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MSc Programme in Urban Management and Development

Rotterdam, The Netherlands

September 2016

Thesis

Title: Exploring Connectivity of Urban networks and their influence in determining Neighborhood Satisfaction, for the city of Rotterdam.

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UMD 12

MASTER'S PROGRAMME IN URBAN MANAGEMENT AND DEVELOPMENT

(October 2015 – September 2016)

Exploring Connectivity of Urban networks and their influence in determining Neighborhood Satisfaction, Rotterdam city as a case study.

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UMD 12 Report number: 909

Rotterdam, September 2016

Summary

The research aims to analyse the extent to which connectivity of urban networks influences Neighbourhood Satisfaction. To achieve this requires that the two concepts be understood independently. Neighbourhood satisfaction is seen to be an important subset of Quality of Urban life (QOUL), hence the research begins with a brief theoretical explanation of QOUL subsequently narrowing down to exploring neighbourhood satisfaction and the features that constitute it i.e. neighbourhood features. Analysing the scope of neighbourhood features provides a vivid description of their influence on other domains of life, and methods of measuring them.

It is further observed that each feature can be assessed through objective and subjective measures and, through theory identified that both forms of measure are significant in determining neighbourhood satisfaction.

The second section of the research explores connectivity of urban networks and its effects in shaping urban structure. In reference to theory by professor and urbanist Bill Hillier urban networks has been defined as the physical network of streets, roads and pedestrian walkways, and connectivity of these networks is seen to influence distribution and development of different parts of the city. The scope of this research is to analyse if connectivity of these networks contributes to the quality of neighbourhood development by comparing it with the people’s satisfaction with their neighbourhood. With the help of spatial analysis tools like Space Syntax this section identifies 2 relevant spatial measures that best represent street connectivity. Together with spatial measures and measures of neighbourhood features an ordinary least square analysis is implemented, with dependent variable Y being neighbourhood satisfaction and independent variables being neighbourhood features and two measures of connectivity. The result of this analysis is a reflection of different relationships between these two concepts.

The results indicated no significant relationship between connectivity of urban networks and neighbourhood satisfaction. It was surprisingly observed to have a negative effect on the level of neighbourhood satisfaction. However connectivity of urban networks were seen to influence neighbourhood features and satisfaction with neighbourhood features, albeit negatively. Nevertheless this indirect measure was considered to test for mediating effects, but the coefficient of influence indicated weak relationships. The research further observed profound effects from control measures ethnic composition and population density.

Keywords

Quality of Urban life, Neighbourhood satisfaction, Neighbourhood features, Connectivity of Urban Networks, Urban Morphology, Space Syntax, Street-integration, multiple linear regression.

Acknowledgements

Firstly I would like to thank my Supervisor Dr Luca D'Acci and co supervisor Marina Salimgareeva for their immense support and guidance in developing this thesis proposal.

Secondly I would like to thank specialisation heads Dr. Ronald Wall, Monserrat Budding Polo and Dorcas for being the unconditional support throughout the course. I would also like to convey my deepest gratitude to Jaap Rozema, my second reader and mentor for the patience and guidance in answering all my queries and providing me with insightful comments.

I am also grateful to Chris de Vries and Rotterdam Wijkprofiel and Roterdam Gemeente for providing me with access to the necessary information that made this research possible, and the patience of listening and answering in detail to many different queries.

Alex Levering and Nicolas for guidance with knowledge of tools without which this research would not have been possible.

To my parents Vinay Raj and Sudha Mysore with giving me the opportunity and confidence in believing that I can achieve anything. My uncle C P Vinod for being the strength and support of family when pursuing such a rigorous course.

And finally my two pillars of strength during this period of study abroad- Hiranmayi Shankavaram and Sneha Gokhale for the endless debates and midnight-odd night, random discussions on the development of this thesis proposal.

Foreword

Abbreviations

IHS	Institute for Housing and Urban Development
OECD	Organisation for Economic Co-operation and Development
Qol	Quality of Life
Qoul	Quality of Urban Life
SCP	Smart City Planner
SWB	Subjective well-being
NS	Neighbourhood satisfaction
NPF	Neighbourhood Physical Features
NSF	Neighbourhood Social Features
NEF	Satisfaction with neighbourhood Economic Features
GIS	Geographic information system
ISQOLS	International Society for Quality-of-Life Studies
SS	Space syntax

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Chapter 1: Introduction

In a world that is under rapid urbanisation, societies and cities are constantly looking to improve assessment of progress by developing and incorporating different tools of measure. The age of economic development has resulted in the frequent use of indictors like foreign direct investment, trade, health and personal wealth in determining life satisfaction. However, a new field of study on happiness economics investigates why some societies transpire to be happier than others. Bordering on the lines of social sciences, the study addresses factors that determine subjective wellbeing and advocate countries to measure societal success, not exclusively through economic growth, but through improved standards of living and better quality of life (Wiking, 2014).
In the scope of this field of study, this research explores spatial factors that determine Quality of Life in urban regions, with particular emphasis on connectivity of urban networks.

1.1 Background

Quality of Life (Qol) is defined as a broad term encompassing all notions of a good, valued and satisfying life. It is often used interchangably with terms of life satsifaction and subjective wellbeing and reflects on different factors responsible in determining life satisfaction.

One of the first recognitions for a context specific analysis identified "quality of life to be reflections, not only, of biological and behavioral factors unique to the individual, but also to the context in which people live their lives" (Leyden et al. 2011). Similar attempts by Marans and Stimson's, improve on this impression by highlighting urban domains of life that are closely related to and effected by place. Redefining the study as Quality of *urban* life (Qoul) they elaborate that "people live their lives in *place*s or series of places, each of which has particular environmental characteristics. Those places might be viewed at various levels or scales – from the dwelling to the local area or neighborhood, to the city, to the broader region or even to a state or a nation" – and it may be argued that where people live will influence their lives and, therefore, their Qol (Marans and Stimson 2013, p.4). The emphasis on "urban" acknowledges that Qol at the scale of the house is different when compared to the scale of the neighborhood, and in urban regions the interactions between house, neighborhood, district and cities are seen to be highly interconnected. The seamless fusion of different scales in an urban environment increases the complexity of understanding the influence of context specific conditions, and for the most part, studies on Qoul have explored geographic and built factors in determining satisfaction.

The city however, is more than just an agglomeration of built and social spaces, it is also a collection of closely linked *networks*. The notion that cities bring people and places together points towards the importance of access and connectivity in determining life in cities. The way spaces connect to each other not only determines how mobility is realized but also seen to influence how economic development distributes through the city. Shops and commercial installations prefer regions within the city that are easily accessible and well connected to the central road network. Similarly "individuals are seen to prioritize their place of residence in light of *access* to public goods and services", deducing that connectivity of urban networks not only influences how spaces develop, but also how they are perceived.

Concurrently, an interesting observation by Leyden and Goldberg (2011) identifies that apart from economic factors, city residents seem happier when they interact and connect with the people and places. This act of feeling connected reflects on spaces that encourage increased interaction such as public parks, community spaces, and recreational facilities. This social element of networks has been described by urbanist and theorist Bill Hillier (2009) as "not merely useful metaphors for how the social world is structured, but the way the social world functions."

The built environment is made of diverse spatial order engulfed in such network models creating relationships of proximity, adjacency and interdependence. Extensive literature in line with architectural studies have also investigated this connection. Studies by Van Ness (2007), in reference to Bill Hillier (1984), demonstrate that a city's level of accessibility and adaptability is highly dependent on its internal connectivity and networking of roadways and motorways. With the help of spatial analysis tools they draw attention to the strength of this system of networks in determining the city's socio – economic performance such as safety and active street life. This social element of networks has been described by urbanist and theorist Bill Hillier (2009) as "not merely useful metaphors for how the social world is structured, but the way the social world functions." In order to understand the influence of spatial element like connectivity requires analysing quality of life at that scale. Hence narrowing down to the local scale, of life within neighbourhoods.

The neighborhood is is seen to comprise of many different dimensions of living- physical, social, environmental, safety, economical, and satisfaction with neighborhood environment is seen to be a reflection of satisfaction in these dimensions. It also seen to contribute to mental wellbeing at the local scale as it acts as a key facilitator to social bonding and connection with place itself (Jacobs, 1992). The importance of neighborhood life and satisfaction have been studied and quoted by many scholars across different disciplines. Even under the banner of QOUL, neighbourhood and satisfaction with the neighbourhood environment is recognised as an integral element to determining urban living. Especially so for the cross-scale effects of its features.

Neighborhood features are an essential component of being satisfied with the neighborhood environment. A neighborhood with weak safety features and accounts of safety is seen to significantly influence the overall satisfaction with the environment. Similarly economic features like cost of housing also determines how residents rate their surrounding environment, albeit indirectly. While most studies reflect on quality of built spaces and distribution of different land uses, little attention is given to understanding how neighborhoods interact and connect with each other or the larger network of the city. In search of this query and acknowledging the significance of network development in shaping quality spaces, this research would like to focus its area of exploration, with Rotterdam city as a case study.

Rotterdam city is the second largest city in The Netherlands, with a population over 600,000 inhabitants(OECD 2014). Located in the province of Zuid-Holland it assumes an important position as the southern hub for the country's economic ring-Randstad Region (OECD 2007). According to the OECD report on Territorial reviews, the metropolitan region of Rotterdam and The Hague (MRDH) plays a significant role for the south Holland quadrant (OECD 2016). Apart from being strategically located in close proximity to the North Sea, making it the much recognized port city and 'Gateway' to Europe (OECD and EDBR 2009), Rotterdam also assumes a central area to travel-to-work for about 1.3 million inhabitants, called Greater Rijnmond (Ungureanu 2010). This discreet arrangement within Randstad and Greater Rijnmond makes the city an important region of economic growth demanding that it be well-integrated and connected.

An important element that shapes the city development is the river Nieuwe Maas. The river, responsible for its "Port status", also divides the city into two very different sections -The north and the south. This form of division has also led to division with how the city has developed. The northern half, comprises of the central business and commercial districts, housing the main railway station. Whereas the southern hemisphere lacks such centralities largely comprising of immigrant and social housing colonies. Through many efforts the municipality and the city have identified that the divide persisted due to lack of connectivity between the two sections.

In order to improve this situation many projects were implemented, one of which was the Kop van Zuid project that focused on rebuilding the southern harbor to reestablish the abandoned area. However, the outcomes of the initial development failed to meet a large degree of its social objectives and also produced physical-spatial fragmentation in between the different neighborhoods due to connectivity and missing functional links. The fragmentation also influenced the use of public spaces (Ungureanu 2010). The municipality further assessed the need for better connectivity with the proposal of new bridges with the intention that the city centre would eventually lie on both banks of the river. However connectivity that links dysfunctional spaces can result in paradoxical situations as experienced.

From the above mentioned, it is evident that connectivity for the city of Rotterdam is crucial for how the city develops. Prior to this assumption there is a need to understand the relation between connectivity and its influence on Qoul. Similar initiatives have indicated connectivity and street integration to influence the level of safety in independent neighborhoods. While other studies have identified well integrated street networks to improve social integration and behavioral patterns of street life (Aghabeik and van Nes 2015). Van Nes suggests that a small local change such as street structure can impact large urban areas or even the entire city. Improvement or implementing a well-connected and evenly accessible street networks are seen to change vitality of several neighborhoods (Van Nes 2007; van Nes 2009b).

1.2 Problem Statement

The process of rapid urbanization and intercity migration into dense agglomerations draws concerns for the quality of life in urban regions. The OECD report states nearly 70% of the world's population to be nested in cities within 20 years (OECD 2015; Durand 2015). To be able to assess Qoul in such conditions requires identifying factors responsible in shaping life in urban regions. While most studies on Quality of life and quality of urban life have studied the influence of economic and geographic factors such as income, housing, education and quality of built environment, little notice is given to spatial factors such as connectivity and network development. Similarly, satisfaction with urban living is seen to occur at various geographic scales (e.g. home, neighborhood, community, city and even regions). However how these scales connect to one another and to their surrounding environment determines how they are used and perceived.

The scale and shape of cities often produce organizational forms that inevitably influence the daily lives of residents. From determining how spaces distribute and are made accessible, city shape and structure is seen to also contribute to residential wellbeing (Brown et al. 2015). Leyden and Goldberg identify individuals and firms to prioritize their place of residence in light of *access* to public goods and services, provokes the scope of access and connectivity on the subjective perception of living environments. This manner indicates the importance of connectivity of urban networks in determining quality of life. Some studies highlight perceived access to local parks and green space to influence Satisfaction, and Quality of Life, however, limited research explores the potential of accessibility and good networking as a factor responsible for maintaining these conditions.

Morrison notes that "people reside in cities largely because cities bring everything closer and, is confirmed in the way access is realized in subjective well-being terms. When access is precluded or made very difficult, it soon reduces people's well-being" (Morrison 2011, p.23)

Similarly, how the urban spatial environment affects and desirably molds the choices of our daily behavior, is a pivotal component of future research for it helps determine whether the cities we build are truly the ones we desire to live in (Sevtsuk 2012).

1.3 Research Objective

The research aims to explore the potential of spatial factors in determining quality of life in urban regions. Particularly aimed at investigating connectivity of urban networks at the scale of the neighbourhood and neighbourhood satisfaction. Urban networks are defined as the bulk of streets, roads and motorways responsible for enabling city functions. Hence how they interact and connect also determines how the city and its neighborhoods interact. Following an extensive theoretical review of the two concepts (neighbourhood satisfaction and connectivity of urban networks) the dissertation hopes to identify the scope of urban networks as a factor determining neighbourhood satisfaction.

Taking Rotterdam city and its 71 neighbourhoods as a case study, the research assess levels of connectivity and neighbourhood satisfaction by identifying three relation effects, namely, effects of neighbourhood features on neighbourhood satisfaction, neighbourhood features and connectivity of urban networks, and neighbourhood satisfaction and connectivity of urban networks. This three step analysis explores plausible mediating effects of neighbourhood features and the overall effects of connectivity on neighbourhood quality of life. The proposal hopes to contribute to planning and policy development initiatives that work with improving networking, neighbourhood development and better quality of life.

1.4 Research Question

<u>1.4.1 Main Question:</u> The main research question summarises the objective of this research proposal, which is to comprehend:

To what extent does connectivity of urban networks (street networks) determine the level of neighborhood satisfaction, for Rotterdam city?

<u>1.4.2 Sub-questions:</u> In order to elaborate the main research question, research sub questions break down the concept of neighborhood satisfaction and connectivity of urban networks. Neighborhood satisfaction is seen to be measured as the sum of satisfaction with neighborhood features. Hence the sub question explores firstly,

What neighbourhood features significantly influence neighbourhood satisfaction, specifically for Rotterdam City?

a. *Physical features*
b. *Social features*
c. *Safety features*

And secondly,

To what extent does connectivity of urban networks (street networks) influence these neighbourhood features (objective measures)?

1.5 Scope and Limitations

The scope of this dissertation focuses on analysing neighbourhood satisfaction for the city of Rotterdam, thus narrowing down to a niche area of study focused at a single city. The research results are unique to context and cannot be generalised to other cities.

The second limitation concerns the validity of data derived from secondary source. The information for neighbourhood satisfaction was obtained from a secondary database- Rotterdam Wijkprofiel, which again is an amalgamation of results derived from two surveys conducted at different times under different themes. The validity of survey findings are subject to modifications such as balancing and raking. Such alteration influence the consistency of results, and hence the validity of this study. A fitting example of this form of manipulation can be observed with merging of information for independent neighbourhoods under a single measure, due to lack of responses from the partnering neighbourhood. Such mergers leave

Another limitation of the research, is the method incorporated to analyse connectivity of urban networks- Space Syntax analysis. Connectivity was measured using two specific syntax measures – Axial integration and Angular Segment analysis, a software definition of the level of connectivity of urban street networks. The limitation of space syntax has been addressed by professors and researchers for theoretical and practical purposes. A detailed account of the theoretical limitation is described in Chapter 5, under Conclusions, while practical drawbacks are as follows. The software makes use of a technique which requires the user to independently trace out streets and road networks (axial lines). This method can result in different interpretations based on the knowledge of the user on the subject and area being studied. Nevertheless similar studies using space syntax analysis for the city of Rotterdam specifically have been conducted and were used as references for this research analysis. Correspondingly, with the use of tools Qgis and Openstreetmaps ensures that from the aspect of representations the maps and measures generated are original and factual. However, the research recommends future studies to exercise alternate tools and methods to assess connectivity of urban networks.

Chapter 2: Literature Review / Theory

2.1 Introduction

This research analyses satisfaction with urban living through the view of accessibility and connectivity. For this purpose, it explores two areas of study- Quality of life studies and Urban Morphology (spatial analysis studies). The first part of the chapter charts a general overview of Quality of life (Qol), advancing towards a place based perspective known as Quality of Urban life (Qoul). The aspect of "urban" lays emphasis on the influence of "place", such as connectivity of urban networks, and analyses domains that are closely affected by place. With the view of connectivity, the study narrows down to study one of the domains of Qoul- Neighbourhood satisfaction.

The second half of the chapter narrates a detailed account of the significance of neighbourhood satisfaction, methods to assess it and the cross-scale effects of its constituents- neighbourhood features. It further elaborates on relevant neighbourhood features that are affected by "place".

The third section discusses in depth, connectivity of urban networks through the influence of urban structure, introducing theories on connectivity and accessibility, and subsequently narrowing down to the approach adopted by this research- Space syntax analysis. Additionally, it narrates a sound understanding of the spatial measures used to analyse urban networks and concludes with a conceptual framework that summarises the plausible relationship between connectivity of urban networks, neighbourhood features and their overall influence on neighbourhood satisfaction.

2.2 Quality of life (Qol) and Quality of *Urban* life (Qoul)

Quality of Life (QOL) is defined as a broad term encompassing all notions of a good, valued and satisfying life. The concept in its versatility is often used with impressions of "well-being", "life satisfaction" and "happiness" (Diener et al. 1999). From a theoretical perspective, Qol is considered a global assessment of life situations based on satisfaction with different life domains. However, Pacione identified quality as "an attribute not inherent to the environment, but a behavior-related function of the interaction of environmental and personal characteristics" (Pacione 2003, p.20). This ideation radically altered the approach to analysing QOL for it discovered that, conditions of place do not exclusively convey the true value of place, and that quality was a measure of the meaning of those conditions to its occupants (Marans and Stimson 2013). This approach later became known as the *subjective approach* to assessing life situations and admittedly created an upsurge in areas of social and natural sciences, exclusively with the formation of the International Society for Quality-of-Life Studies (ISQOLS), and launch of the journal Applied Research in Quality of Life (2006).

Studies on Qol have focused extensively in examining individual-level attributes like income, employment, age, and health to determine life satisfaction. But it has been noted that people reside in places that are pertinent to a larger environment. Encompassing different dimensions of living from built, natural and socio-cultural to being distributed at different scales such as the house, neighborhoods, districts, cities and even regions (Marans 2005: p. 315). All of which are seen to contribute to shaping different living conditions and thus quality of life. This form of living can also be compared to conditions as experienced in urban environments- a seamless merger of symbiotic relations where one form of living is interdependent with another. Given that a large portion of today's population live in such urban agglomerations, it is fundamental to understand the influence of these urban scales on Qol. In this consideration, Marans and Stimson (2013) provide an alternate narrative to the study, constructed towards life in urban regions, classifying it as the Quality of Urban life (QOUL) and reviewing life experiences of residents and individuals with reference to place and setting (Marans and Stimson, 2011).

Quality of Urban Life (Qoul)

According to Marans and Stimson, Quality of Urban life (Qoul) is "the satisfaction that a person receives from surrounding human and physical conditions. Conditions that are scale-dependent and can affect the behavior of people, groups, such as households, and even economic units (firms)" (Mulligan et al. 2004; Marans and Stimson 2011, p.1). It is seen to have large cross-scale effects in:

- ❖ determining livability of cities, by providing matrices useful for planners and policy makers in assessing effectiveness (Marans, 2002)
- ❖ motivating locational decisions for residents (Campbell et al. 1976b; Marans, 2011)
- ❖ influencing patters of intra urban migration and regional- economic/environmental growth (Kemp et al. 1997)

In this context, it is also progressively being incorporated as a relevant tool for developmental policy, manifesting amongst different organizational objectives. For instance, The Organisation for Economic Co-operation and Development (OECD) includes life satisfaction as an important indicator in its Better Life Index.

But what makes life in urban regions distinctive? Marans and Stimson's definition emphasizes two fundamental aspects of urban living. One, the surrounding environment and physical conditions play an important role in shaping quality of life, and two that surrounding physical environment is connected at different scales. Together the two elements of contextual conditions and scale establish the importance of "place" - the physical and spatial environement unique to different regions moulding the character, feeling and Qol. The importance of place has been emphasized by many theorists. Richard Florida (2013) for example, in his book "*Who's Your City"* highlights place as governing *aspects of living*, like income earnt, friendships made and the difference in happiness experienced in different places. The author states "*People are not equally happy everywhere, and some places do a better job of providing a higher quality of life than others."* In the case of metropolitan life "individuals prioritize their place of residence in light of opportunities for work, access to public goods and services. Other factors like feeling of community, safety and familiarity are also determined by place and contribute to quality of life in those places (Florida and Melander 2013,pg no.614). All the mentioned studies indicate significance of place in determines aspects of living when assessing Quality of life.

