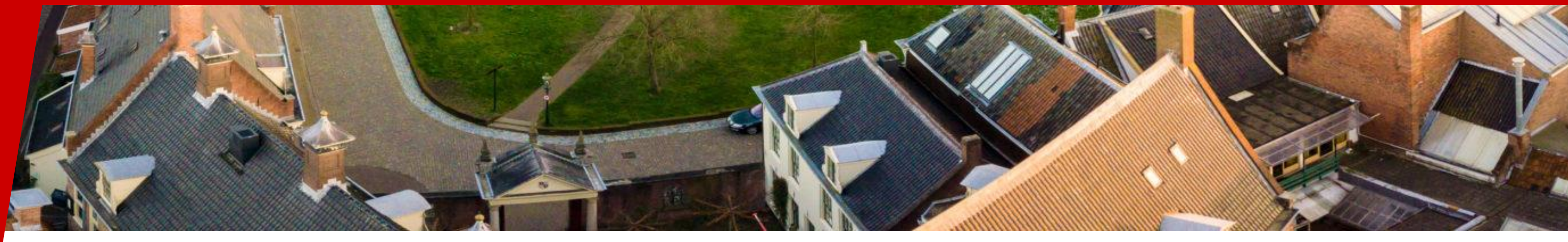
How our Living Environment Influences our Perception of Health

A case study of the Municipality of Groningen

We give shape to our buildings, and they, in turn, shape us

Winston Churchill

1943, Speech to the House of Commons



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Abstract

Health is often researched from a social psychological or medical perspective, even though social psychology proved that space-design is an important factor influencing how we feel and behave. Therefore one can conclude that the design aspect is a major component in the perceived health. Researching how health in cities relates to the design can help improve the overall public health of a city, and in turn reduce health inequalities within cities. As the urbanization rate is increasing, and health issues are arising, it is important to study the relationships and possible points of improvement on a city-level with regards to health and design. Using GIS, the study found that the spatial explanatory variables for self-reported health in Groningen are population density, the amount of females within a neighborhood, physical activity according to the guidelines, satisfaction with greenery, and having an income under or around the social minimum standard. These are thus factors that are important to take into account for city design and the neighborhood characteristics to accommodate. The architectural site-analysis focused on recommendations for improved public health by focusing on opportunities for increased greenery and outdoor recreational activities. The design implementations can positively alter the perception of health by giving citizens more opportunities to improve their health, both directly and indirectly. When the perception of health is improved, actual physical health improves, and health inequalities will be reduced.

Keywords

Health Inequality   *Public Health*   *Self-reported health*   *Site analysis*

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1. Introduction

Urbanization is a very important demographic shift altering how the majority of the world population has lived for the past several thousand years (Galea & Vlahov, 2005). Along with this shift are rising urban health issues. In the last decades the interrelations between urban neighborhood characteristics and experienced health have gotten rising attention in research (Roux, 2001; Stockdale et al., 2009; Arcaya et al., 2016), as in many countries the health in cities is worse in comparison to rural areas (Galea & Vlahov, 2005). There is increasing statistical data showing a rise in non-communicable health issues across the globe with 71% of all deaths globally (WHO, 2021). Amongst non-communicable diseases fall obesity, cardiovascular diseases (CVD), common mental disorders (CMDs), cancer, and chronic respiratory diseases (Nordqvist, 2011). Health and city design is combined in urban health research, studying how characteristics of the urban environment may influence population health (Galea & Vlahov, 2005).

As a city provides opportunities for the improvement of one's socioeconomic status, the city becomes an attractive place for some (UvA, 2022). One individual could thrive in an urban setting, yet others are more vulnerable and could develop mental health problems. Multiple factors lie at the heart of this. For example, living close to a busy road influences your quality of sleep and elevates the experienced stress levels (UvA, 2022; Yang & Matthews, 2010), or living in a neighborhood where social cohesion is perceived higher positively impacts your quality of life (Hoogerbrugge & Burger, 2017). So far, risk factors for CMDs associated with cities are air pollution, crime rates, and the neurobiological - and psychological effect of urban living (van der Wal et al., 2021). The interactions between these factors concerning personal characteristics determine the vulnerability to mental disorders. Our well-being is affected by our surroundings (Monfries, 2020), of which "cities are associated with higher rates of most mental health problems compared to rural areas: an almost 40% higher risk of depression, over 20% more of anxiety, and double the risk of schizophrenia, in addition to loneliness, isolation and stress" (Quoted from The Center for Urban Design and Mental Health, n.d.). Jones et al., (2007) add that mental health is significantly associated with social capital and area deprivation. Similar examples can be found in the relationship between physical health and the neighborhood. It is important to note that with urbanization numbers rising and green space availability decreasing, people's self-reported mental and physical health could decrease (Maas et al., 2009). Green spaces have a positive effect on both mental and physical health. For example, experienced stress is reduced and the likelihood of obesity is decreased with accessible green spaces in the living environment. The Dutch Institute for Public Health (RIVM) provided guidelines to reduce health inequalities through municipal policy on areas such as greenery, traffic sound reduction, or social cohesion and support in neighborhoods with lower health standards (Savenkoul et al., 2011).

To enhance poor health in households an environmental intervention to increase physical activity is necessary, rather than a focus on behavioral interventions (Herrick, 2009). Most often, these lower health standards are linked to lower socio-economic (SES) households that also live in a less healthy physical and social environment (Savenkoul et al., 2011). Additionally, a poor state of health leads to a lower SES through reduced opportunities for training and employment. This is known as social selection. Therefore, it is important to investigate which regulations a municipality can do to improve the physical and social environment to reduce health inequalities. The municipality of Groningen focuses on an integrated approach for area development, which is necessary as, for example, several health problems can be a result of heat stress, which may be higher in that area due to a lack of greenery locally (Verhagen, 2021). The municipality of Groningen set aside 871,000 euros annually for 2018-2021 to focus on healthy ageing, healthy living environments, area development, sports facilities, and health care and prevention (Zwaving, 2017).

This research focuses on the effect of the built design on the self-reported health of citizens of the municipality of Groningen. The research aims to add to the knowledge of neighborhood characteristics and interrelation to self-reported health, and how to design interventions on a neighborhood level can positively impact the lives of the residents. This research is geospatial-oriented, aiming to answer what factors influence self-reported health and if these correlations hold spatially true. First, the research focuses on answering how public health is defined and which factors of the built urban design influence the public health of citizens through a literature review. Thereafter, spatial analysis is performed to research which neighborhoods in the municipality of Groningen have a lower self-reported health rate in comparison to the higher rates of self-reported health using Arc Geographic Information Systems (ArcGIS). In the next step, the factors that influence the self-reported health rate of inhabitants in the municipality of Groningen are spatially regressed using ArcGIS Pro. The final part of the research focuses on a site-analysis to research spatial solutions that can be done to improve poor-quality public areas.

2. Theoretical Framework

2.1 Public Health and Stress

How is 'public health' defined?

Public health is defined by Ancheson (1988) as "the art and science of preventing a disease, prolonging life and promoting health through organized efforts of society" (Rechel & McKee, 2014). This differs from health, which is defined by the WHO (1948) as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". The definition of public health relates to the concept of healthy living; "taking responsibility and making smart health choices for today and the future. Eating right, getting physically fit, emotional wellness, spiritual wellness, and prevention are all a part of creating a healthy lifestyle." (Petersen et al., 2010, p. 391). Public health is also targeted at the population as a whole. Within this research, the focus lies on neighborhood borders.

Mental well-being falls under the umbrella of public health. Mental well-being is defined as a dynamic state in which an individual can develop their potential, work productively and creatively, build strong and positive relationships with others, and contribute to their community (Foresight Mental Capital and Wellbeing Project (2008). It is enhanced when an individual can fulfill their personal and social goal and achieve a sense of purpose in society. Mental well-being is similar to mental health. The latter is defined as a state of well-being in which the individual realizes his or her abilities, can cope with the normal stresses of life, can work productively and fruitfully, and can contribute to his or her community (WHO, 2004).

Research has established links between public health and space. Negative impacts on well-being or mental capital are associated, for instance, with increased levels of anxiety leading to social isolation or disengagement from communal, physical, or educational activities (Cooper et al., 2008). On the other hand, the positive impacts seem to reduce anxiety, increasing involvement in social and intellectual activities. The effect of the built environment on one's well-being is not solely related to the urban environment but includes psychological and neurobiological characteristics (van der Wal et al., 2021). Chapter 2.2 will elaborate on built environment factors that influence public health.

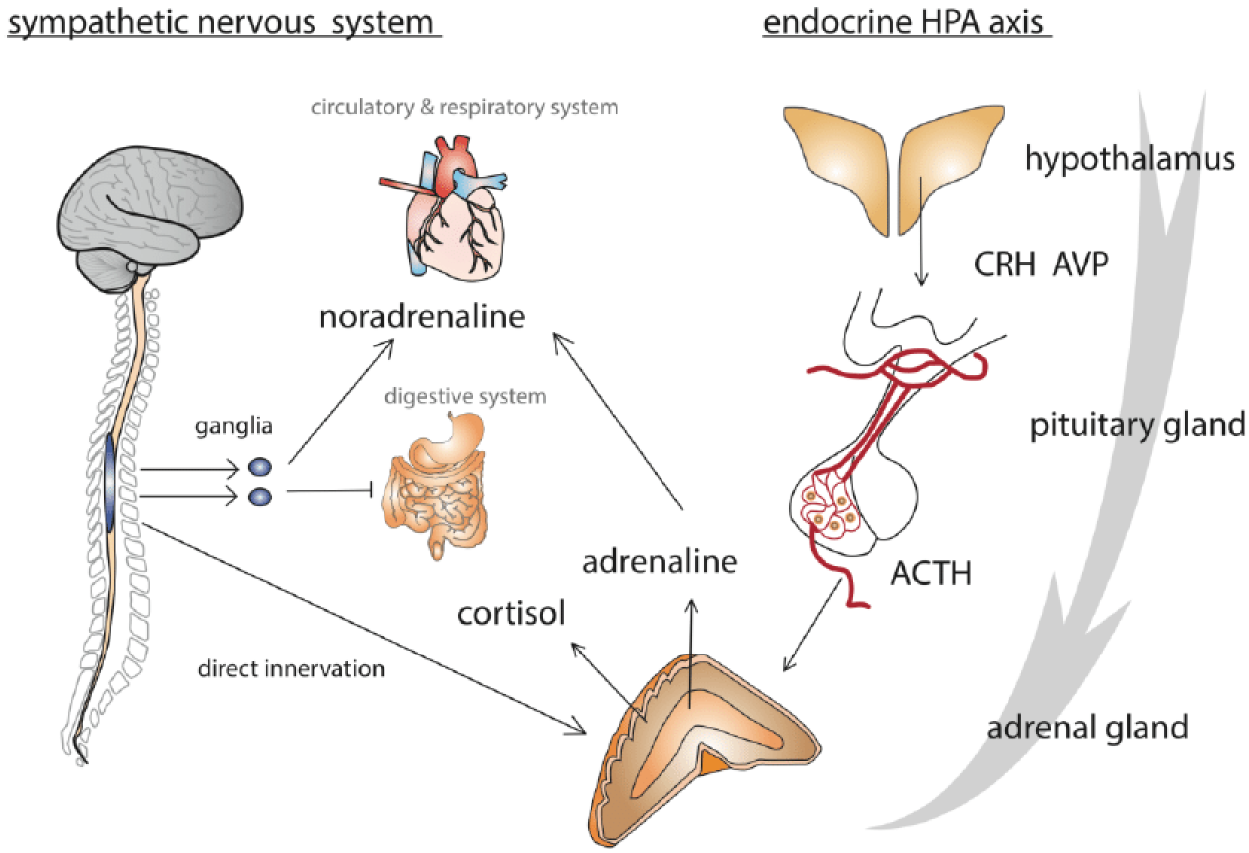
Stress and Resilience

Stress is defined as an “unspecific physiological and psychological reaction to perceived threats to our physical, psychological or social integrity” (Adli, 2011, p.1). In the eye of evolution, the stress mechanism functions as a flight-or-fight response which helps to adapt better to the environment. In this sense, stress is not harmful. Though, periods of extreme stress can lead to chronic health issues. Stress is registered by the brain and affects the autonomic, cardiovascular, metabolic, neural, and immune systems (McEwen, 2008). As mentioned, stress is a reaction to a perceived threat. This threat can consist of experiences in daily life such as the work environment or the neighborhood one lives, major life events amongst losing a parent, or trauma or abuse (McEwen, 2008). The determination of responses to stress is influenced by both genetics and early life experiences.

Stress starts with a stressor that is registered by the brain (McEwen, 2008). The brain determines what is stressful, and determines the behavioral and physiological response to potential and actual stressors. A human organism has two major hormonal stress systems, the automatic response system, and the hypothalamic-pituitary-adrenocortical (HPA) system (see figure 1) (McEwen, 2008; Adil, 2011), which are activated as a response to the registered stressor. The autonomic nervous system controls the adrenaline and noradrenaline release (Adil, 2011). The adrenaline and noradrenaline levels increase heart rate while the heart rate variability decreases.

The second system is the hypothalamic-pituitary-adrenocortical (HPA) system, responsible for the release of cortisol (known as the stress hormone). The release depends on the perceived danger of a particular situation. Cortisol antagonizes insulin, and thus when cortisol remains high due to persistent levels of stress and dysregulation of the HPA system can result in a diabetic metabolic state. This state restructures body fat, suppresses the immune system, can have a toxic effect on neurons mainly the hippocampus area (important for memory functions), and promotes obesity. Important to note is that all of these systems start in the brain, and everyone’s brain is different and thus reacts differently to the same stressors. An overload of experienced stress results in changes in sleep, eating and drinking habits, smoking, and lack of physical activity (McEven, 2008). This has major effects on one’s perceived health.

Figure 1 - Human Response System to Stress



Source: (Even et al., 2012).

The concept of allostatic overload is a combination of chronic stress together with personal behavior such as smoking, poor sleep quality, or excessive eating or drinking (McEwen, 2008). Chronic stress effects are visible after an individual has experienced a certain amount of stress for weeks. The effects are visible in the hippocampus, prefrontal cortex, and amygdala, with altered adaptive plasticity of certain stress mediators such as the excitatory amino acids, and polysulfated neural cell adhesion molecule (PSA-NCAM), tissue plasminogen activator (tPA), and brain neurotrophic factor (BDNF). McEwen (2008) states the importance of the policies of both the private and public sectors in minimizing the burden of chronic stress and related lifestyle choices.

Evidence from the literature supports that rural and urban spaces have different impacts on mental health (Adli, 201; McCay et al., 2019; Buttazzoni, 2022), despite socioeconomic conditions, infrastructure, nutrition, and health care services generally being better in cities compared to rural areas (Adli, 2011). One of the possible explanations for this is the increased experience of stress in urban settlements. More specifically, social stress. For example, living in a crowded area or experiencing social disparities are associated with social stress. Also, the disturbance of chronobiological rhythms is related to an increased experience of social stress. Aside from these components, stress is also related to individual determinants of stress, such as marital-, socioeconomic, and employment status (Yang & Matthews, 2010). Neighborhood crime rates, socioeconomic status, and residential stability are factors of social stress that relate to the aforementioned determinants.

There are multiple ways of coping with stress that are either problem-focused or emotion-focused (Lazarus, 1993). Coping means that one is dealing with a stressful situation at hand. One important factor in this is social support (Evans, 2003), and can be considered a problem-focused coping. There is a direct cause that can be solved. This cause can also be in the spatial design. When the stress is emotion-focused the cause is not directly clear (Lazarus, 1993). Here the creation of a stress-free or stress-reduced environment is the solution. Creating such an environment is known as restorative planning (Bodin & Hartig, 2003).

2.2 Public Health in Relation to the Urban Environment

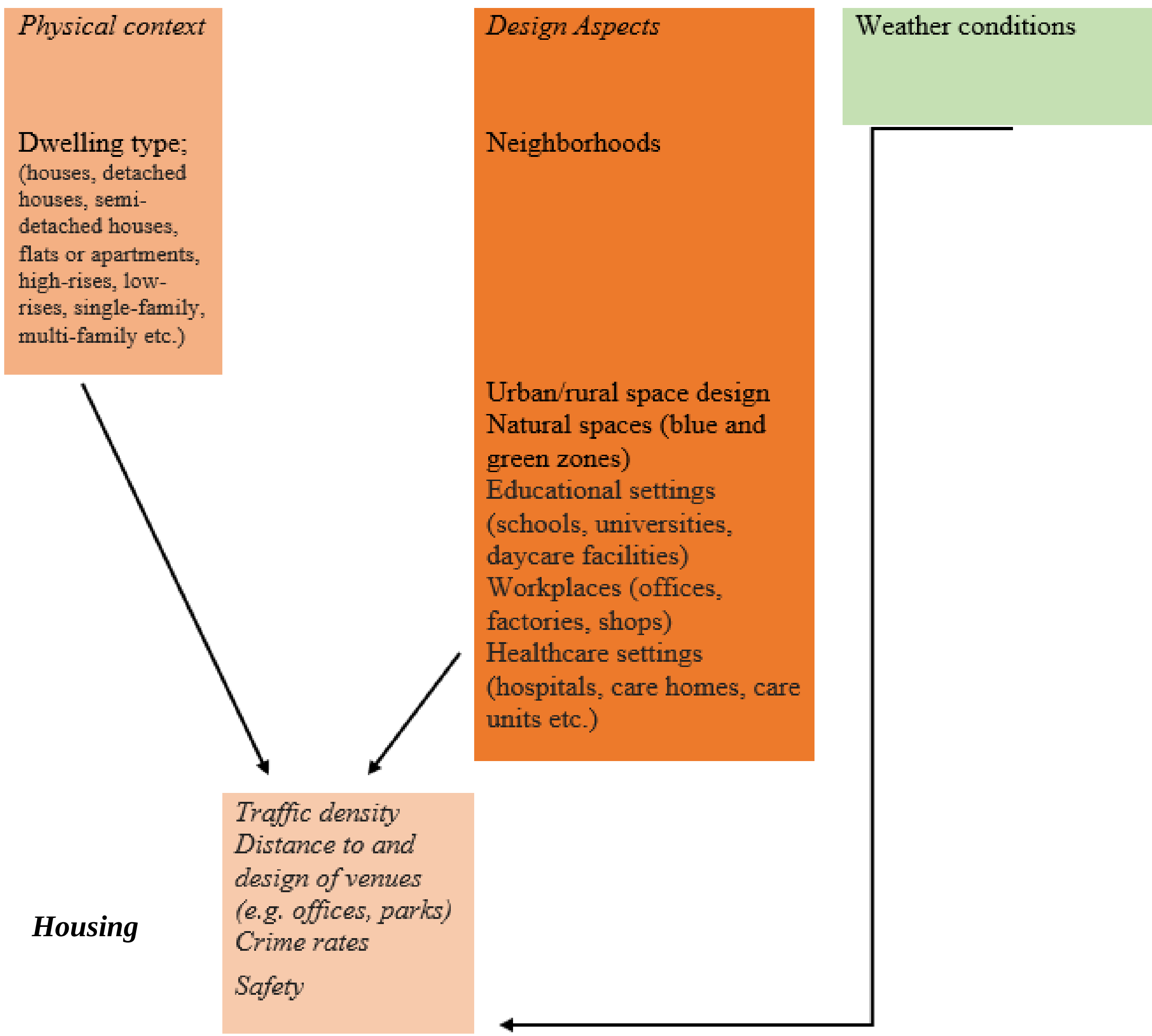
2.2.1 Physical Structures and Public Health

The physical environments are the objective and perceived characteristics of the physical context in which people spend their time (e.g. home, neighborhood, school) including aspects of urban design (e.g. presence and structure of sidewalks), traffic density, distance to and design of venues (e.g. offices, parks), crime, safety and weather conditions (Davison and Lawton, 2006). Cooper et al., (2008) distinguished seven categories to describe different types of physical environments. Figure 2 gives an overview of built factors that influence public health according to Cooper et al., (2008) and Davison & Lawton (2006).

