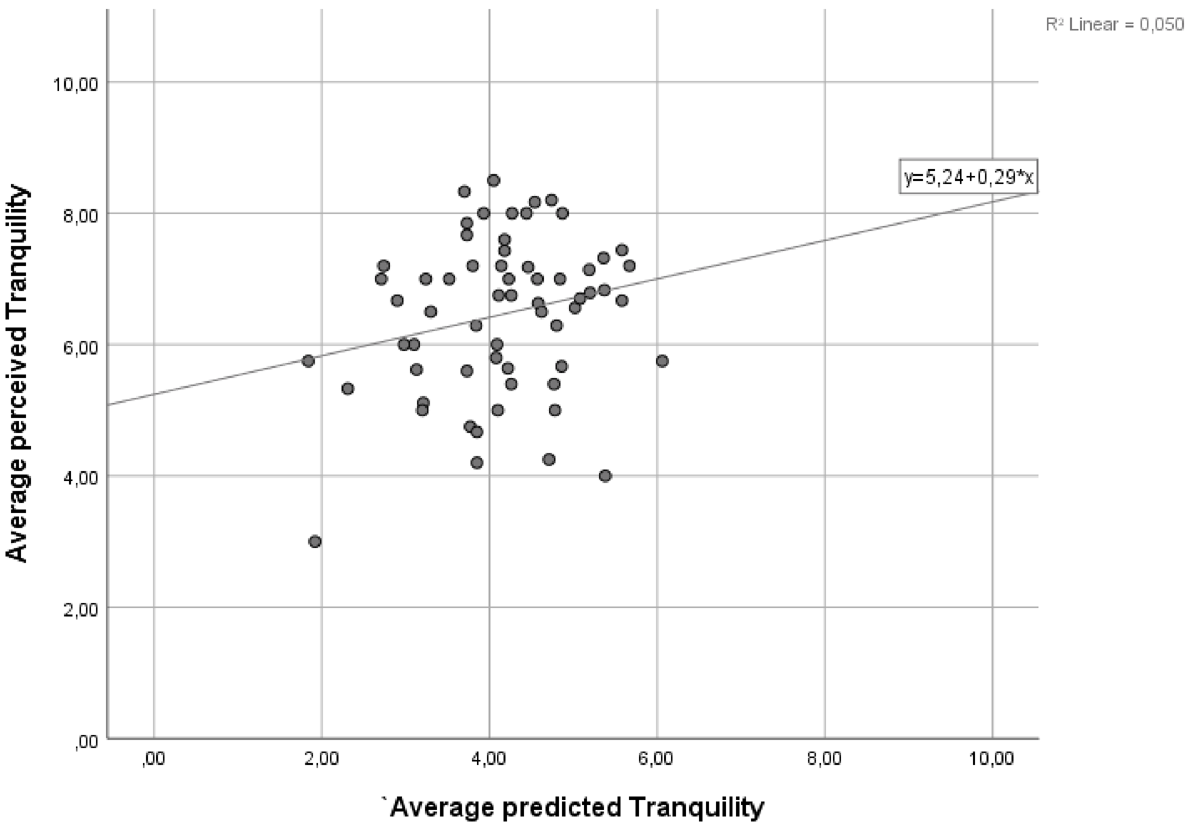

Figure 26. Average predicted and perceived tranquility rate of 62 woonerf streets in Groningen and Leeuwarden.

A second paired sample t-test was conducted, including only streets located in neighborhoods with at least 20 respondents (N = 52), as shown in Appendix E. Again, a significant difference in means ($p < 0.001$) can be observed. Perceived tranquility and predicted tranquility scores were slightly higher but still weakly and positively correlated ($r = 0.318$, $p < 0.05$). A scatterplot of the correlation between the two variables is shown in Figure 27. Here a 2.53 points higher average can be observed between the two variables (95% CI [2.19, 2.87].

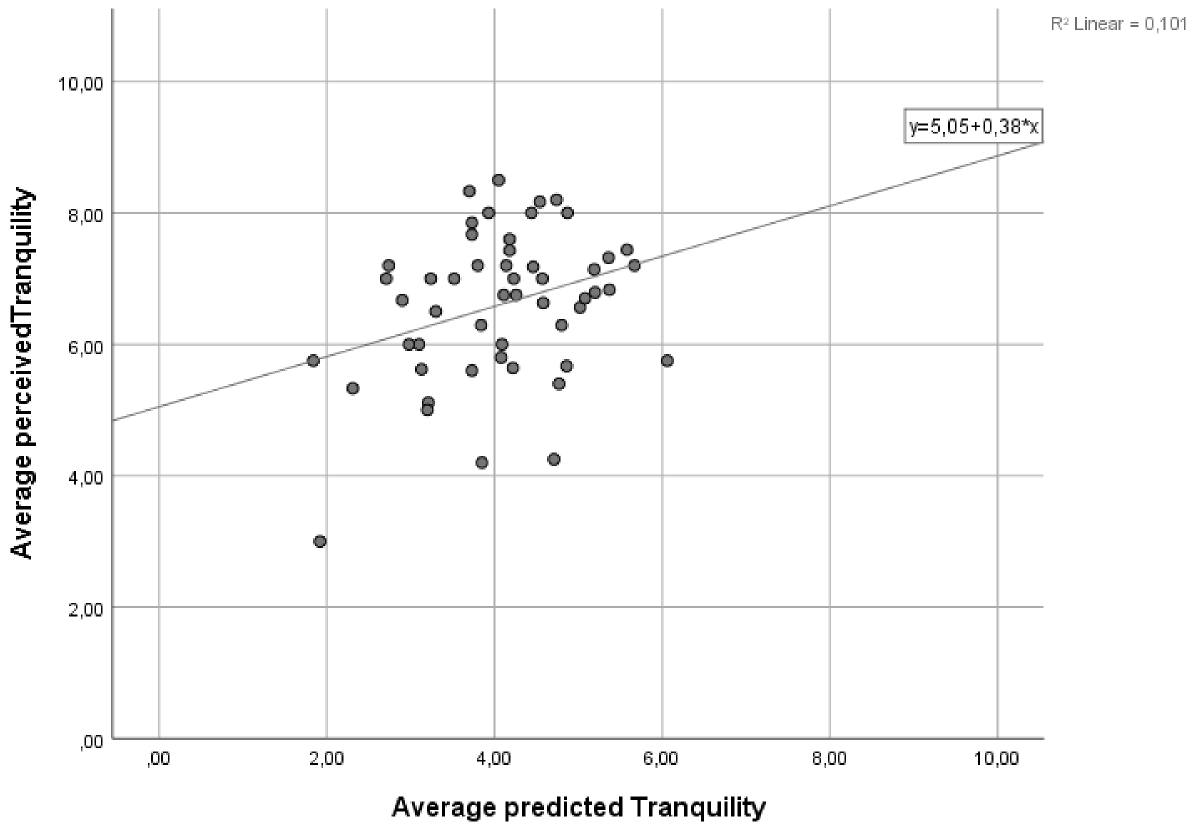

Figure 27. Average predicted and perceived tranquility rate of 52 woonerf streets in Groningen and Leeuwarden. Only streets located in neighborhoods with N ≥ 20 are included.

4.4.2 Comparison within specific woonerf streets

Normality tests and visual inspection were already performed in Section 4.1 of this chapter to check whether perceived tranquility was normally distributed for neighborhoods in Groningen and Leeuwarden. However, the predicted tranquility should still be tested for normality. The Shapiro-Wilk test shows that the predicted tranquility is not normally distributed for all neighborhoods, ($p < 0.05$). Consequently, to analyze the woonerf streets within their neighborhoods, eleven Wilcoxon Signed Rank Test are performed for neighborhoods with $N < 30$ (see Appendix E, p. 76-82). These tests determine whether the median difference between the average perceived tranquility and the predicted tranquility on a woonerf street level is equal to zero. Additionally, paired sample t-test are performed for the two neighborhoods (Oranjebuurt and Schildersbuurt) with $N \geq 30$ (see Appendix E, p. 76-77).

All 11 neighborhoods for which the Wilcoxon Signed Rank Test was performed showed a significant p-value of < 0.01 or < 0.001. Therefore, the null hypothesis is rejected, meaning that differences between the perceived tranquility and the average predicted tranquility can be observed at the woonerf street level for all 11 neighborhoods with $20 \leq N < 30$. Neighborhood 12 shows the highest ratio positive : negative differences (6 : 15) when comparing the predicted tranquility on a woonerf street level and the perceived tranquility by its residents. All neighborhoods report a more than 3 times negative differences ratio between the two variables compared to positives. This provides an indication of the structural undervaluation of the predicted tranquility compared to the perceived tranquility on a street level.

Regarding the woonerf streets in the Oranjebuurt neighborhood, the paired sample t-tests result in a significant difference between the two variables (t_{87} = 13,633, $p < 0.001$). On average, perceived tranquility scores were 2.89 higher than predicted tranquility scores (95% CI [2.47, 3.31]). Also, a non-significant very weak negative correlation is observed ($r = -0.056$, $p > 0.05$). Likewise, the same test for woonerf streets in the Schildersbuurt shows a significant difference (t_{52} = 8,989, $p < 0.001$). However, the differences between the perceived and predicted tranquility scores are with M = 1.94 and (95% CI [1.50, 2.37]) relatively lower compared to the Oranjebuurt. Furthermore, there is also a non-significant weak positive level of correlation found ($r = 0.139$, $p > 0.05$) between the two variables.

Statistical tests between woonerf streets, as well as comparisons within specific neighborhoods at a smaller scale, show significant differences between the average perceived tranquility levels and the average predicted tranquility levels. Between the 52 woonerf streets the strongest, albeit still weakly, positive correlation is found. All other tests result either in weaker positives and/or non-significant correlation.