Studies on Qoul pursue a bottom-up approach wherein overall satisfaction is seen as the result of satisfaction with different life domains. Broad classifications that help distinguish different life circumstances based on, the extent to which circumstances fulfil goals and needs of the individual (Kahneman et al. 2004) or, quality of *objective conditions* that define the domain (Heller et al. 2004). The concept of domains have been employed in many fields of study. Cummins, McCabe, Romeo, and Gullone (1996) provide an empirical and theoretical argument recognizing seven life domains: material well-being, health, productivity, intimacy, safety, community, and emotional well-being, while studies on happiness reflect on life domains directly related to happiness levels of individuals- health, family relations, financial situation and even job satisfaction (Van Praag 2010). Quality of Urban life (Qoul) however, prioritizes exclusively to the influence of "place", hence identifying three specific domains closely related to place:

- ❖ The House,
- ❖ The Neighborhood, and
- ❖ The immediate Community.

Satisfaction with each domain is seen to determine overall satisfaction with Quality of Urban Life (Marans and Stimson 2013).

Of the three domains, the house and satisfaction with housing has been studied and discussed to have the most impact on quality of life. House and housing conditions, quality of the built space and location decisions all are seen to be determined with satisfaction with housing. However the frequency of interaction and interlocked nature of different scales in urban regions, requires analyzing the scope of influence between the three domains and effect of “place”.

2.2.1 Place-based Domains

The house and satisfaction with housing is seen as a place based domain for it accounts for aspects of housing in different urban contexts. The house represents a scale that analyses micro relations, such as quality of house, number of rooms, quality of ventilation and lighting, level of crowding and even quality of family relations. Each of these conditions are related to the quality of place and hence influenced by place effects.

Satisfaction with community is seen as a place based domain, as it measures social aspects of urban living such as frequency of neighborhood interactions, active street life, sense of safety and sense of belonging, through contextual experiences. It acknowledges the principle idea that man is a social being and quality of social relations is an important aspect for life satisfactions, but it also identifies that the quality of the space in which social bonding takes place influences community satisfaction. Unlike the other two domains, community satisfaction is one of the most effected through place dynamics. However, the domain on its own only accounts for quality of place effects, or experiences the place delivers, and does not directly measure the quality of place.

Satisfaction with neighborhood on the other hand, is an area that addresses both aspects of urban living. It is seen to evaluate both physical as well as social aspects of the environment. Physical attributes such as walkways, green spaces, parks, public furniture, quality of roads, and access to public transport play an integral part in determining quality of the environment. The quality of these attributes, further instigates their level of use and there in social aspects of living. This dual role/ capacity of the neighborhood to perceive two aspects of living makes it an essential measure in determining quality of urban life and hence has been recognized and researched by many varied disciplines.

In this context, to understand the influence of place at the local scale and connectivity of urban networks, this dissertation chooses to study the third of the three domains, i.e. neighborhood satisfaction.

2.3 Neighbourhood Satisfaction

Neighbourhood satisfaction is a subjective evaluation, of different aspects of neighbourhood life. According to Marans (2003), it can be defined as a collective measure of satisfaction with different neighbourhood features. Under the banner of Qoul, neighbourhood satisfaction assists in the evaluation of objective conditions of the immediate urban environment and has been incorporated as an essential tool of measure amongst many diverse fields of study.

Empirical research in health, social cohesion, residential mobility, crime, safety and even wellbeing highlight the importance of neighborhood satisfaction in shaping aspects of the urban environment. A study in preventive medicine, analyses the relationship between *perceived* quality of neighborhood characteristics and mental health of residents, through the mediating effects of neighborhood satisfaction (Leslie and Cerin 2008). Perceptions of neighborhood characteristics and neighborhood satisfaction were measured through surveys, and the results presented three neighborhood characteristics (safety and walkability, social networks, traffic and noise) to significantly predicted self-reported mental health. The study deduced that maintaining negative perceptions of one's neighborhood for a sustained amount of time could contribute to overall stress and therefore affect mental health. It further advocates the need for future residential development to support and encourage higher levels of neighborhood satisfaction (Leslie and Cerin 2008).

Another study on level of socioeconomic mix furnished surprising results wherein neighborhoods with a diverse mix of residents and socioeconomic status were seen to negatively influence satisfaction (Baum et al. 2010), questioning the genuine perception of diversity. The impact of socioeconomic characteristics of a neighborhoods have been addressed by Sirgy and Cornwell (2002) and more recently by Kearns and Mason (2007) and Mohan and Twigg (2007), with all three studies finding type of neighborhood one resides in, as measured by tenure or socioeconomic status, to have important impacts on satisfaction.

On the other hand, numerous papers indicate strong associations of neighborhood development and satisfaction with residential mobility (Brown and Moore 1970). A dialogue by Herzog and Schlottmann (1986), Whisler et al. (2008) imparts the influence of personal characteristics, life course attributes and location specific attributes like quality of (neighborhoods) to be the core reason on household migration. Studies have even suggested residential mobility behavior to depend on perceived reputation of the neighborhood. Attributing image and status of the neighborhood, from the outlook of other city residents, as an important factor determining satisfaction (Permentier et al. 2011).

An interesting study on the city of Famagusta, of The Turkish Republic of Northern Cyprus, impresses upon neighborhood structure and development as sculpting social cohesion and neighborhood bonding. The study identifies that for small compact cities like Famagusta with a low rate of mobility and a low to middle socio economic status, binds residents to the physical structure of their neighborhood. The neighborhood encompassed many elements of life acting as both a physical and a social entity, hence the structure of long arterial roads played a significant role in enabling accessibility to different spaces, encouraging active street life. The study further identified, out of all the comparisons, sense of safety, cleanliness, neighborhood attractiveness and sense of community as significantly determining neighborhood satisfaction (Derya and Ahmet 2011).

Neighborhood satisfaction is also seen to be closely related to perception of crime and safety. Studying quality of life in Brisbane, Australia, McCrea *et al*. (2005) encounters a strong *negative* association between perceived crime and neighborhood satisfaction. This result is seen to correspond with research by Parkes *et al*. (2002) who identified a strong association between those reporting crime and lower levels of satisfaction. The spatial scale of neighborhood characteristics is seen to play a significant part in establishing quality of life, especially with the case of social safety and accessibility (Ettema and Schekkerman 2015). In this case then a better integrated neighborhood structure could encourage better levels of safety?

Apart from structural and social factors, satisfaction with neighborhood environment is also to be influenced by socio-economic conditions like income, home ownership and period of stay. Having higher income has been associated with high levels of neighborhood Satisfaction (Galster and Hesser, 1981; Parkes *et al*., 2002), and similarly homeowners, when compared with other tenure forms, are also seen to be more satisfied with their neighborhoods (McCrea *et al*., 2005; Lu, 1999, Mohan and Twigg, 2007). Some studies also suggest housing conditions to influence neighborhood satisfaction but without direct causal determinants (Baker and Arthurson, 2007, Parkes *et al*., 2002). Kasarda and Janowitz (1974) found a positive association between length of residence and satisfaction (see also Lu 1999, Mohan and Twigg 2007), while other work by Marans and Rodgers (1975) illustrated negative.

The diverse scope of neighborhood effects and relations, compels the need to understand how neighborhood satisfaction is measured. In this query the next section provides a detailed overview of methods of assessing and evaluating the same.

2.3.1 Measuring Neighbourhood Satisfaction

Neighbourhood satisfaction is first and foremost a subjective assessment, measured through survey questionnaires that request residents to rate, *"Taking all things together, how satisfied are you with the neighborhood you reside in?"* at a Likert scale of 1-5, where 1 is "extremely dissatisfied" and 4 "extremely satisfied" (Sirgy and Cornwell 2002; Patterson and Chapman 2004; Derya and Ahmet 2011; Herbert 1993; Leyden et al. 2011). This form of measurement, allows residents to perceive the neighborhood environment as an entity on its own, unlinked to other domains of satisfaction. Concurrently, neighborhood satisfaction (NS) is also measured by assessing different features that make up the neighborhood environment.

Neighbourhood features

Neighbourhood features are quantifiable conditions responsible for how the environment functions and is perceived (Sirgy and Cornwell 2002). The conditions contribute to identifying the neighbourhood as a lively, safe, unsafe or isolated environment. They are often categorised under different definitions, but the most conventional classifications used are physical features and social features. Additionally, empirical research also identifies other dimensions such as, economic features and safety features, but fundamentally neighbourhood features are a varied set of neighbourhood living conditions often assessed by measuring different indicators. For example, economic features analyse aspects such as value of property / cost of living, which describe the economic status of the neighbourhood (Sirgy and Cornwell 2002). While crime and safety keep track of incidents of theft, violence, abuse that a neighbourhood is exposed to.

The intention to categorise different features of the neighbourhood is to help residents assess different aspects of the neighbourhood life in clarity (Marans, Robert W.; Stimson 2013). The following table sums up some of the universally used indicators to represent respective neighbourhood features (Table 1).

Table 1. List of Neighbourhood Features and respective Indicators.

Neighbourhood features	Scope of measure	Indicators
Neighbourhood physical features	Measures aspects of neighbourhood built environment, largely focusing on maintenance and quality of spaces. (Sirgy and Cornwell 2002)	- Upkeep of homes and yards, - Landscape in the neighbourhood - Level of street lighting, - Crowding and noise level, - And even access to Facilities.
Neighbourhood social features	Measures aspects of the neighbourhood environment that encourage and enable social relations within the neighbourhood.	- social interactions with neighbours and people living in the neighbourhood, - ties with people in the community, - crime in the community, - race relations in the community, - sense of privacy at home
Neighbourhood economic features	Is an aggregate measure of satisfaction with different economic conditions within the neighbourhood.	-housing value in the neighbourhood, - cost of living in the community, - socio-economic status of neighbourhood, - And neighbourhood improvement.
Neighbourhood safety features	Measures aspects of the environment that ensures levels of crime and safety and also reflecting on accounts of theft and violence.	- number of thefts, - reports of burglary, pickpocketing etc - Perception of crime and safety, - experience of nuisance
Neighbourhood environmental features	Measures the level of environmental quality by reflecting on issues of air, water, noise quality.	- reports on air quality, - reports on noise quality, - reports on traffic congestion, - perception of water supply etc

Of all the features studied, Neighborhood satisfaction is seen to be best predicted by neighborhood interaction and perceived crime, with neighborhood interaction being more important for older people, while perceived crime is more important for younger and single people (McCrea et al. 2005). What this implies is that for the most part being satisfied with neighborhoods greatly depends on the level of safety and sense of belonging. Constant interactions with neighbors and active street life are seen as important aspects that ensure a lively and healthy neighborhood.

Cross scale effects neighborhood features is further elaborated by Sirgy and Cornwall(2002) in an extensive study exploring the potential of neighborhood features as determinants for other domain satisfaction (annex 3, detailed review). The highlight of their research, depict neighbourhood features to effect more than the bounds of neighbourhood satisfaction, and influence perceptions of housing as well as community satisfaction. The authors investigate the concept using three models, progressively increasing complexity of the relationships between neighbourhood features and the three selected domains (physical, social and economic). Their experiment revealed satisfaction with physical features of neighbourhood to predict both neighbourhood satisfaction and housing satisfaction, while satisfaction with the social features predicted neighbourhood satisfaction as well as community satisfaction. Likewise, satisfaction with economic features were perceived to predict housing satisfaction and home satisfaction. The models depict the intricate relationship between domains and features and highlight the complexity of urban relations.

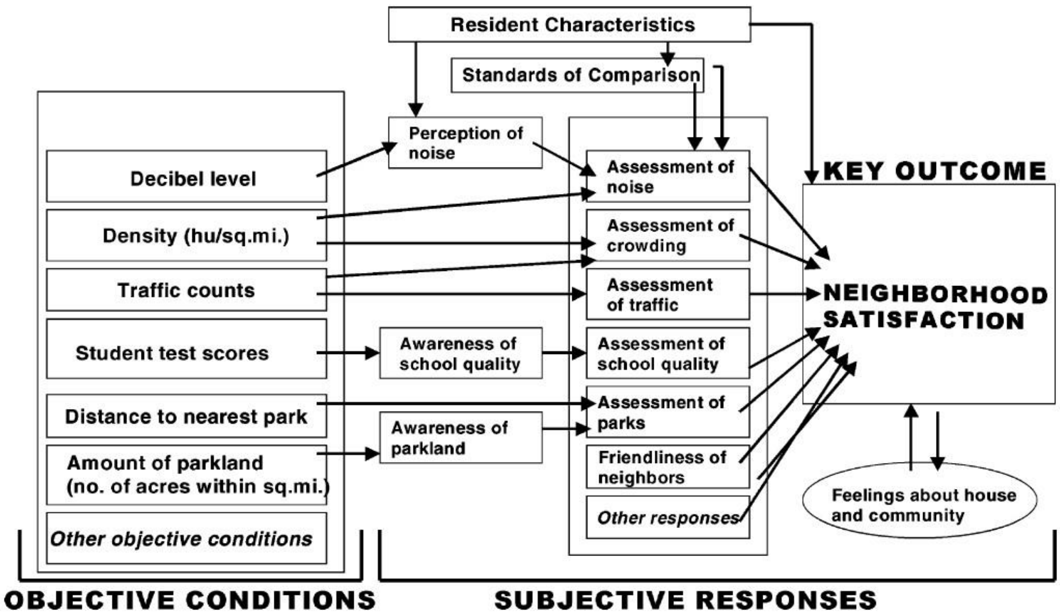
To assume that certain features affect certain domains would be neglecting cross scale relationships.

2.3.3 Methods of evaluation

It has been noted, neighbourhood satisfaction is a subjective evaluation of objective conditions based on the extent to which the conditions mean to the user. This form of assessment is particular in that, quality does not determine satisfaction on its own and that satisfaction is a reflection of personal needs and preferences. In such situations, judging quality and satisfaction can be convoluted. The assumption that good quality conditions of the environment should instigate positive reports on satisfaction is not necessary.

Addressing this complex form of assessment, theorists suggest two measures of assessment–objective and subjective. Objective assessments quantify conditions and characteristics of the neighbourhood through collected information such as government records and data from law enforcement bodies, city management bodies etc. Subjective assessment on the other hand is a reflection of people's perception of different objective conditions, obtained from survey questionnaires. The basis of this form of assessment is similar to that observed with QOL, where in objective conditions are assessed by individuals based on a presumption of the conditions and standards of comparison. Similarly, each neighbourhood feature can be assessed through objective and subjective approaches as elaborated by Marans (2003) in the following model. The model indicates satisfaction to be the sum of perceptions and objective conditions.

Figure 1. Model showing relationships between objective conditions, subjective responses, and neighborhood satisfaction

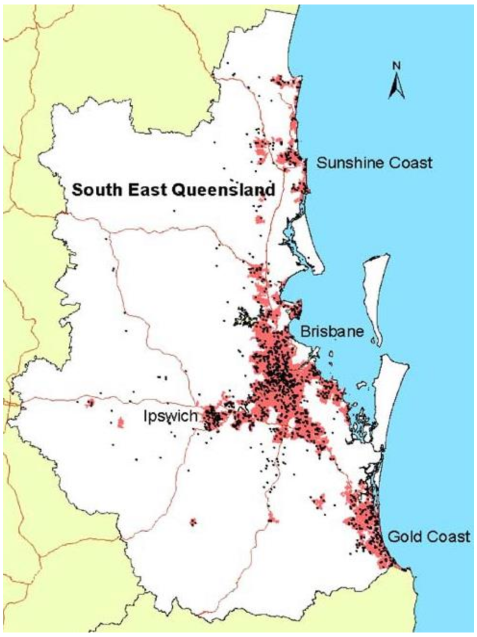


Source: Understanding environmental quality through quality of life studies, Author: Robert W. Marans, (2003)

When weighing observed measures over perceptions, it is seen that *perceptions* better explain satisfaction with neighbourhood conditions (Galster and Hesser, 1981; Parkes *et al.,* 2002). "Studies on neighborhood satisfaction have indicated considerable importance to the perception of housing and neighborhood conditions" (Lu, 1999). Surprisingly when including perception measures into neighborhood attribute models, some neighborhood characteristics are rendered insignificant especially after controlling perceptions (St John and Clark, 1984; Parkes *et al.*, 2002; Mohan and Twigg, 2007). This implies that some objective characteristics only have an indirect effect on neighborhood satisfaction, with perceptions of neighborhood attributes as intermediary variables (Permentier et al. 2011).

Similar studies anticipate *improvements* in objective conditions to improve subjective experience. However, Cummins(2000) distinguishes between the two concepts, identifying objective indicators to quantify public experiences of the environment and subjective indicators to represent private assessments, which are often influenced by *individual comparisons* and *personality traits*. Rod McCrea along with Shyy and Stimson (2006) specify an interesting example of this relation, for South East Queensland, with a study on objective and subjective perceptions of accessibility and crowding, to services and amenities.

Figure 2. The spatial distribution of respondents in South East Queensland



Source: "What is the Strength of the Link between Objective and Subjective Indicators of Urban Quality of Life?" Author: Rod McCrea et al. (2006, pp.84–85)

The study observed subjective measures of access to be predicted by objective measures of access, affirming that closer access to amenities induces a higher feeling of access. Similar results were observed for crowding, however statistical coefficients were seem to explain only 2% of variance.

Qol was significantly predicted by subjective access and overcrowding, with subjective access having a greater influence and accounting for 34% variation. Objective access was completely mediated by subjective access, suggesting that subjective access better described accessibility in general and not actual distance measures. On the other hand, Objective measures were found to correlate with each other than with subjective measures.

All in all the study found no firm relation between objective variables and their subjective measures, suggesting that improvement in objective measures need not improve subjective measures. Nevertheless subjective measures were seen to significantly influence Quality of Urban life (McCrea et al. 2005).

The study concluded with the assessment that subjective evaluations were equally important representors of urban conditions and further affirmed that, when measuring QOUL, both objective and subjective measures need to be considered. Specifically at the scale of the immediate environment like the case of neighbourhoods. Alternatively a weak relation was observed while assessing impact of *improvements*, through subjective measures. Post improvements of objective conditions, satisfaction levels of residents were seen to return to normal levels through a processes such as habituation, homeostasis or rising expectations (Cummins 2000). Similar results were observed from studies on other life domains, where objective indicators were generally found to be weak predictors of satisfaction (see, for example, Cummins 2000; Evans and Huxley 2002).

Table 2: Example of Objective measures and Subjective measures of Neighbourhood Features

Objective Measures	Subjective Measures
Crime statistics	Perception of crime/ theft/ burglary
Accident statistics	Perception of health care service
Accounts of domestic violence	Perception of access to amenities
Number of amenities within standard distance	Feelings about level of privacy
Density and congestion statistics	Feelings of crowding and noise
Accounts of active participation, family visits	Feelings about frequent interactions with neighbours
Percentage of residents with income range,	Perception of cost of living
Percentage of houses with transport in standard distance	Perception of access to transport facilities, satisfied with access to fasciitis

2.3.5 Similar Studies

The abstract nature of QOL studies often allows it to relate to other concepts of "wellbeing", "happiness" and "life satisfaction". This relation is not limited to the concept alone, but is also seen to provoke similar results, that highlight the need to assess contextual setting of the environment and impact of place. In line with Happiness research, Dimitri Ballas notes that, individuals live in households which are part of a neighbourhood which is again part of a larger regional body. Hence, while measuring happiness, one must consider happiness at these different scales, or rather how these different scales influence happiness. This idea throws light on the contextual setting of an urban environment and emphasises that assessment of happiness is subject to influences of grouping. (Ballas and Tranmer 2012).

Similarly, with respect to assessing the influence of connectivity Putnam, suggests happiness to best be predicted by the "breadth and depth of one's social connections" (Putnam 2000, p. 332). By addressing connections as social interactions that result from a vibrant civil society with active urban spaces, pedestrian oriented streets and active neighbourhood life. Putnam explores determinants that enable social connections and debates weather *spatial differences* within urban areas foster different levels of happiness. The highlight of his study, questions the impacts of traditional mixed uses spaces and pedestrian friendly networks in comparison to single use car dependent networks. In conclusion the authors hypothesis that if any relationship exists between spatial parameters and happiness that would be largely because spaces generate complex urban dynamics that connect many different aspects of human lives.

2.4 The Influence of Urban structure

Understanding the bond between spatial structure of human settlements and social processes that take place within them is one of the central challenges of city planning (Sevtsuk 2010). Despite extensive investigation the relationship still remains to be a topic of extraordinary complexity. In reference to Jane Jacobs's theories on cities as "problems in *organized complexity"*, we identify that cities are made up of and influenced by large number of variables, each creating complex relationships with one another. This poses a difficult challenge for planners and analysts for it requires perceiving the city through these multiple relations and understanding combinations that best suit the city's context. A particularly fitting example of this situation is expressed through Jane Jacobs's thoughts on city parks:

"How much a park is used depends, in part, upon the park's own design. But even this partial influence of the park's design upon the park's use depends, in turn, on who is around to use the park, and when, and this again depends on the uses of the city outside the park itself" Jane Jacobs (1961).