Determinants of public health are social, economic, personal, and environmental factors (Healthy People, 2020). Behavioral factors can be influenced by policy. For example, the government can raise taxes on smoking. Another example of policy influencing behavior is related to the public design, such as walkability, providing areas for outside activities, and measurements to improve the overall neighborhood safety. When there is limited access to a safe neighborhood or area, one is less likely to engage in physical activity outside (Molnar et al., 2004). Also, crime rates are correlated with cardiovascular diseases (Sundquist et al., 2006). And due to higher crime rates, people are less willing to go out on the streets, decreasing their daily physical activity levels (Savenkoul et al., 2011). This problem is most common in lower SES neighborhoods. The concept of lower SES-neighborhoods experiencing greater health problems is known as health inequality

(Gelormino et al., 2015). Health inequalities are attributed to the external environment (Badland & Pearce, 2019). The RIVM (2011) conducted a literature review for effective policy measures to reduce health inequalities relating to a lower socio-economic status. RIVM found that greenery in a neighborhood, safety, the noise of traffic, social cohesion and social support, the indoor environment of homes, and the air quality are points to reduce health inequalities within a municipality. Though, the effect of a lower socio-economic status on health is determined firstly by behavioral factors such as excessive alcohol consumption, lack of physical activity, and being overweight. Second are psychosocial factors, such as personality traits such as external mastery orientation and hostility, and prolonged difficulties due to financial difficulties. And lastly, material or structural environmental factors. For example, low income and unfavorable working conditions (physical and psychosocial)

Figure 2 - Overview Cooper et al., (2008) and Davison & Lawton (2006).



In italics: Davison & Lawton (2006); Normal: Cooper et al., (2008).

Scholars have explored the quality of dwellings more than any other physical environment, possibly because of the cultural significance attached to dwellings (Rapoport, 1969), and secondly because of the amount of time that individuals spend in these particular physical environments (e.g. mothers with 0-2 year-olds spend close to 10 hours a day at home, excluding sleep time) (Cooper et al., 2008). Housing is widely recognized as a major social determinant of health (Badland & Perace, 2019). In terms of density, individuals living in conurbations and higher-density areas report higher levels of all types of psychophysiological symptoms, including stress, anxiety, aggression, and increased sense of physical and emotional vulnerability (Evans, 2003). Additionally, crowding is believed to have substantial negative effects on social relations and psychological health (Baum and Paulus, 1987). Generally, individuals living in high-rise buildings suffer significantly higher levels of mental health problems than those in low-rise developments. Mental health problems include alienation, feeling less happy and healthy, complaining about isolation and loneliness, greater social overload, less sense of control and safety, less social support and social relations, and less attachment to the community (Badland & Perace, 2019).

The quality of those physical environments is crucial to learning and mental capital through life, with poorer-quality environments more negatively impacting mental well-being than better-quality environments. Poorer housing quality can lead to poorer mental health (Evans, 2003). This can include increased feelings of isolation, excessive worrying and depression. More research is needed to examine how mental well-being is impacted by multiple environments throughout individuals’ lifetimes (Cooper at el., 2008), and translate these into usable models. The models that are currently profound are child-friendly communities, smart health environments, healthcare industrial cities, age-friendly communities, collaborative healthy cities, and healthy-built environments are six models concerning healthy place-shaping (Forsyth, 2020). Policies impact the public realm, and thus human health (UrbAct, 2021). For example, if a city is designed predominantly for car-use or bicycle use by city planners. Interestingly, health experts are rarely involved in the development of urban policy or plans. To combat this issue, planners can make use of the Health Impact Assessments (HIAs) to better recognize the impact of various urban factors on health.

Exposure and access to nature

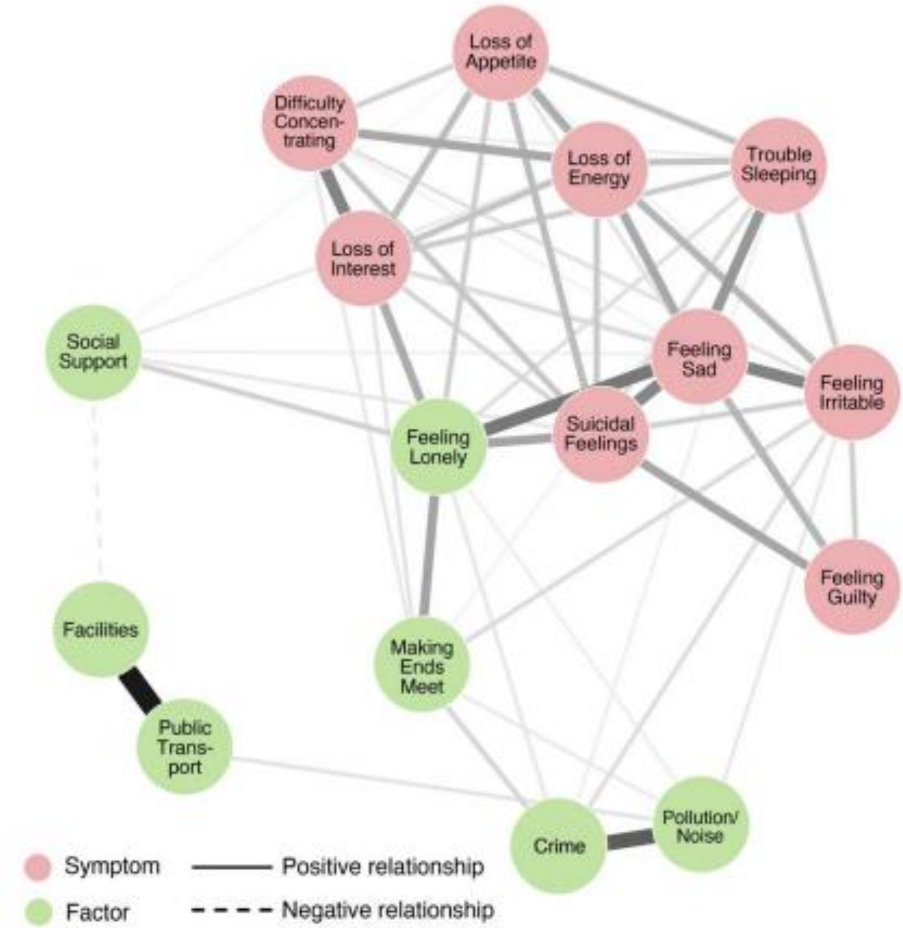
The availability and access to green space have important well-being and health outcomes, such as improved mental health and physical activity, improved child development and social development amongst social cohesion, and reduction in stress levels, blood pressure, and the risk of chronic diseases (Badland & Perace, 2019). Exposure and access to views of nature from a variety of physical environments can improve individuals' health and well-being by providing restoration from stress and mental fatigue (Jimenez et al., 2021). Conversely, an inability to spend time in natural areas may be associated with poor psychological well being (Wells and Evans, 2003). Nature has the restorative power to reduce stress. In neighborhoods, a positive relationship exists between the presence of greenery and residents' health, well-being, and social safety (Wells and Evans, 2003). The RIVM (2011) discussed that self-reported health rates are reported lower in areas where there is a limited amount of greenery. Though, living in a neighborhood with access to a shared recreational space was associated with a higher prevalence of depression (Weich et al., 2001; Weich et al., 2002). Overall, living in a neighborhood with little greenery has a 1.33 higher chance of depression, especially when one has a lower socio-economic status (Maas et al, 2009). The RIVM (2011) discussed that designing hiking networks, and the construction of municipality gardens and a 'greenway' can improve the social cohesion in a neighborhood, and with that improve the local health. Besides, walking improves both physical and mental health. A greenway is an area with recreational facilities outside, walk- and bicycle routes, and educational programs.

Walkability

Walkable neighborhoods encourage public and active transportation and stimulate more frequent social interactions (Badland & Perace, 2019). Walkability increases physical activity, which reduces the risk of obesity and many non-communicable diseases. Though a walkable neighborhood seems better for one's health, these neighborhoods can have higher levels of air and noise pollution due to greater traffic exposure necessary for the street connectivity of public transport stops (King & Clarke, 2015). Additionally, walkable neighborhoods tend to have more high-rise buildings of which the adverse health effects are mentioned. To improve the safety of a walkable neighborhood street lighting is of importance (RIVM, 2010).

Van der Wal et al., (2021) researched various factors influencing mental health in urban settings. Figure 3 gives an overview of their regression-based mixed-geographical model. The thickness of the lines resembles the strengths of the positive (straight line) or negative (dotted line) correlations. The red dots are symptoms associated with depression. The green dots are urban environmental factors. This research shows, for example, that public transport is positively correlated with noise and pollution. Having a city design where street corners meet is positively associated with feeling lonely, reducing the feeling of loneliness. The factors in red are personal factors that can be influenced by the city design. Wells and Evans (2003) came up with three categories that are important pillars in urban design (see table 1). For example, a crowded area in 2.3 has psychological impacts. To reduce these impacts, one can focus on accessibility, density, wayfinding, and feelings of safety when improving the area.

Figure 3 - Network of Urban Factors and Symptoms of Depression



Source: Van der Wal, et al., (2021).

Table 1 - Wells and Evans (2003) categories for urban design

	2.1 Quality of the fabric of the physical environment	2.2 Quality of the ambient environment	2.3 Physiological impacts of the physical and ambient environment
Construct opportunities	Design, construction and maintenance of the buildings, spaces between the buildings, and associated infrastructure	Lightning, noise, thermal quality, access to nature	Density, accessibility, safety and fear, and wayfinding
Examples	Housing requires major repairs. Graffiti or rubbish Lack of recreational space Public drinking or drug use Abandoned buildings	Excessively built with no green space, or no views. Neighbor noise Living near an airport	Crowded settings and lack of privacy High-rise buildings Crime and fear of crime as a result of urban form and poor lightning Poor layout, pavements and/or access

Source: Wells and Evans (2003)

2.2.2 Social structures that influence public health

Housing, the greenery in an area, and the walkability of a neighborhood are factors that can be improved using architectural design. The following factors are important social factors that influence public health. Though, these factors cannot be improved using architectural design. Nevertheless, it is important to take these factors into account.

Employment equals civic participation, long-term health, and personal development (Badland & Perace, 2019). Though, the working conditions determine one's physical and mental health. Higher-paid jobs tend to be located in inner cities, thus requiring a dwelling nearby or commuting opportunities, which may be unavailable to more disadvantaged households. The costs of living near city centers are generally higher making relocation an unavailable option. The disadvantaged households need to invest in private automobiles, and with that come the costs of maintenance and possibly the need for more vehicles per household to commute. Public infrastructure may be insufficiently available to employment hubs, or their working hours do not match with the public transport timetables. Altogether these create a transport disadvantage. Improving the jobs-housing balance across a region can encourage economic participation and reduce inequalities.

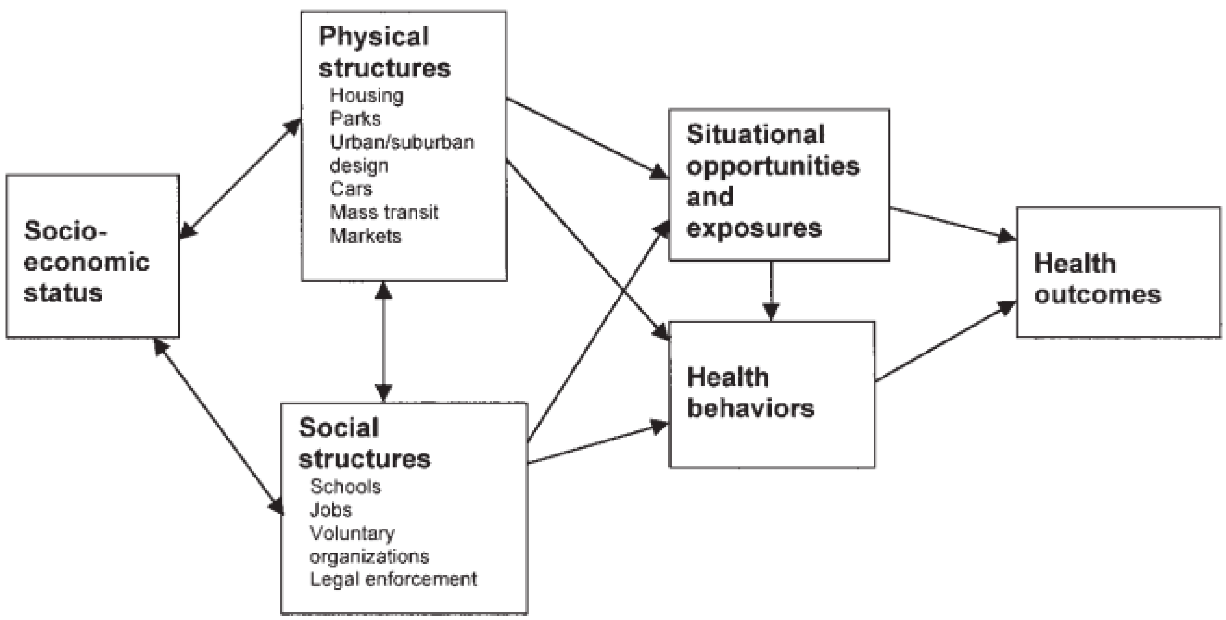
Social Relationships and Social Trust within a neighborhood

As named in figure 2, social support is an important aspect of one's perceived well-being. Cohen et al., (2003) add that maintaining social relationships and having a sense of social trust significantly improves health outcomes. Physical structures may influence the social realm by social controls and relationships. Figure 4 gives an overview of the study outcome of Cohen et al., (2003) concerning health outcomes.

Notwithstanding, the neighborhood effect has to be taken into account. The study by Ludwig et al., (2012) found that moving from a distressed neighborhood to a less-distressed neighborhood positively affected one's subjective well being. Leventhal & Brooks-Gunn (2003) add that this move might also improve both physical and mental health. Yet, it is difficult to study the links between health and neighborhood characteristics, as the datasets have a certain level of bias (Ludwig et al., 2012). For example, high-rise buildings are associated with higher crime rates in comparison to low-rise buildings (Cohen et al., 2003), though these effects are not always included in a zip-code specific location per neighborhood.

Studies have shown that living in commercial inner-city streets results in children experiencing feelings of loneliness and fear. Even though these results were controlled for social class and family composition, individual characteristics and life events, for example, were not taken into account. This proves that there is always a certain level of bias in these results that one should be aware of (Ludwig et al., 2012). This is called the non-differential measurement error (Mooney et al., 2014). Quantifying neighborhood analyses mean that sensitive data is collected that may be measured with errors. The paper found that this holds true for nearly all neighborhood-level contextual factors such as the poverty rate. Expectations are continuously measured income variables and variables expressed as quantiles. Kruize (2007) found that in the Netherlands, people with higher incomes and higher education are more often involved in their neighborhoods in comparison to lower income groups or lower educated households. Research has shown that the development of playgrounds in a neighborhood is the best way to foster social and sports encounters (RIVM, 2010). A playground improves social cohesion and social safety within a neighborhood. By improving, social cohesion tends to make people feel less lonely, which improves their self-reported health.

Figure 4 - Environmental Influences on Health



Source: Cohen et al., (2003).

Education

Maintaining education is a key predictor of morbidity and mortality across the life span (Badland & Perace, 2019). Education is associated with enhanced economic and health trajectories and reduces the likelihood of committing crimes. Education is a way of improving one’s socioeconomic status, though the provision of education facilities is not a sufficient intervention. The availability and quality of the schools should be equally distributed amongst different neighborhoods.

Healthy city planning

Liveable cities and neighborhoods are defined as "safe, attractive, socially cohesive and inclusive, and environmentally sustainable; with affordable and diverse housing linked by convenient public transport, walking and cycling infrastructure to employment, education, public open space, local shops, health and community services, and leisure and cultural opportunities" (Lowe et al., 2015, p. 12). The design of the physical environment is closely linked to social psychology, as the design shapes social processes such as interpersonal relationships and social identity (Meagher, 2020). The physical environment is constraining and guides social-psychological activity and thereby facilitates individual and collective behavior. Additionally, humans learn through social interaction. Social interaction together with the design of the environment determines the individual and collective behavior. For example, a cauliflower neighborhood is designed to increase social interaction. Linking this to spatial theory and determinants of health, one can conclude that in a space with higher social interaction one experiences their health better in comparison to lesser social interaction environments (Cohen et al., 2003). This can be concluded because health is determined by, amongst others, social interaction (Healthy People, 2020). Social interaction also positively influences the feeling of safety in a neighborhood and a stronger sense of community (Francis et al., 2012). The former increases the likelihood of going outside, and thus increases the level of physical activity. Designing a healthy, inclusive city is an integrated process (Gehl Institute, 2018). Factors to take into account are accessibility, safety and security, community stability, social participation, civic trust, and quality of the public space, to name a few. The full diagram of the Gehl Institute that illustrates healthy, inclusive city planning can be found in Appendix 8.