4.5 Correlation between average greenspace maintenance and GVI levels

A Levene's test shows equal variances between groups ($p > 0.05$). Because group sizes are $N \geq 30$ but unequal in size, a Welch ANOVA is performed to compare the active participation in the maintenance of greenspace between the woonerf streets located in the neighborhood located in Groningen and Leeuwarden with $N \geq 20$. The test shows a significant difference ($p > 0.01$). A Tukey HSD post-hoc test indicates that there are significant differences between neighborhood 3 (De Hoogte) and neighborhoods 4, 8, 9, 13 (Schilderbuurt, Ulgersmaborg – Zuid, Hollanderwijk, Transvaalwijk).

Two Pearson correlation test are performed to examine on the street level how the correlation is between woonerf GVI levels and the level of active participation of streetscape greenery maintenance. A significant moderate positive correlation can be found ($r = 0{,}516$, $p < 0.001$) when comparing 62 woonerf streets in Groningen and Leeuwarden. A slightly lower correlation is found when only the woonerf streets located in neighborhoods with N ≥ are included ($r = 0{,}508$, $p < 0.001$). Linear relationship between the variables are displayed in Figure 28 and Figure 29. Average greenery maintenance is shown from 0 to 10 and the average GVI is displayed in percentages derived by the same approach used in sub question 4.3. This graph shows that even with no greenery maintenance, an average GVI of 3% can be present in a woonerf street. It can be observed that when the average greenery maintenance increases, the average GVI also becomes higher.

When comparing the total amount of respondents on a macro level, it can be observed that Groningen scores lower (mean = 4.18) compared to Leeuwarden (mean = 5.04). As already noted in section 4.3, Groningen average GVI scores (16%) are also lower compared to Leeuwarden (21%). These city GVI averages correspond to the linear line drawn in Figure 28 and 29.

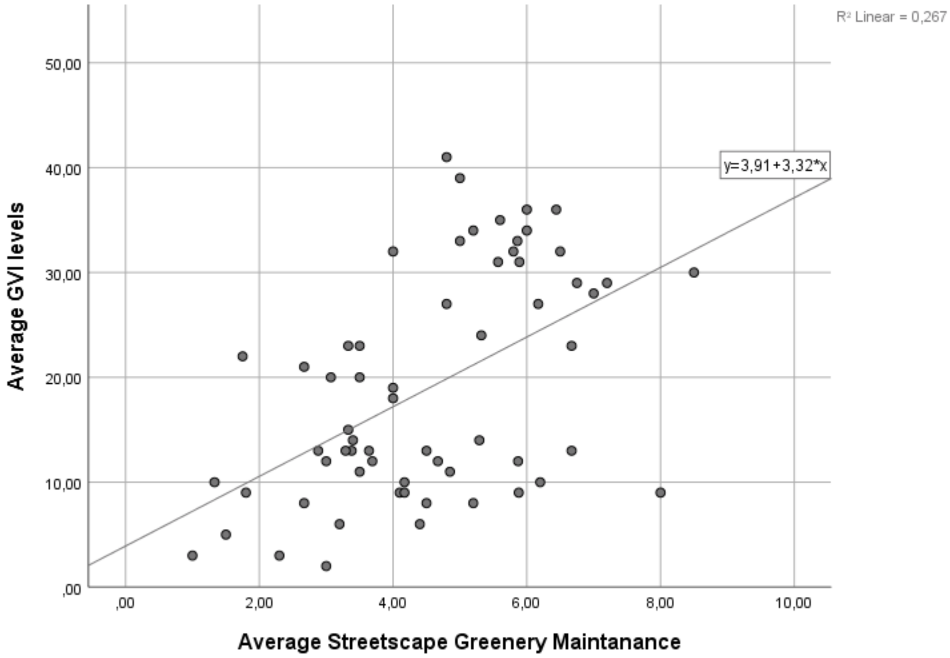

Figure 28. Correlation between average Greenery maintenance and GVI levels of 62 woonerf streets in Groningen and Leeuwarden.

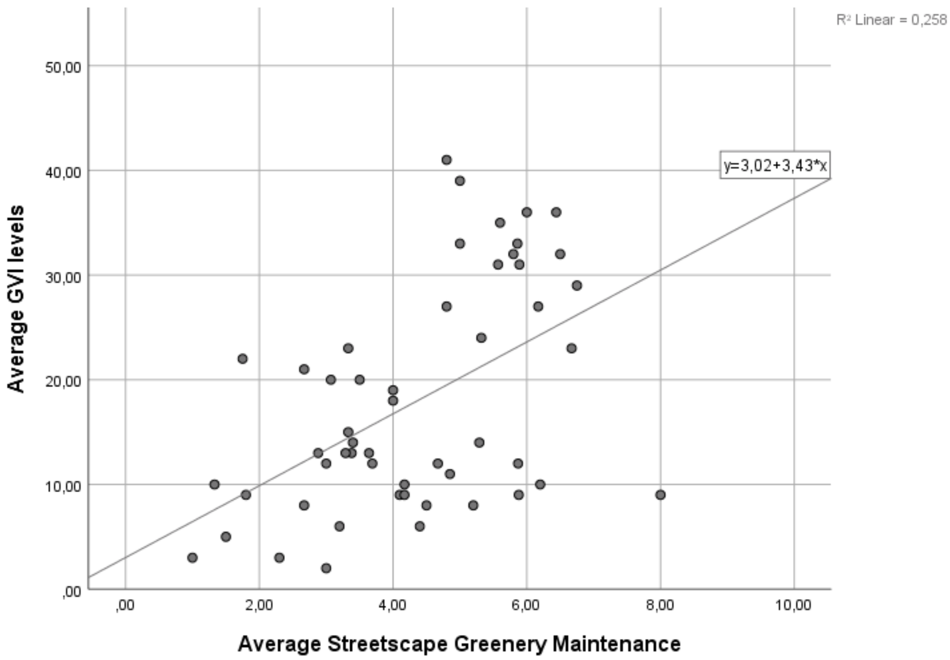

Figure 29. Correlation between average Greenery maintenance and GVI levels of 52 woonerf streets in Groningen and Leeuwarden. Only streets located in neighborhoods with N ≥ 20 are included.

Chapter 5 Conclusion

The main aim of this study was to examine to what extend the tranquility rate of woonerf areas can be predicted by its visual and auditory levels. In this chapter, an answer to the sub-questions and main research question stated in chapter one is formulated. These conclusions are derived from analysis of collected data within the context of woonerf streets. This chapter will start by answering the sub-questions in the same order of questions as stated in chapter one. After these five sub-questions have been answered, a final conclusive answer will be given for the main research question.

5.1 Sub-questions

1. What are the perceived tranquility levels between the woonerf areas?

- There are differences in perceived tranquility levels between 52 woonerf streets located in 13 neighborhoods of Groningen and Leeuwarden as shown in Figure 13. Results (see Appendix E) show a significant difference of perceived tranquility ($p < 0.05$) between neighborhood 13 (Transvaalwijk) and neighborhoods 1, 3, 10, 11 (Binnenstad Noord, De Hoogte, Huizem-Bornia, Achter de Hoven).
- Across educational background categories (Figure 14), a non-significant differences of perceived tranquility is observed among the 52 woonerf streets located in 13 neighborhoods of Groningen and Leeuwarden with $N \geq 20$ ($p > 0.05$).
- Between age groups (Figure 15), a significant difference in perceived tranquility levels is observed between the age group 55 – 65 and the younger age groups (< 25 years, 25 – 35 years, and 36 – 45 years) ($p < 0.001$).

2. To what extent are the noise levels affected by the perceptual attributes of the woonerf areas?

- Motorized traffic sounds and People sounds are the most dominant sound sources perceived by residents in woonerf streets (Figure 16).
- The perception of street noise according to the eight perceptual attributes shows a cluster of neighborhoods slightly above neutral regarding Pleasantness and slightly more towards uneventfulness (Figure 17).
- Data measurements of equivalent sound (Leq) and average noise levels (Lday) in woonerf neighborhoods are within the range of 39-61 dB (Figure 18Figure 19,Figure 20).
- Comparison of neighborhood sound levels (Figure 20) and the bidimensional circumplex model (Figure 17) indicate that lower noise levels does not automatically result in a higher level of pleasantness. Contrary results are shown by higher sound levels, which seems to cause a soundscape to be perceived as more eventful.

3. *How do the visual levels of greenery/cultural vary between the woonerf areas?*
    - Visual measurements and pixel analyzes show that visual NCF levels vary between woonerf streets (Figure 21Figure 22). However, statistical test results (see Appendix E) indicate non-significant differences between Groningen and Leeuwarden on a city level ($p > 0.05$), as well as no significant difference on a neighborhood level ($p > 0.05$).
    - In less than 10% of the streets cultural buildings were found. However, if such buildings are indeed present, a relatively high increase in NCF levels may occur (Figure 24).

4. *How does the level of perceived tranquility differ from the predicted tranquility rate within woonerf areas?*
    - Comparison of average predicted and perceived tranquility levels between 62 woonerf streets in Groningen and Leeuwarden (Figure 26) shows a significant difference in means ($p < 0.001$).
    - When only including woonerf streets located in neighborhoods with $N \geq 20$ within Groningen and Leeuwarden (Figure 27), a significant difference between average predicted and perceived tranquility levels between 52 woonerf streets is again observed ($p < 0.001$).
    - The highest correlation ($r = 0.318$, $p < 0.05$) is found between the average predicted and perceived tranquility levels when comparing 52 woonerf streets in Figure 27. It can be concluded that average predicted and perceived tranquility levels are weakly and positively correlated.
    - Significant differences ($p < 0.01$ or $p < 0.001$) between the perceived tranquility and the average predicted tranquility can be observed on a woonerf street level for all 11 neighborhoods with $20 \leq N < 30$ (see Appendix E, p. 67-82).
    - Between woonerf streets, average predicted tranquility scores are found to be (95% CI [1.97, 2,65]) points lower compared to the average levels of perceived tranquility and (95% CI [1.50, 2.37]) lower when comparing woonerf streets smaller level within specific neighborhoods (see Appendix E).