Her observations highlight that the function of space is dependent on its position and interaction within the larger urban network. In the case of urban realities, the cityscape acts as a spatial system of, built clusters within a complex network of roads and streets. And it is this complex network of roads and streets that allows the space to extend beyond its limit of a physical body, and become a social space. This dual role of space has also been recognized by renowned professor and urban planner Bill Hillier in his theories on Space and society. Defining them as "Urban networks", he further categorizes space as a "reproductive space" when it reflects social needs and "morph genic space" when it shapes social processes. His idea of "city as a spatial system" emphasize that configurational nature of cities and the need for a configurational approach to studying them (Hillier and Iida 2005). Relative studies by Akkeilies van Ness (2009) also depict how spatial structure of neighborhood layouts influence crime and safety, questioning whether certain spatial layouts foster unsafe environments. Their extensive research forms the back bone for spatial analysis of this study, and will be discussed in detail through the next section.

The influence of urban structure has been debated and discussed under other headings as well. The Neo-Marxist planning theory, for instance, addresses urban development while acknowledging the diverse actors and institutions affecting spatial structure of cities. The theory visualizes the city to comprise of a series of transactions that determine land use and functional distribution (Sevtsuk 2010).

Noted urban planners Kevin Lynch(1960) and Jan Gehl(1996) take on a different outlook to urban networks comparing them to the built environment, as "the space between buildings". Pockets of open space that are shared by public and considered valuable assets to the city. Their perspective address built aspects of urban design like, visual esthetics of buildings, quality and maintenance of the streetscapes, quality of lighting and even quality of greenery. However, Sevtsuk notes that even the most outstanding individual buildings or public spaces can fail to be adopted by their users "if the spatial configuration around them disincentives their working" (Sevtsuk 2010).

Substantial literature on health and transportation point out the positive effects of urban structure in increasing physical activity and creating healthy environments. The studies discuss impacts of level of density, land use diversity, connection of streets and access to public transport as facilitators for pedestrian movement and less motorised travel within a neighbourhood. The studies hypothesize land-use diversity with increase in neighbourhood walkability, as it increases the number of available destinations. This within a dense network of well-connected streets, makes the space more accessible to residents and encourages them to engage in non-vehicular travel. And as walking leads to more social interaction called “neighbourliness”, the studies assumes fewer depressive symptoms (Miles et al. 2012).

Empirical research in urban and regional economics also incorporate spatial analysis in their studies stating “*neo-traditional, mixed-use, and walkable neighborhoods to generate higher socio-economic benefits than typical suburbs”* (Sevtsuk 2010). “Similarly in the case of, encouraging the location of economic activities in city centers, one has to understand how shop and retail locate themselves in vital areas in urban grids. These kinds of economic activities depend on potential movement patterns and optimal strategic places in an urban network.” (van Nes 2007). The United Nations Habitat in collaboration with the International Society of City and Regional Planners (ISOCARP) addressed particularly, the importance of spatial development and managing spatial solutions at the World Urban Forum, Medellin. The conference debated radical concepts of “spatial justice” and identified that compact, better connected and integrated urban patterns can help improve policy choices oriented towards social cohesion (ISOCARP 2014).

The essence gained from all the addressed studies is that cities are primarily large social networks, consisting not only of agglomerations of people, but more so of social and physical links. Furthermore, space and infrastructure are fundamental elements that enable these links to persist (Bettencourt 2013). Embracing concepts from these theories, this dissertation concentrates on analyzing urban structure through the connective strength of its street layouts, termed “urban networks”. Unlike traditional urban design studies that examine built quality of buildings and streets, this dissertation will focus predominantly on spatial interdependence between urban networks and processes. As professor and urban theorist Sevtsuk notes, the spatial configuration of urban environments can significantly influence social use of spaces, to a much greater extent than the “sensory qualities”, and a better recognition of the strength of these urban networks can lead to a better recognition of the fundamental interactions they stimulate (Sevtsuk 2010).

2.4.1 Urban Networks

Referring to works by Hillier, Hanson, Iida and Van ness, urban networks can be understood as the physical network of streets and roads that connect and give form to urban agglomerations. Some also refer to it as the counter-space between buildings and built objects in the city (Schaasberg 2012). While other refer to it (amongst architects and planners) as "Form" or "morphology" of a city. The core principle behind analyzing urban form, is to identify patterns of social connections amongst the cities physical connections and accentuate the manner in which physical networks interact and facilitate connective development.

Hiller and Hanson (1984) define the city as a "spatial system", comprising of different spatial configurations that are not unique to place, but are seen to recur at different situations and through different societies. To understand why patterns recur requires understanding the city through a "configuration approach", that is, to understand the relationships they create. Popularly known as the "structure-function theory" it states that form and function are inseparable, and society is seen to take up a definite spatial form (Hillier and Hanson 1984, p.27).

The physical process of forming societies is seen to involve placing people in relation to one another in some form of spatial order. Hillier identifies two such orders where in space *Reflects* what the society needs, reproducing simple societal/ cultural models of living, and, where space *Shapes* the society through placing strong markers of buildings, boundaries, paths and zones, which are often specific to context and location. Nevertheless in both senses, "society acquires a definite and recognizable spatial order" (Hillier and Hanson 1984, p.27).

When comparing this process to cities it is observed that cities are nothing but "spatialized societies" (Hillier 2014), constituting a dense cluster of buildings, and a sweeping network of interconnected streets, motorways and pedestrian walkways. These interconnected streets and motorways interact at different scales and can be categorized into two– "the foreground network" possessing linear characteristics and usually spanning through the entire urban structure connecting different portions of the city (a global scale), and a "background network" – largely small straight and short stretches of streets that connect at the local scale. Ultimately the two types together form the core space for movement and accessibility. Research has shown that about 50 to 80 percent of the movement flows in a city, occur due to the structure of this network. This does not mean that space determines individual movement, but is an indication that some spaces get used more often than others (Hillier 2009).

Often, it is the emergent effects that planners and urban theorists seek to study, but in order to understand how these emergent effects occur requires first understanding how these networks connect with each other. There have been many attempts to measure urban networks, abundantly reflecting on emergent effects and limited on analysis of the network itself. This dissertation focuses largely on the second method of measurement (analysis of networks themselves), described in the next section, with a brief narrative of some popular theories.

2.4.2 Measuring Urban Networks

Aforementioned, when measuring urban networks, one fundamentally measures two network effects- mobility and accessibility. While mobility is the measure of individuals moving through a network and is essential in accessing space, it does not account for spatial features of the environment. It is rather a measure of the capacity/ capability for individuals to be mobile.

Accessibility alternatively, is a direct measure of spatial strength of the network itself. Accessibility, has been defined by many scholars (Wachs and Koenig 1979; Handy and Niemeier 1997; Bhat, Handy et al. 2000), but a collective description provided by Sevtsuk and Ratti is "the *ease of an individual to pursue an activity of a desired type, at a desired location, by a desired mode"* (2010, p.35). Some theorist also refer to the measure as *Place-accessibility, which* emphasizes on geometrical properties of places that encourage through movement (Schaasberg 2012). It is seen as an important element when selecting a location for activities. The underlying measure for place accessibility is metric distances as it quantifies other variables based on distance measures, for example transportation costs which are an important aspect of activity location and distribution. This metric form of measure is also referred to as *objective accessibility* (Sevtsuk 2010).

However, researchers suggest the use of alternate measures, other than metric measures, that highlight the *notion* of access or the sense of proximity of an individual to a given location. Harnessing *cognitive assessment* of location positions the measure aims at the experience of physical travel through an urban environment, not inclined through the measure of distance or time costs (Sevtsuk 2010). This form of measures is also known as *subjective accessibility*.

Unlike metric accessibility measures, subjective accessibility describes movement reflecting on paths chosen (longest or shortest) and directions preferred (angle of movement), also termed way-finding skills. Empirical studies of pedestrian path choices in urban settings have found that though distance or travel time are reported as dominant criteria for path choice, the actual paths taken are often longer than the shortest available path, typically remaining within a 20 per cent distance threshold of the shortest path (Takeuchi 1977; Li and Tsukaguchi 2005). In addition to minimizing distance, researchers also argue that urban travelers tend to minimize route complexity and maximize opportunities along the process of moving.

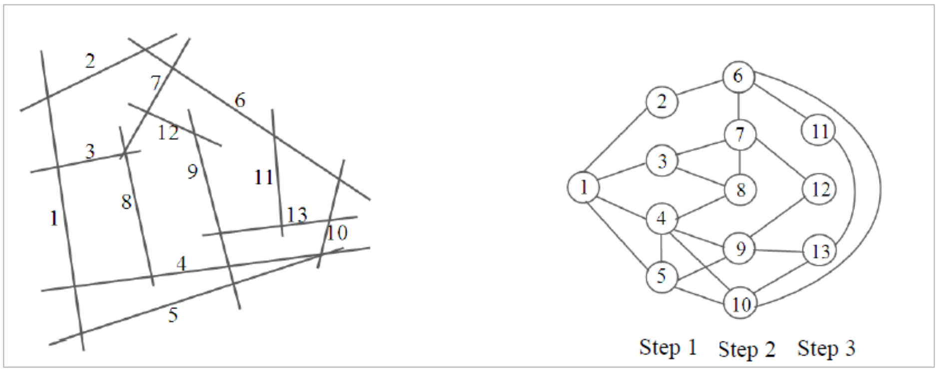
Subjective accessibility is an important tool that helps analyze physical structure of urban networks from the perspective of the resident/ user. Similar to studies on satisfaction and quality of life that reflect on experiences by the user, the measure of subjective accessibility allows a qualitative assessment of the connective strength of urban networks. For this reason, the current research incorporates cognitive access as the instrument of measure. Such characteristics, which capture cognitive aspects of path choice, has best been described by Space Syntax. A spatial tool created by professors from University College London, under the guidance of urban planner, philosopher and theorist, Bill Hillier. Space syntax is a computational tool to describe spatial configuration of urban cities. It helps urban planners analyze patterns of movement through the streets and pedestrian walkways of the city urban structure depending on how well connected the street structure are to each other. Some of the popular functions of space syntax applied are pedestrian modelling, criminal mapping and way finding (Peponis et al 1990; Jiang, 1999, Jiang and Claramunt, 2002).

2.4.3 Measuring Urban networks through Space Syntax

Space syntax theory analyses urban networks through the idea that cities and buildings have an underlying social dependence on interactions and movement flows (Hillier and Hanson 1984). It is derived from a theory on 'natural movement' that validates configurational qualities of well integrated streets to increased movement flows, and the theory on 'movement economy' that states movement flows to influence distribution of land uses and land value (Hillier 1996).

In this process space syntax analyses street and road networks in their degree of interconnectedness, through a dual graph representation of nodes and links. All street networks and roads are represented through a set of linear elements called 'axial lines". These lines represent the longest visibility lines (sight lines) that can be drawn through a linear urban space. They cut across the bulk of streetscapes and open public spaces of an urban environment to form a map of lines called an "axial map" (Jiang and Lui 2011).

Figure 3. Example of axial line representation for a fictional street network along with connectivity graph



(a) Axial line based street model (b) corresponding connectivity graph

Source: A comparative study of space syntax methods, Author: Xiaolin and Jiang (2013), Based on Jiang and Claramunt(2002)

Analyzing the axial maps follows three specific distances- metric, topological, and geometric distances, and two specific measures – integration and choice measures.

The *metric distance* measures the city's street and road network as a system of shortest paths, while the *topological distance* calculates the urban networks as a system of fewest turns paths. Finally, the *geometrical distance* describes networks as a system of least angle change paths. Geometric measures record angular change from one connecting street segment to another. The idea develops from theory on cognitive movement, where in it has been established that people find it hard to assess direction of movement beyond a given angel. This given measure allows to trace the linearity of a urban network, often corresponding to main access ways and highways. (Hillier and Iida 2005, pp.557–558)

Integration (also known as closeness) measures how close each street segment is with respect to all others. In practice it defines the number of alternate routes available for pedestrians to reach a specific location more often and with less effort (Charalambous and Mavridou 2012). Substantial research involving movement and pedestrian accessibility points towards the consistency of this measure in replicating realistic results (Hillier, 1999), specifically when calculated locally (Turner 2001). ``Integration values in line maps are of great importance in understanding how urban systems function because it turns out that how much movement passes down each line is very strongly influenced by its `integration value' " (Hillier, 1996, page 160).

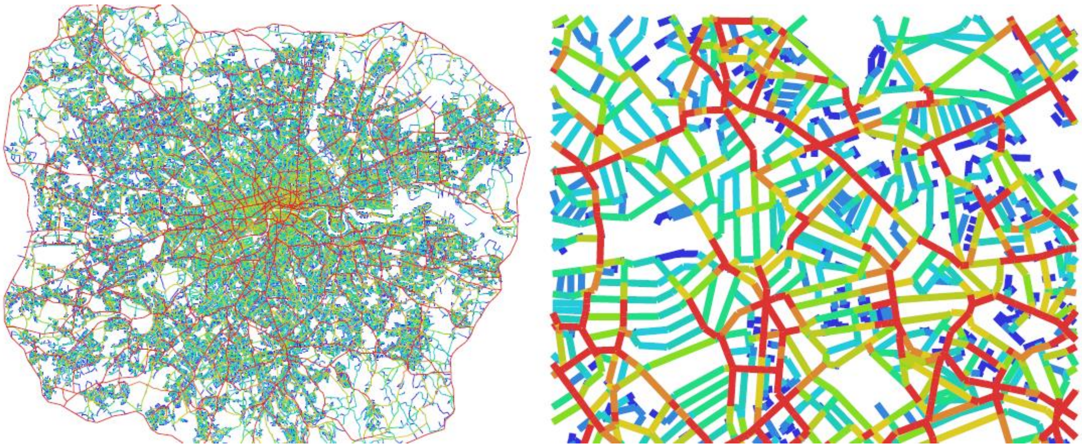
Formula 1:

$$\text{Integration} = 1/\Sigma d_{ik}$$

Where $\mathbf{d_{ik}}$ refers to the shortest-path between line **i** and line **k** (Xiaolin and Jiang 2013).

Axial lines that indicate high levels of integration with other streets within the network are marked red, and axial lines with lowers level of integration blue, as depicted in the illustration bellow.

Figure 4. Space Syntax analysis of street networks for city of London



Large scale movement for 285000 segments within M25 (left), and close up of segments for local movement at 750meter (right), Source: "Space Syntax as a theory" , Author: Bill Hillier (2014)

Choice (betweeness) is the measure of how many times a segment is likely to be passed while making trips between all other segments, highlighting the potential for a route. This measure can also be made using different types of distance and different radii (Hillier and Iida 2005). The less the number of paths one has to pass through the more integrated the network is. Similarly a space that requires having to pass through many different paths implies low integration levels. Both measures can be further differentiated with the three distance measures. "Apart from the measures each type of relation can be calculated at different radii determining shortest paths, fewest turns or least angle paths" (van Nes 2009a).
Formula (2):

$$\text{Choice} = \Sigma_k \Sigma_j \, \mathbf{d_{jk}(i)} / \mathbf{d_{jk}}$$

Where $\mathbf{d_{jk}}$ refers to the shortest-path between line j and line k; $\mathbf{d_{jk}(i)}$ refers to the shortest-path containing line i between line j and line k.(Xiaolin and Jiang 2013)

For this dissertation the following measures have been considered relevant:

- ❖ Axial Integration at a radius of 3 topological turns, and
- ❖ Angular Segment Analysis at a radius of 3 segment steps

<u>Axial integration analysis with topological distance (R=3):</u> Measures the connectivity of street within a given vicinity determined by the radius. The most frequently used radius measures for local integration are 2, 3 and 5 depending on the type of analysis required. This measure can be further categorized under metric, topological and angular. The radius changes depending on this distance measure to a minimum of 2 steps for topological distance and two times angular change for angular analysis, etc.

Bill Hiller in an interesting study on spatial sustainability exposes the influence of such foreground network in determining land value and land use, taking the city of Ludstown as an example (Figure 5). Figure 5a represents global integration, that is, how integrated the street network is with respect to all streets for the entire city street structure, highlighting principle street networks that also coincide with positions of high value properties through a residential background, with a diminution in values and prominence. While 5b represents level of integration at local level of radius 300 meters highlighting local centers and most frequented streets (2009).

Local centers are seen to coincide with people movement and active street life, including attracting economic and social development. Well integrated local streets also allow for through movement of traffic making the space easily accessible for commercial development.

For this dissertation axial integration with topological distance is selected to help identify the local centers and concertation of such spaces amongst different neighborhoods. It is assumed that neighborhoods with a better integrated street network pose better and active street life hence also maintaining an active social atmosphere (Nes and ZhaoHui 2009). Well integrated streets are also seen to coincide with better and safer neighborhood layouts. Van Nes in studies identifies poorly integrated streets to be prone to theft as compared with high integrated streets. Similarly another review on informal policing of streets and neighborhood layouts emphasize the need for street connectivity to encourage through movement (Aghabeik and van Nes 2015).

Figure 5. Space Syntax analysis of street networks 7000+segments, for the city of Ludstown.

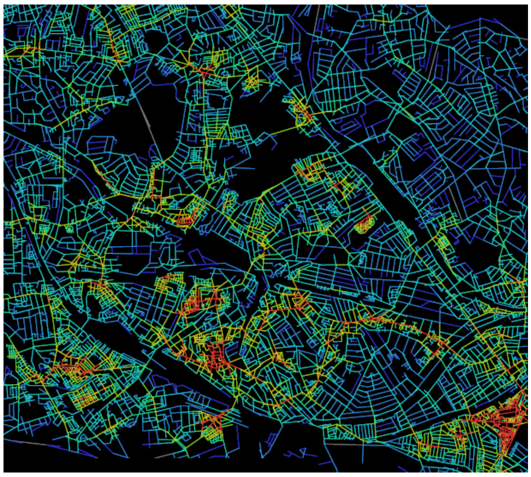
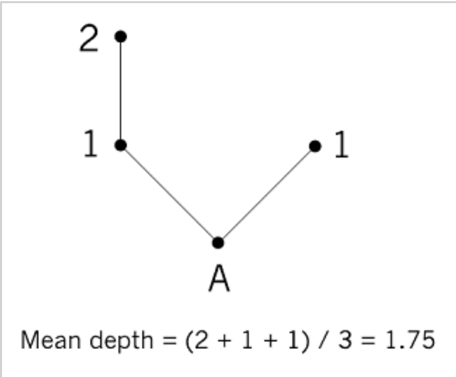


Figure 5a: Global integration at a distance of (n)   Figure 5b: local integration at a distance of 300 meters
Source: 'Spatial sustainability in cities', Author: Bill Hillier (2009)

<u>Angular Segment Analysis at a radius of 3 segment steps:</u> Research has shown that when traversing through streets and urban spaces, individuals tend to follow certain patterns of paths. These paths have been found to consider of distinct angular turns and linear typologies. When considering this element of angular change the linearity of streets can be highlighted often corresponding to main access routes along which shops and establishments locate. In technical terms, angular analysis adds the weight of angle of connectivity of the streets to help distinguish between different paths of movement.
"In essence, angular analysis uses a weighted graph to calculate space syntactic metrics rather than the non-weighted standard measures" (Turner 2001). Sadalla and Montello (1989) show that subject's memory of turns is better for right-angles than other angles, and if in doubt, angles are rounded to the nearest right angle. (Turner 2001).

This tool of local angular segment analysis when combined with metrical distances highlights the most vibrant and active streets within the local scale. Neighborhood's that are connected to such networks have a better opportunities to amenities and services. Van ness (2007) while studying the level of street network integration for the Randstad region in the Netherlands, uses this measure to highlight the most *frequented streets* in local areas and the main routes passing through urban areas.

Figure 6. Difference between calculating mean depth: Topological analysis vs Angular segment analysis



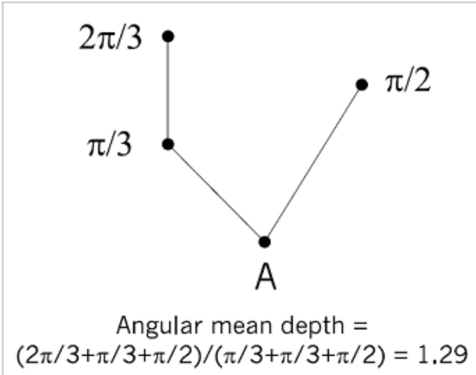


Figure 7a: Mean depth through number of turns Figure 7b: mean depth through angular change, from A
Source: Angular Analysis, proceedings from 3rd International Space Syntax Symposium, (2001)
Author: Alasdair Turner

Inferences

All together space syntax provides many techniques by which network connectivity can be analysed. Many of these analysis are often compared to socio economic performances of urban structure. Up until now space syntax research has dwelled on understanding the influence of connectivity on diverse issues corresponding to effect of safety and crime in different street typologies (Hillier and Iida 2005), connectivity of urban function in neighbourhoods of Sao Paulo (Schaasberg 2012), and even level of sustainable development for the city of Mashaad, Iran (Mokhtarzadeh et al. 2012). Through these studies it can be said that connectivity of urban structure significantly influences diverse aspects of urban living.

2.5 Summary and Lessons Learnt

Beginning with a comprehensive understanding of concepts on Quality of urban life and neighborhood satisfaction, the literature review demarcates the roles and relationships between the two concepts. Quality of life in the urban environment is crucial in today’s world for a large percentage of the population live in such urban settings. The outcome of living in urban environments is that many place based dynamics influence quality of that life. The influence of these place dynamics can be measured effectively through their influence on three specific life domains– housing, neighborhood and community. Through the three domains, neighborhood satisfaction is selected as the scope of measure for this research for the neighborhood is seen to affect and be affected by place based effects, at the local scale.