2.3 Architectural Design Implementations

As mentioned, the social aspects cannot be solved by design implementations alone. As mentioned in chapter 2.1, stress can have negative health effects in the long run. One important aspect of stress reduction is social support (Evans, 2003). The lack of social support is known to be an urban stressor (Burton, 1990). This urban stressor can be triggered by various factors. For example, crowding results in social withdrawal, which negatively affects social support. Several design criteria support social relations and create restorative environments that reduce stress in the long run. The reduction of stress positively affects public health. Restorative urbanism aims to foster human flourishing through urban design, focusing on improving mental health and reducing exposure to social stress (Roe & McCay, 2021).

An example of a restorative city design is the mixing of workplaces, shops, restaurants and cafes, and residences to bring people out at various times of the day (Roe & McCay, 2021). Another example is having design elements that promote curiosity, such as public arts and murals (illustration 1). Lastly, it is important to have community amenities, such as libraries and community gardens, facing the street to suggest 'open doors'.

Illustration 1 - Mural Art in Stoepemaheerd, Beijum

Source: Ter Veen (2022), Sikkom.

As mentioned above, housing, walkability of a neighborhood, and greenery in an area are factors that can be improved using architectural design. These will be the factors that this thesis will focus on. Green space focuses on a stronger sense of place attachment, which may in turn strengthen the social cohesion in an area (Roe & McCay, 2021). The improved social cohesion leads to a better experience of social support, which positively affects the experienced health. Nature interactions can provide stress relief and can improve one's mood. Design implementations for a green city are the following:

Illustration 2 - Design Implementations for a Green City

Green courtyards	 Design example
Large downtown parks	 Noorderplantsoen, Groningen
Green roofs	

	Rooftop in Groningen
Large park	 Kardinge, near Beijum and Lewenborg
Shared playing field	 Oosterpark

Green edges	 Design example
Pocket park	 Oosterpark
Green walls	 Universidad del Claustro de Sor Juana, Mexico City

Linear park	 Design example

These design implementations are based on city-scale.

Along with greenery come blue spaces and its positive effects on stress reduction and public health. Waterways are a design implementation to reduce stress in a restorative way. Waterways also reduce heat stress and increase opportunities for physical activity and social interaction. In Lewenborg Le Roy (1924-2012) designed parks with water connecting throughout the neighborhood (figure 8). This is an example of combining blue and green city design to flourish public health.

There are also multiple important design factors to take into account on a neighborhood level (Roe & McCay, 2021). The division between public and private is important to safeguard safety, privacy and positive social interactions. This can be done by clearly setting the boundaries of public and private space. Also the creation of ‘bumping places’ where people can encounter each other in safe, informal settings such as a park or the street, is important. Other design implementations that can be done to improve social cohesion and public health are:

Ilustration 3 - Design Implementations for Social Cohesion

<table>
<tr><td>Investing in third spaces that are welcoming to all and require no money, such as community gardens and libraries.</td><td>
Torteltuin Beijum</td></tr>
<tr><td>Provide pet amenities such as a dog park to promote social interaction.</td><td>
Design example</td></tr>
<tr><td>Create areas with benches, facilities to exercise outside for all ages to improve social cohesion and interaction.</td><td>
Oosterpark: benches, a playground and a Jeu de Boules court.</td></tr>
</table>

Lastly, a way of improving public health is the creation of an ‘active city’. The design implementations for these are the following (table 2):

Table 2 - Design Implementation for an Active City

Place features: Mixed land-use, residential density, and multi-modal streets	**Transportation infrastructure:** Public transport and hubs
Workplace: Active building design and public transit	**Schools:** Safe routes, outdoor recreation
Improved cognitive health	Improved mood through endorphin release
Improved sleep	Increased exposure to restorative environments

Source: Roe & McCay, (2021), based on p. 116

3. Methodology

In this quantitatively-oriented research two methods were used to measure the urban environment objectively, namely Geographic Information Systems (GIS) and an independent site-analysis. The latter was conducted in areas that performed poorly compared to higher ranked areas in the municipality of Groningen (see chapter Results). The GIS analysis had the potential to explore the role of the dimensions discussed in the themes above concerning a geographical area (Talen & Shah, 2007). The use of GIS had multiple advantages compared to regular statistical analysis. Namely, the data became visible, interactive, dynamic, and interrelated. A methodological advantage of GIS was that this method allowed for interactive analysis of a neighborhood, where data layers can be added or subtracted to create an interactive view. The GIS method allowed for areas-specific analysis. The method needed to be area-specific as one of the aims of the study was to contribute to reducing health inequalities. Health inequalities are a spatial phenomenon, in which GIS helps to find and visualize these inequalities.

The GIS analysis answered which factors spatially hold true as explanatory variables for self-reported health found in the literature review. The independent site-analysis allowed for further exploration of the GIS results, with an outcome of design implementations with regards to improving public health in poor-quality public areas. The site-analysis was the bridge of bringing the study outcome to real recommendations for the municipality of Groningen. The design recommendations were slighthy based on RIVM research on public health and the healthy ageing plans of the municipality of Groningen (see 3.2.1).

3.1 Data

The GIS analysis was performed using the neighborhood borders of 2020 set out by the *Centraal Bureau voor de Statistiek* (CBS). Most datasets on possible explanatory variables were available from 2020, therefore it was chosen to use 2020 as a foundation year. The research used secondary data sets from the CBS, which included gender, the age-category 25-44, home-ownership, availability of several services such as a large supermarket within one kilometer, and percentage of social contacts in the neighborhood to name a few. The *Rijksinstituut voor Volksgezondheid en Milieu* (RIVM) provided datasets on social cohesion, self-reported health measures and health rates in the neighborhoods. The national police data bank provided criminality records on a neighborhood scale. These datasets were joined together based on similar neighborhood codes. All these factors were combined in one shapefile, and used for further analysis. Table 3 gives an overview of all variables that were evaluated in different models using the OLS regression. The in-depth explanation of the regression can be found in chapter 3.2.2.

It was hypothesized that in neighborhoods with lower socioeconomic statuses the self-reported health would be lower. To further explore the explanatory factors of self-reported health rates in specific neighborhoods, a spatial regression was performed. It was hypothesized that self-reported health would positively correlate with having a higher income, having greenery in the neighborhood, having social cohesion in the neighborhood, and having enough exercise in one's daily routine.

Table 3 - Overview of the dependent and independent variables

Variable name	Description	Data source

Dependent		
Self-reported health (good/really good)	How the respondent rated their health, of which the good/very good rates are published.	RIVM
Independent		
gm_naam	Name of the municipality	CBS
WW_uit_tot	Social security receivers within a neighborhood	CBS
Sted	Urbanicity rate	CBS
Bev_dichth	Population density	CBS
A_vrouw	Gender: female, the amount per neighborhood	CBS
A_man	Gender: male, the amount per neighborhood	CBS
P_gesch	Marital status: divorced	CBS
a_ongeh	Marital status: not married	CBS
a_gehuwd	Marital status: married	CBS
a_verwed	Marital status: widow	CBS
P_koopw	Properties for sale	CBS
p_huurw	Rental properties	CBS
Nabijheidheid booschappenwinkel 1 km	Having a large supermarket within 1 kilometer	CBS
Nabijheidheid huisarts 1 km	Having a general practitioner within 1 km	CBS
A_00_14, a_15_24,	Age categories	CBS

a_25_44, a_45_64, a_65_oo		
Crim_indicidents	Number of criminality incidents per neighborhood	National Police records
Langdurige_aandoening	Having one or more long-term health condition	RIVM
Depressie_risico	Risk of depression	RIVM
Hoog_risico_depressie	High risk of depression	RIVM
Stress	Experienced stress levels	RIVM
Lichamelijke beperkingen	Physical disability	RIVM
Eenzaamheid	Feeling lonely	RIVM
Roker	Smoking	RIVM
Overgewicht	Obesity rate	RIVM
Alcoholgebruik	Drinking alcohol	RIVM
Bewegen voldoende	Having enough exercises according to the guidelines	RIVM
Gehecht aan de buurt	neighborhood attachment	OIS
Inkomen 110 van sociaal minimum	Income is 110% compared to the social minimum standard	OIS
Inkomen onder of rond sociaal	Income is under or around the social minimum standard	OIS

minimum		
Buurt cohesie	Social cohesion within the neighborhood	Kompas
Tevredenheid groenvoorzieningen	Satisfaction with green spaces in the neighborhood	Kompas
Tevredenheid winkelvoorzieningen	Satisfaction with the shopping facilities in the neighborhood	Kompas
Tevredenheid openbaar vervoer voorzieningen	Satisfaction with the public transport connections in the neighborhood	Kompas
SES-WOA	Is the average score for social-economic well being, based on welfare, level of education, and the recent work experience per household	CBS

3.2.1 Literature research

To establish factors that were possibly correlated with self-reported health, a literature study was performed. Notably, as the study area was the municipality of Groningen, a factor that reflected density was important to add. The literature review formed the basis for the regression analysis factors (table 3). An important theme in the literature study was the analysis of relevant policy documents and strategies of the municipality of Groningen to tailor the study recommendations of this research to, and built upon measures taken. The RIVM "*Terugdringen van gezondheidsachterstanden door gemeentelijk beleid: een literatuurverkenning naar effectiviteit van fysieke en sociale omgevingsmaatregelen (2010)*"[1] and the council proposal of the municipality of Groningen with regards to healthy aging and Groningen Gezond 2018-2021 were analyzed in Atlas.TI 9 and used as input for this research. The documents were coded in three categories: plan, approach and outcome. Plan meant the idea, approach was the means to do it and in what timeframe, and the outcome referred to the expected outcome and timeframe.

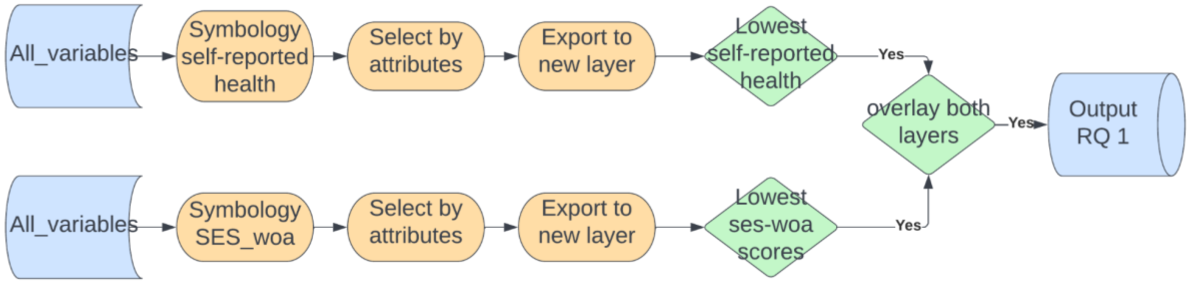
[1] Reducing health inequalities through municipal policy: a literature review on the effectiveness of physical and social environmental measures (2010)

3.2.2 Spatial Analysis using GIS

The CBS provided a shapefile for all neighborhood divisions in the Netherlands in 2020. From this shapefile, the municipality of Groningen was selected using the ‘select by attributes’ tool. Thereafter the datasets visible in table 4 were tailored to the same neighborhood codes present in the CBS shapefile, using Excel. Once the Excel files were adapted, they were imported into GIS and transformed into a table. The table then was joined to the shapefile based on similar neighborhood codes. The shapefile with all relevant variables formed the basis for the analysis.

To test the hypothesis listed above, two spatial analyses were performed using GIS. First, the distribution of self-reported health rates was made visible using ‘symbology’. Thereafter, the lowest category (rates below 70.8%) was selected using the ‘select by attributes’ tool and exported as a new shapefile. Second, the symbology tap was used to visualize the SES-woa variable. The negative SES-woa variables were selected using the ‘select by attributes’ tool and exported as a new shapefile. The low SES-woa areas and the low self-reported health areas were then combined in one layer. This answered the first research question. This process is illustrated in flowchart 1. Appendix 1 gives the distribution of all self-reported health rates for the municipality of Groningen in 2020. To be able to say more about the relationship between SES-woa and self-reported health, a linear regression was performed using STATA to analyze the relationship between the self-reported health (dependent variable), the level of education and the average score for social-economic well being. ArcGIS Pro would give errors to using an excel file in the regression analysis, which was according to multiple online fora a recurring bug in the ArcGIS program. To perform this analysis in STATA, the table with the relevant variables was first exported to excel using the ‘table to excel’ tool. Thereafter, the table was imported into STATA. The data was summarized, which showed the education variables were read as ‘strg4’, meaning a string variable. The variables were encoded through the following formula: encode b, gen(nb), where b was the name of the variable. Hereafter, the regression was performed. The output is listed in Appendix 2. The results are discussed in the results chapter on regression.

Flowchart 1 - Overview Analysis step 1



Source: made by author using Lucid Flowcharts (2022).

Starting the regression analysis for the factors influencing self-reported health, first the rates below 70.8% were selected, which was the lowest category-boundary within the dataset. This selection would only give seven cases to perform the regression analysis with. Though, to avoid problems applying the regression, a N of ≥25 was recommended to have a higher variance and accurate inference (Jenkins & Quintana-Ascencio, 2020). Therefore, it was decided to select all cases with a self-reported health rate of ≤76.9%, which was the second category-boundary in the dataset. This left the regression with 27 cases. The second hypothesis was tested through a spatial regression. Prior to the regression a global Moran's I test was performed to provide information about the presence of spatial dependency of the dependent variable self-reported health and the etiological factors. The spatial autocorrelation measured whether there were clustered or randomized patterns represented (Mahara et al., 2016). A statistically significant Moran's I z-score of ≥ 1.96 would indicate that the neighborhood districts had a similar incidence of self-reported health clusters. The standardization K nearest neighbor was chosen. First, the average nearest neighbor tool gave clarity on the number of nearest neighbors, namely 1,210247, which is rounded off to 2 to allow the tool to work. The outcome of the Moran I's is given in table 4.1. The null hypothesis of Moran I's, which stated that the self-reported health variable is randomly distributed among the features in the study area, is accepted with a p-value of 0,496460. Thus, the pattern does not appear to be significantly different from random. Hereafter, the regression analysis was performed. First, the ordinary least squares (OLS) model was run to estimate the effect of various factors on the self-reported health. The outcome is given in table 4.2. Though, when adding necessary variables that could possibly explain the relationship between self-reported health and neighborhood characteristics, the variables did not have sufficient data available for the selected neighborhoods.

Therefore it was decided to perform a regression analysis based on all the neighborhoods within the municipality of Groningen.

Again, a spatial autocorrelation was performed using the dataset with all neighborhoods within the municipality of Groningen. The average nearest neighbor tool gave a ratio of 0,937552, which was rounded off to 2 as the Moran I otherwise would not execute. The null hypothesis of Moran I's stating that the self-reported health variable is randomly distributed among the features in the study area, is accepted with a p-value of 0,153526. Thus, the pattern does not appear to be significantly different from random. Hereafter, the OLS was performed. The outcome of the OLS was given in table 7.1 and 7.2 in the results chapter.

Table 4.1 - Moran I's Spatial Autocorrelation

Moran's Index	-0,157776
Expected Index	-0,038462
Variance	0,030781
Z-score	-0,680071
P-value	0,496460

Table 4.2 – OLS Model Outcome selection ≥76.9%

Summary of OLS Results - Model Variables

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	74,062681	3,615145	20,486782	0,000000*	2,479984	29,864182	0,000000*	--------
BUURT_2020_V	-0,689690	0,690785	-0,998415	0,330007	0,529509	-1,302510	0,207543	2,988049
BUURT_2020_V	-0,000265	0,000326	-0,813275	0,425638	0,000228	-1,163947	0,258145	4,032916
BUURT_2020_V	0,001087	0,000890	1,220856	0,236340	0,000550	1,977597	0,061918	3,644900
BUURT_2020_V	0,000000	0,000000	0,765424	0,452958	0,000000	1,996761	0,059641	5,251905
BUURT_2020_V	0,000000	0,000000	0,349067	0,730687	0,000000	0,273201	0,787500	5,345440
BUURT_2020_V	-0,000000	0,000000	-1,332499	0,197681	0,000000	-1,402266	0,176167	7,127701

Variables: sted, bev_dichth, aant_vrouw, p_gescheid, p_koopwon, ww_uit_tot

3.2.3 Site Analysis

After the regression analysis was done, a site analysis was performed to overcome the limitations of solely statistical data by designing location-based interventions. The neighborhoods used for this analysis were the four neighborhoods identified through the first spatial analysis, namely Vinkhuizen-Zuid, de Kring, Beijum-Oost and Lewenborg-Noord.

The site analysis focused on taking an inventory of the neighborhoods and listing relevant information about the sites. The analysis focused on the physical, cultural/man-made and sensory factors. Table 5 gives the selection of the analysis criteria. The aim of the site analysis was to design spatial opportunities to reduce health inequalities in the municipality of Groningen.

Table 5 - The Elements of the Site Analysis

Theme	**Components**	**Scale**	**Level**	**Legend**
Public Space	Water	Neighborhood	Element	Ditch Portwadic Deep
	greenery	Neighborhood	Element	allotment garden Park Meadow wet bank Thinly wooded area Densely wooded area
Buildings	Construction year	Neighborhood	Building	before 1945 1945-1960 1960-1975 1975-1985 1985-1995 1995-2005

				2005-2015 after 2015
	Building height	Neighborhood	Building	<10 m 10-15 m 15-20 m 20-25 m >25 m
Street structure	Street structure	Neighborhood	Element	Main streets Secondary streets Bike lanes Footpaths
	Street structure	Neighborhood	Element	Crossings: zebra, traffic lights
Urban blocks *Block = area surrounded by streets*	Structure	Neighborhood	Element	Sizes Lengths
Distribution of functions	Structure	Neighborhood	Element	Shops Cafes Public spaces/social hubs Public health facilities

Source: C. Wagenaar (2022).