5. *To what extent may active participation in the maintenance of a woonerf greenspaces influence the GVI levels?*
    - Active participation in the maintenance of greenery within a woonerf street has a moderate positive relationship with the GVI levels (Figure 28 Figure 29).
    - When residents report a higher active participation in maintenance of greenspace, a higher GVI may be expected. However, this is not true for all cases.

5.2 Main research question

To what extent can the tranquility rate of woonerf areas be predicted by its auditory and visual levels?

- Auditory or visual levels alone cannot be used separately to predict tranquility of woonerf areas.
- Tranquility may be predicted to some extend by the noise and green/cultural visual levels.
- However, significant differences are observed between the average predicted and perceived tranquility levels ($p < 0.001$) (see Appendix E).
- The predictive TRAPT tool shows a structural undervaluation of predicted tranquility compared to actual tranquility levels by approximately 5 points in the context of woonerf streets (Figure 26Figure 27).

Chapter 6 Discussion

In this chapter, analyzed data of Chapter four will be linked to already existing literature discussed in Chapter two. Furthermore, the limitations of this study will be discussed, followed by a reflection of the research process. Finally, recommendations will be offered for planning practices and additional suggestions will be given for potential follow-up studies.

6.1 Connection of findings with theory

The results initially seemed to show that tranquility levels are on average perceived different between woonerf areas. Perceived tranquility ranged between 5.6 and 7.8 on a neighborhood level with city averages of 6.68 and 6.78. Guidelines can be used to categorize tranquility levels (< 5 unacceptable, 5.0 - 5.9 just acceptable, 6.0 - 6.9 fairly good, 7.0 - 7.9 good, ≥ 8:0 excellent) in an attempt to asses scenes (Watts et al., 2011). When applying this for the woonerf areas that have been studied, this means that no neighborhood is perceived as unacceptable (< 5), but also not a single neighborhood is perceived as excellent. According to this categorization, the woonerf streets score an average of 6.7, which can be considered fairly good.

When categorization according to age and educational background occurred, tranquility levels were still rated differently across age groups, but equal when ordered based on demographic categories, considering educational background. A change of tranquility assessment when grouped into different demographic categories is in accordance with expectations of Yang and Kang (2005), as they state that personal characteristics may be of influence on the assessment of a person's soundscape.

The data also shows that the presence, or rather absence, of greenery has a negative influence on the perceived levels of tranquility. According to Hunter et al. (2010), there is a higher probability of experiencing tranquility when natural elements are present. Scenes dominated by human development are considered to be non-tranquil (Hewlett et al., 2017). However, not all tranquility differences can be explained by greenery levels alone, as not all areas with lower greenery levels automatically show a lower perceived level of tranquility. Noise levels could be a determining factor, as well as other moderating factors which are not taken into consideration in this study.

In residential areas, (LAeq) of 50-55 decibels on average (dBA) may result in severe annoyance (WHO, 2011). In this study, it is found that at least for residential woonerf streets in Groningen and Leeuwarden, no severe annoyance is perceived by residents on average. However, as the circumplex model of soundscape is average based, it does not necessarily mean that severe annoyance never occurs. Less noise does not automatically implies higher pleasantness levels (Yang and Kang 2005a, 2005b; Van Kempen et al. 2014). This is also observer when average Lday sound levels are laid next to the bidimensional cirumplex model of the eight perceptual attributes. While Yang and Kang (2005a) have for example found that the sound quality is not automatically improved when sound levels are reduced, the woonerf neighborhoods in this study are clustered and sound levels no Lday outliers are observed. It is therefore not possible to make decisive statements on this subject. While no outliers are found on a neighborhood level, this does not mean that sound levels on a street level are not sensitive for outliers as well. In this study, average Leq sound levels are based on one-minute measurements. Occasional high level sound sources may greatly influence the sound level measurements. This will be further discussed in the limitations.

According to Ouis (1999), road traffic noise is considered to be the main source of noise. However, this research has shown that also other sources can be perceived as most dominant (e.g. People sounds) in the woonerf environment. Perceived tranquility and pleasantness are positively associated with natural sounds while motorized sounds are regarded as a negative influence and associated with annoyance (Tamura, 2002; Alvarsson et al., 2010; Watts, 2017). Peoples sounds and children playing are in general perceived as pleasant or neutral (Dubois et al., 2006; Nilsson and Berglund, 2006). Given these statements, it is interesting to note that while in the context of woonerf streets, motorized sounds are perceived as one of the most dominant sound sources in general, but a neutral feeling between pleasantness and annoyance is reported by the resident. This restates that urban soundscape should be considered complex sound environments due to multiple different sound sources and contrasting interpretation and personal preferences as stated by (Aletta and Kang, 2018).

While active participation in maintenance of streetscape greenery is positively associated with increased GVI levels, some neighborhoods score low on maintenance but still relatively high on GVI levels. This may be due to the fact that not all greenery in the street is privately owned. This may occur when large public green areas are maintained by the municipality. Also, maintenance of greenery does not always result in higher GVI levels. Maintenance can also be performed for upkeep of existing greenery or even to replace existing greenery. For example, when a tree is removed by the municipality under the guise of maintenance and no greenery is provided as a replacement, it can even cause a negative effect on the overall streetscape greenery levels. As reported in research by Chalmin-Pui et al. (2019), the main reasons for people to prefer pavement over greenery were creation of off-road parking and to minimize the maintenance of their garden. It is expected that the first reason does not apply within the context of this study, as adequate parking space is one of the initial criteria for woonerf areas (Kraay, 1986).

Investigative studies into the desires of residents regarding the woonerf design, or research into participative behavior or residents in greenery maintenance may benefit policy makers and urban designers in their decision making process. However, in-depth explanatory reasoning goes beyond the main aim of this study, as the focus was on differences in tranquility and NCF levels between woonerf areas and is therefore not included. Nevertheless, qualitative data analysis is conducted and provided in Appendix F. Three conclusive lessons can be drawn from this. First of all, residents in the woonerf context report less parking and increase of greenery as the two main aspects they would like to change. Secondly, data shows that less parking space and more greenery might be more in line with the current wishes of woonerf residents nowadays. The characteristic design and elements of a woonerf also contributes to the spatial dilemma between parking facilities and streetscape greenery.

The TRAPT tool developed by Pheasant et al., (2008) may be an appropriate tool to provide an indication for relative tranquility levels in other context instead of predicting actual tranquility levels of woonerf streets. One could argue that, when certain sound sources (e.g natural sounds) are excluded, sound levels will be lower, as well as predicted tranquility levels. However, in this research, no sound sources were excluded in the sound collection process. Therefore, it can be argued that the highest possible sound levels are used when calculations were made regarding the predicted tranquility levels, combining all potential sound sources in the woonerf context. However, even with the calibration for urban green spaces, which means an increase in the constant, the tool prediction was still low compared to the actual feeling of tranquility as perceived by woonerf residents.

The main reasons for the undervaluation of tranquility levels may be due to the time of year this study was conducted. During the study period, a decrease in greenery is observed due to the naturally occurring seasonal change from summer to fall. Given the fact that greenery is one of the two main factors for predicting tranquility levels, an overall change in greenery due to the yearly seasons will also result in the predicted tranquility value to change. However, after modification of the TRAPT tool by multiplying the GVI levels and sound levels through different constants, there was still no significant increase in correlation between the average predicted and perceived tranquility levels to be found. This gives an indication that even when GVI levels were higher and sound levels were lower, correlation is still found to be weak between the predicted and actual tranquility levels in the context of woonerf streets.

Another aspect worth considering, is the fact that residents are inside their homes when filling in the questions related to sound perception. These responses will form the basis of the two-dimensional measurement system for the affective soundscape quality by Axelsson et al., (2010). However, Method A of ISO/TS 12913-2:2018 entails questionnaires to be filled in-situ. It is debatable if filling in the questionnaire indoors instead of outdoors affected the participants' perception of the sound in their street. Because multiple studies (e.g. Raimbault and Dubois 2005; Yang and Kang 2005; Van Kempen et al. 2014) highlight the importance of including the subjective nature of sound, the TRAPT prediction method relies for a significant part on quantitative equivalent sound levels to answer this subjectivity. The TRAPT tool might be insufficient to explain complex urban soundscapes, or at least for woonerf streets within the urban context, but would benefit from additional information provided by the two-dimensional measurement system for the affective soundscape quality by Axelsson et al., (2010). A combination of the TRAPT approach including visual measurements with soundscape might provide a holistic method, to connect the sound environment with urban design.

6.2 Limitations

During this study, multiple factors need to be considered that may have influenced the results. First of all, while 63 woonerf streets form the basis of this study, only two cities were compared. While the woonerf concept is the same throughout the Netherlands, differences between countries may result in different outcomes. Because this study only includes a limited amount of cases within specific cities, results may not be generalized for all woonerf streets.

The second aspect which should be considered is that woonerf streets are embedded in the larger urban environment of the city. While the interpolation techniques used in this study add value in terms of visually sound representation, they do not take into account influences of the surrounding physical urban environment. Also, no sample data between the different neighborhoods can lead to average scoring woonerf streets to be overlooked or disappears entirely. Clipping the raster to mask layer option can be considered a highly simplified representation of the actual urban sound environment. In this study, additional noise mapping software might provide a solution to this issue.

While the noise measurements were performed when the weather conditions were most favorable, differences can still occur due to the wind. Secondly, one-minute measurements are taken and converted into Lday. This is a general approach for sound conversion of non-motorized streets. However, the urban sound environment is complex and may include noise levels which may be missed when a conversion of sound is used. While this generalization may result in errors, daily sound measurements for this many locations would not also be an practicable option.

Recordings were taken at a similar time across different woonerf streets, between 8:00 a.m. and 11:00 a.m. to ensure comparability. However, this does not imply a perfect representation of the individual woonerf streets. Besides potential error caused by measurement duration, measurements were only performed once per location point. While this still equates to more than two data points per street, repeatability of measurements within the same location could have been performed on different times of the day and within different days of the week. Averages of multiple data point would have made the data more reliable and may prevent potential errors.