While assessing satisfaction with the neighborhood environment it is necessary to consider the features that constitute the environment. Through studies in literature it is seen that of all the features- safety, accessibility, cleanliness, sense of belonging are significant predictors of neighborhood satisfaction. Safety relates to quality of streets, safety of neighborhood complex and, while community environment is seen to reflect on active street life and interaction amongst neighbors and a sense of informal policing. On the topic of assessment it is seen that neighborhood features can be assess through objective and subjective measures. While objective measures monitor feature conditions, subjective measures describe what the conditions mean to the user, it is observed that both objective and subjective measures are equally important in analyzing quality of life. Hence for this research, both measures are considered for the analysis. The literature helps demarcate the significant relationship between influence of place, neighborhood features and neighborhood satisfaction.

With the emphasis of influence of place, the literature also reflects on connectivity of urban networks - the physical structure of streets and roads that give shape to life in cities. It is seen to be an important element that allows spaces to become accessible and extend beyond their physical limit. Many studies examine urban structure but reflecting largely on emergent effects, and limited on analysis of the structure itself. This dissertation focuses on the second method of measurement (analysis of structure themselves) and hence sorts to understand works by Bill Hillier, Ida and Van Nes. Hillier provides an in-depth analysis of the composition of urban structure defining them as urban networks. His theory places importance on place accessibility through the concept of cognitive access. Cognitive access is a subjective measure that analyses space within a given number of turn and has been found to relate to many pedestrian route models. This cognitive aspect of path choices acts as useful tool to assess the strength of existing street networks and movement flows. It reflects on how spaces can be shaped to improve and encourage through movement- an essential element for neighborhood safety and social bonding.

The literature further suggests two fitting measures that best describe urban networks at the local scale (neighborhoods). The two measures provide different perspectives of connectivity. While the first measure describes street networks through cognitive element of turns and shortest turn paths, the second measure accentuates on *angle* of turn and describes network structure through least angle turns. Both measures are seen as essential in understanding network complexity and connectivity.

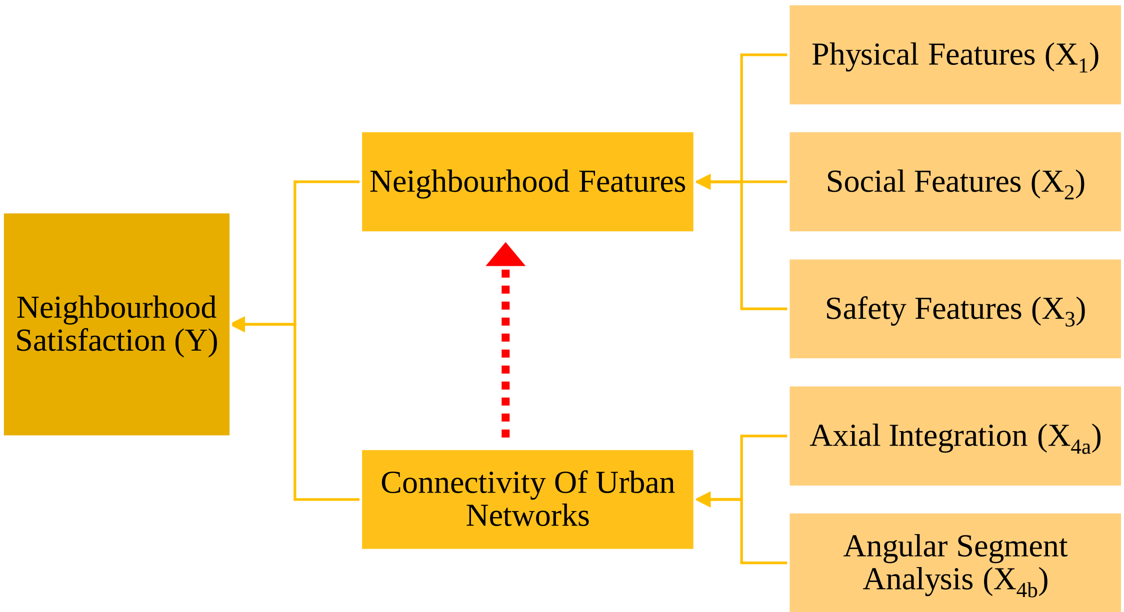
Together the literature studies provoke many different queries, regarding the scope of objective condition. Considering connectivity of neighborhood, and its influence on subjective perception of the neighborhood, the literature review instigates the thought of, well connected and integrated neighborhoods to also demonstrate better perception of satisfaction from its residents. As increased interaction and the sense of being connected influences satisfaction, and increased interaction and movement flows through neighborhoods also reduces crime and theft. Then well integrated street networks that provide access to better movement flows and connectivity should also influence the level of neighborhood satisfaction. If not directly, they should assume to influence independent place based features of the neighborhood environment as described by independent studies on neighborhood safety and community. In search of this query, this research considered Rotterdam city as a relevant case study.

2.6 Conceptual Framework

Through the review conducted it is evident that urban living is a complex process of cause and effect, interconnected at different scales. Different domains of urban life are not only related to the characteristics that define them, but also to the cross effects of the other domains. Consequently while assessing measures like Quality of urban life or life satisfaction one needs to consider these intricate relationships. With the emphasis of place, urban networks of the city is seen to greatly influence life in the city. This implies that place and how the places connect are significant contribute to QOUL. In order to understand the influence of place it is necessary to study domains directly affected by place, in this case neighborhood satisfaction. Satisfaction with neighborhood is defined as the overall level of satisfaction with neighborhood quality of life. The neighborhood comprises of different objective features and hence while assessing neighborhood satisfaction, one needs to assess satisfaction with different features. When incorporating the effects of place to this relationship one can assume that the effects will influence both NS and neighborhood features.

The framework on the whole indicates that satisfaction with neighborhood quality of life is dependent on satisfaction with neighborhood features and connectivity of urban networks. This denotes that measures of connectivity could contribute to how the neighborhood features develop, are perceived and therein their evaluation.

Figure 7. Research Conceptual Framework



Source: Author, 2016

(Y): Neighborhood satisfaction: is a measure of subjective assessment of overall satisfaction with neighborhood quality of life. As mentioned in theory it will be a measure of people’s perception of neighborhood environment and is also measured as the sum of satisfaction with neighborhood features. Hence introducing the first set of dependent variables – Neighborhood features.

(X): Neighborhood features: are a set of conditions that determine quality of life in the neighborhood. According to theory, the features are categorized under physical, social, environmental, safety, economic, and so on. However the aim of this research is to analyze the influence of place, hence narrows down to features that are closely related to place and place effects, such as *physical, social and safety*. The features can be further measured through objective and subjective measures. Theory states both objective and subjective measures to be important in determining satisfaction, hence each of the 3 selected features are further categorized into an index of objective and subjective measures.

X_1: Physical Features		X_2: Social Features		X_3: Safety Features	
Objective Index	Subjective Index	Objective Index	Subjective Index	Objective Index	Subjective Index

While objective measures vary from a range of socio-economic performance measures to demographics and survey evaluations, subjective measures are focused on people's perceptions and opinions. The index that best represents the independent features will be retained to use for further analysis.
The relationship between neighborhood features and

(X): Connectivity of Urban networks, as mentioned in the literature review, is a composition of 2 measures– Axial Integration and Angular segment analysis. As a "place based" feature connectivity of urban networks is introduced as the second dependent variable.

X_{4a}: Axial Integration	X_{4b}: Angular Segment Analysis
at a radius of 3, provides the measure of local integration for every street in every neighborhood.	at a radius of 3, analyses street networks through the angular change from street segment to segment, corresponding to the least angle changed paths.

The conceptual framework is expound further, in section 3.3 Operationalization.

Chapter 3: Research Design and Methods

This chapter charts out in detail the research design, data collection and data analysis methods required to achieve the research objective.

3.1 Research questions

<u>1.4.1 Main Question:</u>

To what extent does connectivity of urban networks (street networks) determine the level of neighborhood satisfaction, for Rotterdam city?

<u>1.4.2 Sub-questions:</u> In order to elaborate the main research question, research sub questions break down the concept of neighborhood satisfaction and connectivity of urban networks. Neighborhood satisfaction is seen to be measured as the sum of satisfaction with neighborhood features. Hence the sub question explores firstly,

What neighbourhood features significantly influence neighbourhood satisfaction, specifically for Rotterdam City?

a. *Physical features*
b. *Social features*
c. *Safety features*

And secondly,

To what extent does connectivity of urban networks (street networks) influence these neighbourhood features?

3.2 Conceptualisation

The process of deriving and identifying variables and indicators from the conceptual framework is described in this section. Based on the conceptual framework, variables are categorised under 3 types: the Dependent variable(Y) and Independent variables (X) and Control variables.

The Dependent Variable: (Y) Neighbourhood Satisfaction

Neighbourhood satisfaction to be put simply is the overall level of satisfaction with neighbourhood quality of life based on satisfaction with different neighbourhood characteristics (Sirgy and Cornwell 2002). It is first and foremost a subjective measure for it tries to capture an individual's *perception* and evaluation of the neighbourhood environment. Neighbourhood satisfaction is often measured by asking questions such as –

"Taking all things together, how satisfied are you with the neighborhood you reside in?"

1- Extremely dissatisfied, 2 – dissatisfied, 3- satisfied, 4- extremely satisfied,

For this research neighborhood satisfaction will be measured as –

"Percentage of people that say they are "extremely satisfied" and "satisfied" with their neighborhood."

The measures has been framed as derived from the database source- Rotterdam Wijkprofiel, 2016.

Independent Variable: (X) Neighborhood features
Neighborhood features are conditions of the neighborhood environment responsible for how it functions and is perceived. As the focus of this research is on influence of connectivity of urban networks, it narrows down to neighborhood features that can be influenced by connectivity. In this case Physical features, Social Feature and Safety features. All three features can be assessed through objective and subjective measures and as described from theory, both measures are found to significantly influence neighborhood satisfaction. Hence, for this research both measures were considered, as two independent indices. The following list of features have been adapted from Sirgy and Cornwall, in reference to other authors, as mentioned in chapter 2.

X_1: Physical Features, represent objective conditions of the immediate physical environment. *Objective measures* consider observable conditions of the environment such as – number of street lights, number of tram stops, bus stops, percentage of green space, etc. while *Subjective measures* account for people's level of satisfaction/perception with objective conditions. Such as satisfaction with upkeep of homes and yards, satisfaction with street lighting in the neighborhood, etc. For this research the following set of measures have been considered relevant:

List 1. Physical Features (Source: Rotterdam Wijkprofiel 2016)	
Objective Features	**Subjective features**
% of Vacant Homes % of houses with over crowding % Satisfied with maintenance of own homes % Satisfied with maintenance of buildings near % of houses with bus stops within standard distance % of houses with underground station in standard distance % of houses with tram stops in standard distance % of houses with playground in standard distance % of houses with schools in standard distance	% Satisfied with accessibility area for cars % Satisfied with quality street % Satisfied with facilities together % Sufficiently present use green (picnic, sports, games) % Sufficiently present sports % Sufficiently present elementary schools % Sufficiently present secondary schools % Sufficiently present OV % Ample parking % Inclination to move from neighbourhood % Often aggressive road behaviour % Adequate supply stores groceries % Many hourly activity % Much traffic noise

From the selected feature list the most influential were combined to create two representative indices- Physical Objective Features Index and Physical Subjective Features Index.

X_2: Social Features, are measures of social patterns in the neighborhood. *Objective measures* represent measures of percentage of people that –make weekly outdoor activities, weekly religious gatherings, percentage of people who visit cinema, library etc., while *subjective measures* account for satisfaction with social interactions with neighbors, Satisfaction with the outdoor play space; Satisfaction with people living in the neighborhood, Satisfaction with ties with people in the community. For this research a set of measures have been considered relevant and the most influential were combined to create indexes.

List 2. Social Features (Source: Rotterdam Wijkprofiel 2016)	
Objective Features	**Subjective features**
% of residents with low household income	% Of residents who say they do not have problems with neighbours
% of residents with weekly neighbour contact	% Residents saying that dealing ages well with each other in the neighbourhood
% of residents with contact with other neighbourhoods	% Locals which says that the relationship between ethnic groups in the area is good
% of residents that visit hobby/ club monthly	% Locals that says that in the neighbourhood are plenty of places to joint activities residents
% of residents that participate in cultural events monthly	% Locals that says there is near enough places for religious and philosophical meetings
% of residents that visit religious events monthly	% Locals that says that in the neighbourhood there are plenty of elderly facilities
% of residents that practice weekly sports	% Locals that says that in the neighbourhood there are plenty of leisure facilities for young people
% of residents that weekly visit family contacts	% Residents that says no to experience discrimination in and outside their own neighbourhood
% of residents that have lived long in the neighbourhood	% Residents who say they are proud of the neighbourhood
% of residents committed to neighbourhood	% Residents who say they find around nice
	% Residents who said they experienced no problems in the neighbourhood
	% Of residents who say they feel connected to neighbourhood
	% Residents who say they feel responsible for neighbourhood

X_3: Safety Features, measures level of safety of the neighborhood environment by keeping track of reports on crime and violence in the environment.

List 3. Safety Features (Source: Rotterdam Wijkprofiel 2016)	
Objective Features	**Subjective features**
Number of thefts on vehicles	Bicycle theft often occurs as a neighbourhood problem
Number of reports of pickpocketing	Thefts from cars often occurs as a neighbourhood problem
Number of reports on crime abuse	Threats often occurs as a neighbourhood problem
Number of reports on graffiti	Violent crime often occurs as a neighbourhood problem
Reports on drug case per 1000 inhabitants	Snatching violence often occurs as a neighbourhood problem
Reports on conflict with environment per 1000 inhabitants	percentage of residents have been victims of threats of violence last year in their own neighbourhood
Reports of nuisance per 1000 inhabitants	Percentage of residents have been victims of abuse last year in their own neighbourhood
% of victims to violence	Burglary in homes often occurs as a neighbourhood problem
% of victims to abuse	Arguing Making and / or screaming street youth in their own neighbourhood is experienced as much nuisance
% of residential burglary	Trafficking of drugs on the streets of their own neighbourhood is experienced as much nuisance
% of attempted burglary	

Independent Variable: (X) Urban Networks

Urban Networks in reference to chapter 2, will be measured using 2 syntactic measures that best represent the level of street integration at the local scale. The local scale identifies street connectivity within a given metric radius or topological distance (steps/turns). Taking this into account Integration is measured at radius of 3 (represents level of street integration within 3 metric and topological distances).

X_{4a}: Axial Integration-HH- (R=3) Topological Distance - Calculates how integrated and connected a street is in relation to its other streets in its vicinity in terms of 2 and 3 times of direction change (Hillier et al. 1976). Topological distance measures are essential for local scale analysis as individuals use space at that scale based on the sensory perception of access, and that according to research is identified as between two and three steps/turns (van Nes 2009b). Research has shown that often they coincide strongly with local shopping centers and pedestrian flows and neighborhoods that have such interactive street flows are found to be livelier encouraging more social interactions (Schaasberg 2012)

X_{4b}: Angular Segment Analysis (R=3) - Calculates how integrated a street is in relation to its vicinity in terms of the degree of angular change. This concept developed by Hillier and Turner in the later developments of Space syntax research, categorizes the angle at which streets intersect. It is assumed that individuals find it easier to assess stark angular turns than mild. Hence streets with sharp angular intersections are given different values in comparison to streets with low angular intersections.

On the other hand, Space syntax produces different measures for each line (street); and neighborhood satisfaction level is an indicator for each neighborhood. Thus, in order to be able to correlate these two types of indicators, the *mean values* of the syntactic measures for each of the 71 neighborhoods of the city are needed. This can be calculated by generating the mean value of integration at the above radius and weighted with length segment lines for each neighborhood selection in Depthemap (Mokhtarzadeh et al. 2012).

Control Variables (X)

Satisfaction with neighbourhood environment, at the individual level, is seen to depend on other factors such as income, employment, household composition, etc. However as this research deals with analysing aggregate measures at the neighbourhood scale, it considers factors at a similar scale, such as - average income, population density and ethnic composition.

X_5: Average Income: Income is seen to determine location of residence and there in type of neighborhood. Neighborhoods comprise of collection of residents from different socio economic backgrounds, most of whom are clustered to define the neighborhoods socio economic status. Some neighborhoods are of a higher socio economic status as compared to others, hence also influencing the quality of life in those neighborhoods. Thus to compare diverse neighborhoods with residents from different economic status, average income is controlled for.

X_6: Neighborhood Population Density: neighborhood population density is the measure of total number of residents within a given square area of measure. When comparing neighborhoods of different areas, it is seen that some neighborhoods constitute larger concentration of residents as to others. Contrary to the assumption that neighborhoods of larger areas contain larger residential population, it is observed that smaller neighborhoods that are closer to the city center can also be densely populated. This pattern is significant at the heart of the city for its active commercial life and proximity to work. Similarly other factors like quality of life in the neighborhood, income, larger housing typologies, student housing and even social clustering in the case of social housing, determine different densities. Comparing neighborhoods of such diverse densities can yield different values for satisfaction, hence neighborhood population density is considered the second control variable.

X_7: Ethnic Composition: an important aspect of satisfaction with neighborhoods is the type of residents living in that neighborhood. Research has observed that native residents report to be more or less satisfied with their environment as compared to non-native and new migrants.

For Rotterdam city specifically, with a diverse composition, certain neighborhoods are seen to concentrate different types of residents. Students are seen to concentrate around neighborhoods close to universities while working migrants around employment opportunities or low cost housing. Also especially for Rotterdam city is the concentration of social housing and low income migrants. This form of clustering influences the lifestyle within their neighborhoods and unbalanced measures of satisfaction. As the current study is focused on analyzing neighborhood satisfaction from the perspective of connectivity, it controls for ethnic composition and compares all neighborhoods with the same weight.

The Model

The first model analyses the direct relationship between dependent variable – neighborhood satisfaction and independent variables, connectivity of urban networks – X4a and X4b.

Since both measure of connectivity address the same concept, they are assumed to exhibit collinearity, hence analyzed in two separate models.

$$y = b_0 + b_4x_{4a} + e \qquad y = b_0 + b_4x_{4b} + e$$

The second model measures the effects of connectivity while controlling for the overall effects of neighborhood features and control variables.

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_{4a} + b_5x_5 + b_6x_6 + b_7x_7 + e$$

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_{4b} + b_5x_5 + b_6x_6 + b_7x_7 + e$$

Where,
Y – Neighborhood satisfaction
X1- significant physical features
X2- significant social features
X3- Significant safety features
X4a – Axial integration
X4b- Angular segment analysis
X5 – average income
X6- population density
X7- ethnic composition

3.3 Operationalisation – Variables and Indicators

The following table presents a summary of the most relevant concepts, variables and indicators related to the research proposal.

Table 3. Dependent Variable (Y)

Concept	Variable	Indicator	Scale	Source
Quality of urban life	Neighborhood satisfaction (y)	Survey Question – "Percentage of people that say they are extremely satisfied and satisfied with their neighborhood."	interval	Secondary data base: Rotterdam Wijkprofiel , 2016

Table 4. Independent Variable (X)

Concept	Variable	Indicator	Scale	Source
Neighborhood Features	X_1: Physical Features	Object features Index Subjective Features index	interval	Secondary data base: Rotterdam Wijkprofiel 2016
	X_2: Social Features	Object features Index Subjective Features index		
	X_3: Safety Features	Object features Index Subjective Features index		
Connectivity of Urban networks	X_{4a}: Axial Integration Analysis (r=3)	Calculates how integrated and connected a street is in relation to its other streets in its vicinity in terms of 3 times of direction change from each street	Ordinal	Space Syntax analysis, ArcGis for mapping analysis results
	X_{4b}: Angular Segment Analysis (r=3)	Calculates how integrated a street is in relation to its vicinity in terms of the degree of angular changes.	Ordinal	
Control Variables	Socio Demographic	X_5: Average income X_6: Neighborhood population Density X_7: Ethnic composition	Ordinal	Secondary data base: Rotterdam Wijkprofiel , 2016

3.4 Research Strategies

The research falls under the category of deductive research, as the primary focus is to study and explain the extent of influence of process A (Urban networks) on the evolution of process B (Neighborhood satisfaction). The research hopes to achieve this through reference of existing theories and the predominant use of secondary quantitative data. With this intention the research uses Secondary Quantitative Analysis as its main strategy. Secondary Quantitative analysis is understood as analysis of data originally generated for an alternate purpose (Dale et al. 2014). The method has gained popularity with the increasing access to high quality open source information through national archives.

The research covers a broad overview of the subject of Neighborhood satisfaction for 71 different neighborhoods of Rotterdam city. This emphasizes the scale of the study as city/ regional phenomenon. Apart from the scale of the study, the variables addressed are subjects that influence a broad audience and can be measured as a generalization. The aim of the study does not involve generating qualitative data, or identifying new set of characteristics/ determinants for the theme of neighbourhood satisfaction, but making use of existing indicators. In reference to Verschuren (2010) the research characterizes large number of research units, which requires extensive data in the form of surveys on QOL.

Also, with the given time frame and the scale of research, the process of primary data collection will not generate satisfactory information. On the other hand, availability of raw data in the form of existing surveys conducted and generated by the municipality of Rotterdam, under the Research body OBI, asserts the use of Secondary Quantitative analysis as the adequate research strategy.