3.3 Ethical Considerations

The datasets used in the study were anonymized by CBS. The level of analysis did not run into any issues regarding personal or zip-code information as the level of analysis was done on the neighborhood-level. The presentation of the results of the regression analysis was done objectively, discussing the results with considerations of minimizing the harm done to the inhabitants of these neighborhoods. The data used in the shapefiles were stored on a two-way authentication account, managed by the University of Groningen. The field analysis was done in favor of the inhabitants of that neighborhood, keeping in mind again the principle of minimisation of harm to the study objects.

Validity of the data

The validity of the data is reviewed through the reliability and validity of the data (Punch, 2014). Reliability is the consistency of measurements of the data. All data reviewed in this study was measured by research institutes such as the RIVM and the CBS. The reliability of the secondary data cannot be calculated, though given the resources of the data as well as overlapping results of different data studies, one can assume that the data is reliable. Validity is the extent to which an instrument has measured what it claims to measure. To assure validity in secondary data, it is important to take note of the collector, the purpose of the collected data, when and how the data was collected, and if the data is consistent with other sources. Within the scope of this study, the validity of the data can be assured for the data collectors used within this study. The secondary data used in this study was collected between 2019 and 2020 by CBS, RIVM and the Kompas Groningen. The data was collected through surveys and using registered information from the government. The RIVM and CBS are authorized to use this information.

The datasets had the fallacy of measuring adequately all of the individual and family-level characteristics that influence life outcomes and neighborhood selection (Ludwig et al., 2013). This type of bias can affect the estimation of neighborhood effects.

To be able to analyze multiple factors influencing self-reported health several organizations gathering data were evaluated. Unfortunately, these different organizations used different neighborhood distinctions or had a less detailed division of the municipality of Groningen in comparison to the CBS neighborhood boundaries of 2020. This led to the loss of data when combining the different datasets to shapefile. The different measurement areas also led to possible wrong conclusions about a geographical area. The study did not take into consideration the effect of life events on experienced health or stress-levels, as well as day-to-day personal commuting stress was not included in the analysis. This has influenced the outcome of the data and following results of the analysis.

3.4 Positionality

The researchers' site analysis may have been less objective as the researcher has a history in Groningen and had been familiar with the neighborhoods for years. The researcher has not lived in the neighborhoods that were analyzed in the site-analysis. The living experience can influence one's perception, and can often give a better understanding of the area. Therefore, it is recommended to, for some neighborhoods with specific issues, to explore the area in a qualitative manner and collect the stories behind the data.

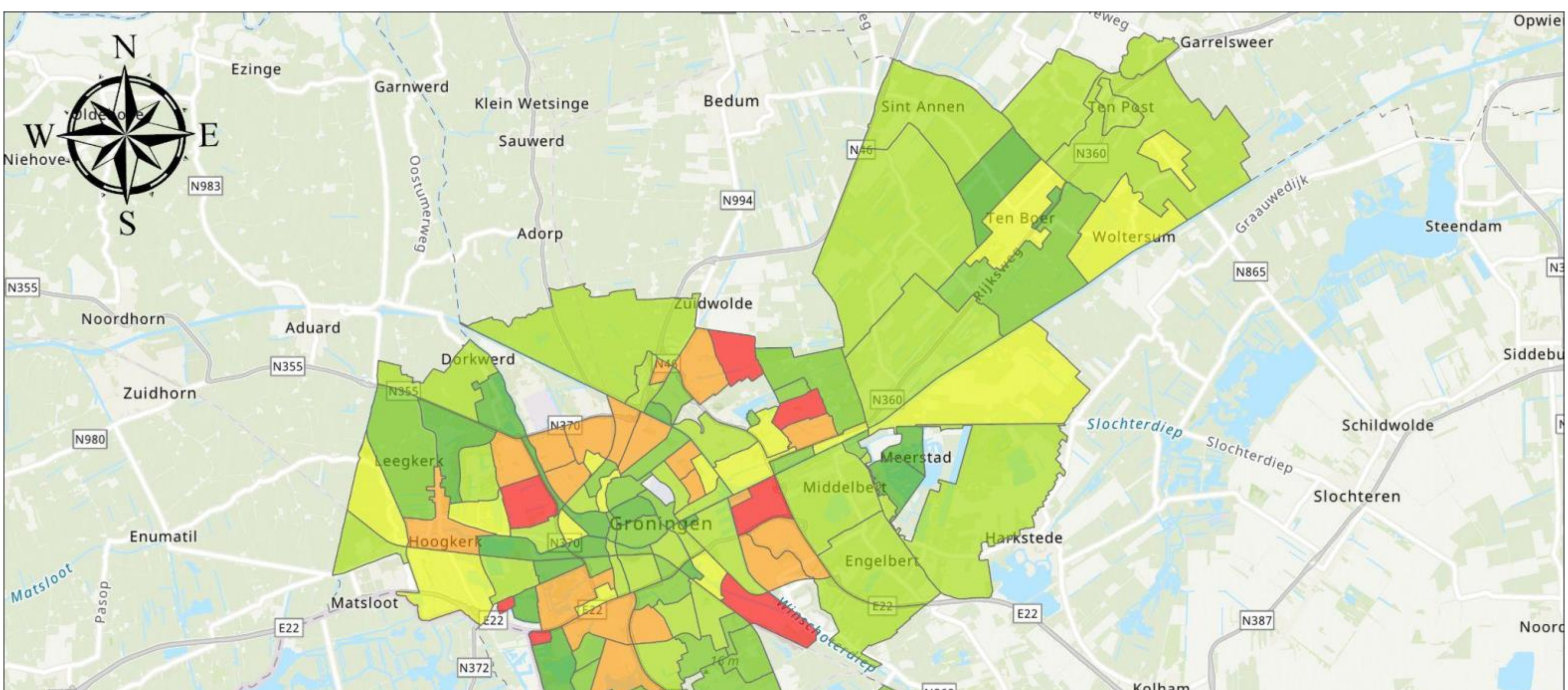
4. Results

As visible in figure 4, people that live in neighborhoods around the city center have reported their health to be lesser in comparison to the inner city neighborhood, as well as neighborhoods to the south-east of the municipality. There are many factors that could explain why these inhabitants in these neighborhoods experience their health to be less. The OLS regression that was performed gives more insight in the significant factors (*see regression results*).

Figure 5 shows the distribution of the SES-WOA scores of welfare, level of education and labor force participation. It is clear from this map that the areas that are performing tend to be around the north side of the city center. This variable seems to illustrate that the majority of the inner city is performing low, though it is important to note that the inner city of Groningen consists of many students. These students have as their highest level of education either high school or a bachelor's degree, an income that is either a loan (which means that their income is 0) or a side-job that is below minimum wage, and their labor participation is below average as they are full time students. The same cannot be said for Selwerd, Beijum, Paddepoel, Vinkhuizen and Lewenborg. The pink areas, Beijum-Oost, Lewenborg-Noord, Vinkhuizen-Zuid and De Kring are the areas where the lower self-reported health rates and the decreasing SES-WOA rates overlap. These areas are evaluated in the site analysis later on. Interestingly, there seems to be a correlation between SES-WOA and self-reported health. To distinguish a correlation between the self-reported health and SES-WOA, an OLS regression was performed. The model was significant with a p-value of 0,011621, thus there was a spatial relationship between SES-WOA and self-reported health. Both the Koenker and Jarques-Bera statistics were insignificant, rejecting the null hypotheses stating that the modeled relationships are consistent, and rejecting the null hypothesis that the model predictions are biased. One unit increase in self-reported health is associated with an increase of 0,010408 of ses_woa. The output map is given in appendix 5. Thus, as hypothesized neighborhoods with lower socioeconomic statuses correlate with a lower self-reported health.

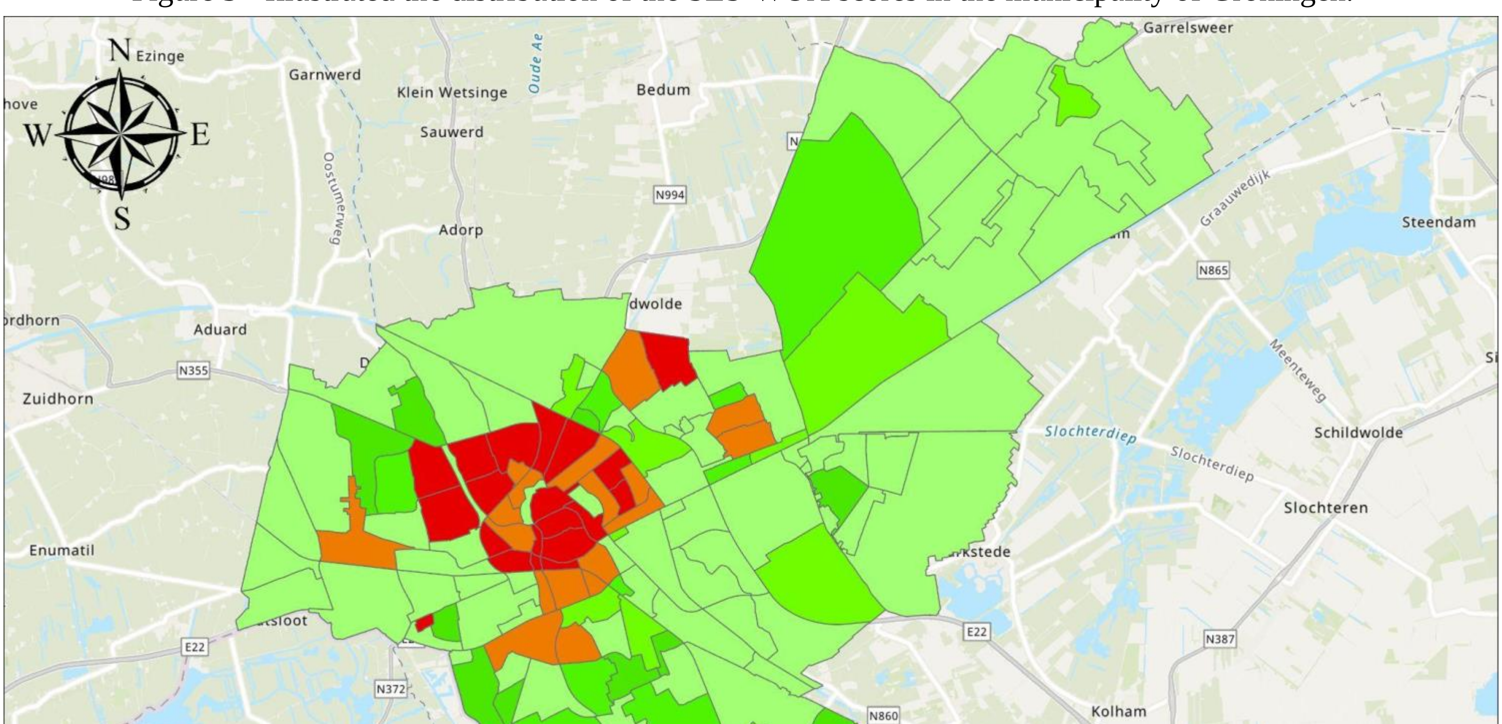
Figure 6 illustrates the neighborhoods in the municipality of Groningen with self-reported health rates of ≤70.8% (purple/pink), according to the RIVM dataset, and the areas where the SES-WOA scores were below zero (CBS, yellow). This indicates that the neighborhoods in yellow were performing less on welfare, level of education and labor force participation in comparison to other neighborhoods (Swagerman, 2022). Again, note the mentioned influence of students on the SES-WOA variable. The neighborhoods that scored both lower on SES-WOA and self-reported health areVinkhuizen-Zuid, Beijum-Oost, de Kring, and Lewenborg-Noord. De Kring will not be taken into account as this neighborhood is known to be a caravan neighborhood. Therefore this area is regarded as a cultural site that is not under the influence of architectural design. To further explore the explanatory factors of self-reported health rates in specific neighborhoods, a spatial regression was performed.

Figure 4 - Self-reported health distribution in the municipality of Groningen



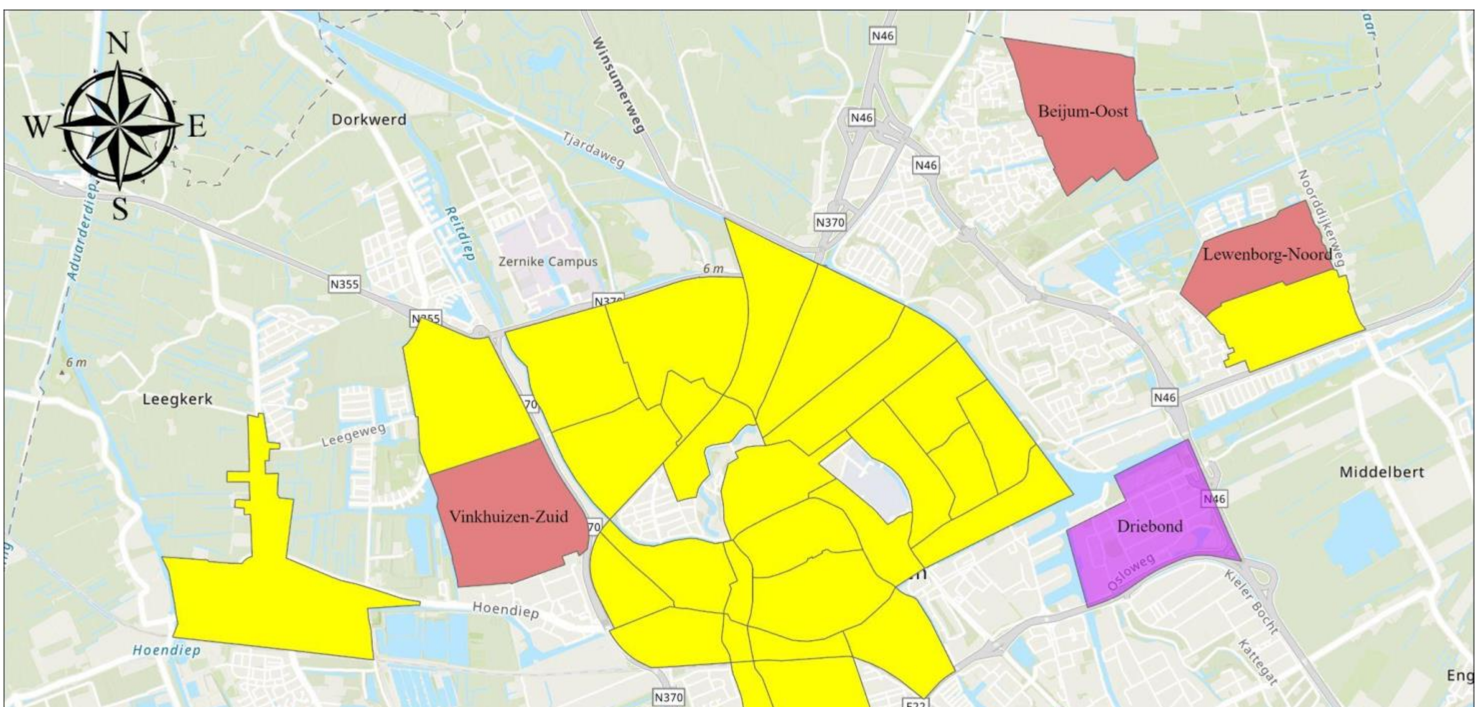
Source: I.S. Krottje. “Self-reported health distribution in the municipality of Groningen” [map]. 1:125.000. Using: ArcGIS Pro.

Figure 5 - Illustrated the distribution of the SES-WOA scores in the municipality of Groningen.



Source: I.S. Krottje. “The distribution of the SES-WOA scores in the municipality of Groningen.” [map]. 1:125.000. Using: ArcGIS Pro.

Figure 6 - Self-Reported Health Rates ≤70.8% and SES-WOA minus scores



Source: I.S. Krottje. “Self-Reported Health Rates ≤70.8% and SES-WOA minus scores” [map]. 1:125.000. Using: ArcGIS Pro.

Regression Outcome

Based on the literature review it was hypothesized that self-reported health would positively correlate with having a higher income, having greenery in the neighborhood, having social cohesion in the neighborhood, and having enough exercise in one’s daily routine. The dependent variable of this study is the self-reported health (good/very good). After testing multiple models, the model in table 6.1 had the highest explanatory power. The model is significant with a p-value of 0,000000* (p<0.01) looking at the Joint F-Statistic (table 7.2). The Koenker is not statistically significant, namely p=0,153827, meaning that the model relationships are consistent. The Jarques-Bera is not statistically significant, with a p-value of 0,299476, which means that the residuals are normally distributed and that the model predictions are not biased. The p-value for each independent variable tests the null hypothesis stating that the variable has no correlation with the dependent variable. The variables population density, the amount of females within a neighborhood, physical activity according to the guidelines, satisfaction with greenery, and having an income under or around social minimum standard have a significant p-value (see table 7.1). Meaning, the null hypothesis is rejected for the entire population, meaning that there is a correlation between self-reported health and aforementioned factors. A change in these independent variables has either an increasing or decreasing effect on the self-reported health rates on an individual level. One unit increase in self-reported health is associated with a decrease of an income around or under the social minimum by -0,608922, holding all the other independent variables constant. This can mean that the social economic status improves as the share of incomes around or under the social minimum is decreasing. This is in line with the theory that higher socioeconomic status groups have a higher perceived health. With regards to greenery, one unit increase in self-reported health is associated with a decrease of -0,053392 of greenery satisfaction, holding all the other independent variables constant. This is also not in line with the theory, as self-reported health should increase in relation to greenery. One unit increase in self-reported health is associated with a positive correlation of population density, namely 0,000435, holding all other variables constant. In theory, density aspects such as crowding would have a negative effect on self-reported health. Therefore, this study outcome is not in line with the theory. Lastly, one unit increase in self-reported health is negatively correlated with the amount of females in a neighborhood (-0,001071), holding all other variables constant. Thus, in Groningen this would mean that self-reported health is lower for females.

The variables social cohesion within the neighborhood and ages 45-64 are not significant. For these independent variables the null hypothesis cannot be rejected. There is insufficient evidence in the sample to conclude that non-zero correlations exist between the dependent and these independent variables. The output map is given in figure 8.