Furthermore, the visual measurements conducted on multiple different points in the woonerf streets may not encompass the complete location under study. Because these locations are point based instead of continuous, the location of measurement can be of influence on the GVI level. For example, a hedge close to a measurement point, may result in a higher GVI the data is collected a few meters further instead. Instead of point based data, continuous data collection may be a solution in preventing these errors in GVI levels. However, gathered visual data still does not represent how people experience the environments on a street level in a day to day life.

Regarding the questionnaire data collection process, a higher response rate would have been beneficial for the data analysis later on in the process. A deliberate decision could have been made for additional performance of a survey collection from door-to-door in person. However, this would have been a highly time consuming effort and success would still not be guaranteed. Instead the decision was made to exclude some woonerf streets with little respondents and to analyze the results on different urban scales. As a result of this aggregation of street level into neighborhoods, data became less specific which may have caused valuable differences on a woonerf street level to be missed in the averaging process.

6.3 Reflection of the research process

Reflecting back on the duration of the research process, the following planning aspects are worth mentioning. First of all, the preparation of this research is performed before the academic summer break. This discontinuation in research process was unfortunate, but could not have been prevented and was therefore anticipated upon. However, when starting before the summer, another planning issue arises due to other academic obligations during the first half of this research. A lack of time at the initial beginning phase was noticeable in the second half of the research process. The sound measurements were taken outdoors, only under favorable weather conditions. It was also necessary for the data to be collected in approximately the period of time within the year. This was required to achieve the required level of consistency between measurements and to prevent possible error. However, this also made the data collection period dependent on external factors. A flexible planning attitude during this time period was therefore required.

6.4 Recommendations

6.4.1 Recommendations for urban planners and policymakers

When asked residents of woonerf streets what they wanted to change in their street, a few aspects stood out. First of all residents indicate they would like to see more greenery in their streets. However, streets are in general full of parking spots for cars limiting the space for greenery. Therefore, parking space seems to be perceived as a negative element present in the streets. These two woonerf elements seem to contradict one another. This should be considered in the early design of new woonerf streets.

Hedges could for example be placed in these spots, drastically improving the GVI levels with little maintenance and effort. Also, when no space available for additional greenery, vertical greenery could still be an option as well. Some streets were located adjacent to each other but showed a significant difference in GVI levels. This was for example the case between the Hereweg and the Lodewijkstraat. Vertical greenery could provide the solution here. A relatively simple measure can improve the street appearance drastically without the compromise of available space. However, current policy implications hinder residents who would like to make the adjustments to improve greenery levels in their streets (e.g. vertical greenery). This shows that greenery in the urban context it is not only a design issue, but rather a combination of urban planning and policy making. Therefore, both will benefit from looking for common ground of interests to provide adequate solutions in the woonerf context.

6.4.2 Recommendations for future research

Future studies may be conducted in woonerf streets within more cities in the Netherlands to form more generalizable results. The Woonerf concepts is not only implemented in urban environment of cities in the Netherlands but also other countries (e.g. Israel, United Kingdom) have used similar concepts. Therefore, research can be conducted on how woonerf streets differ between countries and how this may affect sound levels in combination with the perception of these sounds. In this study, only two categorizations were made regarding personal characteristics. More studies could provide a further extension of these categories and investigate how this relates to a person's attitude towards different sound sources. Additionally, instead of only focusing on woonerf streets, a comparison can be made between other streets as well. This wider orientation towards other types of streets will provide further validation of the TRAPT tool as a useful method in predicting the tranquility compared to the perceived tranquility. Furthermore, studies could be conducted in the soundscape field and combine this with the visual aspect of the TRAPT tool. This may provide further insights into an comprehensive assessment of the experienced environment through sound and visual sensory inputs. Consequently, other urban areas can be includes as well to reveal more information on the correlation between active maintenance of greenery and the GVI levels of such areas. Also, a laboratory setting based on virtual reality devices may offer a more realistic visual representation of how streets are perceived by pedestrians. Furthermore, a longitudinal study may be performed to investigate how streetscape greenery, as perceived by pedestrians, changes over time between different seasons. Such a study could also provide valuable information on the question if perceived tranquility levels change throughout the year.

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Appendices

Appendix A

```
/*

This has been generated by the overpass-turbo wizard.

The original search was:

“highway=living_street and maxspeed=15”

*/

[out:json][timeout:25];

// gather results

(

  // query part for: “highway=living_street and maxspeed=15”

  node["highway"="living_street"]["maxspeed"="15"]({{bbox}});

  way["highway"="living_street"]["maxspeed"="15"]({{bbox}});

  relation["highway"="living_street"]["maxspeed"="15"]({{bbox}});

);

// print results

out body;

>;

out skel qt;
```

Appendix B

	Groningen streets			Leeuwarden streets	
	Street name	**Length in meters**		**Street name**	**Length in meters**
1	Grote Leliestraat	291,64	33	Halbertsmastraat	102.55
2	Kleine Leliestraat	107,97	34	Nieuwe Hollanderdijk	258.24
3	Grote Rozenstraat	235,93	35	Nieuwe Schrans	202.52
4	Kleine Rozenstraat	98,45	36	Matthias van Pellicomstraat	169.91
5	Grote Appelstraat	133	37	Sportlaan	206.23
6	Kleine Appelstraat	**61,25**	38	Wiardastraat	169.79
7	Plantsoenstraat	179,16	39	Buygersstraat	162.89
8	Selwerderstraat	177,2	40	Jouwsmastraat	163.77
9	Kloosterstraat	202,04	41	Van Sytzamastraat	267.04
10	Kolfstraat	161,81	42	Bernhardus Bumastraat	264.04
11	Louise Henriëttestraat	186,8	43	Ypeijstraat	205.87
12	Zwarteweg	168,96	44	Van Heemstrastraat	139.89
13	Kleine bergstraat	115,75	45	Willem Loréstraat	**494,01**
14	Albertine Agnesstraat	166,39	46	Rembrandtstraat	263.56
15	Koolstraat	157,16	47	Saskiastraat	162.23
16	Bedumerstraat	306,09	48	Accamastraat	103.76
17	Leeuwarderstraat	162,04	49	Bisschopstraat	189.24
18	Nieuwe Blekerstraat	235,39	50	Cornelis Frederiksstraat	202.96
19	Rubensstraat	272,53	51	Van der Kooijstraat	109.43
20	Mondriaanstraat	178	52	Pieter de Swartstraat	100.96
21	Eelderstraat	86,65	53	Jacob Binckesstraat	388,88
22	Oosterbadstraat	165,5	54	Maerten Gerritszstraat	83.23
23	Wester Badstraat	167,69	55	Piet Heinstraat	**72.89**
24	Davidstraat	264,69	56	Auke Stellingwerfstraat	201.98
25	Fongersplaats	377,36	57	Barent Fockesstraat	243.04
26	Parklaan	147,94	58	Koestraat	130.11
27	Lodewijkstraat	260,4	59	Veestraat	152.53
28	Polderstraat	240,78	60	Schalk Burgerstraat	155.39
29	Marjoleinstraat	**542,95**	61	Transvaalstraat	475.32
30	Melisseweg	62,56	62	Cronjéstraat	164.03
31	Bieslookstraat	92,57	63	Paul Krugerstraat	136.67
32	Wolfsklauwstraat	218,93			
	Average length streets	**194.55**			**189.64**

Appendix C

Beste bewoner(s),

Mijn naam is Theun Leereveld en voor mijn Master ‘Environmental Infrastructure Planning’ aan de Rijksuniversiteit Groningen - Faculteit Ruimtelijke Wetenschappen doe ik onderzoek naar woonerf straten. Ik ben hierin specifiek benieuwd naar omgevingsgeluid en hoe de straat wordt beleefd door de bewoners zelf.

Dit onderzoek doe ik onder andere aan de hand van een vragenlijst. Hierin zou u mij enorm kunnen helpen. Het invullen van de vragenlijst duurt ongeveer 5 minuten en is volledig anoniem.

Alvast bedankt!

QR-code Voor de Nederlandse vragenlijst:

URL: https://mpt.link/rugwoonerf_nl

Dear resident(s),

My name is Theun Leereveld and for my Master's degree 'Environmental Infrastructure Planning' at the University Groningen - Faculty of Spatial Sciences I am researching ‘woonerf’ residential streets.
I am especially curious about ambient noise and how the street is experienced by its residents.

I do this research on the basis of a survey. By filling in the survey you could help me a lot. Filling in the survey takes 5 minutes and is completely anonymous.

Thanks in advance!

QR-code For the English survey:

URL: https://mpt.link/rugwoonerf_en

Beste bewoner(s),

Mijn naam is Theun Leereveld en voor mijn Master ‘Environmental Infrastructure Planning’ aan de Rijksuniversiteit Groningen - Faculteit Ruimtelijke Wetenschappen doe ik onderzoek naar woonerf straten. Ik ben hierin specifiek benieuwd naar omgevingsgeluid en hoe de straat wordt beleefd door de bewoners zelf.

Dit onderzoek doe ik onder andere aan de hand van een vragenlijst. Hierin zou u mij enorm kunnen helpen. Het invullen van de vragenlijst duurt ongeveer 5 minuten en is volledig anoniem.

Alvast bedankt!

QR-code Voor de Nederlandse vragenlijst:

URL: https://mpt.link/rugwoonerf_ldw_nl

Dear resident(s),

My name is Theun Leereveld and for my Master's degree 'Environmental Infrastructure Planning' at the University Groningen - Faculty of Spatial Sciences I am researching ‘woonerf’ residential streets.
I am especially curious about ambient noise and how the street is experienced by its residents.

I do this research on the basis of a survey. By filling in the survey you could help me a lot. Filling in the survey takes 5 minutes and is completely anonymous.

Thanks in advance!