The main limitation to secondary research is access to information, for much of the required data are restricted for safety of privacy. Often data sets that are available are outdated, representing information that has long changed or are incomplete. A frequent issue with validity in Secondary quantitative analysis is when the available data sets don’t meet the required research needs. Large data sets that are generated by the municipality or other sources have their own agenda for collection, thereby shaping indicators and questions based on a personal theme. This miss match creates issues for external validity, often requiring the research to 1. Incorporate proxy measures that can replace or replicate results or 2. Change the scope of research, entirely.

In the case of the current study, data is gathered from two sources of the municipality of Rotterdam – Rotterdam Wijkprofiel and OpenstreetMaps (OSM), both of which have been developed by the city in recent years. Rotterdam Wijkprofiel, records data for the years of 2014 and 2016, minimizing errors of time, while also addressing key issues related to the area of research (neighborhood satisfaction) strengthening the “fit”. However, this benefit of having recent information does not reduce the risk of reliability and validity. Reliability as Neuman (1991) states is the degree of dependability or consistency in the measurements and information gathered that ensures that under identical conditions similar results will be generated.

3.5 Data Collection Methods

Data from primarily two sources, Rotterdam Wijkprofiel (Rotterdam Neighbourhood Profile) and OpenstreetMap (OSM) were used. Rotterdam Wijkprofiel is associated with the City Municipality – Rotterdam Gemeente and constituted of secondary quantitative data comprising of survey reports and objective data regarding city features. To aid the research in spatial analysis, references from OpenstreetMap (OSM) were used. This part of the research involved generating primary data but from a secondary source (streetmaps).

DATA SET 1: Rotterdam Wijkprofiel (Neighbourhood Profile)

Data Base Source – Rotterdam Gemeente (City Municipality)
Data Base type – Secondary quantitative,
Year of process – 2016, 2014
The Wijkprofiel is a supporting framework that was launched by the municipality of Rotterdam in 2014. It was designed to behave as a monitoring instrument to help different organisations involved in maintaining the city, to keep track of progress and improvements made over time. The Wijkprofiel can be perceived as a coherent picture of the actual situation for it also represents residential experiences that are collected over a time span of 2 years. The first measurement was made in 2014 and forms the baseline, while measurements for 2016 is the first follow-up.

The profile represents three sectors of neighbourhood development: Physical, Social and Safety. These three sectors comprise of a set of themes that best represent the sector (figure 8).

Figure 8. Wijkprofiel Information

Physical	Social	Safety
Real estate	Social Capacities	Theft
Public space	Participate	Violence
Services	Habitat	Burglary
environment	Bond	Vandalism
Living experience	Experiential quality of life	Safety Experience

Source: The Author, 2016 based on "Rotterdam Wijkprofiel Toelichting" (Gemeente Rotterdam 2014)

The themes are further distinguished and measured through objective and subjective indicators. The objective indicators are incorporated from various records that measure factual responses about the environment like "level of education", "crime rate", etc. And survey questions procure behavioural information, such as "level of participation in social activities". The subjective score comprises of indicators derived from two surveys, "Vragenlijst Wijkonderzoek Rotterdam" which is the survey analysing social and physical aspects of the city and "Vragenlijst Wijkonderzoek Veilig Rotterdam" which focuses on safety aspects of the city.

Vragenlijst Wijkonderzoek Rotterdam poses questions under different categories for physical and social evaluation. The subjective perception of physical aspects of the city asks for opinions like "satisfaction with living situation", while social aspects reflected opinions such as "having confidence in the government". Vragenlijst Wijkonderzoek Veilig Rotterdam posed questions that review opinions such as "feeling of being unprotected". Most questions were measured along the Likert Scale of 1-5, 1= "Very satisfied" and 5= "Very dissatisfied".

Overall the data base records 92 observation, for 74 different neighbourhoods and 14 districts.

The data base contributes to forming the measure for Dependent variable Y- Neighbourhood satisfaction as "% of people that say they are satisfied and very satisfied with their neighbourhood" and also contributes to forming the measure for main independent variables X1- Physical Features, X2- Social Features and X3- Safety Features.

DATA SET 2: Google Open-street-maps

Open street map is an online portal for open source geographic data, mainly displaying maps and cartographic details of cities and neighbourhoods. The maps are open source and are an amalgamation of inputs from diverse users. The maps contribute to generating data for the second part of independent variables X_{4a} and X_{4b} (Urban network variables). The data will be used in combination with spatial software's ArcGIS 10.0 and Space Syntax, to generate the final measures for urban network variables.

Being an open source and built on inputs from diverse users the data reliability can be low. Nevertheless it is also recognised by many urban planning organisations and institutes of design, for its high accuracy in map projections and up-to-date information.

3.6 Sample Size and Selection

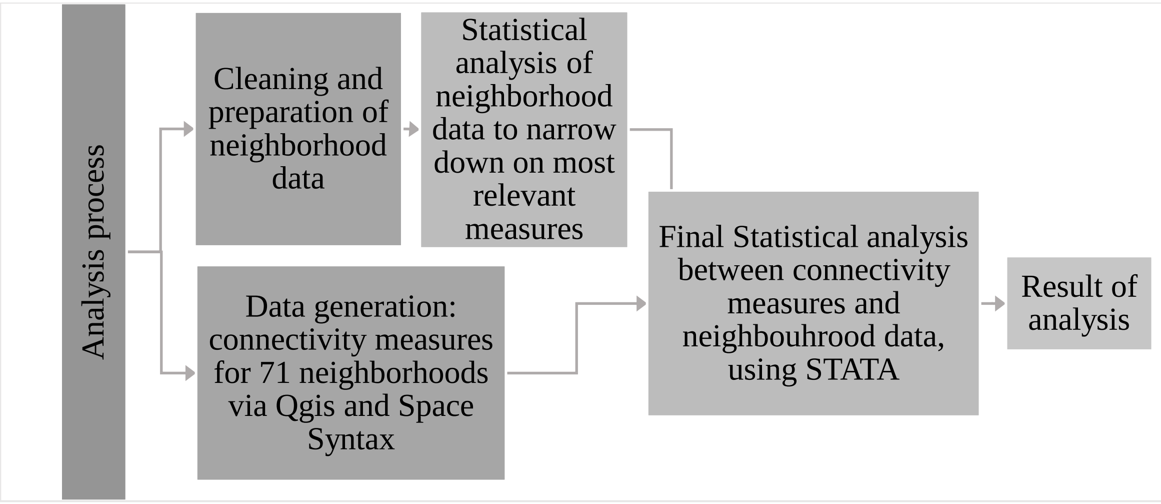
As the research depended on secondary data for its analysis, the sample size and selection was for this research was derived by the secondary data. Rotterdam Wijkprofiel extracts information from two different surveys for its analysis – "Vragenlijst Wijkonderzoek Rotterdam" which is the survey analysing social and physical aspects of the city and "Vragenlijst Wijkonderzoek Veilig Rotterdam" which focuses on safety aspects of the city.

Both surveys were conducted through the year 2016 and a total of 30,000 participants participated. The participants were chosen between ages +15 years to 75 years. However when the final selection of survey respondents were filtered, a total of 300 respondents per neighbourhood represented the selection size. However in some neighbourhoods, the response rate does not increase +/- 100 responses. The sample selection for this survey followed Random sample selection, wherein a representative portion of the population were selected and contacted for surveys through the internet, written and verbal interviews. Overall 55% participated via internet, 15% participated in writing and 30% participated through a telephone interview (Gemeente Rotterdam 2014).

3.7 Data analysis methods

This research focuses on quantitative analysis using primary and secondary data. Primary data is generated for analysis of connectivity measures, while secondary data is used for analysis of neighbourhood satisfaction and features. The process of data analysis takes place in three steps, starting with Data preparation and sorting, generating primary data for connectivity measures using QGis and Space Syntax, and finally modelling regression analysis using STATA.

Figure 9. Data analysis process



Source: Author, 2016

<u>Data Preparation:</u>

While dealing with secondary data, much of the information is tailor made for other research subject. Data names, codes and units of measure are represented in sight of previously required measures and, hence need to be renamed according to the current scope of study. Duplicates are analysed and excluded to minimise errors. Relevant information are sorted and extracted from the total data base to reduce complexity during analysis. Concurrently, with reference to theory, the most relevant neighbourhood features were identified, and grouped into respective categories. These measures were further compared with Neighbourhood satisfaction (dependent variable) for the second step of statistical analysis.

<u>Data Generation:</u>

The second half of the study required generating primary data for urban networks, from Open street maps (secondary source). The process involved use of QGis Software, a mapping and projections tool, to manually draw a street structure maps for the entire city of Rotterdam. This manually drawn map was further converted into relevant Space Syntax maps. Axial Map for the first measure of connectivity (X_{4a}) and Segment Map for second measure of connectivity (X_{4b}). Information from both maps are extracted and tabulated to create the data on urban networks.

Space syntax generates measures for individual streets lines and segments, whereas the current study focuses on neighbourhood level information. Hence, in order to correlate data, it was necessary to demarcate all street lines and segments that fall under a neighbourhood boundary and extract their cumulative measure. With the help of ArcGis and data from Open Street Maps this process was executed and the final information tabulated. As mentioned previously, some of the neighbourhood level data is represented as a combination of 2 or 3 neighbourhoods, hence while extracting data on connectivity, similar combinations were considered.

Statistical Regression Analysis (using STATA)

Post data preparation, this study used Ordinary Least Square (OLS) analysis to build statistical models to answer respective research questions. The first step involved analysing neighbourhood features and creating indexes to represent each of the three features (Physical, Social and Safety). As each of the three comprised of objective and subjective indicators, *Pearson's bivariate correlation* was used to narrow down on significant indicators that best predicted neighbourhood satisfaction. These significant indicators were then combined to create indexes (objective and subjective). These indexes are used in the first model to identify which of the three features significantly influence neighbourhood satisfaction. The results of this model were further incorporated in the final statistical model.

The second step involved analysing, influence of connectivity measures on neighbourhood satisfaction. A similar OLS regression model was executed, with connectivity measures introduce separately to exclude errors from collinearity. The final model measured the most significant connectivity measures and neighbourhood features together, along with the three control variables, to assess their overall influence on neighbourhood satisfaction.

It needs to be mentioned that significant relations observed in this research refer to statistical significance where the observed p-value of a test statistic is less than the significance level defined for the study. Statistical significance plays an important part of statistical hypothesis testing. It determines whether the null hypothesis has been rejected, that is when the p-value of a statistical test is less than the predetermined value of below 5%.

3.8 Validity and Reliability

Neuman (1991) defines reliability as a research that contains a degree of dependability or consistency in the measurements and information gathered, that ensures that under identical conditions similar results will be generated. In this requirement, the research is prone to procure slight inconsistency in results, as it makes use two software's ArcGIS and Space syntax. Both software's used at an individual level are seen to produce different interpretations and data error. Space syntax especially has been criticized by many regarding the subjectivity of its methods of analysis, as it requires manually charting out all the street and roadways of the city, in the form of "axial line" maps. Axial lines are the longest possible visibility lines that represent a street, and the manner in which the lines are drawn influences much of the analysis. However, in the case of this research, sufficient data was available on space syntax and axial line maps for Netherlands, and specially Rotterdam city, ensuring that the final map representations were factual.

Validity on the other hand focuses on research objectives and how well the data collection instrument enables the analysis to acquire satisfactory results with minimal error. The secondary data used in this research largely followed survey as its instrument, and the main limitations of survey as a research instrument is the validity and lack of control over responses (Van Thiel, 2007). The subjective indicators in the Wijkprofiel derived from two surveys; namely District Investigation and Security Monitor. The responses differ from the sample in both surveys (and population) that some segments of the response are under- or overrepresented. In order to counteract these "non-response bias" the survey used weights and process of raking and sample balancing (Gemeente Rotterdam 2014). This form of manipulation of data representation is one of the major limitations of the results of this research.

A third issue is, statistical analysis can suffer from statistical artefacts (Van Thiel, 2007) resulting in some amount of variance. Nevertheless, presence of variance leaves options for further research.

Chapter 4: Research Findings

This chapter is divided into two parts. The first half describes the most relevant points for data preparation and description, while the second half elaborates on empirical results.

Emphasis has been given to the first half of data preparation and description, as it significantly influenced how the research was conducted. Especially in the selection and preparation of Independent variables – neighbourhood features and connectivity of urban networks. Preparing data for variable neighbourhood features, followed multiple steps of correlation analysis and simple linear regressions, to assist with narrowing down from the large data set. Following which the most significant variables were selected to create indices. Similarly data for independent variable - connectivity of urban networks, required manually generating the information through secondary sources. Hence also described in detail in this first section.

4.1 Data – Preparation and Descriptive Statistics

4.1.1 Neighbourhood Data

Neighbourhood data for this research was obtained from Rotterdam Wijkprofiel. The profile represents information on 74 neighbourhoods and 14 districts. A total of 92 observations divided into 6 categories- Physical: objective and subjective data, Social: objective and subjective data, Safety: objective and subjective data. As the current research deals specifically at neighbourhood level, information on districts were omitted and duplicate neighbourhood data were examined and excluded. The final list consisted of 71 observations- 62 independent neighbourhoods and 9 combined neighbourhoods.

The concept of combined neighbourhoods represents limitations in information gathered. While studying the process of data collection for this profile, it was observed that neighbourhoods that lacked sufficient responses were clubbed together to represent a single aggregate measure. While other neighbourhoods like “Kralingen Bos” and “Blijdorp” representing largely open spaces (green parks/lakes and the zoo) were clubbed to adjoining neighbourhoods to minimise empty values. Similar process was adopted for special function neighbourhoods like “Zestienhoven” which constitutes entirely of Rotterdam Airport.

4.1.2 Dependent Variable (Y): Neighbourhood Satisfaction

Neighbourhood satisfaction for this study, is a measure of “Percentage of people that say they are “extremely satisfied” and “satisfied” with their neighborhood.” The measure is derived from the survey questionnaire “Taking all things together, how satisfied are you with the neighborhood you reside in?” where 1= extremely dissatisfied, 2=dissatisfied, 3=satisfied, 4= extremely satisfied (Gemeente Rotterdam 2014).

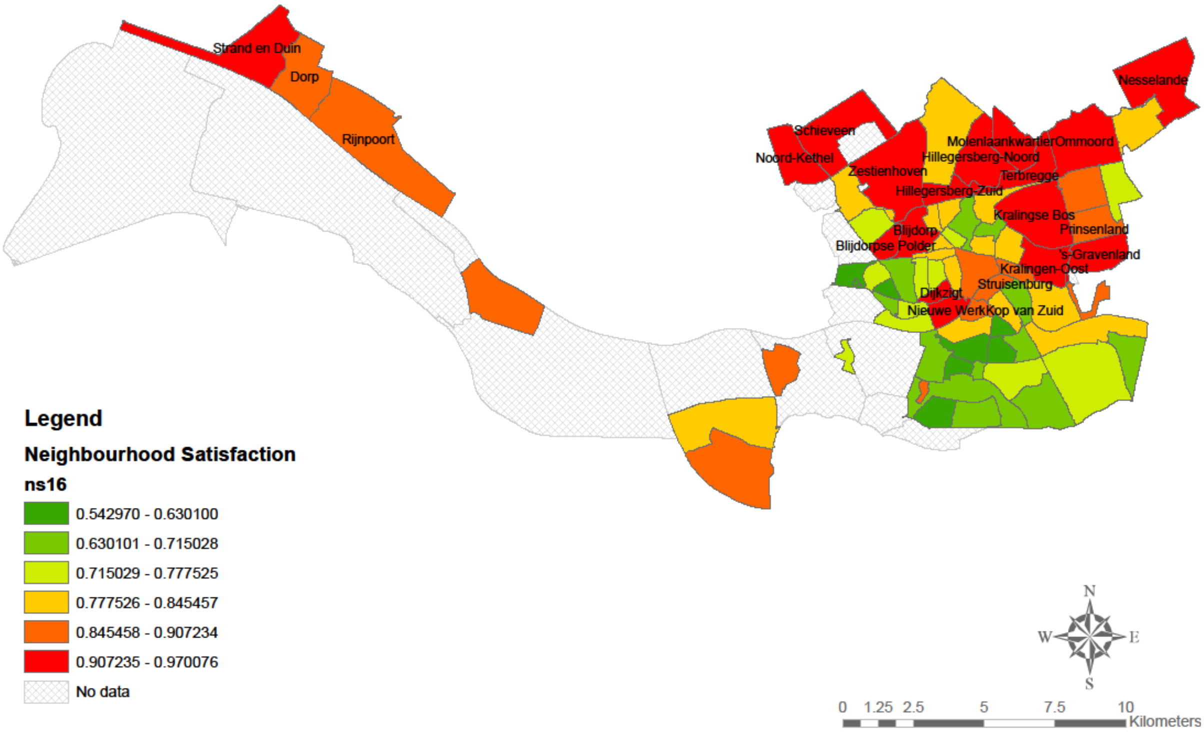
Table 5. Descriptive Statistics: Dependent Variable **Source: Author, 2016**

Y	N	Mean	Minimum	Maximum	Std. Deviation
Neighbourhood Satisfaction	71	0.7927384	0.5429697	0.9700757	0.1117207

Between 71 different neighbourhoods of the city, it is observed that the city experiences high levels of neighbourhood satisfaction, with only a minimum of 54% of respondents saying they were satisfied with living in their neighbourhood, while in other neighbourhoods a maximum of 97% respondents felt the same way.

On analysing distribution of neighbourhood satisfaction throughout Rotterdam city, it is distinctly visible that the northern and western half of the city experience greater levels of satisfaction as compared to the south (see Map 1). However, on further exploration, it is observed that the most satisfied neighbourhoods are open green spaces such as parks and fields for North Rotterdam, and the port regions for West Rotterdam. Whereas least satisfied neighbourhoods are seen to concentrate at the city centre corresponding to commercial and economic cores, and southern neighbourhoods all comprising of residential layouts. This form of distribution of satisfaction, could indicate that residents of Rotterdam city, prefer living towards the periphery with large amounts of green spaces, but can also reflect other important factors. To have a comprehensive idea, this information was further compared to data on “type of neighbourhoods”, “population density” and “average income”.

Map 1. Distribution of Neighborhood Satisfaction, for Rotterdam City.

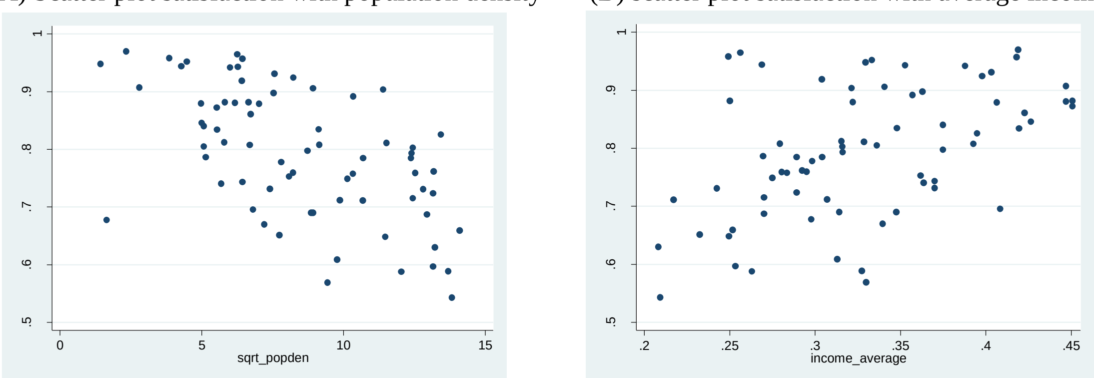


Source: Author, 2016

When comparing neighbourhood satisfaction (map 1) alongside type of neighbourhoods (map 6) it is observed that the most satisfied neighbourhoods correspond to neighbourhood Type 5. Residential districts with largely higher and middle income households and single family housing, concentrated along the northern and western half of the city. On the other hand when comparing this result along population density (Annex 2, map 9), it is not surprising to notice that the most satisfied neighbourhoods are also the ones least populated.

Figure 10. Scatter plot comparison for Correlation,

(A) Scatter plot satisfaction with population density (B) scatter plot satisfaction with average income



Source: Author, 2016

Crowding and over density are seen to have a negative effect on happiness and satisfaction (McCrea et al. 2006; Marans and Stimson 2013). From the comparison it is clear that income and population density seem to significantly influence neighbourhood satisfaction, for this city. This further confirms the use of these three measures as control variables.

Control Variables:

This research incorporates all 71 neighbourhoods in its analysis and does not distinguish between neighbourhoods of different population density, average income or ethnic composition. Hence in this section a brief description of the distribution of control measures are provided only to assist in the reflection of research results, and do not contribute to research analysis.

Table 6. Control Variables **Source: Author, 2016**

Variable	N	Mean	Minimum	Maximum	Std. Deviation
X5: Population Density	71	81.93795	2.056772	198.6389	56.67935
X6: Average Income	71	0.3283984	0.2083333	0.4507042	0.0633105
X7a: Ethnic Composition Native	71	0.5209296	0.136	0.896	0.1970646
X7b: Ethnic Composition Migrants	71	0.4790704	0.104	0.865	0.1969875

Population density provides a holistic overview of the distribution of residents across the 71 neighbourhoods while keeping track of neighbourhood area. The standard deviation of 56.67 indicates the contrasting distribution of density, with some neighbourhoods being highly populated as compared to others. To perceive their disposition through the city an ArcGIS map projection was created. Highly dense neighbourhoods are seen to cluster around the centre of the city while, the least dense around the peripheral (Annex 2, map 9).