Table 6.1 - Outcome Spatial Regression (OLS)

Variable	**Coefficient [a]**	**StdError**	**t-Statistic**	**Probability [b]**	**VIF [c]**
Intercept	76,560908	7,079625	10,814261	0,000000*	--------
Bev_dichtheid *Population density*	0,000435	0,000132	3,297735	0,002656*	6,976416
Aant_vrouw *Number of women*	-0,001071	0,000362	-2,960798	0,006190*	2,508634

Jr_45-64 *Ages 25-44*	0,019276	0,061454	0,313663	0,756101	4,445222
Bewegen volgens de richtlijn *Exercises according to guidelines*	0,226532	0,102050	2,219808	0,034704*	4,518707
Buurt Cohesie *Social cohesion in neighborhood*	-0,020174	0,721243	-0,027971	0,977885	4,048695
Tevredenheid groenvoorzieningen *Satisfaction with greenery*	-0,053392	0,023948	-2,229466	0,033983*	1,566395
Inkomen op of onder sociaal minimum *Income under or around social minimum standard*	-0,608922	0,066439	-9,165102	0,000000*	3,232088

* An asterisk next to a number indicates a statistically significant p-value (p < 0,01).

Table 6.2 - Output report

Input Features:	buurt_2020_GR_AlleVar	Dependent Variable:	Gezondheid_goed_zeergoed

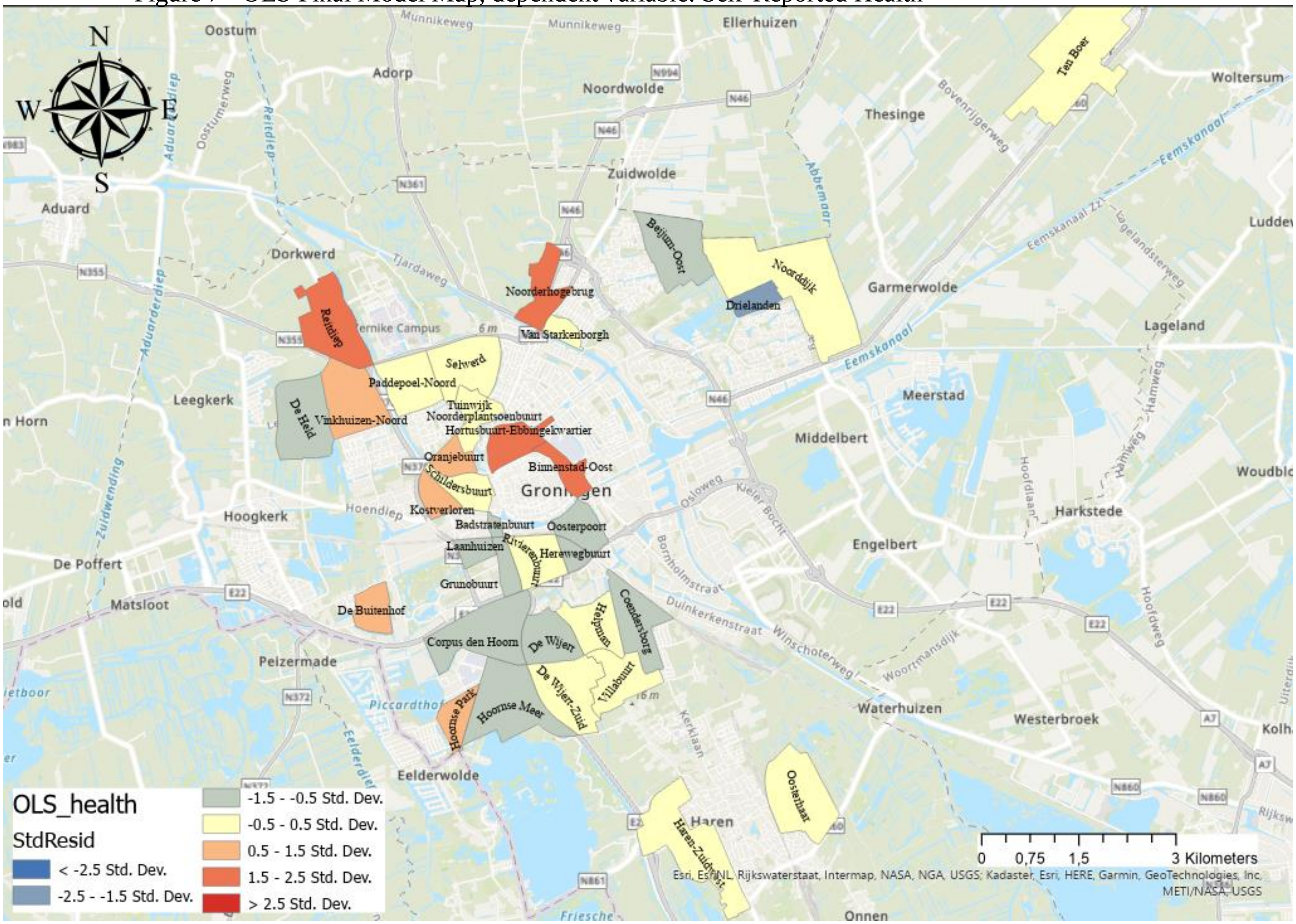
Number of Observations:	36	Akaike's Information Criterion (AICc) [d]:	138,827699
Multiple R-Squared [d]:	0,923607	Adjusted R-Squared [d]:	0,904508
Joint F-Statistic [e]:	48,360671	Prob(>F), (10,11) degrees of freedom:	0,000000*
Joint Wald Statistic [e]:	520,001830	Prob(>chi-squared), (10) degrees of freedom:	0,000000*
Koenker (BP) Statistic [f]:	10,666817	Prob(>chi-squared), (10) degrees of freedom:	0,153827
Jarque-Bera Statistic [g]:	2,411442	Prob(>chi-squared), (2) degrees of freedom:	0,299476

* An asterisk next to a number indicates a statistically significant p-value ($p < 0,01$).

Figure 7 shows the final OLS model. First, the pattern appears to be random, which shows that the model fit is good. This is also clear from the output report given in table 6.2, with both the Jarque-Bera and Koenker Statistics being not significant. None of the neighborhoods appear to be either underpredicted with +2.5SD or overpredicted with -2.5SD. The combining of statistical data of different sources using different neighborhood divisions lead to a loss of data. As a result one can see that not all neighborhoods that were visible in previous graphs have an output now (figure 7).

In the discussion the relevance of other variables is discussed as well as reoccurring problems, and recommendations are described.

Figure 7 - OLS Final Model Map, dependent variable: Self-Reported Health



Source: I.S. Krottje. " OLS Final Model Map, dependent variable: Self-Reported Health " [map]. 1:125.000. Using: ArcGIS Pro.

Site Analysis: Description and Architectural Background

1. Oosterparkwijk

The Oosterparkwijk was built between 1925 and 1935, led by the architect Berlage (1856-1934). The Oosterparkwijk is an example of the *tuinstad* concept (garden city) that was arising in the reconstruction period between 1940 and 1965 (Rijksdienst voor Cultureel Erfgoed, 2016). These types of neighborhoods are considered paragons of the Reconstruction Period. The Rijksdienst set out three neighborhood types, namely: the reconstruction core sites (recovered war damage), the post-war residential areas (planned expansion areas) and the rural areas (agricultural land consolidation and land development areas) (Rijksdienst voor Cultureel Erfgoed, 2016, p. 2). The Oosterparkwijk is an example of the latter.

After WWI there was a major housing shortage in the Netherlands, poor living conditions and a lack of social cohesion within neighborhoods. The housing typology are terraced houses and stacked multi-family homes, often in a serial construction. The building blocks would be repeated with an alternation of high- and low-rise buildings according to the urban planning principles of CIAM (Rijksdienst voor Cultureel Erfgoed, 2016). These are the types of dwellings one can find in Oosterparkwijk. There are smaller neighborhoods within Oosterparkwijk, for example 'Het Witte Dorp' and 'het Blauwe Dorp', both built around 1925. The latter is a village with small farm houses, and became Rijksmonumenten in 1993. 'Het Rode Dorp' was demolished in the 1960s and rebuilt. After 2006 new social housing was built along the area where the Oosterparkstadion had been. The new developments in the neighborhood are high-rise buildings reaching up to 5 or 6 stories high.

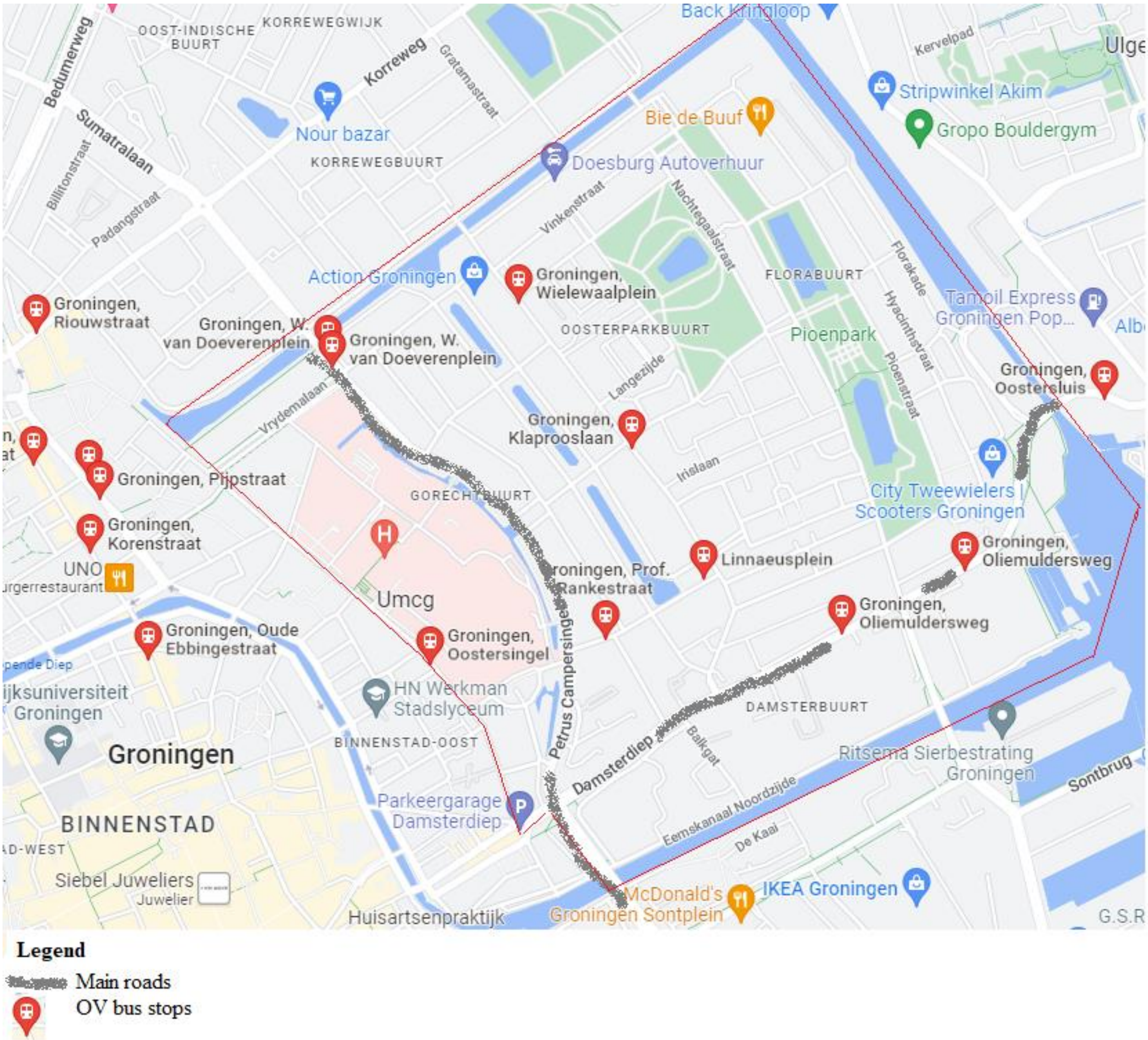
During the time Oosterparkwijk was built, a movement was upcoming focusing on the essence of social well-being of citizens, and fostering a feeling of attachment to their neighborhoods, alongside a rise in urban living (Wagenaar, 2013). The aim was to design a compact city with a focus on single-family houses. From a sociological point of view this neighborhood approach assumed a maximum size of the neighborhood and the family-household became the cornerstone of the society (Rijksdienst voor Cultureel Erfgoed, 2016). Living, working, traffic and recreation became carefully arranged and often separated from each other. Daily amenities would be within walking distance, and facilities such as a library, a barber or bank office should be within the neighborhoods' district. The expansion neighborhood principles were light, space and airy, with an aim of community building. The neighborhood should not be merely a living place, but also one of development, education, relaxation and recreation. Note that the working space was not included; working should be done in another part of the city. In the Oosterparwijk one can see that there is no central shopping center. The facilities are spread across the neighborhood.The area has no highschool, five elementary schools, nine day-care centers, a Jumbo and a Lidl, and several other facilities. With regards to sports facilities, the neighborhood has two gyms, a tennis court, judo, and two outside fitness parks to name a few. Overall, the neighborhood seems to fit the idea of walkability. There are almost no companies located in this area other than a car rental. There is no central core within the neighborhood (Jansen, 2000). Oosterparkwijk was the second expansion neighborhood in Groningen after WWI (1949).

Oosterparkwijk is the red outlined area visible in map 1.1. It is south of the city center of Groningen. The road network is characterized by a hierarchical structure. There are two main roads that branch off from the city avenues to the homes to smaller roads and courtyards. The main roads are the Petrus Campersingel and the Damsterdiep, that distinguish the slower traffic roads from the faster paced roads. These two roads connect to the existing traffic structure of the city, along with the Zaagmuldersweg and the Petrus Camper Singel. The neighborhood roads are asymmetrical. The distinction between slower and faster traffic is an important pillar in the 'functional city' concept (Rijksdienst voor Cultureel Erfgoed, 2016, p. 13). There are no distinct bicycle roads in this area. All roads have a pavement to include the walkability aspect of the neighborhood. There are 9 bus stops in the Oosterparkwijk, which are the red points in map 1. There are many bus stops connecting the neighborhood to other parts of the city, or towards Kardinge P+R. From this bus stop at the end of the city of Groningen many buses travel to rural destinations. Map 1 shows that the urban blocks are smaller in comparison to Vinkhuizen (map 2). The longer stretching urban blocks follow the structure of either a park or waterway. The first part of the neighborhood, 'het witte dorp' and 'het blauwe dorp' have more condense urban blocks (area around the Irislaan). The main roads have pedestrian crossings,

The green space in the neighborhood should allow for social connectivity and stress release (Wagenaar, 2013). According to the tuinstad concept, the greenery follows the hierarchical structure of the traffic network and flows into parks. This set-up was designed so that citizens would stay in touch with the neighborhood as well as with greenery, and be able to relax in the parks. There is no clear structure of the type of greenery. In the Oosterparkwijk there are several parks, the Oosterpark, Pioen Park and greenery in the Florabuurt. All three parks are highly accessible, and are designed English Style. There are walking paths and benches, and playgrounds for children. The neighborhood is surrounded by the Eemskanaal and the Oosterhamrikkanaal. All three parks also have a pond. The Oosterparkwijk was set up to have shared gardens, along the principle of the 'three magnets diagram' of Ebenezer Howard (1898) (Jansen, 2000). After the realization of these gardens it appeared that the maintenance costs were too high after which it was divided into gardens for the downstairs residents. The safe playing fields for children became smaller, also due to the building of bicycle sheds and garages.

Lastly, the neighborhood has several monumental buildings, amongst them the Oosterkerk (*Rijksmomument*).The neighborhood has a special status as it housed the stadium of FC Groningen, a professional football club association based in Groningen. The dwelling type in the Oosterparkwijk is categorized as pre-war social rent. Table 8 gives an overview of the level of education, self-reported health, SES-WOA score, and the social cohesion within the neighborhood.

Map 1.1 - Maps Oosterparkwijk (red outline)



Map 1.2 - Oosterpark analysis map

2. Vinkhuizen-Zuid (Nieuw Zakelijkheid)

In the era that Vinkhuizen was built the design focused on creating the perfect environment for fostering new cultural and social relations (Wagenaar, 2013). The aim was to provide the working class with decent houses alongside the issue of housing shortage. Vinkhuizen was built in the 1960s and 70s. During the 60s the quantity of the houses mattered more than the quality of the houses. The neighborhood has many straight roads and is characterized by high-rise buildings and single-family homes, with a focus on open areas and greenery. The urban structure stems from the architect Henk Eysbroek. The neighborhood would be designed in a way that it was self-sufficient in terms of facilities. Vinkhuizen was a part of the *structuurplan 1960*, in which it was described that Paddepoel, Selwerd and Vinkhuizen would be built (Jansen, 1999). All neighborhoods would follow the design principle of a garden city. Vinkhuizen followed the principles of a garden city with a more urban design, by using more high-rise buildings and having many single-family homes. (Jansen, 1999). Part of the houses would become private sector, the others would be subsidized houses.