QR-code For the English survey:

URL: https://mpt.link/rugwoonerf_ldw_en

Thank you for participating in this research on woonerf streets. This survey takes about 5 minutes to fill in. You can stop the survey at any time you would like. Your answers are fully anonymous. The data will be kept confidential at all times and will not be shared with third parties.

In this survey the term "tranquility" is defined as: “how much do you think this setting is a quiet, peaceful place, a good place to get away from the demands of everyday life.”

You may select your preferred language at the bottom left side.

If you have any questions feel free to contact me by email on: T.Leereveld@student.rug.nl

Thanks in advance!

---

1. What is your educational background?

- ◯ Primary education
- ◯ Lower secondary education
- ◯ Upper secondary/Post-secondary non-tertiary education
- ◯ Bachelor or equivalent
- ◯ Master or equivalent
- ◯ Doctoral or equivalent

---

2. What is your age?

- ◯ <25 years
- ◯ 25-35 years
- ◯ 36-45 years
- ◯ 46-55 years
- ◯ 56-65 years
- ◯ >65 years

3. I live in one of the following streets:

Here a X amount of options is given based on the city a respondent lives

---

4. Are you aware of the fact that your street is a woonerf street?

- ◯ Yes
- ◯ No

5. Are you familiar with the concept of a woonerf street?

- ◯ Yes
- ◯ No

6. What was the main reason for you to come and live in this street ?

7. In your street, what sound attracts your attention the most?

- ◯ Natural sounds
- ◯ Bicycle sounds
- ◯ Motorized traffic sounds
- ◯ People sounds
- ◯ Children playing

8. I perceive the sound environment of my street as:

	Disagree	Somewhat disagree	Neither agree, nor disagree	Somewhat agree	Strongly agree
Pleasant	◯	◯	◯	◯	◯
Annoying	◯	◯	◯	◯	◯
Vibrant	◯	◯	◯	◯	◯
Monotonous	◯	◯	◯	◯	◯
Calm	◯	◯	◯	◯	◯
Chaotic	◯	◯	◯	◯	◯
Eventful	◯	◯	◯	◯	◯
Uneventful	◯	◯	◯	◯	◯

9. In your street, what visual elements attract your attention the most?

- ◯ Natural/Cultural elements
- ◯ Man-made elements (not including natural/cultural elements)

10. In your street, which of the following visual elements attract your attention the most? (1 being the most present according to you and 10 being the least).

	1	2	3	4	5	6	7	8	9	10
Trees	○	○	○	○	○	○	○	○	○	○
Hedges & Shrubs	○	○	○	○	○	○	○	○	○	○
Vertical gardening	○	○	○	○	○	○	○	○	○	○
Heritage buildings	○	○	○	○	○	○	○	○	○	○
Buildings	○	○	○	○	○	○	○	○	○	○
Street furniture (benches, bollards)	○	○	○	○	○	○	○	○	○	○
Cars	○	○	○	○	○	○	○	○	○	○
Bicycles	○	○	○	○	○	○	○	○	○	○
Gardens	○	○	○	○	○	○	○	○	○	○
Playground	○	○	○	○	○	○	○	○	○	○

11. Please rate how important you find tranquility in your street by choosing a number between 0 and 10, where 0 is "Not important" and 10 is "Very important".

0 ———————— 10

12. Please rate the tranquility of your street by choosing a number between 0 and 10, where 0 is "least tranquil" and 10 is "most tranquil".

0 ———————— 10

13. Please rate how active you are with the maintenance of greenery within your street by choosing a number between 0 and 10, where 0 is "Not active at all" and 10 is "Very active".

0 ———————— 10

14. If you could change anything with respect to streetscape greenery/other fysical elements in your street, what would it be?

Appendix D

Street name	Spot number	Total pixel area	Sky pixel area	Total relevant pixel area	Green pixel area	Cultural pixel area	NCF ratio	C ratio	GVI ratio
Grote Leliestraat	62.2	486416	51811	434605	5568	0	1%	0%	1%
	55.4	486416	47277	439139	42350	0	10%	0%	10%
Kleine Leliestraat	60.4	486416	31472	454944	34862	35550	15%	8%	8%
	61.3	486416	22846	463570	41412	0	9%	0%	9%
Grote Rozenstraat	53.2	486416	16206	470210	39813	3731	9%	1%	8%
	57.8	486416	15549	470867	55112	6030	13%	1%	12%
	58.3	486416	15667	470749	86792	119961	44%	25%	18%
Kleine Rozenstraat	55.2	486416	12489	473927	36555	3983	9%	1%	8%
	54.7	486416	23070	463346	55745	11568	15%	2%	12%
Grote Appelstraat	50.2	486416	9878	476538	99740	0	21%	0%	21%
	50.5	486416	12661	473755	151306	0	32%	0%	32%
	52.1	486416	4075	482341	69075	0	14%	0%	14%
Kleine Appelstraat	51.9	486416	11858	474558	128893	0	27%	0%	27%
	60.6	486416	17202	469214	146227	0	31%	0%	31%
Plantsoenstraat	47.6	486416	42415	444001	29140	0	7%	0%	7%
	51.1	486416	57294	429122	17027	0	4%	0%	4%
Selwerderstraat	45.6	486416	34620	451796	47010	0	10%	0%	10%
	53.4	486416	21335	465081	41821	0	9%	0%	9%
Kloosterstraat	53.4	486416	26579	459837	50595	0	11%	0%	11%
	43.3	486416	24388	462028	87863	0	19%	0%	19%
	47.2	486416	20715	465701	60457	0	13%	0%	13%
Kolfstraat	48.5	486416	23621	462795	153265	0	33%	0%	33%
	52.2	486416	34431	451985	56156	0	12%	0%	12%
Louise Henriëttestraat	47.3	486416	34920	451496	116600	11894	28%	3%	26%
	47.5	486416	23350	463066	61622	126403	41%	27%	13%
	55.6	486416	32664	453752	109907	93144	45%	21%	24%
Zwarteweg	47.8	486416	34955	451461	63470	0	14%	0%	14%
	47.9	486416	21784	464632	75785	0	16%	0%	16%
	48.7	486416	19850	466566	73961	0	16%	0%	16%
	52.1	486416	17232	469184	157139	0	33%	0%	33%
Kleine bergstraat	48.2	486416	37684	448732	28377	0	6%	0%	6%
	48.8	486416	20153	466263	50307	0	11%	0%	11%
Albertine Agnesstraat	59.3	486416	44384	442032	61987	0	14%	0%	14%
	58.9	486416	43953	442463	95077	0	21%	0%	21%
	54.1	486416	69806	416610	87459	0	21%	0%	21%
Koolstraat	50.5	486416	25562	460854	45686	0	10%	0%	10%
	52.8	486416	34390	452026	70180	0	16%	0%	16%
Bedumerstraat	45.6	486416	32215	454201	18108	0	4%	0%	4%
	48.7	486416	44507	441909	9815	0	2%	0%	2%
	49.6	486416	44952	441464	18712	0	4%	0%	4%
Leeuwarderstraat	41.1	486416	28313	458103	45784	0	10%	0%	10%
	42.3	486416	23295	463121	38826	0	8%	0%	8%
Nieuwe Blekerstraat	45.0	486416	45218	441198	52299	0	12%	0%	12%
	50.6	486416	52083	434333	29257	0	7%	0%	7%
	53.2	486416	49410	437006	21689	0	5%	0%	5%
	60.3	486416	43633	442783	50349	0	11%	0%	11%
Rubensstraat	46.0	486416	34142	452274	91271	0	20%	0%	20%
	42.5	486416	61729	424687	154427	0	36%	0%	36%
	42.3	486416	39455	446961	72748	0	16%	0%	16%
Mondriaanstraat	47.9	486416	52936	433480	43004	0	10%	0%	10%
	49.6	486416	52211	434205	223117	0	51%	0%	51%
Eelderstraat	58.5	486416	22963	463453	25100	0	5%	0%	5%
	59.2	486416	50229	436187	6465	0	1%	0%	1%
Oosterbadstraat	45.9	486416	41819	444597	44192	0	10%	0%	10%
	45.4	486416	39419	446997	71598	0	16%	0%	16%
	46.9	486416	45245	441171	49569	0	11%	0%	11%
Wester Badstraat	43.1	486416	39349	447067	63342	0	14%	0%	14%
	52.8	486416	28893	457523	61041	0	13%	0%	13%
	45.4	486416	27320	459096	57775	0	13%	0%	13%
Davidstraat	52.1	486416	44618	441798	8215	0	2%	0%	2%
	55.6	486416	22163	464253	5872	0	1%	0%	1%
Fongersplaats	44.0	486416	48482	437934	97560	0	22%	0%	22%
	45.2	486416	34183	452233	11904	0	3%	0%	3%
	47.3	486416	22546	463870	46071	0	10%	0%	10%
Hereweg/Parklaan	60.7	486416	72936	413480	19573	0	5%	0%	5%
Lodewijkstraat	57.4	486416	50248	436168	187217	0	43%	0%	43%
	59.6	486416	69059	417357	153904	0	37%	0%	37%
	60.2	486416	63412	423004	114276	1328	27%	0%	27%