The measure of *average income* for this study represents "percentage of residents in the neighbourhood that fall under the average income category" and does not measure the overall value of income for the neighbourhood. It is observed that for Rotterdam city 40% of its population fall under this category. Hence to identify neighbourhoods that host this population requires understanding their distribution. From the summary statistics it is interesting to note that the some neighbourhoods host as much as 45% of this income group. Spatially, it is observed that peripheral neighbourhoods concentrate the highest portions of average income residents (Annex 2, map 8).

Ethnic composition for this study represents percentage of native residents and non-native residents residing in each neighbourhood. The statistics summary shows an equal distribution of both kinds of ethnicity within 71 neighbourhoods. As Rotterdam city is known for its diverse and multi-cultural population, is not surprising that some such neighbourhoods concentrate entirely of a single ethnic background. Spatially, a clear division is observed between ethnic distributions (annex 2, map 7). Peripheral neighbourhoods are seen to comprise largely of native residents while city centres and southern banks with non-natives. When comparing this to projections on neighbourhood satisfaction (map 1), it is noted that least satisfied neighbourhoods are the ones with higher concentration of non-native residents- a particular situation for the city of Rotterdam.

4.1.3 Independent Variable: Neighbourhood features

With reference to theory a list of features were selected that best represent each category (Physical Objective features and Physical Subjective features). These features were further compared through simple multivariate regression with the dependent variable, and most significant were combined to form respective indices. The process of creating indices is explained towards the end of this section.

Physical Features Selection

Physical objective features selected for this research represent records of housing situation and quality of surrounding built environment, records of accessible transport facilities and accessible amenities, such as green parks. The selection criteria for this group also focused on features of the environment that were prone to be influenced by connectivity of urban networks.

Table 7. Descriptive statistics: Physical Objective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
% of houses with overcrowding	71	0.8151	0.022559	0.18658	0.0398
% of residents satisfied with own home	71	0.6014	0.3546	0.90484	0.11648
% of residents satisfied with buildings around	71	0.5134	0.25276	0.90912	0.1579
% of houses with bus stops in standard distance	71	0.62706	0	1	0.29505
% of houses with underground stations in standard distance	71	0.6946	0	1	0.3977
% of houses with tram stops in standard distance	71	0.77356	0	1	0.4000
% of houses with playgrounds in standard distance	71	0.70518	0	1	0.30656
% of houses with schools in standard distance	71	0.48250	0	0.98868	0.26689

It is interesting to observe a trend in portion of residents that are satisfied with their own home and buildings around. The drastic variance between neighbourhoods that quote 90% to be satisfied while others at a minimum of 25% is intriguing and suggests that some neighbourhoods clearly have the potential to host better quality housing and buildings.

Multiple models were run to understand independent variable influence and correlated effects. Of the list of Indicators **Percentage of houses with overcrowding, Percentage of residents satisfied with buildings around, Percentage of residents satisfied with own home and Percentage of houses with playgrounds in standard distance** were found to significantly influence neighbourhood satisfaction explaining a variance of 76%.
In order to correct for potential heteroscedasticity and autocorrelation, robust standard error was employed. In addition, variance inflation factor tests were completed to control for possible multicollinearity, with a factor typically less than 2. Similarly Log values for some variables were generated in order to minimise errors, as they exhibited uneven distribution.

"Houses with overcrowding" is seen to negatively influence neighbourhood satisfaction with a decrease in coefficient by 0.157 points and explaining 47% variance of the model (fig 11, model 1). While "percentage of residents satisfied with own home" and, "buildings around", positively influenced neighbourhood satisfaction with the latter having a higher score of 0.231 points per increase in satisfaction. Both variables, "percentage satisfied with own home" and "buildings around" were introduced separately as they were seen to be correlated[1], with "percentage satisfied with buildings around" masking the former entirely (model 5).

Figure 11. Simple Linear Regression model with Physical Objective Features and Neighbourhood Satisfaction

	Model 1	Model 2	Model 3	Model 4	Model 5
FEATURES	Y	Y	Y	Y	Y
(Log) % of houses with overcrowding	-0.157***	-0.0764***	-0.0592***	-0.0716***	-0.0996***
	(0.0199)	(0.0164)	(0.0192)	(0.0172)	(0.0195)
(Log) % of residents satisfied with buildings around		0.231***	0.220***	0.220***	
		(0.0261)	(0.0267)	(0.0288)	
% of houses with tram stops in standard distance			-0.0149		
			(0.0179)		
% of houses with schools in standard distance			-0.0487		
			(0.0330)		
% of houses with playgrounds in standard distance				-0.0269	-0.0666**
				(0.0281)	(0.0322)
(Log) % of residents satisfied with own home					0.226***
					(0.0482)
Constant	0.380***	0.757***	0.829***	0.780***	0.697***
	(0.0530)	(0.0559)	(0.0691)	(0.0610)	(0.0702)
Observations	71	71	71	71	71
R-squared	0.476	0.757	0.768	0.760	0.662

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Surprisingly having "tram stops" and "schools within standard distance" did not seem to influence neighbourhood satisfaction (model 3), while "having playgrounds" was seen to be mildly important, when controlling for satisfaction with buildings around (model 5).
The most significant features forms the final selection of variables for the first index - Physical Objective features Index.

Table 8. Descriptive statistics: Physical Subjective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
% of residents satisfied with car accessibility	71	.684892	.318533	.848408	.0990289
% of residents satisfied with street quality	71	.722571	.579963	.859550	.0565574
% of residents satisfied with number of facilities	71	.5263835	.2836894	.7689498	.0996603
% of residents that say Sufficient number of sport facilities	71	.5722354	.1400585	.8817642	.1849285
% of residents that say there is sufficient transport facilities present	71	.8725488	.3928224	1	.132206
% of residents that say they experience too much traffic noise	71	.1520911	.029397	.4154376	.0671931
% of residents that say the neighbourhood is hourly active	71	.0315881	0	.2369066	.0436467
% of residents satisfied with quality of buildings around	71	.5814736	.2279815	.974364	.1730736

Physical subjective features selected for this research represent resident's opinions on aspects of housing, surrounding built-environment quality, sufficient access to transport facilities and amenities, and also measure of level of activity in the neighbourhood. The selection criteria for this group emphasised on features of the environment that were prone to be influenced by connectivity of urban networks.
Even distribution of satisfaction with built quality, car access, street quality and sport facilities, as seen from the mean score of 57% indicates that some neighbourhoods are better exposed to these features than others. With respect to traffic noise, it is noticed that overall the city of Rotterdam experiences less noise pollution. But another interesting evaluation is the value for hourly activity. With a low average of 3% it is observed that most neighbourhoods are either extremely quiet or inactive, with empty street life.

Of the list, **satisfaction with car accessibility, satisfaction with number of facilities, sports facilities, transport facilities and satisfaction with quality of buildings** all proved to have notable influence on neighbourhood satisfaction explaining a variance of 77%.

Model 1 compared measures on satisfaction with facilities- metro facilities, sports and number of facilities, all of which were found to significantly influence neighbourhood satisfaction, explaining a variance of 55%. "Satisfaction with number of facilities" had a positive effect on neighbourhood satisfaction while "sufficiently present metro facilities" had a negative effect. This kind of result could be explained by the process that more number of metro facilities bring in more noise and human traffic. It was surprising to note that "satisfaction with sufficient sport facilities" had a negative impact on neighbourhood satisfaction by decreasing in 0.143 points. The next model assessed variables on "satisfaction with car accessibility" and "street quality" and found both variables to be highly correlated, with "satisfaction with street quality" masking effects of the former. However in the final model, "satisfaction with car accessibility" was found to have stronger influence with neighbourhood satisfaction increasing satisfaction by 0.165 points.

Table 9. Simple Linear Regression model of Physical Subjective Features

	Model 1	Model 2	Model 3	Model 4	Model 5
FEATURES	Y	Y	Y	Y	Y
% of residents satisfied amount of greenery		-0.0573	-0.0661	-0.0970**	
		(0.0682)	(0.0665)	(0.0437)	
% of residents satisfied with car accessibility		0.132	0.118	0.141**	0.165**
		(0.104)	(0.102)	(0.0681)	(0.0747)
% of residents satisfied with street quality		0.499**	0.499**	0.188	
		(0.189)	(0.188)	(0.132)	
% of residents satisfied with number of facilities	0.881***	0.683***	0.665***	0.339***	0.323***
	(0.104)	(0.124)	(0.121)	(0.0755)	(0.107)
% of residents that say there is sufficient metro facilities present	-0.400***	-0.287***	-0.276***		-0.190***
	(0.0756)	(0.0794)	(0.0774)		(0.0605)
% of residents that say they experience too much traffic noise		0.103			
		(0.158)			
% of residents inclined to move				-0.619***	
				(0.0604)	
% of residents that say Sufficient number of sport facilities	-0.143**				-0.110**
	(0.0571)				(0.0443)
% of residents satisfied with quality of buildings around					0.401***
					(0.0560)
Constant	0.759***	0.254	0.285*	0.708***	0.505***
	(0.0781)	(0.159)	(0.151)	(0.109)	(0.0765)
Observations	71	71	71	71	71
R-squared	0.555	0.596	0.593	0.814	0.776

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author, 2016

The final model (model 5) measured the effects of satisfaction with car accessibility, satisfaction with number of facilities, sports facilities, transport facilities and satisfaction with quality of buildings. This selection of variables formed the basis for Index 2 – Physical subjective features.

Social Features Selection

According to theory social features reflect objective conditions that encourage interactions with neighbours, social bonding within community, and even sense of privacy.

Social Objective features selected for this research reflected on records of neighbourhood interactions and contacts, weekly and monthly visits to hobby/ cultural club, visits to religious spaces, and participation in cultural events/gatherings. Through simple multivariate regression the most significant were combined to form respective indices.

Table 10. Descriptive statistics: Social Objective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
% of residents with low household income	71	.2234736	.0330861	.4743025	.1171179
% of residents with weekly neighbour contact	71	.5060588	.2501133	.8288685	.0995812
% of residents with contact with other neighbourhoods	71	.2937626	.1274245	.4928021	.0837986
% of residents that visit hobby/ club monthly	71	.3700129	.215902	.6200904	.0780669
% of residents that participate in cultural events monthly	71	.3970774	.1725313	.7097058	.1194293
% of residents that visit religious events monthly	71	.1970719	.0466319	.4334796	.0926889
% of residents that practice weekly sports	71	.4600978	.2685796	.6748966	.0958933
% of residents that live long in the neighbourhood	71	.4141473	.067142	.605042	.097093

Statistical description provides an approximate picture of the current social trends within neighbourhoods of the city. While some neighbourhoods are seen to encourage neighbourly contacts with 82% of residents reporting so, other reported only 25% of residents felt the same way. Similarly some neighbourhoods also seem to host an active sport and fitness life with about 62% of residents claiming to visit a health club. This distribution could indicate differences in lifestyles and neighbourhood composition, suggesting some neighbourhoods perhaps concentrate more youth that participate in health activities. Or even the presence of more spaces that encourage active

Statistical tests were run to understand which of the mentioned features encourage neighbourhood satisfaction. Residents with low income seen to *decrease* level of neighbourhood satisfaction by a significant 0.355 points. Percentage of residents with weekly contacts with other neighbourhoods was seen to have a *greater* influence on satisfaction than "contact with neighbour". When the two measures compared together, the former was seen to completely mast the effect of "neighbour contacts". This is not surprising considering many residents have family and friends dispersed within the city, however how this determines neighbourhood satisfaction is interesting in the possibility of a reflection of how the neighbourhood is connected to the city. Surprisingly participation in cultural even had no effect on satisfaction and participation in religions events *decreased* the level of neighbourhood satisfaction with a significant change of coefficient by 0.482 points. Similarly living long in the neighbourhood is seen to *positively* influence satisfaction, contrary to theoretical arguments that suggest longer residence to result in knowledge of inconveniences and discomfort to changes around.

Table 11. Simple Linear Regression model of Social Objective Features

	Model 1	Model 2	Model 3	Model 4	Model 5
FEATURES	Y	Y	Y	Y	Y
% of residents with low household income	-0.355***	-0.347***	-0.322***	-0.298***	-0.297***
	(0.0980)	(0.0976)	(0.101)	(0.0976)	(0.104)
% of residents with weekly neighbour contact	-0.185	-0.201	-0.119		0.186**
	(0.159)	(0.158)	(0.160)		(0.0817)
% of residents with contact with other neighbourhoods	0.422**	0.413**	0.474**	0.312***	
	(0.182)	(0.181)	(0.186)	(0.0939)	
% of residents that participate in cultural events monthly	0.169	0.149	0.0701		
	(0.108)	(0.106)	(0.105)		
% of residents that practice weekly sports	0.287**	0.279**	0.323**	0.367***	0.313***
	(0.132)	(0.132)	(0.135)	(0.107)	(0.109)
% of residents that visit religious events monthly	-0.394***	-0.400***	-0.444***	-0.466***	-0.482***
	(0.114)	(0.114)	(0.116)	(0.114)	(0.120)
% of residents that live long in the neighbourhood	0.252**	0.258**			
	(0.107)	(0.106)			
Constant	0.550***	0.615***	0.677***	0.671***	0.696***
	(0.113)	(0.0885)	(0.0879)	(0.0778)	(0.0857)
Observations	71	71	71	71	71
R-squared	0.756	0.753	0.730	0.724	0.702

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 12. Most significant Social Objective features

VARIABLES	Neighbourhood Satisfaction
% of residents with low household income	-0.298***
	(0.0976)
% of residents with contact with other neighbourhoods	0.312***
	(0.0939)
% of residents that practice weekly sports	0.367***
	(0.107)
% of residents that visit religious events monthly	-0.466***
	(0.114)
Constant	0.671***
	(0.0778)
Observations	71
R-squared	0.724

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

This final list composed of the most significant features as described in table 10, explaining a variance of 72%. This forms the third index- Social objective Index.

Table 13. Descriptive statistics: Social Subjective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
% Of residents who say people help each other	71	.570719	.2663922	.9240563	.1347508
% Of residents who say they do not have problems with neighbours	71	.6846836	.5200366	.8300137	.0631911
% Locals that says that in the neighbourhood are plenty of places to joint activities residents	71	.5058944	.2691063	.9080485	.1180227
% Locals that says there is near enough places for religious and philosophical meetings	71	6110725	.2019384	.9222625	.1725651
% Locals that says that in the neighbourhood there are plenty of elderly facilities	71	.3514061	.0905339	.6271549	.1269024
% Locals that says that in the neighbourhood there are plenty of leisure facilities for young people	71	.350534	.0641727	.8262021	.148332
% Residents who say they are proud of the neighbourhood	71	.5618428	.2862819	.8670912	.1430269
% Residents who say they find around nice	71	.7479243	.4803767	.9395065	.1209106
% Residents who said they experienced no problems in the neighbourhood	71	.5535635	.2404411	.9057251	.2026829
% Of residents who say they feel connected to neighbourhood	71	.5553604	.2577724	.8002465	.1124726
% Residents who say they feel responsible for neighbourhood	71	.8420249	.7033288	.9852485	.051996

Social subjective features measures resident's opinions and satisfaction with conditions within the neighbourhood that encourage social activities. The statistical summary indicates a clear divide of roughly 55% to 60% on level of satisfaction with different social conditions. Of the 71 neighbourhoods, an average of 57% found "people in their neighbourhood to be helpful", with some neighbourhoods noting as less as 25%. Similarly 55% felt connected to their neighbourhood experiencing no problems. And an average of 60% of all resident's in all neighbourhoods had no problems with neighbours. However with respect to presence of facilities and activities for young and old on, some neighbourhoods scored as low as 6-9% while others scored up to 82%. This indicates a clear divided in the supply of spaces and facilities for all ages. However the measure of standard deviation for this selection indicates a slight bias in the responses, with most features scoring above 10%. As in the case, of "residents who say they experience no problems in neighbourhood" the standard deviation is seen to be above 20% which means some of the residents within neighbourhoods scored significantly above the average for that measure.

While comparing the different features ability in determining neighbourhood satisfaction it is surprising to note that only a handful emanate a significant relationship. Of the list, **percentage of residents who say people help each other", "percentage of residents who say they do not have problems with neighbours", "% Residents who said they experienced no problems in the neighbourhood" and "percentage who find surrounding atmosphere nice"** were found to significantly influence neighbourhood satisfaction with aggregate variance of 65%.

Table 14. Simple Linear Regression model of Social Subjective Features

	Model 1	Model 2	Model 3	Model 4	Model 5
FEATURES	Y	Y	Y	Y	Y
% Of residents who say people help each other	0.319	0.293***	-0.0731	-0.0716	-0.0753
	(0.219)	(0.0868)	(0.0616)	(0.0887)	(0.0835)
% Of residents who say they do not have problems with neighbours	0.952***	0.953***	0.0313	0.0597	0.0560
	(0.173)	(0.171)	(0.131)	(0.133)	(0.129)
% Locals that says that in the neighbourhood there are plenty of leisure facilities for young people			0.0366		
			(0.0438)		
% Residents who say they are proud of the neighbourhood			0.181*		
			(0.0995)		
% Residents who say they find around nice			0.393***	0.503***	0.496***
			(0.138)	(0.133)	(0.121)
% of residents who say they know each other	-0.0232				
	(0.178)				
% Locals that says that in the neighbourhood are plenty of places to joint activities residents	-0.0626	-0.0691			
	(0.110)	(0.0972)			
% Locals that says there is near enough places for religious and philosophical meetings	-0.0323	-0.0318			
	(0.0637)	(0.0631)			
% Locals that says that in the neighbourhood there are plenty of elderly facilities	-0.0268	-0.0222			
	(0.106)	(0.0990)			
Sqrt % Residents who said they experienced no problems in the neighbourhood			0.310***	0.303***	0.304***
			(0.0999)	(0.103)	(0.102)
% Of residents who say they feel connected to neighbourhood				0.112	0.114
				(0.116)	(0.113)
% Residents who say they feel responsible for neighbourhood				-0.0234	
				(0.177)	
Constant	0.00925	0.0153	0.158*	0.133	0.120*
	(0.138)	(0.129)	(0.0805)	(0.115)	(0.0677)
Observations	71	71	71	71	71
R-squared	0.515	0.515	0.844	0.838	0.838

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Author, 2016

This final list that formed the index can be found in Annex 5.1

Safety Features

Safety feature account for reports on crime, theft and the feeling of security. *Objective measures* reflect on reports of crime, vandalism of amenities, abuse and harassment, destruction to public property etc.

Subjective measures on the other hand reflect resident's opinions on level of safety and number of times they have been subjected to abuse, harassment or have knowledge of safety levels within their neighbourhood.

Table 15. Descriptive statistics: Safety Objective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
Number of thefts on vehicles	71	1.794428	0	5.769815	1.086739
Number of reports of pickpocketing	71	8.027643	0	180.5293	27.1005
Number of reports on crime abuse	71	5.838248	.591133	41.87967	7.254481
Number of reports on graffiti	71	4.70484	3.877907	4.967662	.2042663
Reports on drug case per 1000 inhabitants	71	1.362702	0	4.3256	.9738633
Reports on conflict with environment per 1000 inhabitants	71	24.33853	3.543407	110.4994	18.10397
Reports of nuisance per 1000 inhabitants	71	30.6386	9.848059	102.4381	17.46491
% of residents that have been subject to violence	71	.0299457	0	.1063425	.0179231
% of residents that have been subject to abuse	71	.0104792	0	.0333265	.0080974
% of residents that have been subject to burglary	71	.0447111	0	.1182635	.0245714
% of residents that have been subject to attempted burglary	71	.0285404	0	.1113112	.0209328

The overall objective reports on safety indicate varied trends of levels of safety through the neighbourhoods of Rotterdam city. While some indicate high levels of crime abuse (41 accounts) and pickpocketing (180 accounts), other neighbourhoods report a minimum of 1 and 4 accounts. Similarly with respect to percentage subject to incidents of burglary and theft, a maximum of 11% is observed.

Of the list of safety objective features **reports on conflict with the environment, number of reports of abuse, percentage of residents subject to attempted burglary and attempted abuse** are seen to significantly influence neighbourhood satisfaction explaining a model variance of 65%.

Percentage of residents subject to attempted burglary and subject to crime abuse are seen to significantly influence satisfaction decreasing the value of coefficient change by 1.4 and 2.5 points. While reports on environment conflict is seen to decrease satisfaction by 0.133 pints.
This final list was selected to make the index on safety objective features.