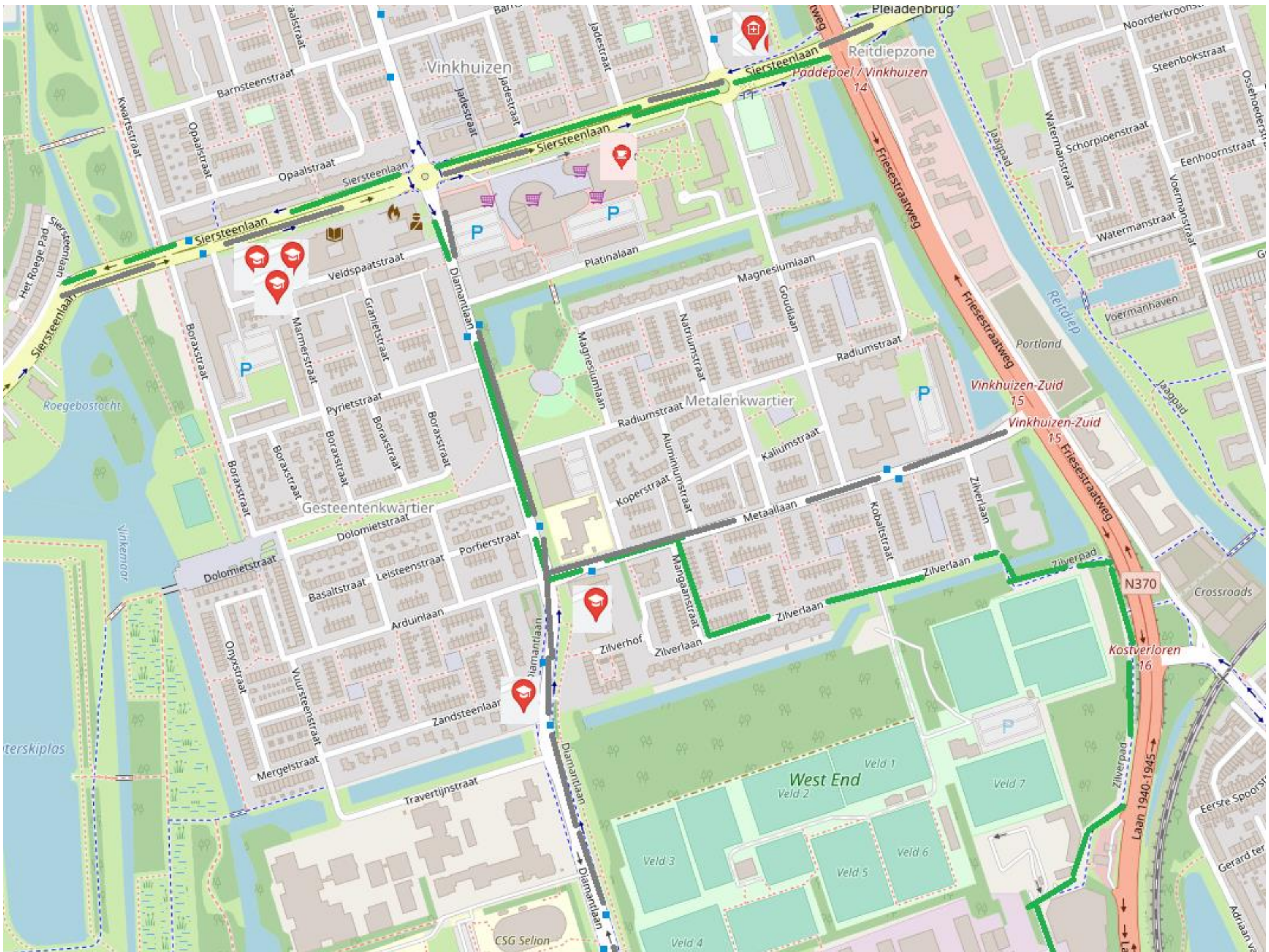
High-rise buildings were designed to reduce the loss of space and allow people to keep in close contact with nature. Map 2 shows that Vinkhuizen-Zuid is more spacious in comparison to Oosterparkwijk. The traffic grid has more vertical and horizontal streets, which differs from the asymmetrical grid of a typical garden city. The main roads that connect Vinkhuizen-Zuid to the main city roads are the Siersteenlaan, the Diamantlaan and the Metaallaan. Although the structure differs it still adheres to the importance of a ‘functional city’ where slower and faster paced traffic are segregated. Furthermore, the neighborhood has a solid OV connection with multiple bus stops on the main roads in the neighborhood, as well as bus stops connecting the outer sides of the whole of Vinkhuizen. Vinkhuizen was built to accommodate for the growing percentage of car ownership, which meant that more space was used to accommodate for this need. The green lines roads are bicycle lanes within the neighborhood. Clearly, the main roads that lead one to other parts of the city are equipped with bicycle lanes.

Vinkhuizen does have a central shopping center with several clothing shops and grocery stores. The centrality of the shopping center and the wider design of the streets allow for car-use, seemingly the neighborhood was built for car-use, and commuting to the city center. The neighborhood has several sport facilities to offer, namely fitness, basketball and soccer. The facilities, except for spots, seem to be agglomerated. All healthcare facilities are located at the Vuursteen. The educational facilities are clustered as well. The neighborhood has several highschools that are focused on VMBO (low level), and special support schools for children with learning disabilities.

The greenery in the neighborhood has as a primal function to support the structure of the neighborhood, using trees and grass patches. There are shared gardens, as well as an area in the north of Vinkhuizen that can be used for gardening. Though, the amount of greenery in the neighborhood seems to be limited. The neighborhood suffers from heat stress (Wijkoverleg Vinkhuizen, 2022). Therefore, the municipality has set up plans to increase the amount of greenery in the neighborhood, and reduce the amount of pavement. Citizens can apply for *geveltuintjes* (facade gardens) to reduce the heat in the neighborhood, as well as increasing the greenery and give the neighborhood a more beautiful street scenery.

Table 8 gives an overview of the level of education, self-reported health, SES-WOA score, and the social cohesion within the neighborhood.

Map 2: Vinkhuizen-Zuid

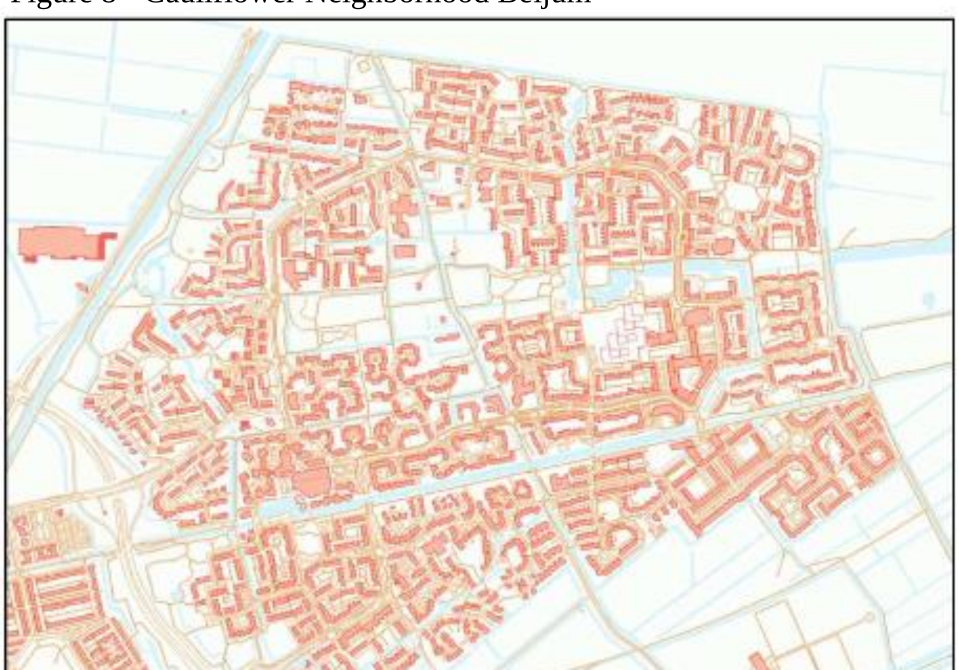


3. Lewenborg-Noord & Beijum-Oost (reactie op Nieuw Zakelijkheid stroming)

Lewenborg and Beijum are neighborhoods built in the 70s, known as 'cauliflower neighborhoods'. These types of neighborhoods are characterized by sufficient greenery and blue zones, a central shopping mall, built for bicycle-walk usage, and has 'woonerven' (*residential areas with no/limited car use, 15km/p hour*). These woonerven were designed to increase social interaction with neighbors. The construction of Lewenborg started in 1971, Beijum in 1978.

The housing design of a cauliflower neighborhood focused around single-story family houses. The cauliflower neighborhood was an experiment to build neighborhoods that were different from the other post-war neighborhoods (Abrahamse, 2019). The cauliflower neighborhood design turned out to be another failure of post-war urban planning. A recurring problem in cauliflower neighborhoods is the degradation of the dwellings, of which the majority are social rent. This type of neighborhood was built during a change in the regulations where individual rental subsidy became a possibility. A characteristic of houses in a cauliflower neighborhood is that the kitchens were located at the front of the house, facing the street. The described structure is present in both Lewenborg-Noord and Beijum-Oost. Though, the difference is that the neighborhood Lewenborg set-up is less socially oriented. For example, the set-up of Beijum has courtyards with the front door visible to other households living in the same courtyard. In Lewenborg the front doors of neighbors are less visible and one can see less of what other people are doing. This makes that one is more anonymous in Lewenborg, which could affect the social cohesion within the neighborhood. The modernist planning that was done before the rise of cauliflower neighborhoods had the criticism that the street lost its function as a meeting place. The woonerven in the cauliflower design was used to combat this criticism.

Figure 8 - Cauliflower Neighborhood Beijum



Cauliflower neighborhoods are further away from the city center. Therefore, a good infrastructure was important to connect the neighborhoods to other areas of the city. Though, car use within the neighborhood has been discouraged due to the setup of the neighborhood, making it more difficult to go to other woonerven. Using a bike or going by foot allows one to move more conveniently around the neighborhood. The woonerven are still reachable by car. There is a bus route going through the main roads of the neighborhood, connecting it to P+R Kardinge and the city center. The former has many bus lines that connect to rural areas surrounding the city of Groningen.

The functional facilities in a cauliflower neighborhood are brought together in multi-purpose buildings. Both Beijum-Oost and Lewenborg-Noord have a central shopping center. There are several elementary schools. There are no highschools, though there are several options close to the neighborhood, with higher levels of education a bit further away. The absence of high-school facilities is a characteristic of a cauliflower neighborhood. The majority of the healthcare facilities of Beijum-Oost are located at the Emingaheerd, which is seemingly in the middle of the neighborhood Beijum. Lewenborg-Noord has all its facilities located near the shopping center, even the schools. These are clustered as well. Daycare facilities are spread across the neighborhood.

Beijum was designed to have respect for the existing natural surroundings, such as Kardinge, and use brick roads instead of concrete. This results in a neighborhood that is surrounded by the greenery and waterways already existing in Kardinge. Throughout the neighborhood there are many trees, as well as smaller green fields, with a central green park across the neighborhood, as is visible in map 3. The neighborhood design has respected the waterways somewhat. For example, the Beijumerzuidwending and the Zuidwending are waterways that are still present in the neighborhood (Van den Broek, 2015). These waterways were watersheds between two polders. Lewenborg-Noord is also connected to Kardinge. Throughout the neighborhood there are many trees and green patches similar to Beijum. Lewenborg-Noord has more blue spaces. The greenery in Lewenborg was designed by Le Roy (1924-2012). Figure 8 is the blueprint of Le Roy for Lewenborg. Here the green and blue zones are coloured. It is evident that these areas were meant as a connector throughout the neighborhood. Table 8 gives an overview of the level of education, self-reported health, SES-WOA score, and the social cohesion within the neighborhood.

Figure 8 - Le Roy Plattegrond, Lewenborg

Map 3: Beijum-Oost

Map 4: Lewenborg-Noord

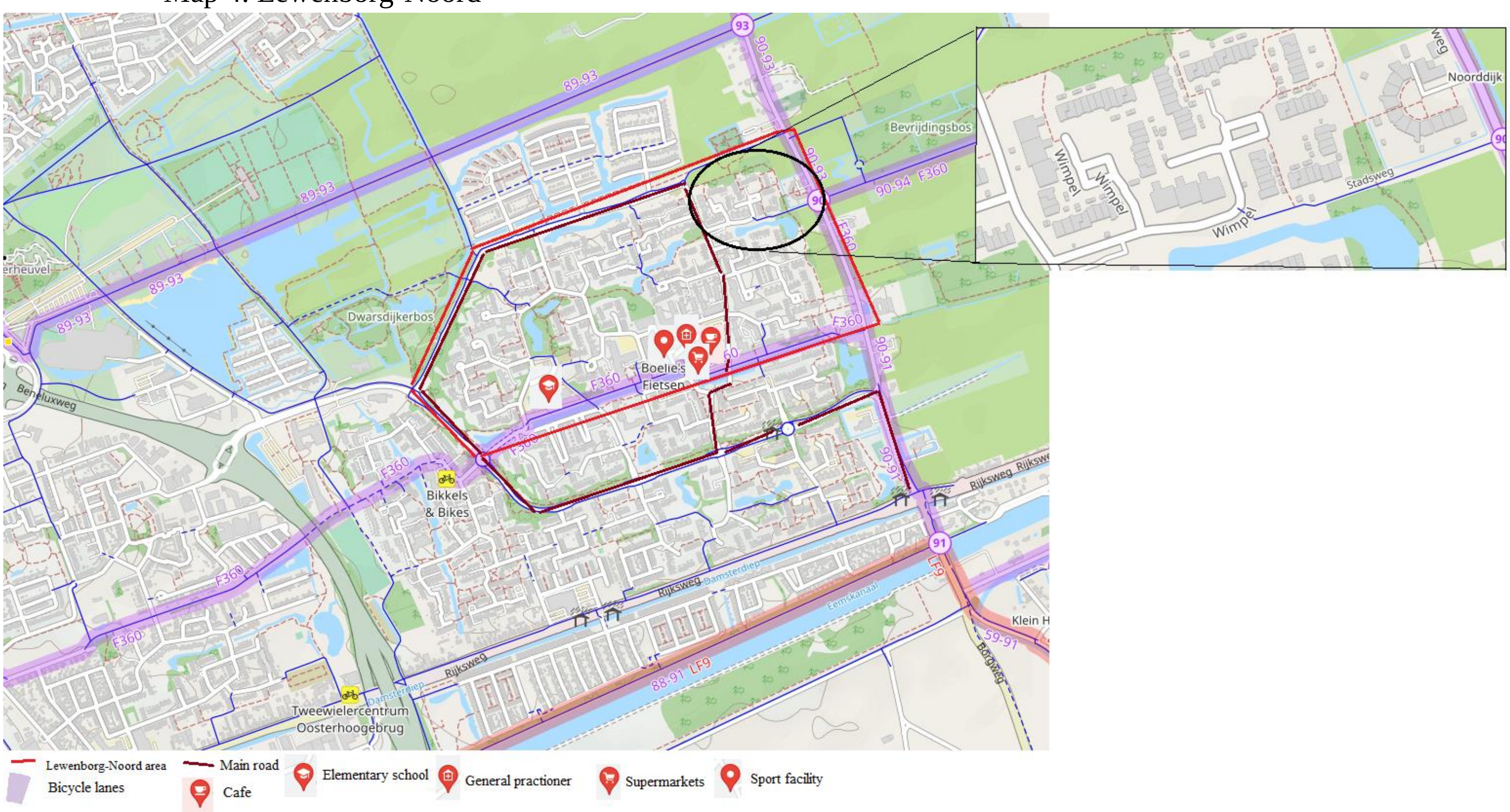


Table 8 - Overview data neighborhoods

	Oosterparkwijk	**Vinkhuizen-Zuid**	**Lewenborg-Noord**	**Beijum-Oost**
Opleiding	Low: 17,4% Middle: 35,7% High: 46,9%	Low: 35,4% Middle:45,8% High:18,8%	Low: 38,3% Middle:41,6% High:20,1%	Low: 30% Middle:45,3% High:24,7%
Self-reported health	78,1%	69.6%	69.8%	70.8%
SES-WOA	-0,462	-0,554	-0,398	-0,462
Social cohesion	5.8	5.1	6.0	6.1
home-ownership	24%	23%	54%	35%
Bouwjaar	80% before 2000	80% before 2000	91% before 2000	1000% before 2000
Level of income on average, annually	23,300	18,500	20,200	19,400

Table 8 shows that, apart from Oosterparkwijk, the self-reported health (good/very good) is somewhat low. This was also evident in figure 5. All neighborhoods have a negative SES-WOA score. This means that the neighborhood is performing less on welfare, labor participation, and level of education in comparison to surrounding neighborhoods. The annual income of Groningen is €25.500. We can see that most of the neighborhoods score substantially lower, apart from Oosterparkwijk. Oosterparkwijk also has the highest share of higher educated people.

The bridge between architecture and city planning is formulated in the design implementations. Illustration 4 gives the main focus areas found in the literature study that could have a positive impact on health once designed properly. These focus areas are outside recreational facilities, the green city concept, social interaction, housing and neighborhood design, and walkability. In the next section the design implementations will be discussed for the four neighborhoods.

Site Analysis: Design Implementations

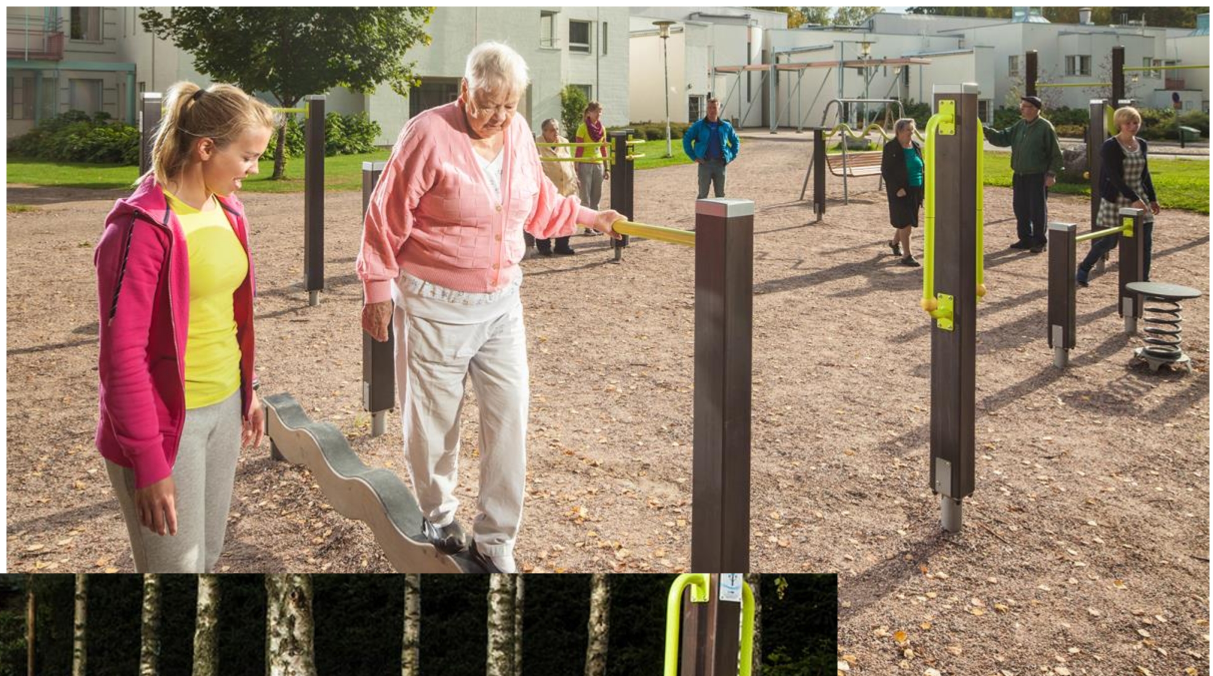
Illustration 4 - Design Outcomes for Public Health Improvement

Source: made by Author, I.S. Krottje (2022).