Polderstraat	50.9	486416	34031	452385	71523	0	16%	0%	16%
	54.1	486416	12798	473618	56152	0	12%	0%	12%
	54.7	486416	22107	464309	61042	0	13%	0%	13%
Marjoleinstraat	59.1	486416	47884	438532	124008	0	28%	0%	28%
	63.1	486416	72631	413785	119907	0	29%	0%	29%
	53.7	486416	67242	419174	121166	0	29%	0%	29%
	52.5	486416	85278	401138	100491	0	25%	0%	25%
	50.2	486416	73021	413395	218169	0	53%	0%	53%
Melisseweg	54.3	486416	83233	403183	128115	0	32%	0%	32%
Bieslookstraat	51.9	486416	114129	372287	56068	0	15%	0%	15%
Wolfsklauwstraat	52.5	486416	60428	425988	108649	0	26%	0%	26%
	51.7	486416	61072	425344	158612	0	37%	0%	37%
	50.1	486416	77688	408728	140308	0	34%	0%	34%
Halbertsmastraat	52.2	486416	48164	438252	146155	163428	71%	37%	33%
	50.7	486416	65146	421270	103370	166137	64%	39%	25%
Nieuwe Hollanderdijk	47.8	486416	59636	426780	108199	19243	30%	5%	25%
	49.4	486416	73785	412631	183779	64418	60%	16%	45%
	55.0	486416	66330	420086	121701	46384	40%	11%	29%
Nieuwe Schrans	47.8	486416	94733	391683	27933	0	7%	0%	7%
	54.4	486416	30313	456103	41250	0	9%	0%	9%
	62.0	486416	53694	432722	30189	0	7%	0%	7%
Matthias van Pellicomstraat	44.3	486416	62238	424178	98292	0	23%	0%	23%
	50.5	486416	48007	438409	126592	0	29%	0%	29%
	62.3	486416	47111	439305	126789	0	29%	0%	29%
Sportlaan	49.4	486416	41610	444806	59851	0	13%	0%	13%
	50.8	486416	37182	449234	42753	0	10%	0%	10%
	55.8	486416	49646	436770	31056	0	7%	0%	7%
Wiardastraat	47.7	486416	68083	418333	35569	0	9%	0%	9%
	51.2	486416	74104	412312	63858	0	15%	0%	15%
Buygersstraat	39.8	486416	48836	437580	60392	0	14%	0%	14%
	44.4	486416	47416	439000	90518	0	21%	0%	21%
Jouwsmastraat	42.0	486416	48986	437430	20727	0	5%	0%	5%
	49.4	486416	52422	433994	30202	0	7%	0%	7%
Van Sytzamastraat	41.2	486416	44513	441903	54766	0	12%	0%	12%
	41.20	486416	45066	441350	76108	0	17%	0%	17%
	45.0	486416	38041	448375	51048	0	11%	0%	11%
Bernhardus Bumastraat	41.3	486416	58327	428089	42088	0	10%	0%	10%
	42.6	486416	42125	444291	54749	0	12%	0%	12%
	44.1	486416	47985	438431	14371	0	3%	0%	3%

Ypeijstraat	48.9	486416	54564	431852	49305	0	11%	0%	11%
	49.0	486416	63320	423096	23909	0	6%	0%	6%
Van Heemstrastraat	41.5	486416	47035	439381	55970	0	13%	0%	13%
	47.5	486416	52224	434192	137328	0	32%	0%	32%
Willem Loréstraat	45.7	486416	98789	387627	15568	0	4%	0%	4%
	49.3	486416	78088	408328	75610	0	19%	0%	19%
	50.3	486416	56155	430261	59430	0	14%	0%	14%
	52.0	486416	48842	437574	53023	0	12%	0%	12%
	53.8	486416	40406	446010	17527	0	4%	0%	4%
Rembrandtstraat	43.8	486416	80182	406234	49117	0	12%	0%	12%
	50.5	486416	75122	411294	138295	0	34%	0%	34%
Saskiastraat	46.6	486416	44011	442405	77294	0	17%	0%	17%
	47.1	486416	73042	413374	164587	0	40%	0%	40%
Accamastraat	47.9	486416	56861	429555	22028	0	5%	0%	5%
	51.7	486416	43656	442760	87339	0	20%	0%	20%
Bisschopstraat	44.2	486416	55046	431370	173419	0	40%	0%	40%
	54.2	486416	29786	456630	135188	0	30%	0%	30%
Cornelis Frederiksstraat	41.4	486416	53886	432530	70169	0	16%	0%	16%
	43.3	486416	57917	428499	127154	0	30%	0%	30%
	45.4	486416	59524	426892	148236	0	35%	0%	35%
Van der Kooijstraat	43.5	486416	39430	446986	42695	0	10%	0%	10%
	49.7	486416	43190	443226	27412	0	6%	0%	6%
Pieter de Swartstraat	42.2	486416	51028	435388	35521	0	8%	0%	8%
	43.0	486416	46868	439548	67393	0	15%	0%	15%
Jacob Binckesstraat	52.1	486416	42760	443656	139139	0	31%	0%	31%
	52.5	486416	53041	433375	154937	0	36%	0%	36%
Maerten Gerritszstraat	44.8	486416	52866	433550	155824	0	36%	0%	36%
	57.4	486416	64965	421451	81272	0	19%	0%	19%
Piet Heinstraat	42.8	486416	46637	439779	16466	0	4%	0%	4%
	48.5	486416	56718	429698	93219	0	22%	0%	22%
Auke Stellingwerfstraat	42.7	486416	103101	383315	147287	0	38%	0%	38%
	43.6	486416	64138	422278	89757	0	21%	0%	21%
Barent Fockesstraat	47.3	486416	99974	386442	81457	0	21%	0%	21%
	49.8	486416	68114	418302	21911	0	5%	0%	5%
	50.8	486416	44155	442261	63223	0	14%	0%	14%
Koestraat	48.2	486416	51006	435410	103764	0	24%	0%	24%
	55.4	486416	41503	444913	192694	0	43%	0%	43%
Veestraat	45.4	486416	47796	438620	241844	0	55%	0%	55%
	46.7	486416	37425	448991	41888	0	9%	0%	9%
Schalk Burgerstraat	54.5	486416	33353	453063	162867	0	36%	0%	36%
	55.9	486416	33968	452448	160594	0	35%	0%	35%
Transvaalstraat	43.2	486416	22510	463906	94436	0	20%	0%	20%
	43.3	486416	26276	460140	174234	0	38%	0%	38%
	48.0	486416	44234	442182	154792	0	35%	0%	35%
Cronjéstraat	48.9	486416	34611	451805	139270	0	31%	0%	31%
	51.3	486416	21952	464464	231124	0	50%	0%	50%
Paul Krugerstraat	45.4	486416	48929	437487	54613	0	12%	0%	12%
	57.2	486416	35850	450566	124191	0	28%	0%	28%

Appendix E

SUB QUESTION 1

- Neighborhoods -

ANOVA

Perceived TR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	75,557	5	15,111	4,443	,001
Within Groups	1265,257	372	3,401		
Total	1340,815	377			

Robust Tests of Equality of Means

Perceived TR

	Statistic[a]	df1	df2	Sig.
Welch	4,918	5	161,318	,000

a. Asymptotically F distributed.

Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Perceived TR is the same across categories of Neighborhood.	Independent-Samples Kruskal-Wallis Test	,006	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Independent-Samples Kruskal-Wallis Test

Perceived TR across Neighborhood

Independent-Samples Kruskal-Wallis Test Summary

Total N	378
Test Statistic	27,968[a]
Degree Of Freedom	12
Asymptotic Sig.(2-sided test)	,006

a. The test statistic is adjusted for ties.

- Educational Background -

Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Perceived TR is the same across categories of 1. Wat is uw opleidingsniveau?.	Independent-Samples Kruskal-Wallis Test	,683	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Independent-Samples Kruskal-Wallis Test

Perceived TR across 1. Wat is uw opleidingsniveau?

Independent-Samples Kruskal-Wallis Test Summary

Total N	378
Test Statistic	3,111[a,b]
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	,683

a. The test statistic is adjusted for ties.

b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Oneway

Descriptives

Perceived TR

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	20	6,10	2,447	,547	4,95	7,25	2	9
2	46	6,98	1,680	,248	6,48	7,48	2	10
3	148	6,64	1,945	,160	6,32	6,95	1	10
4	134	6,77	1,806	,156	6,46	7,08	2	10
5	28	6,86	1,758	,332	6,18	7,54	2	9
Total	376	6,71	1,881	,097	6,52	6,90	1	10

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Perceived TR	Based on Mean	2,145	4	371	,075
	Based on Median	1,431	4	371	,223
	Based on Median and with adjusted df	1,431	4	358,990	,223
	Based on trimmed mean	2,060	4	371	,085

ANOVA

Perceived TR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12,646	4	3,162	,892	,468
Within Groups	1314,332	371	3,543		
Total	1326,979	375			

Robust Tests of Equality of Means

Perceived TR

	Statistic[a]	df1	df2	Sig.
Welch	,702	4	78,157	,593

a. Asymptotically F distributed.

- Age Groups -

Oneway

Descriptives

Perceived TR

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
< 25 years	48	6,29	2,042	,295	5,70	6,88	1	10
25-35	95	6,31	1,913	,196	5,92	6,70	1	10
36-45	58	6,40	1,806	,237	5,92	6,87	2	9
46-55	71	6,82	1,900	,225	6,37	7,27	2	10
56-65	50	7,52	1,594	,225	7,07	7,97	1	10
> 65 year	56	7,18	1,717	,229	6,72	7,64	2	10
Total	378	6,70	1,886	,097	6,51	6,89	1	10

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Perceived TR	Based on Mean	1,300	5	372	,263
	Based on Median	,691	5	372	,631
	Based on Median and with adjusted df	,691	5	363,859	,631
	Based on trimmed mean	1,246	5	372	,287

ANOVA

Perceived TR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	75,557	5	15,111	4,443	,001
Within Groups	1265,257	372	3,401		
Total	1340,815	377			

Robust Tests of Equality of Means

Perceived TR

	Statistic[a]	df1	df2	Sig.
Welch	4,918	5	161,318	,000

a. Asymptotically F distributed.