Table 16. Simple Linear Regression model of Safety Objective Features

	(1)	(2)	(3)	(4)
FEATURES	Y	Y	Y	Y
(Log) Reports on conflict with environment per 1000 inhabitants	-0.131***	-0.123***	-0.155***	-0.133***
	(0.0330)	(0.0376)	(0.0317)	(0.0211)
(Log) Reports of nuisance per 1000 inhabitants	0.0846**	0.103**	0.0687*	
	(0.0406)	(0.0404)	(0.0383)	
% of residents that have been subject to attempted burglary	-1.692***	-1.877***	-1.475***	-1.421***
	(0.388)	(0.383)	(0.369)	(0.369)
% of residents that have been subject to attempted abuse	-3.188***	-2.572**	-2.331**	-2.526**
	(1.123)	(1.118)	(1.082)	(1.060)
Reports on drug case per 1000 inhabitants		-0.0261		
		(0.0214)		
Constant	1.014***	0.936***	1.110***	1.240***
	(0.0654)	(0.0885)	(0.0679)	(0.0498)
Observations	71	68	71	71
R-squared	0.594	0.624	0.651	0.651

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Author, 2016

Table 17. Descriptive statistics: Safety subjective Features **Source: Author, 2016**

Features	N	Mean	Minimum	Maximum	Std. Deviation
Bicycle theft often occurs as a neighbourhood problem	71	.2066197	0	0 .37	.0796052
Thefts from cars often occurs as a neighbourhood problem	71	.1091549	0	.23	.0499928
Threats often occurs as a neighbourhood problem	71	.0691549	0	.16	.0432847
Violent crime often occurs as a neighbourhood problem	71	.2462996	0	.4622246	.1142464
Snatching violence often occurs as a neighbourhood problem	71	.2189399	0	.4145063	.0985625
Percentage of residents have been victims of abuse last year in their own neighbourhood	71	.0433803	.01	.14	.0226112
Arguing Making and / or screaming street youth in their own neighbourhood is experienced as much nuisance	71	.2156707	0	.4482741	.1052894
Back and forth loudly drug addicts in your street is widely perceived as a nuisance	71	.2305164	0	.4482741	.1052894
Trafficking of drugs on the streets of their own neighbourhood is experienced as much nuisance	71	.2305164	.0590686	.4618493	.0882774

Of the list of features, cycle theft, theft from cars are seen to significantly influence neighbourhood satisfaction. However when included with other variables like percentage of residents who think destruction of amenities often occurs as a neighbourhood problem the effects are completely mediated. Many of such indicators that measure subjective perception of safety were seen to be highly correlated. Hence multiple models were run introducing variables independently and together. The most significant measures that did not represent duplicates were selected for the final list. An example is the correlation explained when the measure of violent crime was introduced to mode 5, the effects of cycle theft and car theft were completely mediated for.

Table 18. Simple Linear Regression model of Safety Subjective Features

	(1)	(3)	(4)	(5)	(6)
FEATURES	Y	Y	Y	Y	Y
Bicycle theft often occurs as a neighbourhood problem	-0.406***	-0.403***			-0.0502
	(0.148)	(0.148)			(0.114)
Thefts from cars often occurs as a neighbourhood problem	-0.990***	-0.974***			-0.250
	(0.235)	(0.237)			(0.173)
Threats often occur as a neighbourhood problem		-0.368		0.354	0.352
		(0.466)		(0.355)	(0.359)

Street harassment often occurs as a neighbourhood problem			-0.878***		
			(0.210)		
Percentage of resident who find neighbours as nuisance			-1.253***		
			(0.211)		
(Sqrt) destruction to amenities as neighbourhood problem				-0.221***	-0.241***
				(0.0737)	(0.0845)
Trafficking of drugs on the streets of their own neighbourhood is experienced as much nuisance				-0.349***	-0.278**
				(0.106)	(0.105)
Violent crime often occurs as a neighbourhood problem				-0.504***	-0.465***
				(0.106)	(0.111)
Constant	0.984***	0.998***	0.992***	1.042***	1.059***
	(0.0312)	(0.0358)	(0.0182)	(0.0236)	(0.0323)
Observations	71	71	71	71	71
R-squared	0.401	0.407	0.705	0.746	0.754

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 19. Most significant Safety Subjective Features

	(1)	(2)
VARIABLES	Neighbourhood satisfaction	Neighbourhood satisfaction
(Sqrt) destruction to amenities as neighbourhood problem	-0.221***	-0.185**
	(0.0737)	(0.0763)
(Sqrt) Trafficking of drugs on the streets of their own neighbourhood is experienced as much nuisance	-0.349***	
	(0.106)	
Violent crime often occurs as a neighbourhood problem	-0.504***	
	(0.106)	
Percentage of resident who are victims to theft	0.354	
	(0.355)	
Street harassment often occurs as a neighbourhood problem		-0.873***
		(0.206)
Percentage of resident who find neighbours as nuisance		-1.217***
		(0.209)
Constant	1.042***	1.015***
	(0.0236)	(0.0223)
Observations	71	71
R-squared	0.746	0.713

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

The final list of features considered for creating the safety subjective features index is described in Table 19.

Creating Indices

Having identified the most significant predictors of neighbourhood features, the next step involved generating indices that could summarise their total effect. Objective and subjective measures were grouped under different categories as the measures assess two very different perceptions of the environment.

Table 20. Neighbourhood Features Index **Source: Author, 2016**

Independent Variables	N	Mean	Minimum	Maximum	Std. Deviation
X1a: Physical objective index	71	5.149482	2.566136	8.222206	1.28206
X1b: Physical subjective index	71	11.78341	6.573469	17.1556	2.57497
X2a: Social objective index	71	5.531472	1.668735	9.341507	1.512502
X2b: Social subjective index	71	4.931037	1.458405	10.02034	2.041421
X3a: Safety objective index	71	4.47456	1.201819	11.21977	2.150934
X3b: Safety subjective index.	71	7.080263	1.923237	12.99349	3.188612

Penas distance was used to create indices from the different measures. Selection of the indicators is based on theory and the calculation of the Penas distance (p2distance) by Perez- Luque et al. (2015) is not affected by the categories used to group the satisfaction pillars.

The computation of the pillars used the P2 distance index, a synthetic index that combines all of these indicators into a single value (Garcia et al., 2015). This approach has also been used to build indicators in other disciplines such as well-being and other social indicators (Garcia et al, 2015). It allows comparisons between entities (both temporal and spatial) and is considered to be an exhaustive synthetic indicator because it is not based on a reduction of information.
It considers all the valuable information contained in the indicators used to build it, allowing the inclusion of a large number of indicators, since all redundant variance is removed by the process itself, as is the multicollinearity. (Montero et al., 2010; Garcia et al., 2015).

To calculate the P2 distance, a matrix X of order (m, n) was developed in which m represents the number of spatial units (countries) and n, the number of variables. Each element of this matrix, xri, is the value of the variable i in the spatial entity r. The P2 distance indicator calculates the distance of each spatial entity with regard to a theoretical spatial entity of reference. Initially, a distance matrix D is calculated as:

$$d\text{ri}=|X_{ri}-X_{*i}|$$

where $x_{*}i$ is the r-th element of the reference base vector
$X_{*} = (x_{*}1, x_{*}2, \ldots, x_{*}n)$. For each variable a reference value must be defined to compare different spatial entities. Garcia et al. 2015)

The calculation of the P2 distance follows the formula

$$DP2 = \sum_{i=1}^{n} \{\binom{di}{\sigma i}\ 1 - R_i^2, \text{i-1,1-2,....,1)}\}$$

With R_i^2=0; where d_i=|X_{ri}-X_{*i}| with the reference base x_*=(x*1,x*2…x*n) where

- n=no. of variables
- xri = value of variable I and the spatial entity r
- σi = standard deviation of variable i
- R_i^2, i-1,1-2,….,1)} is the coefficient of determination in the regression of X_i over X_{i-1}, X_{i-2},…..X_1 already included

The numerical value of the Dp2 index has no real meaning but it's useful for comparing the happiness levels of different neighborhoods

4.1.4 Connectivity of Urban networks

In order to measure connectivity of urban networks using Space syntax, axial maps were prepared by manually replicating road and street network (axial lines) for the entire city. With the help of Openstreetmaps (OSM) a total of 14728 axial lines were drawn, representing all main roads, motorways and residential streets.

Only public roads that are accessible and connect different parts of the city were considered. Private roads within industrial and institutional boundaries were not considered, for such networks do not facilitate connectivity within and between individual neighbourhoods. Hence the western wing that includes Rotterdam Port area, towards the sea is portrayed rather empty. But nevertheless the main routes have been represented. For similar reasons private street networks within green parks and industrial sectors, were excluded. The drawing file is further converted into an Axial map and the first measure of connectivity, i.e Axial Integration Analysis at a given radius of 3 steps (n=3) is processed.

Map 2. Axial Integration Analysis at n=3 steps for Rotterdam City, using Space Syntax

Source: Author, 2016

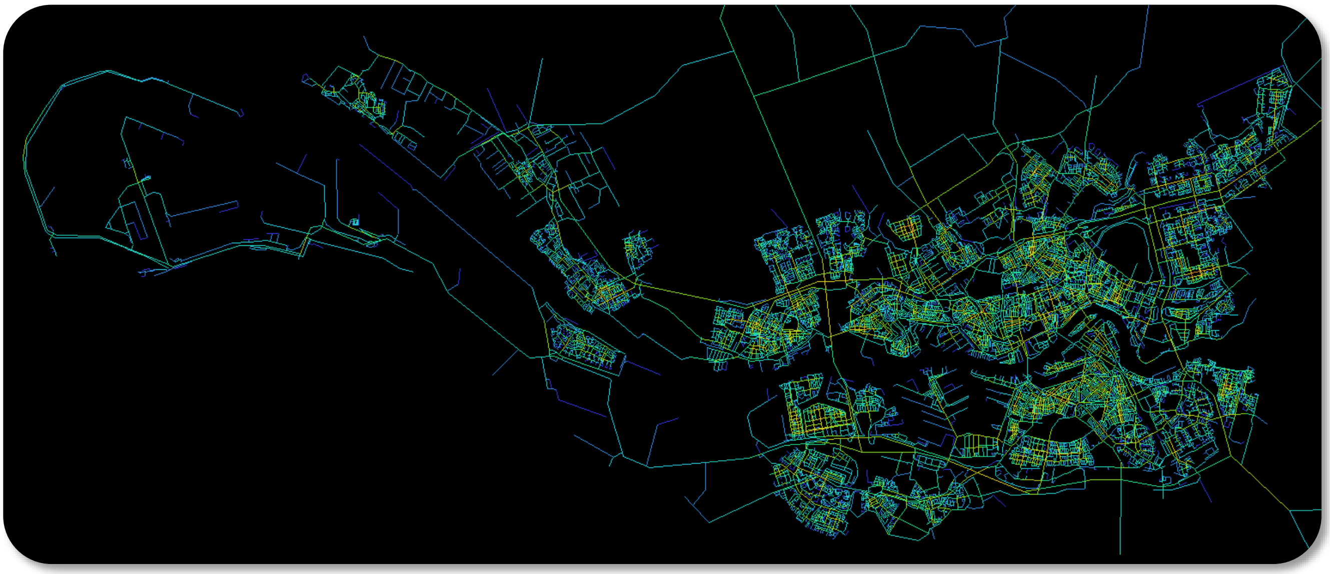
Table 21. Summary Statistics **Source: Author, 2016**

Independent Variable (X_{4a})	Count*	**Mean**	Minimum	Maximum	Std. Deviation
Axial Integration Analysis @ n=3	14728	**1.52**	0.33	6.06	0.54

Average values indicate the level of street integration for the give network structure, while Count refers to the number of axial lines that make up the network structure. For this configurational structure of a total of 14728 lines, the mean axial integration at a radius of 3 turns is 1.52. This means that on average the street network has relatively low level of axial integration, visible from the spread of largely blue lines across the city. Small clusters of yellow and red networks distributed through the city structure indicate potential spaces that are nevertheless well integrated.

This axial map is further converted into a Segment map to conduct the second connectivity measure, Angular Segment analysis (n=3). Segment analysis considers the angle of change from one street segment to another, within a given radius. When considering angular change, it is observed that clusters of well integrated streets are spread throughout the network structure. Yellow and Red lines indicate higher levels of angular integration. This form of distribution highlights that some neighbourhoods do hold potential of being better integrated and accessible as compared to other neighbourhoods.

Map 3. Angular Segment Analysis at n=3 steps for Rotterdam City, using Space Syntax



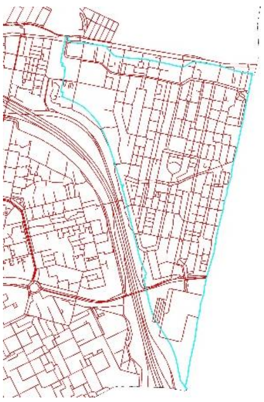
Source: Author, 2016

Table 22. Summary Statistics **Source: Author, 2016**

Independent Variable (X4b)	Count*	**Mean**	Minimum	Maximum	Std. Deviation
Angular Segment Analysis @ n=3	33169	**16.32**	2.58	42.40	6.38

Space syntax however provides integration values for the entire network structure and in order to extract values for 71 independent neighbourhoods, it was necessary to demarcate the streets and roads that comprised each neighbourhood. With the help of ArcGIS and OSM data, the boundaries and network constituents were identified and defined to use as a base for selection. An example of the process is depicted below:

Neighbourhood name: Beverwaard



Open street map selection

Selection of streets on SS

Axial Integration

Angular Segment Analysis

Table 23. Summary statistics for individual neighbourhood **Source: Author, 2016**

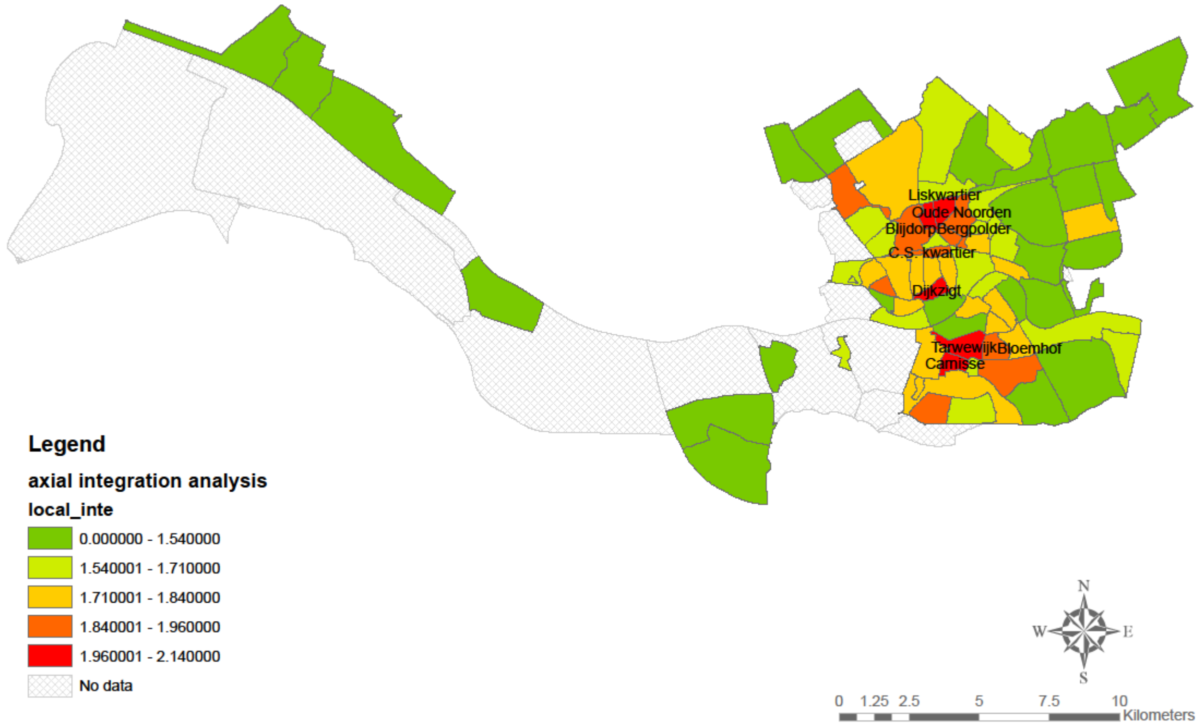
Independent Variable	Count*	**Mean**	Minimum	Maximum	Std. Deviation
Axial Integration Analysis @ n=3	237	**1.65**	0.33	2.94	0.50
Angular Segment Analysis @ n=3	578	**17.32**	3.32	37.83	6.30

All together data for 71 neighbourhoods was generated for the two measures of connectivity X_{4a}- Axial Integration Analysis (n=3) and X_{4b}- Angular Segment Analysis (n=3). The entire list can be found under Annexure 2.

Table 24. Summary statistics for Independent Variables **Source: Author, 2016**

Variable	N	Mean	Minimum	Maximum	Std. Deviation
X_{4a}: Axial Integration Analysis @ n=3	71	1.6735	1.34	2.14	0.18800
X_{4b}: Angular Segment Analysis @ n=3	71	17.59	13.42	32.22	2.676

Map 4. Spatial Distribution of Axial Integration Analysis @ n=3, for Rotterdam City

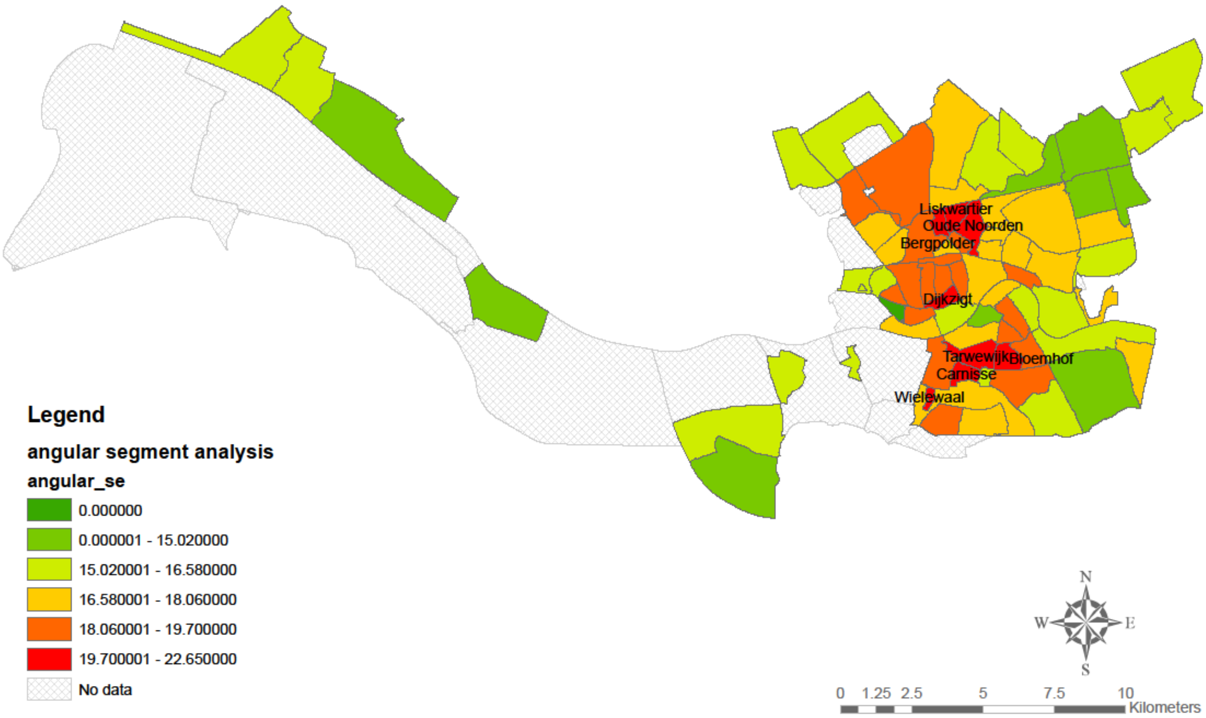


Source: Author, 2016

On analysing spatial distribution of "Axial integration" for the entire city, no distinct pattern arises apart from that the north and south seem to contain centres of high integration, which are unconnected and drastically diminish towards the periphery. However, it is interesting to note that between the two sections of the city there is missing link, in that concentration of integration seems to occur at two independent clusters. Similarly city centre neighbourhoods are seen to be amongst the less integrated, which is surprising considering the heart of any city is expressed as the core of all mobility and accessibility. Only one neighbourhood "Dijkzigt" is seen to indicate high levels of integration.

When comparing this to maps on type of neighbourhoods the highly integrated neighbourhoods correspond to type 3 compact residential layouts. The highest integrated neighbourhoods are Liskwartier, Oud Noorden and Dijkzigt for the northern half of the city exhibiting values such as 2.14, 2.03 and 1.8 respectively. While in the southern half "Tarwewijk" and "Carnnise" exhibit similar levels of integration. The least integrated neighbourhoods correspond to type 5, old villages and green spaces. The analysis is confirmatory as green neighbourhood's exhibit larger open spaces like parks, gardens and green belts, with less street networks.

Map 5. Spatial Distribution of Angular Segment Analysis @ n=3, for Rotterdam City



Source: Author, 2016

Distribution of Angular Segment analysis seems to provide a different explanation of network integration, as the city centre is seen to be better integrated than the periphery, (red indicating higher level of integrations). To reiterate, the measure describes level of street integration with respect to angular change at a radius of 3 steps. As Angular analysis indicates cognitive access, with the focus on the threshold of angle of direction change as experienced by the user/ resident, it can be stated that network structure of Rotterdam city is better integrated through angular change, as compared to local integration.

The projection notes neighbourhoods “Liskwartier”, “Oude Nooerden” and “Bergpolder” to exhibit higher integration through angular change, for the northern part of the city. While for the south neighbourhoods “Tarwewijk” and “Carnnise” exhibit the same. However, the difference in both measures can be observed with the change in values of integration for peripheral neighbourhoods. Unlike in the previous measure, some of the green neighbourhoods and southern regions are seen to be better integrated (orange neighbourhoods), indicating some variance in network constitution.

Nevertheless the subject of analysis for this research, is to understand the relationship between network integration and neighbourhood satisfaction, and *not* to examine in detail their effects on individual neighbourhoods. Hence, only statistical comparative investigation is pursued.
Having derived the necessary information to perform the comparative analysis, the next section describes in detail empirical results.