Beijum-Oost

Beijum is connected to Kardinge, which is considered a large park. There are multiple waterways through the neighborhood, as well as some grass fields to play outside or walk one's dog. With regards to outside facilities the main provider is Kardinge. For children there are many playgrounds. For elderly and less mobile inhabitants the options are limited. Therefore, it is suggested to create a low-impact outside training facility that is adapted to less mobile users. An example is a functional senior park. An example is given below in the pictures. Such parks can also be used by children, and thus targets different age groups.

The majority of the daily facilities are within walking distance. The shopping center could function as a meeting place, as well as the area where the healthcare facilities are centered, and the library. The library is located in a multi-purpose building, with for example the WIJ and obstetric practice located. There are no recommendations for this neighborhood with regards to walkability.



The social cohesion in Beijum scores a 6.1, which is sufficient. To improve social interaction more benches could be placed in Kardinge. This makes the area also better accessible for people with walking difficulties. Benches could be placed slightly facing each other to stimulate contact. The housing and neighborhood design in Beijum is built to be more social. A point of improvement could be the overall feeling of safety. This can be done by traffic lights or placing mirrors in shady areas or corners.

Lewenborg-Noord

The parks and waterways situated in Lewenborg-Noord are connected throughout the neighborhood, by the La Roy greenery design. Lewenborg is also connected to Kardinge. Here the same recommendations for Kardinge apply to improve both physical health and social interaction. The social cohesion scores a 6.0. Lewenborg has the same social design as Beijum, and similar design recommendations apply. Kardinge also has a small area where children can learn and play outside with water. Such an area allows children to connect with other children. This space can be improved by adding activities for older children, such as a climbing area in the already existing playground area.

Oosterparkwijk

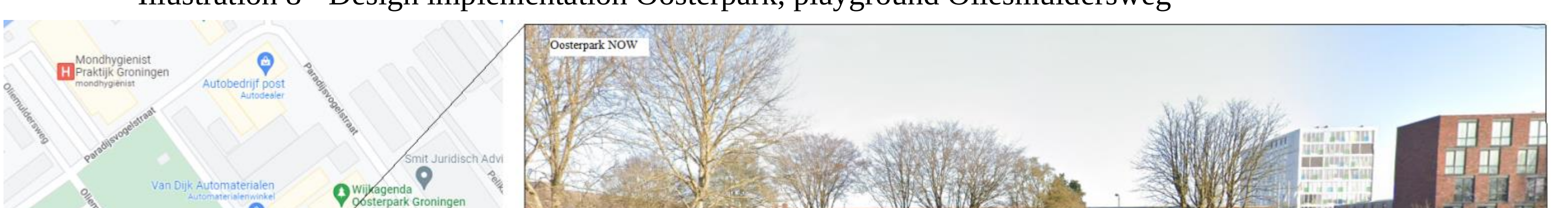
All three parks in the neighborhood have ponts. These parks should in theory allow for stress relief and relaxation. There are plenty of benches in the park. An interesting recommendation is to design an outside sports area in one of the parks, for example in the Oosterpark where also a youth center is housed.

Illustration 7 - Example of an outside sports facility, Stadspark Groningen.

The majority of the neighborhood consists of low-rise single-family homes. Though, the design of the homes would in theory make a less social environment in comparison to Beijum or Lewenborg, both cauliflower neighborhoods. Table 8 shows that indeed the social cohesion is experienced lower, though the difference is very minimal. The meeting places in the neighborhood are the three parks. There is no central shopping center or area where inhabitants would meet others regularly, except for the *wijkcentrum Bij van Houten* who organizes several events, or can take part in a course.

An idea to create a central meeting point is to increase or improve a playground. As there are many families with young children in this neighborhood, it improves the physical health of children, the social cohesion in the neighborhood, and possibly the feeling of safety for both the parents and the children. An idea could be to enlarge the existing playground in Oliesmuldersbrug (illustration 8).

Illustration 8 - Design implementation Oosterpark, playground Oliesmuldersweg



Source: made by Author, I.S. Krottje

The playground would be similar to the illustration 8. The area could also be adapted to accommodate for various age groups by mixing playground elements with outdoor activities for older children, such as a basketball field or workout equipment. The existing tennis court will remain there.

Vinkhuizen-Zuid

There are no real parks in Vinkhuizen. The amount of green comes from the trees placed along the housing grid, as well as the new initiative of the municipality of Groningen to increase the amount of gardens. One one side this improves the aesthetic of the neighborhood, and second, the green could benefit the health of its citizens.

Another important opportunity is the redevelopment of the *metalenkwartier* (illustration 9). This area is now a plain site with trees. The opportunity lies in the creation of a playground in this area, along with benches and more greenery. This can improve social interaction.

Illustration 9 - Design implementation playground Vinkhuizen-Zuid

Source: made by Author, I.S. Krottje

All neighborhood designs show how it affects the social cohesion, perceived quality of life and safety within the neighborhood. The design implementations recommended above are targeted around greenery and outside activities. The greenery has a positive effect on physical and mental health. The increased opportunity for outside activity will allow for a possible increase in physical health. The outside activities can foster social interaction. The social interaction can lead to increased connectivity to the neighborhood, positively affecting one's quality of life, and the perceived safety in the neighborhood. Areas that feel unsafe must be improved in order to make people feel safe and go out more often at various times of the day. The activities proposed are all within walking distance, and can accommodate the needs of various age groups.

5. Conclusion and Recommendations

The study hypothesized that in neighborhoods with lower socioeconomic statuses the self-reported health would be lower. Figure 4 and 5 revealed that there was some overlap between these variables, except for the inner city centre where self-reported health was high. Figure 6 revealed that some areas with a lower ses-woa score also had a lower self-reported health rate, though it seemed that for Groningen this relationship did not hold true. An important note here was that the inner city of Groningen houses a lot of students with a low income, low education, or a combination of the two that have affected the overview of the ses-woa score. Therefore, the relationship between socioeconomic statuses and health might be less clear in Groningen. The relationship between the SES-woa score and self-reported health was studied in a regression to determine a possible relationship. The regression revealed that there is a relationship between SES-woa and self-reported health. Namely, one unit increase in self-reported health is associated with an increase of 0,010408 of ses_woa.

To further explore the explanatory factors of self-reported health rates in specific neighborhoods, a spatial regression was performed. The OLS model predictions give an insight in the relationship between self-reported health and different explanatory variables. The tool can help predict variability in the self-reported health for the municipality of Groningen. It was hypothesized that self-reported health would positively correlate with having a higher income, having greenery in the neighborhood, having social cohesion in the neighborhood, and having enough exercise in one's daily routine. The adjusted R-square was used as a determinant for the predictive power of the model, which was 90.4% in this research. The maximum variability for self-reported health outcomes was explained by the model listed in table 7.1, table 7.2 and figure 7. The spatial explanatory variables for self-reported health in Groningen are population density, the amount of females within a neighborhood, physical activity according to the guidelines, satisfaction with greenery, and having an income under or around the social minimum standard. Meaning, the null hypothesis is rejected for the entire population, meaning that there is a correlation between self-reported health and aforementioned factors. The hyptohesis was not met by the OLS regression, expect for the income variable and having enough exercises in one's daily routine. The factor 'having social cohesion in the neighborhood' was moved from the model as the VIF would be above 7.5, despite various model variations. The factor 'having greenery in the neighborhood' was negatively correlated with self-reported health. This is not in line with the theory on greenery and the positive impacts it can have on public health. The RIVM (2010) suggests that the construction of municipality gardens, walk and bicycle lanes, and outside recreational facilities improve the social cohesion of a neighborhood, as well as improving the mental and physical health due to the positive side-effects of greenery. Wells and Evans (2003) also discovered this positive relationship between social safety, well-being and the presence of greenery. Notably, the satisfaction rate of greenery does not include the actual amount of green and blue spaces available. Nor does it give any information about the shared recreational green or blue spaces, or any specific locations that people have evaluated. Therefore, an improvement of this variable by Kompas Groningen is recommended to be able to say something about the correlation between public health and greenery.

The site analysis focused on social interaction, outside recreational facilities, green city, housing and neighborhood design, and walkability as important pillars for public health improvement. The neighborhoods that scored the lowest for self-reported health being good-very good were Beijum-Oost, Lewenborg-Noord, Vinkhuizen-Zuid, Driebond, Winschoterdiep, De Kring, and Bruilweering. The neighborhoods that scored both low on self-reported health and SES-WOA were Beijum-Oost, Lewenborg-Noord, Vinkhuizen-Zuid, and De Kring. For the site analysis Beijum-Oost, Lewenborg-Noord, Vinkhuizen-Zuid, and Oosterparkwijk were evaluated. The main point of improvement focused on the development of playground and outdoor physical activities to both enhance the attractiveness of a park or green site within a neighborhood, as well as improve the physical health of its inhabitants. The improvements could possibly improve the social cohesion within the neighborhood.

Overall, the study contributed to the knowledge on the relationship between public health and the design of the environment. It has shed light on the importance of greenery and social cohesion in relation to public health, and has given spatial recommendations to do so. It is important to give attention to public health in a fast urbanizing world with rising health issues. It is recommended for local research institutes to have area-specific surveys to monitor design implementations and visualize the effects of a certain implementation. This way one can see wether a certain implementation had the wanted effect. In academic research, more attention should be given to creating social and healthy places, and how this can be done. This is specifically important in relation to mental health. The spatial recommendations made in this research are targeted directly at physical health and social cohesion, and indirectly to improve mental health. There are many research gaps in terms of mental health and space. Therefore, it is recommended to specifically study mental health in relation to the public environment, possibly in a qualitative manner.

Limitations of the study

It is important to note that the results within this study were not controlled for social class, individual characteristics, household composition, dwelling type, or life events. Therefore, there is always a certain level of bias in these results (Ludwig et al., 2012). Secondly, health was measured by the RIVM in a good/very good variable, which gives a suggestive direction to the variable of health. The variable does not say how you experience your health, for example, being good or bad. It gives the overview of how much the respondent agrees with him/her feeling good or very good. Also, health is generally known to be skewed with a majority of the respondents reporting their health as either good or very good (Doorslaer & Jones, 2002), thus this kind of surveying health does not do justice. It would be wise for the RIVM to develop a survey that does more justice to health. When health is correctly measured the policies that stem from this are better connected to the real life situation. The data that is then retrieved is of more help and more accurately. For this specific research a smaller area could be targeted, where one can distribute surveys and have an area-specific outcome. For example, study Vinkhuizen in more depth.

KompasGroningen and CBS both provided datasets relating to greenery. Though, the CBS data was not available on a neighborhood level, only on a municipal level. This does not allow for area-specific research. The KompasGroningen data provided a satisfaction rate per neighborhood. Here, the neighborhood division differed from the national CBS division. This led to loss of data due to a difference in administrative regions. The performance of the regression was impacted by this as well. This was also the case for social cohesion related variables studied by KompasGroningen. The satisfaction with greenery was the only variable that was available on a neighborhood level in terms of greenery. This does not accurately represent the green within a neighborhood, as well as the positive health benefits that can be derived from this. Possibly, the local research could benefit more from targeted surveys on specific areas in the neighborhood so that they can improve areas that need improvement. The satisfaction with the greenery in the neighborhood does not say much about the quality of the green space, the availability of green space, the accessibility, the possible improvements for an area, or what is actually meant by greenery. The Kompas Groningen can highly improve on their surveys and data collection.

Lastly, it is worth mentioning that some factors are also better researched in a qualitative manner. A qualitative study gives more insight into the problems that are at play within a specific region or neighborhood. For specific neighborhoods that endure long periods of health inequalities it is recommended to proceed with a qualitative study to research the problems that cannot be captured into numerical data.

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Appendix

Appendix 1: Self-reported health for the municipality of Groningen in 2019

Figure XX: Self-reported health for the municipality of Groningen in 2019 with text

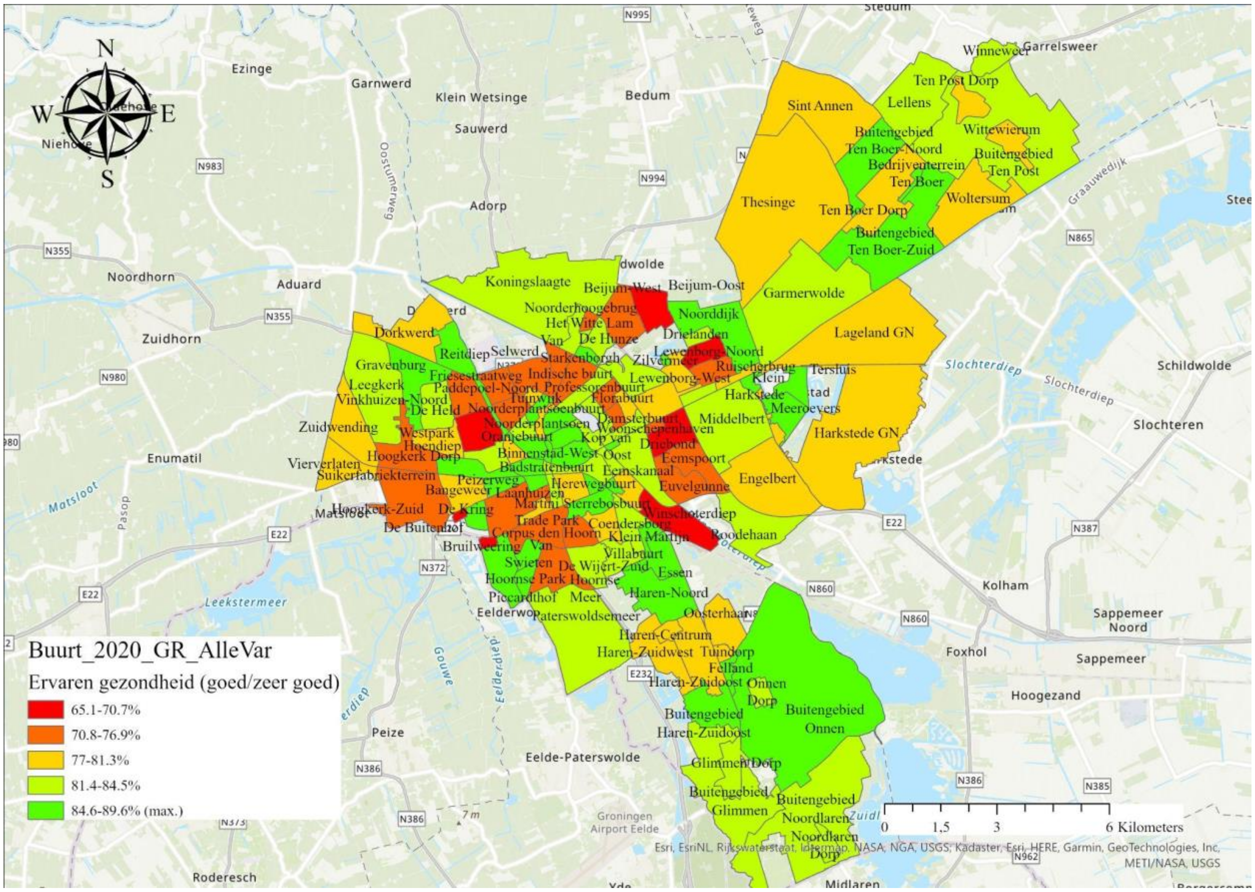
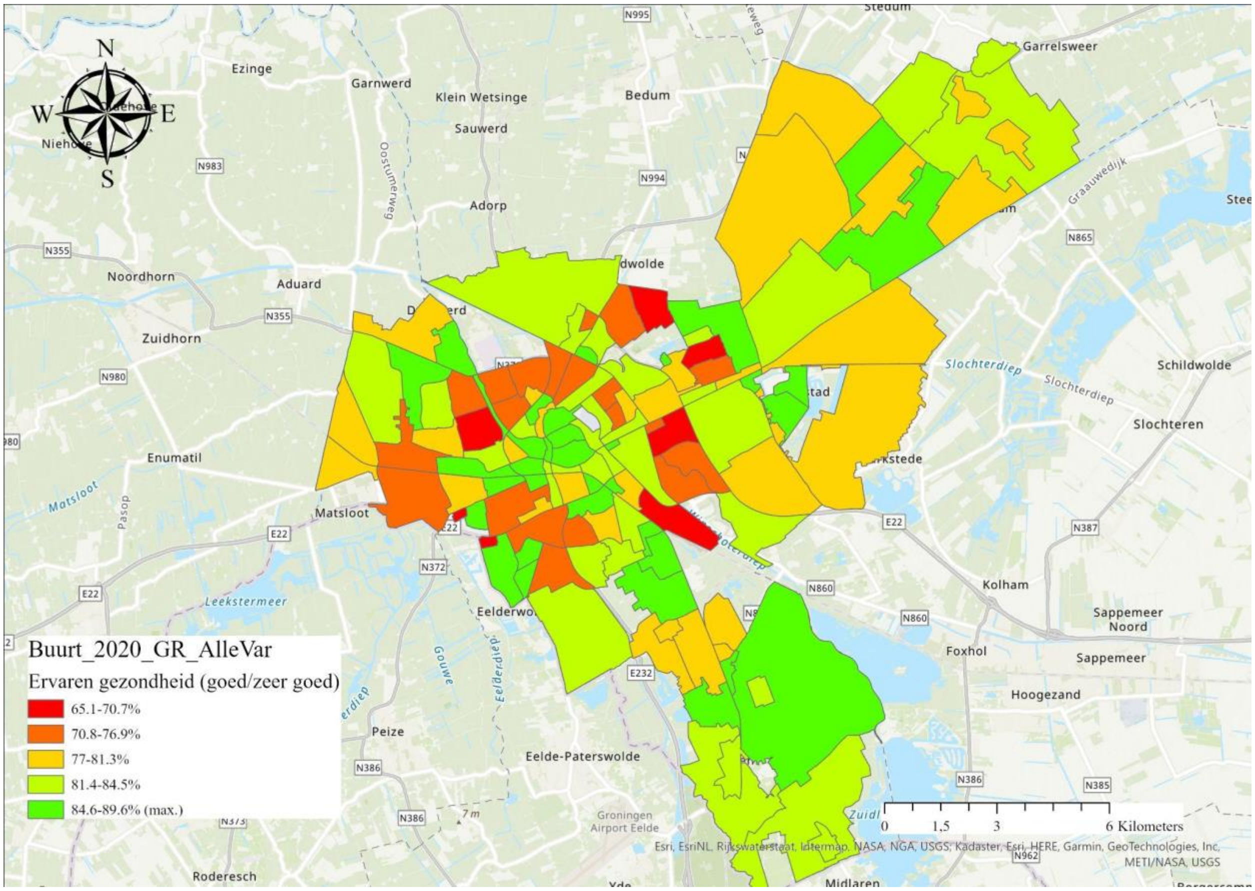