SUB QUESTION 3

- NCF levels between neighborhoods

Independent-Samples Kruskal-Wallis Test

Nonparametric Tests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of NCF levels is the same across categories of Neighborhoods.	Independent-Samples Kruskal-Wallis Test	,092	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Independent-Samples Kruskal-Wallis Test

NCF levels across Neighborhoods

Independent-Samples Kruskal-Wallis Test Summary

Total N	63
Test Statistic	22,644[a,b]
Degree Of Freedom	15
Asymptotic Sig.(2-sided test)	,092

a. The test statistic is adjusted for ties.

b. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

- NCF levels between the Cities -

T-Test

Group Statistics

	City	N	Mean	Std. Deviation	Std. Error Mean
NCF levels	Groningen	32	17,3594	10,88817	1,92477
	Leeuwarden	31	23,0645	13,77422	2,47392

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NCF levels	Equal variances assumed	1,349	,250	-1,827	61	,073	-5,70514	3,12284	-11,94964	,53936
	Equal variances not assumed			-1,820	57,074	,074	-5,70514	3,13449	-11,98168	,57140

SUB QUESTION 4

MESO SCALE

Paired sample T-Test of 62 woonerf streets of Groningen and Leeuwarden combined:

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Average_TR	6,4597	62	1,19232	,15142
	Predicted_TR	4,1495	62	,91041	,11562

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Average_TR & Predicted_TR	62	,224	,080

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Average_TR - Predicted_TR	2,31016	1,32839	,16871	1,97281	2,64751	13,693	61	,000

Paired sample T-Test of 52 woonerf streets of Groningen and Leeuwarden combined for only the ≥20 neighborhoods:

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Average_TR	6,6060	52	1,13185	,15696
	Predicted_TR	4,0735	52	,94288	,13075

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Average_TR & Predicted_TR	52	,318	,021

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Average_TR - Predicted_TR	2,53250	1,22094	,16931	2,19259	2,87241	14,957	51	,000

MICRO SCALE - *listed according to neighborhood number -*

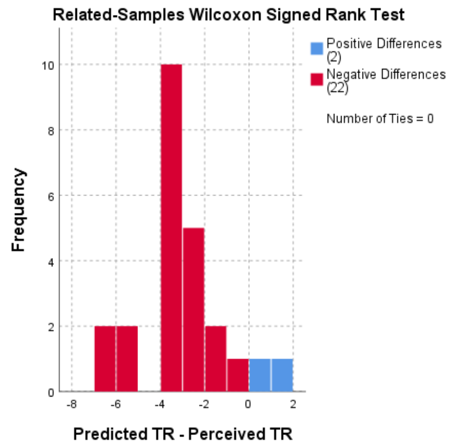
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between Perceived TR and Predicted TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	24
Test Statistic	4,000
Standard Error	34,977
Standardized Test Statistic	-4,174
Asymptotic Sig.(2-sided test)	,000



Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
2	Perceived TR	6,95	88	1,911	,204
	Predicted_TR	4,0630	88	,45613	,04862

Paired Samples Correlations

		N	Correlation	Sig.
2	Perceived TR and Predicted_TR	88	-,056	,604

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
2	Perceived TR - Predicted_TR	2,891 59	1,98967	,21210	2,47002	3,31316	13,63 3	87	,000

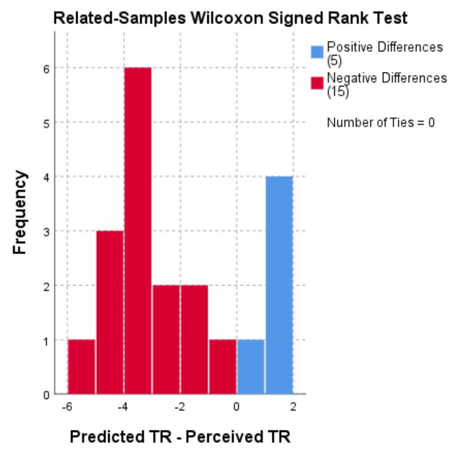
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
3	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	20
Test Statistic	28,000
Standard Error	26,667
Standardized Test Statistic	-2,887
Asymptotic Sig.(2-sided test)	,004



Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
4	Perceived TR	6,96	52	1,508	,209
	Predicted_TR	5,0254	52	,63834	,08852

Paired Samples Correlations

		N	Correlation	Sig.
4	Perceived TR and Predicted_TR	52	,139	,325

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
4	Perceived TR - Predicted_TR	1,93615	1,55326	,21540	1,50372	2,36858	8,989	51	,000

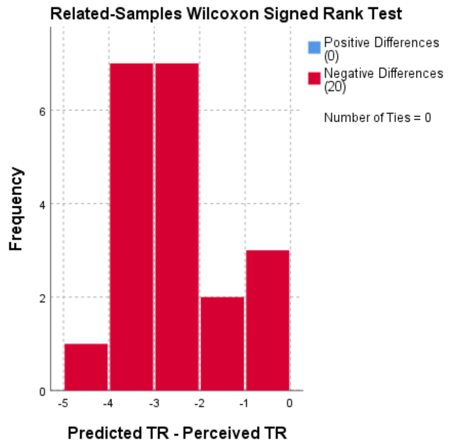
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
5	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	20
Test Statistic	,000
Standard Error	26,702
Standardized Test Statistic	-3,932
Asymptotic Sig.(2-sided test)	,000



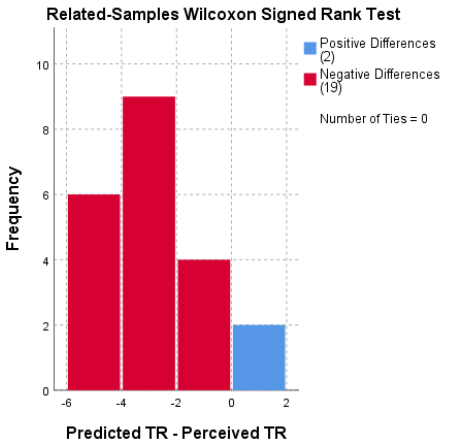
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
6	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	21
Test Statistic	11,000
Standard Error	28,677
Standardized Test Statistic	-3,644
Asymptotic Sig.(2-sided test)	,000



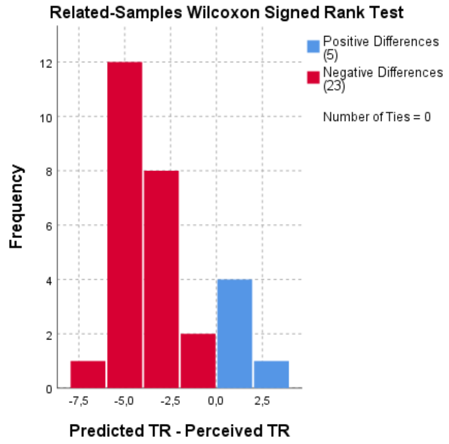
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
7	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	28
Test Statistic	18,000
Standard Error	43,828
Standardized Test Statistic	-4,221
Asymptotic Sig.(2-sided test)	,000



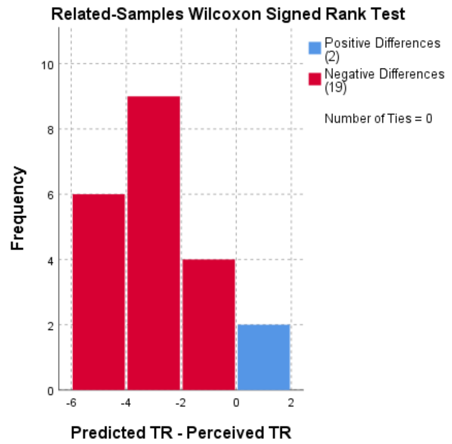
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
8	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	21
Test Statistic	11,000
Standard Error	28,747
Standardized Test Statistic	-3,635
Asymptotic Sig.(2-sided test)	,000



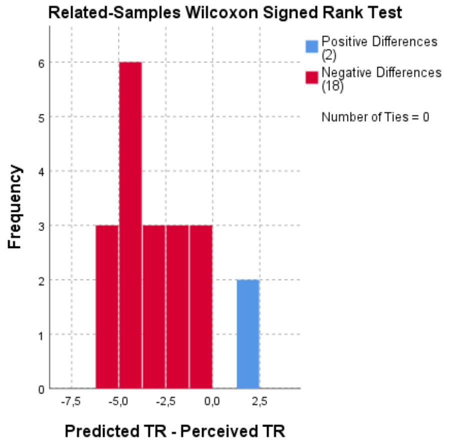
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
9	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	20
Test Statistic	11,000
Standard Error	26,768
Standardized Test Statistic	-3,512
Asymptotic Sig.(2-sided test)	,000



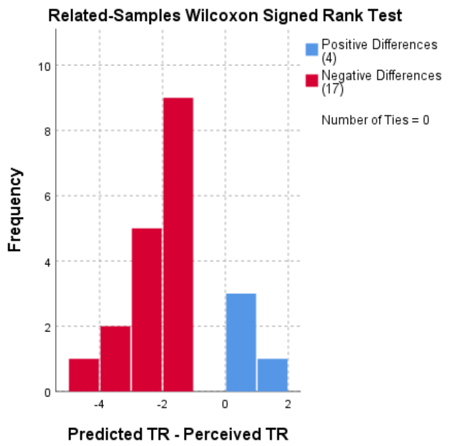
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
10	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	21
Test Statistic	10,000
Standard Error	28,738
Standardized Test Statistic	-3,671
Asymptotic Sig.(2-sided test)	,000



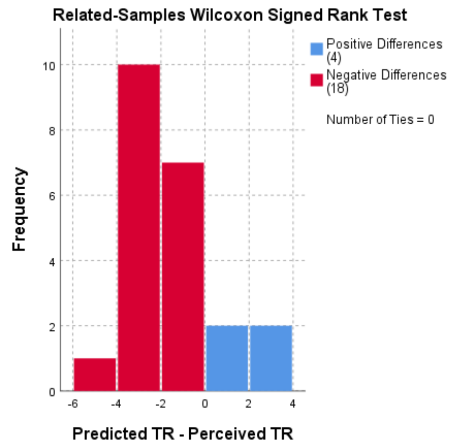
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
11	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,007	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	22
Test Statistic	44,000
Standard Error	30,781
Standardized Test Statistic	-2,680
Asymptotic Sig.(2-sided test)	,007