Figure XX: Self-reported health for the municipality of Groningen in 2019 without text



Appendix 2: Output Regression Ervaren_Gezondheid, Ses_woa, opl_laag, opl_middel, opl_hoog

Command 'summarize' gave:

Variable	Observations	Mean	Std. Dev.	Min	Max
A	241	5147.124	6404.092	95	13397
Ervaren_gezondheid	128	81.10547	5.038455	65.1	89.6
Nopl_laag	150	21.31333	23.65159	1	69
Nopl_middel	150	23.17333	25.10455	1	76
Nopl_hoog	150	24.41333	26.73765	1	82

The command 'regress' gave:

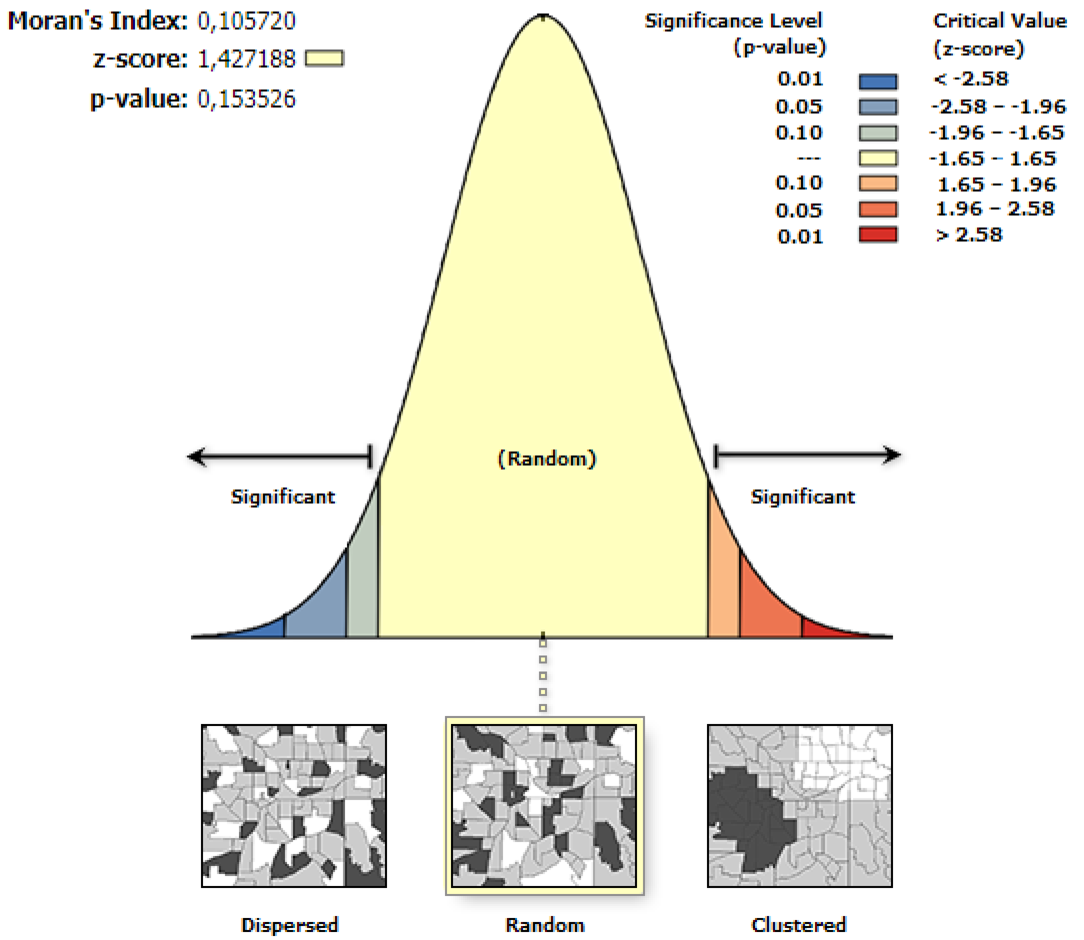
```
. regress Ervaren_gez Nses_woa Nopl_hoog Nopl_middel Nopl_laag

      Source |       SS           df       MS      Number of obs   =       128
-------------+----------------------------------   F(4, 123)       =      8.99
       Model |  729.409684         4  182.352421   Prob > F        =    0.0000
    Residual |  2494.61649       123  20.2814349   R-squared       =    0.2262
-------------+----------------------------------   Adj R-squared   =    0.2011
       Total |  3224.02617       127  25.3860328   Root MSE        =    4.5035

------------------------------------------------------------------------------
 Ervaren_gez | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    Nses_woa |   .0149819   .0273227     0.55   0.584    -.0391016    .0690654
   Nopl_hoog |   .0631571   .0214757     2.94   0.004     .0206473    .1056669
 Nopl_middel |  -.0500489   .0225759    -2.22   0.028    -.0947366   -.0053612
   Nopl_laag |   .0177951    .023878     0.75   0.458    -.0294699    .0650601
       _cons |   79.55891   1.377161    57.77   0.000      76.8329    82.28491
------------------------------------------------------------------------------
```

Appendix 3: Moran I Spatial Autocorrelation dataset 'all variables'

Spatial Autocorrelation Report



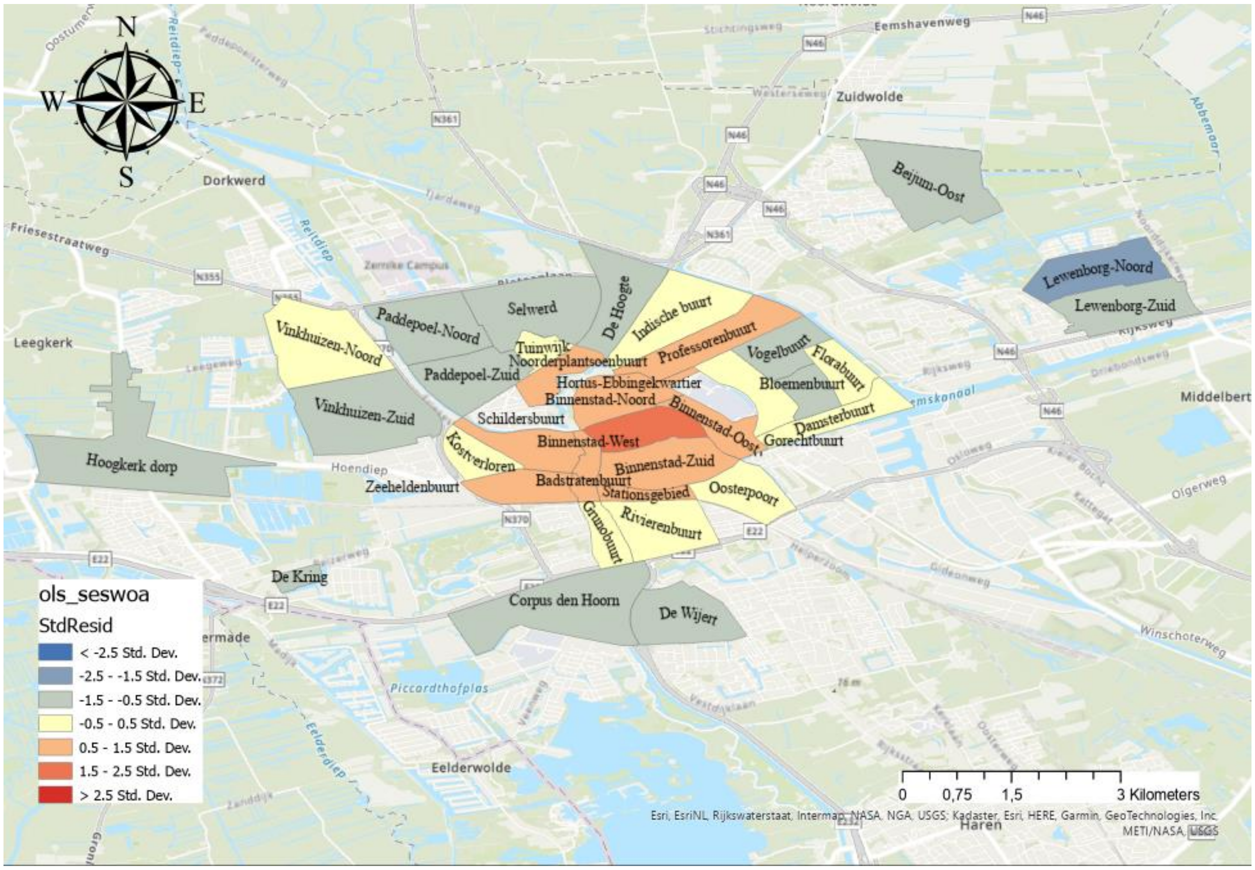
Given the z-score of 1.427188, the pattern does not appear to be significantly different than random.

Global Moran's I Summary

Moran's Index:	0,105720
Expected Index:	-0,007874
Variance:	0,006335
z-score:	1,427188
p-value:	0,153526

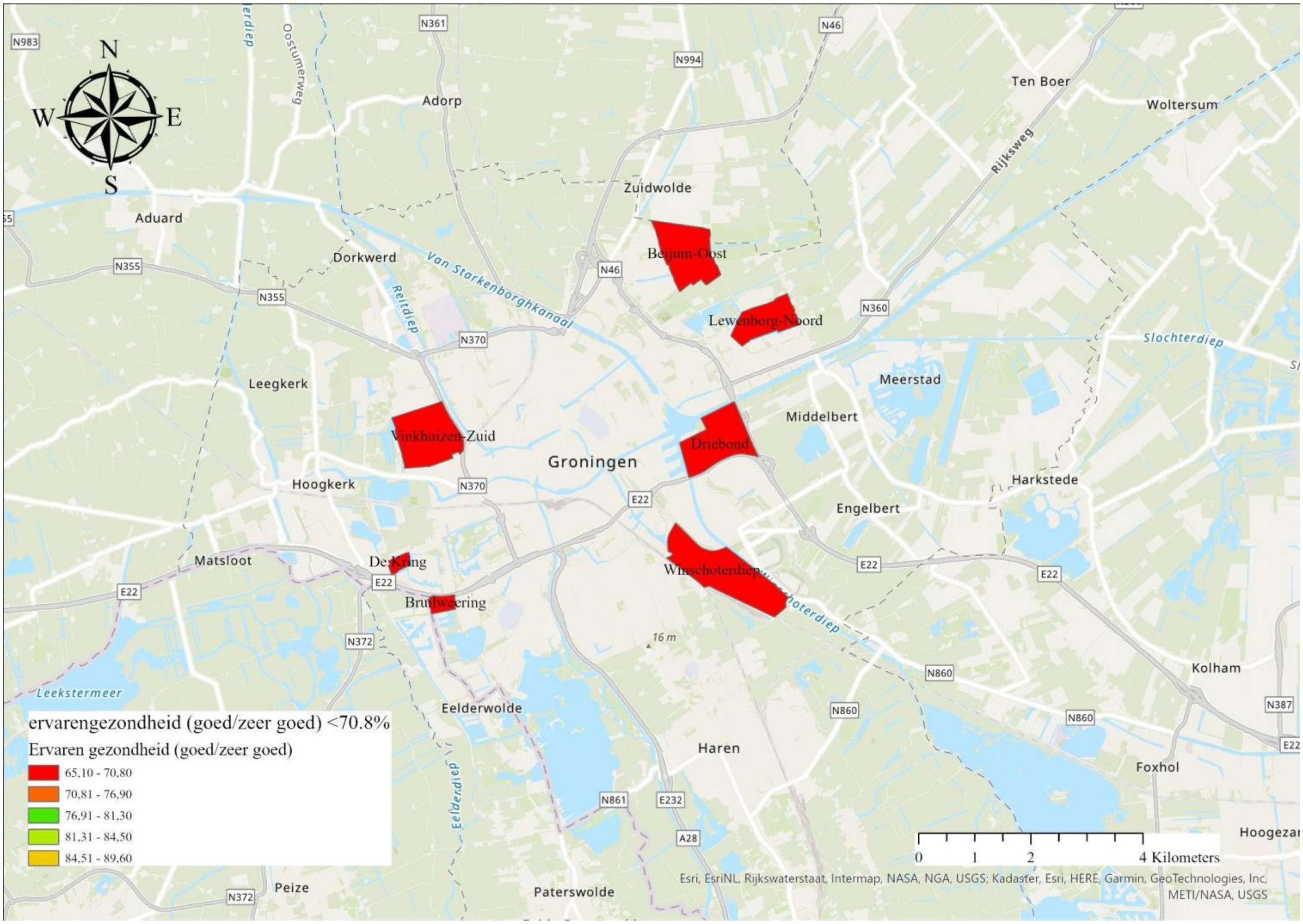
Appendix 4: Health Rates across the Municipality of Groningen

Appendix 5: OLS Self-Reported Health and SES-woa

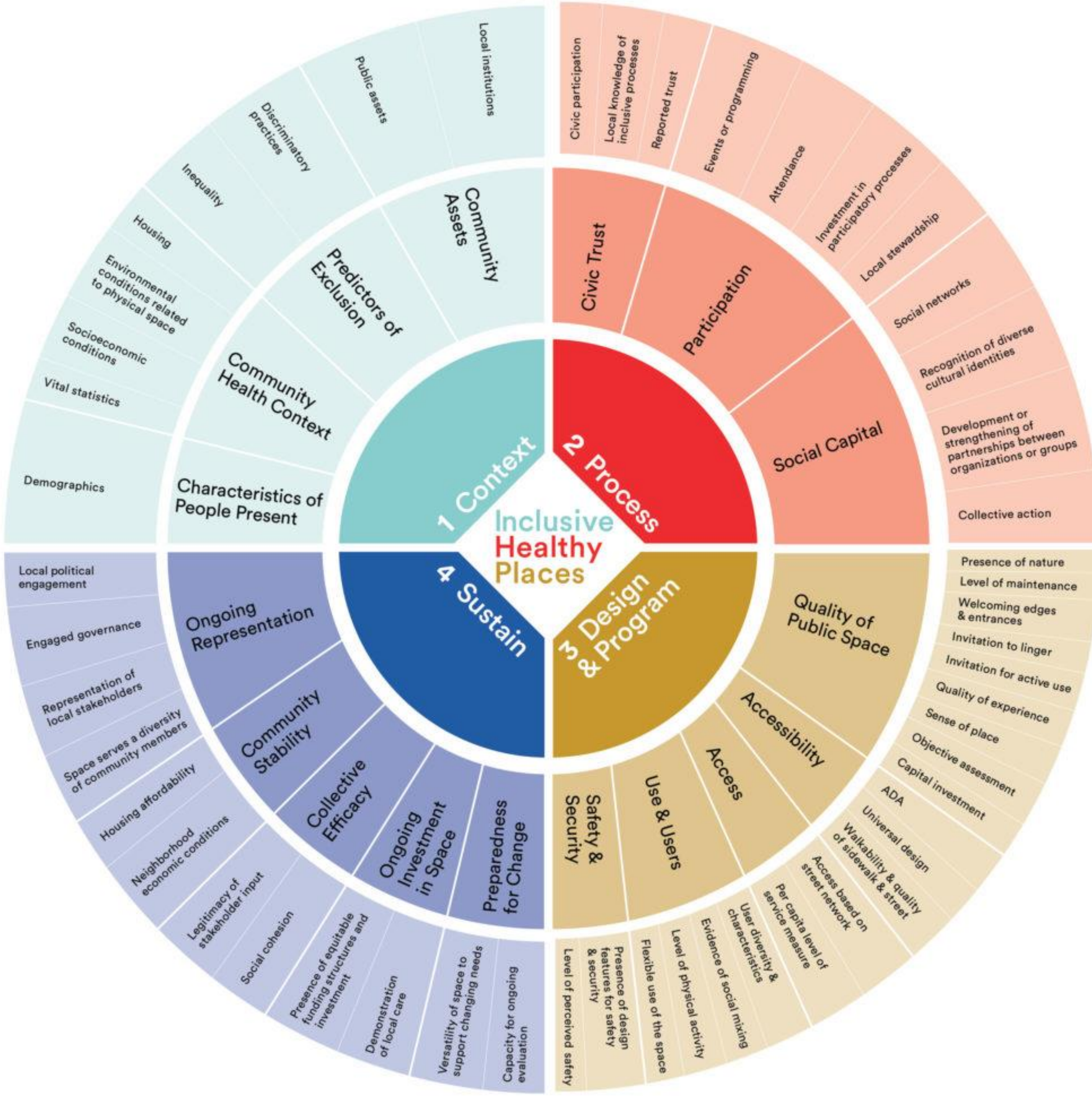


Appendix 6: OLS Report Final Model

Appendix 7: Areas with a self-reported health (good/very good) below 70.8%



Appendix 8: Gehl Institute Diagram of Inclusive Healthy Places



Source: Gehl Institute, Inclusive Healthy Places. Retrieved from https://www.a-u-h.eu/origins-of-the-healthy-city/.