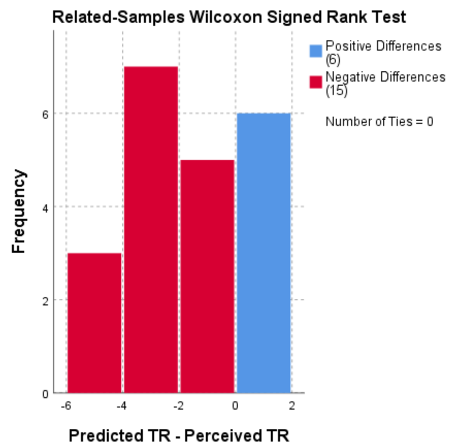
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
12	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	21
Test Statistic	32,000
Standard Error	28,753
Standardized Test Statistic	-2,904
Asymptotic Sig.(2-sided test)	,004



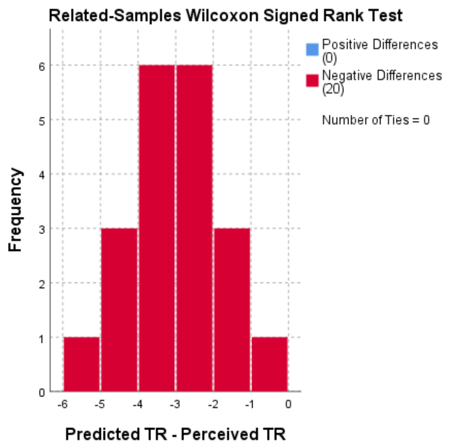
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
13	The median of differences between Perceived TR and Predicted_TR equals 0.	Related-Samples Wilcoxon Signed Rank Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,050.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	20
Test Statistic	,000
Standard Error	26,716
Standardized Test Statistic	-3,930
Asymptotic Sig.(2-sided test)	,000



SUB QUESTION 5

Correlation between GVI and Greenery Maintenance

Correlations

		GVI_average	Average Greenery Maintenance
GVI_average	Pearson Correlation	1	,508**
	Sig. (2-tailed)		,000
	N	52	52
Average Greenery Maintenance	Pearson Correlation	,508**	1
	Sig. (2-tailed)	,000	
	N	52	52

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		Average GVI levels	Average Greenery Maintenance
Average GVI levels	Pearson Correlation	1	,516**
	Sig. (2-tailed)		,000
	N	62	62
Average Greenery Maintenance	Pearson Correlation	,516**	1
	Sig. (2-tailed)	,000	
	N	62	62

**. Correlation is significant at the 0.01 level (2-tailed).

- Difference of Greenery Maintenance between the neighborhoods of Groningen and Leeuwarden -

Descriptives

13. Beoordeel hoe actief u bezig bent met het onderhoud van groen in uw straat door een cijfer tussen 0 en 10 te kiezen, waarbij 0 staat voor 'helemaal niet actief' en 10 voor 'zeer actief'.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	24	3,54	3,297	,673	2,15	4,93	0	10
2	88	4,06	2,894	,309	3,44	4,67	0	10
3	20	2,30	3,080	,689	,86	3,74	0	9
4	52	5,02	3,006	,417	4,18	5,86	0	10
5	20	4,40	2,563	,573	3,20	5,60	1	9
6	21	3,52	3,010	,657	2,15	4,89	0	10
7	27	4,04	3,044	,586	2,83	5,24	0	10
8	22	5,68	2,124	,453	4,74	6,62	1	8
9	20	5,35	2,581	,577	4,14	6,56	1	10
10	21	3,71	2,686	,586	2,49	4,94	0	9
11	22	4,91	2,910	,620	3,62	6,20	0	10
12	21	5,05	2,617	,571	3,86	6,24	0	9
13	20	5,45	1,959	,438	4,53	6,37	0	8
Total	378	4,37	2,903	,149	4,08	4,67	0	10

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
13. Beoordeel hoe actief u bezig bent met het onderhoud van groen in uw straat door een cijfer tussen 0 en 10 te kiezen, waarbij 0 staat voor 'helemaal niet actief' en 10 voor 'zeer actief'.	Based on Mean	1,713	12	365	,062
	Based on Median	1,713	12	365	,062
	Based on Median and with adjusted df	1,713	12	314,230	,063
	Based on trimmed mean	1,736	12	365	,058

ANOVA

13. Beoordeel hoe actief u bezig bent met het onderhoud van groen in uw straat door een cijfer tussen 0 en 10 te kiezen, waarbij 0 staat voor 'helemaal niet actief' en 10 voor 'zeer actief'.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	256,220	12	21,352	2,669	,002
Within Groups	2920,185	365	8,001		
Total	3176,405	377			

Robust Tests of Equality of Means

13. Beoordeel hoe actief u bezig bent met het onderhoud van groen in uw straat door een cijfer tussen 0 en 10 te kiezen, waarbij 0 staat voor 'helemaal niet actief' en 10 voor 'zeer actief'.

	Statistic[a]	df1	df2	Sig.
Welch	2,778	12	112,909	,002

a. Asymptotically F distributed.

Appendix F

Qualitative data analysis

To gain insight into the initial reasoning of residents to come and live in a woonerf street, to provide knowledge on woonerf street improvements and recommendations for future planning, a qualitative analysis two open ended questions is performed. After multiple thorough readthrough of the data, codes are based on recurring themes. This basis of codes is complemented by codes that are formulated based on the factors related to the tranquility construct and the main design criteria of woonerf streets. For the analysis the qualitative data analysis software Atlas.ti is used. During the coding process, adjustments are made where needed. The final coding scheme is displayed in Table 1x.

Potential sub Questions/Recommendations	Code	Keywords
	Auditory level	*low noise levels, noise, sound, low traffic noise, quiet, peaceful*
	Visual level	*appearance, aesthetic, charming, natural, beautiful*
	Location	*proximity, close to, convenience, near*
	Price	*cheap, affordable, low cost, low rental, low house price*
	Other	*if not one of the above keywords*
	Increase greenery	*trees, plants, vegetation, flowers, greenery*
	Improve greenery maintenance	*trim, care, repair, paint, upkeep, neglected*
	Add or improve amenities	*benches, seating, playground, amenities, parking facilities*
	Remove parking space/cars	*less parking space, less cars, less parking facilities*
	Other	*overall layout, design, issues/problems not related to the other categories*

Table 1x

Results

Responses of participants to the question *"What was the main reason for you to come and live in this street?''* is categorized according to five codes. Six age groups are merged into three to equalize the amount of respondents between groups. These results are displayed in Table 2x. Aside from the 'other' category, which entails a variety of responses, the location, auditory and visual levels complement the top three reasons for people to decide to come and live in the woonerf streets under study. To the question *"Please rate how important you find 'tranquility' in your street'* resulted in an average score of 7,88 out of 10. Location and price (e.g. close to work, house/rental price) seems to become of less importance as people get older.

	Age:: ≤ 35 years 159 318	Age:: ≥ 56 years 109 218	Age:: 36 - 55 years 142 283	**Totals**
Auditory level 103	34	31	38	**103**
Location 143	59	32	52	**143**
Other 145	53	46	46	**145**
Price 55	35	8	12	**55**
Visual level 89	28	23	38	**89**
Totals	**209**	**140**	**186**	**535**

Table 2x

To provide knowledge and insights on further improvements of the street, participants were asked the question: *"if you could change anything with respect to streetscape greenery/other physical elements in your street, what would it be?"*. It is evident that the main aspect residents would like to change is an increase in streetscape greenery from the results in Table 3x. However, while there is a willingness to increase greenery, residents are also facing policy barriers which withhold actual implementation of streetscape greenery. This is for example shown by the following respondents who would like to implement vertical gardening in their street:

"The garden areas around the trees are maintained by the municipality and they mostly do a good job, even if it all looks a bit generic . I try to make my balcony like a little jungle, but I have VvE restrictions on not being allowed to hang anything on the walls so any vertical gardening is sort of forbidden. Pity."

(Respondent Bedumerstraat, 2022)

"Strict penalties for dumping waste/garbage, reducing space/banning cars, allowing for vertical green spaces (changing the bylaws of a homeowners association)"

(Respondent Fongersplaats, 2022)

The secondary change residents would like to see is the removal of parking spaces/cars. Often residents respond in a combination of less parking space/cars and replacement by greenery. However, street elements such as shrubs, planters and front gardens, typically found and implemented in the woonerf design, often result in streets to be narrow. Resident are also aware of the fact that limited space is available. The following respondents acknowledge this lack of space and highlight the spatial dilemma within the woonerf design:

"Preserve greenery by reducing cars (but that is impossible)"

(Respondent Kloosterstraat, 2022)

"Fewer cars parked on the street. I understand that people prefer to park the car in front of the house, but the street is already very narrow and cars result in the street to be even more narrow."

(Respondent Koolstraat, 2022)

"Possibly more trees, but there is very little room for improvements given the narrow street."

(Respondent Jacob Binckesstraat, 2022)

Residents are well aware of the fact that parking spaces for cars is not the most visual appealing aspect of their street. Nevertheless, they also see how beneficial and convenient it is to have your car parked close to home. Residents often suggest to centralize or relocate parking space elsewhere. However, residents still prefer the parking facilities to remain in relative close proximity to their street. This dilemma between convenience and visual appearance is illustrated by the following examples:

"Park cars out of sight (but nearby) and more green"

(Respondent Rubensstraat, 2022)

"Centralize parking of cars close to our house and more green."

(Respondent Nieuwe Blekerstraat, 2022)

		Age:: ≤ 35 years 159 318	Age:: ≥ 56 years 109 218	Age:: 36 - 55 years 142 283	Totals
Add or improve amenities	46	18	17	11	46
Improve streetscape greenery maintenance	35	16	6	13	35
Increase streetscape greenery	191	76	44	71	191
Other.	48	15	15	18	48
Remove parking space/cars	79	25	17	37	79
Totals		150	99	150	399

Table 3x