4.2 Empirical Results

Prior to pursuing statistical analysis, some simple tests were conducted to understand frequency of data distribution and identifying standard errors. Exclusively so for neighbourhood feature indices, and measures of connectivity of urban networks.

Neighbourhood feature indices seem to be evenly distributed with minimal errors. However the index of "Safety objective features", variable X_{3a}, is seen to be slightly skewed. Histogram of observations shows a skewed distribution, for which log values were generated. The variable is represented as a new variable called "(Log) X_{3a}". Similar analysis was conducted with measures of connectivity. Both variables are seen to depict highly skewed distribution of data, hence log values were generated and the new variables termed "Log_X_{4a}" and "Log_X_{4b}".

Table 25. Generating Log variables to minimise Errors **Source: Author, 2016**

Log Independent Variables	N	Mean	Minimum	Maximum	Std. Deviation
(Log) X_{3a}: Safety Index (objective)	71	1.379409	.1838358	2.417678	.5076262
Log_X_{4a}: Axial Integration Analysis	71	0.50872	0.292669	0.760805	0.112178
Log_X_{4b}: Angular Segment Analysis	71	2.857629	2.596746	3.472587	.137331

Testing for Collinearity:
As both measures for connectivity of urban networks represent similar concepts, the possibility of collinearity arises. For this purpose Pearson's bivariate correlation was conducted, along with VIF test. The test confirmed both measures to be highly correlated and with this intention, are introduced into the testing model independently.

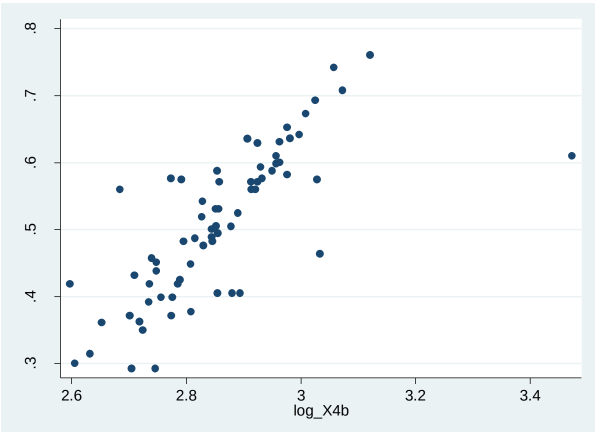
Figure 12. Collinearity between connectivity measures

(a) Perasons Bivariate correlation

```
. pwcorr log_X4a log_X4b, sig star(.05) obs

             |  log_X4a  log_X4b
-------------+------------------
     log_X4a |   1.0000
             |
             |       71
             |
     log_X4b |  0.7520*  1.0000
             |   0.0000
             |       71       71
             |
```

(b) Scatterplot between the two measures of connectivity



Source: Author, 2016

4.2.1 Neighbourhood Satisfaction and Neighbourhood Features

Sub Question 1: What neighbourhood features are seen to significantly influence neighbourhood satisfaction?

- *Physical features*
- *Social features*
- *Safety features*

From theory it is understood that neighbourhood satisfaction is also a measure of the sum of satisfaction with different neighbourhood features. With this intension it was mandatory to identify features that significantly contributed to this assessment. As described from the first section of this chapter (4.1.3), 6 indices were created to best represent each of the 3 features. In order to distinguish the effects of objective and subjective measures a set of ordinary least square regressions were run, taking heed of change in the coefficient values (beta) and significance of P. Separate comparisons with objective indices and subjective indices were processed, starting independent of control measures to understand direct effects (See Table 26 and 27, respectively).

In the case of *objective features,* all three indices were seen to significantly influence neighbourhood satisfaction, with social and safety indices influencing change in coefficient by more than 0.30 points (table 26). However all three features are also seen to negatively influence satisfaction, and this result can be explained by analysing the effects of independent features that constitute the index.

Table 26. Simple Linear regression model comparing Objective Indices and Neighbourhood satisfaction.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
VARIABLES	Y	Y	Y	Y	Y	Y	Y
X1a: Physical Index (objective)	-0.0304***			-0.00658			0.00865
	(0.00983)			(0.00740)			(0.00789)
X2a: Social Index (objective)		-0.0340***			-0.0181***		-0.0269***
		(0.00789)			(0.00606)		(0.00680)
(Log) X3a: Safety Index (objective)			-0.150***			-0.0826***	-0.0902***
			(0.0193)			(0.0185)	(0.0167)
X6				-0.154	-0.282	-0.114	-0.304*
				(0.190)	(0.185)	(0.167)	(0.154)
X8				0.449***	0.451***	0.308***	0.295***
				(0.0809)	(0.0757)	(0.0784)	(0.0711)
X7				-1.28e-05	2.02e-05	-0.000146	-0.000106
				(0.000237)	(0.000224)	(0.000210)	(0.000187)
Constant	0.949***	0.981***	1.000***	0.644***	0.749***	0.796***	0.976***
	(0.0522)	(0.0452)	(0.0284)	(0.0809)	(0.0791)	(0.0724)	(0.0812)
Observations	71	71	71	71	71	71	71
R-squared	0.121	0.212	0.467	0.595	0.639	0.685	0.760

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author, 2016

For example the Safety Index is a measure of percentage of negative accounts of violence and theft that have been experienced by residents in neighbourhoods. Hence an index score of greater value indicates greater accounts of negative effects. This implies that with the increase in negative aspects of safety features, a decrease in satisfaction can be expected, as realized with the results.

Conversely though, the results for physical and social index are surprising, considering they measures positive accounts of environment quality and social bonding. While including control measures of average income, ethnic composition and population density the overall effects change, with physical features becoming insignificant and variance of the models improve to 68%. Control measures were introduced independently, to study direct effects on change in coefficient of each features. Of the three, ethnic composition is seen to have the highest influence on neighbourhood satisfaction as well as neighbourhood features. A detailed account of this influence is described in the Annex 5.

The final model (table 26, model 7) compared all three features together, physical objective features is seen have no influence on neighbourhood satisfaction construing social aspects like gatherings, knowing neighbours and participating in social activities to be more important for satisfaction than quality of built space and overcrowding. Similarly safety features is seen to have a significant impact stating elements of noise, burglary and theft to also be important factors determining neighbourhood satisfaction.

Comparison of *subjective features* also depict social and safety features to be more influential (table 27). Subjective measures of neighbourhood features addresses people's opinions and accounts of satisfaction, and a positive association indicates- increase in satisfaction with independent features to influence increase in neighbourhood satisfaction. This analysis is also concurrent with literature review. While analysing subjective features, it is observed that effects of physical features is masked with the introduction of social features to the same model due to collinearity between the two variables.

Table 27. Simple Linear regression model comparing Subjective Indices and Neighbourhood satisfaction

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
VARIABLES	Y	Y	Y	Y	Y	Y	Y
X1b: Physical Index (subjective)	0.0261***			0.0103**			0.00198
	(0.00417)			(0.00398)			(0.00326)
X2b: Social Index (subjective)		0.0470***			0.0400***		0.0212***
		(0.00338)			(0.00623)		(0.00768)
X3b: Safety Index (subjective)			-0.0301***			-0.0242***	-0.0159***
			(0.00216)			(0.00349)	(0.00427)
X6: Average Income				-0.110	-0.0352	-0.196	-0.115
				(0.182)	(0.150)	(0.145)	(0.140)
X8: Ethnic composition native				0.378***	0.0587	0.187**	0.0535
				(0.0829)	(0.0888)	(0.0727)	(0.0815)
X7: Population density				-1.37e-05	-0.000170	0.000101	-1.61e-05
				(0.000227)	(0.000188)	(0.000182)	(0.000177)

Constant	0.485***	0.561***	1.006***	0.511***	0.590***	0.923***	0.789***
	(0.0503)	(0.0180)	(0.0168)	(0.0721)	(0.0519)	(0.0682)	(0.0812)
Observations	71	71	71	71	71	71	71
R-squared	0.361	0.737	0.738	0.629	0.748	0.764	0.795

Another interesting observation was the difference in variance explained by objective and subjective measures. While objective measures described a model variance of 12% to 40%, individual subjective measures described variances above 35% and up to 73%. This further highlights that subjective measures are seen to better represent neighbourhood satisfaction. Conversely, the subjective method of assessment of both dependent and independent variables can result with multicollinearity, a relationship that “makes it tedious to assess the relative importance of the independent variables in explaining the variation caused by the dependent variable”. Though standard errors indicate negligible values, a VIF tests was run to correct for this effect.

The final regression included 4 of the significant feature indices in a single model (table 28), while controlling for average income, ethnic composition and population density. Social objective features, Social subjective features and Safety subjective features are seen to significantly influence neighbourhood satisfaction, with a two-tail P value significantly below the required 0.05 value (as indicated by 3 asterisks). However the magnitude of influence is relatively small as indicated by the low beta values. Between the two safety indices, safety subjective index is seen to provide a better explanation of satisfaction as compared to objective index (model 1). The variables and the model are seen to explain 84% of variance in determining neighbourhood satisfaction.

Table 28. Simple Linear regression model comparing significant Neighbourhood Indices and Neighbourhood satisfaction

	Model 1	Model 2
VARIABLES	Y	Y
X2a: Social Index (objective features)	-0.0200***	-0.0230***
	(0.00448)	(0.00426)
X2b: Social Index (subjective features)	0.0288***	0.0355***
	(0.00705)	(0.00667)
(Log) X3a: Safety Index (objective features)	-0.00473	-0.0334*
	(0.00409)	(0.0178)
X3b: Safety Index (subjective features)	-0.00875**	
	(0.00431)	
X6: Average Income	-0.234*	-0.214
	(0.126)	(0.129)
X7: Population Density	-5.89e-05	-0.000141
	(0.000158)	(0.000157)
X8: Ethnic composition native	0.0297	0.0317
	(0.0727)	(0.0749)
Constant	0.911***	0.856***
	(0.0716)	(0.0716)
Observations	71	71
R-squared	0.843	0.831

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Neighbourhood Features and Connectivity measures

Sub Question 2: To what extent does connectivity of urban networks (street networks) influence neighbourhood features?

The second research question investigates the influence of connectivity of urban networks on neighbourhood features, to test for *mediating effects*. Logarithmic values were generated for both measures of connectivity, due to skewed data distribution (refer to annex 4 for charts) and to minimize errors in analysis. The first step analyzed direct relationships with six models reflecting each measure of connectivity against six neighborhood indices (table 29), while the second step included control measures to test for variance in results (table 30). The results observed to have high coefficient values with equally high standard errors, indicating potential heteroscedasticity and autocorrelation.

Table 29. Simple Linear regression comparing Axial Integration (X4a) and neighbourhood feature indices

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	X1a: Physical index (objective)	X1b: Physical index (subjective)	X2a: Social index (objective)	X2b: Social index (subjective)	(Log) X3a: Safety index (objective)	X3b: Safety index (subjective)
(Log) X4a: Axial integration	1.190	-12.65***	1.015	-9.868***	2.411***	14.80***
	(1.368)	(2.306)	(1.619)	(1.841)	(0.461)	(2.922)
Constant	4.544***	18.22***	5.015***	9.951***	0.153	-0.447
	(0.713)	(1.201)	(0.843)	(0.959)	(0.240)	(1.522)
Observations	71	71	71	71	71	71
R-squared	0.011	0.304	0.006	0.294	0.284	0.271

Robust Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 30. Including control measures to the relationship between X4a and neighbourhood feature indices.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	X1a: Physical index (objective)	X1b: Physical index (subjective)	X2a: Social index (objective)	X2b: Social index (subjective)	(Log) X3a: Safety index (objective)	X3b: Safety index (subjective)
(Log) X4a: Axial integration	-2.450	-9.720***	-3.494*	-4.019**	2.178***	3.683
	(1.837)	(2.686)	(1.912)	(1.701)	(0.509)	(3.449)
X6: Average Income	-2.156	-4.137	-8.128**	-3.108	0.574	-1.837
	(3.011)	(5.931)	(3.566)	(3.535)	(1.039)	(5.438)
X7: Population Density	0.00517	0.00980*	0.00671	0.00819**	-0.00394***	0.00107
	(0.00439)	(0.00577)	(0.00595)	(0.00360)	(0.00129)	(0.00727)
X8: Ethnic Composition	-1.579	7.584***	-0.557	9.908***	-1.776***	-11.13***
	(1.193)	(2.086)	(1.611)	(1.369)	(0.404)	(2.319)
Constant	7.503***	13.33***	9.719***	2.164*	1.332***	11.52***
	(1.571)	(1.884)	(1.744)	(1.147)	(0.350)	(2.326)
Observations	71	71	71	71	71	71
R-squared	0.176	0.433	0.227	0.733	0.460	0.648

Robust Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 29, depicts direct effects of the first measure of connectivity X_{4a} (Axial Integration) with each of the six neighbourhood feature indices. It is interesting to note that four of the six relationships are statistically significant, with the Two-tail P values well below 0.01. Surprisingly though, Axial integration is seen to negatively influence physical subjective features and social subjective features, implying better integrated space decrease satisfaction with physical and social elements of the neighbourhood. Axial integration is also seen to positively influence both safety objective and subjective features, with high statistical significance and increasing coefficient values by 2.4 and 14.8 points. However high measure of standard errors, especially for safety subjective features indicates a bias in results. Overall the result is also contradictory to theoretical analysis that state better integrated street structure to reduce effects of crime and theft, and improve subjective perception of safety. For all six models, the measure of variance is significantly small between the range of 1% and 25%, thus stating a poor representation of the relationship.

To provide a better understanding of the analysis three control measures were introduced, first independently and further together (table 30). Inclusion of control measures unpredictably change some relationships, as seen in the case of social objective index and safety subjective index. In the previous model social objective index is seen to have no statistical significant relationship with axial integration but with the inclusion of control measures, changes results by 2.4 points and to a negative association. Similarly safety subjective index changes from being highly statistical significant to insignificant. This sudden change in relationships can be accounted for by the large standard errors observed for the same variable in table 29. Robust standard errors were carried out to correct for this, and table 30 depicts the final relationship.

Overall, Axial integration is seen to significantly influence Physical subjective index but with a decreasing effect of 9.72 points (model 2), and by 4.01 points for Social subjective index (model 4). The measure of variance explained by the models significantly improve, with model 2 explaining 43% and model 4, 73%. The inclusion of control measures does not seem to effect the relationship between axial integration and safety objective features, with coefficient of change only slightly decreasing from by 0.3 points, but overall influencing positively.

Similar tests were performed with second measures of connectivity X_{4b}: Angular Segment Analysis and neighbourhood features. Table 31 and 32 provide a detailed account of the evolution of this relationship. Angular Segment analysis depicts a substantially lower impact on neighbourhood features as compared axial integration. Independently this second measure is seen to influence four of the six neighbourhood features but the resulting change in coefficient and standard errors indicate highly biased results. While introducing control measures and performing robust standard errors the results change dramatically, leaving only two statistically significant relationships that is Physical subjective index (model 2) and Safety subjective index (model 5). Angular segment analysis is seen to decrease the level of satisfaction with physical features by 5.5 points significantly so with the measure of two tail P values well below 0.01.This model is seen to explain 39% of variance (model 2).

The drastic change of significance as seen with Safety objective features (model 5), from coefficient change of 1.1 points to 0.6 points, indicates that the measure of angular segment analysis is only marginally effective. When considering the effects of other important variables such as control measures in explaining neighbourhood features and satisfaction with neighbourhood features, angular segment analysis is seemingly insignificant.

Table 31. Simple Linear regression model comparing Angular Segment Analysis (X4b) and neighbourhood features.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	X1a: Physical index (objective)	X1b: Physical index (subjective)	X2a: Social index (objective)	X2b: Social index (subjective)	(Log) X3a: Safety index (objective)	X3b: Safety index (subjective)
(Log) X4b: Angular Segment Analysis	1.020	-7.624***	1.493	-5.896***	1.100***	9.149***
	(1.052)	(1.435)	(1.049)	(1.274)	(0.308)	(2.172)
Constant	1.254	40.91***	-0.173	27.46***	-2.824**	-27.87***
	(3.993)	(5.553)	(3.969)	(4.911)	(1.172)	(8.241)
Observations	71	71	71	71	71	71
R-squared	0.016	0.221	0.025	0.210	0.119	0.208

Robust Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 32. Including control measures to the relationship between X4b and neighbourhood features.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	X1a: Physical index (objective)	X1b: Physical index (subjective)	X2a: Social index (objective)	X2b: Social index (subjective)	(Log) X3a: Safety index (objective)	X3b: Safety index (subjective)
(Log) X4b: Angular Segment Analysis	-1.409	-5.593***	-1.456	-2.023	0.683*	1.273
	(1.479)	(1.731)	(1.253)	(1.325)	(0.390)	(2.014)
X7: Population Density	0.00491	0.00877	0.00532	0.00723**	-0.00267*	0.00300
	(0.00476)	(0.00605)	(0.00605)	(0.00354)	(0.00151)	(0.00630)
X6: Average Income	-2.713	-6.349	-8.596**	-3.851	0.734	-1.497
	(3.391)	(6.308)	(3.958)	(3.364)	(1.277)	(5.445)
X8: Ethnic composition native	-1.331	8.570***	-0.276	10.28***	-1.922***	-11.40***
	(1.255)	(2.136)	(1.819)	(1.217)	(0.471)	(2.128)
Constant	11.71*	30.05***	13.62**	7.978	-0.249	8.400
	(6.059)	(6.726)	(5.226)	(4.965)	(1.512)	(7.861)
Observations	71	71	71	71	71	71
R-squared	0.167	0.396	0.201	0.719	0.353	0.641

Robust Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

The important point taken from the analysis of neighbourhood features and measures of connectivity is the *degree of association*. As theory assumes better integrated and connected urban networks to encourage a positive effect on satisfaction with neighbourhood features, is not the case perceived for Rotterdam city. Surprisingly enough the negative association with physical and social features as compared to the positive association with negative accounts of safety indicate that for the city, connectivity of urban networks do not significantly influence neighbourhood features.

Having understood the effects of connectivity of urban networks on independent features, the next and final analysis was to perceive its overall effects on neighbourhood satisfaction.

4.2.3 Neighbourhood Satisfaction and Connectivity measures

Research Question: To what extent does connectivity of urban networks (street networks) influence neighborhood satisfaction, for Rotterdam city?

Two models of analysis were conducted, the first model considered individual effects of the two measures of connectivity, while the second measured overall effects taking into account control measures and independent variables- significant neighborhood features.

Model A – Individual effects

Simple linear regression models were run introducing the measures independently and subsequently together (Table 33). Of the two measures of connectivity, variable X4a is seen to better predict neighbourhood satisfaction by instigating a change in coefficient by 0.496 points, as compared to variable X4b with only 0.272 points. When compared together, variable X4a is seen to mask the second measure X4b rendering it entirely insignificant. This conflicting effect can be explained due to collinearity between the two variables, as both measures are conceptually related. This apart, what is surprising is the negative influence of both variables on dependent. The result of this analysis states that an increase in level of integration (measures of X4a and X4b) produces a decline in level of neighbourhood satisfaction, Contradictory to theory that states better integrated neighbourhoods to present better spaces for interaction and therein better perception of neighbourhood satisfaction. Nonetheless, the model is seen to explain only 25% variance, indicating a weak influence.

Table 33. Model A: Simple Linear regression model with independent variables X_{4a} and X_{4b}

	Model 1	Model 2	Model 3
VARIABLES	Y	Y	Y
(Log) X_{4a}: Axial integration	-0.496***		-0.549***
	(0.104)		(0.183)
(Log) X_{4b}: Angular Segment Analysis		-0.272***	0.0457
		(0.0781)	(0.129)
Constant	1.045***	1.834***	0.898**
	(0.0541)	(0.298)	(0.420)
Observations	71	71	71
R-squared	0.248	0.150	0.250

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

As explained in theory control measures like population density, ethnic composition and average income are seen to have significant influence on perception of neighbourhood satisfaction, hence the next step analysed effects of X_{4a} and X_{4b} alongside control measures. Table 32, describes the change in influence of variable X4a (axial integration) when compared along with control measures. Overall the significance greatly differs, suggesting that, when accounting for other factors, level of street integration has no significant influence on level of satisfaction. Especially when comparing along ethnic composition and population density. Model 1 (table 34) with a variance of 59% depicts the influence of axial integration when controlling for ethnic composition. The change in coefficient value indicates that with a unit change in axial integration produces a decrease in neighbourhood satisfaction by 0.128 points. However the two tail P-values rejects the null hypothesis with a value of 0.268 and hence concludes the relationship to be insignificant.

Table 34. Simple Linear regression of independent variable X4a along with control variables

	Model 1	Model 2	Model 3	Model 4
VARIABLES	Y	Y	Y	Y
(Log) X_{4a}: Axial integration	-0.128	-0.365***	-0.202	-0.159
	(0.0902)	(0.106)	(0.126)	(0.102)
X6: % of residents with Average Income		0.595***		-0.159
		(0.188)		(0.187)
X7: Population density			-0.000899***	0.000155
			(0.000250)	(0.000262)
X8: Ethnic composition	0.396***			0.455***
	(0.0513)			(0.0792)
Constant	0.652***	0.783***	0.969***	0.676***
	(0.0647)	(0.0973)	(0.0543)	(0.0803)
Observations	71	71	71	71
R-squared	0.599	0.345	0.369	0.605

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Table 35. Simple Linear regression of independent variable X4b along with control variables

	Model 1	Model 2	Model 3	Model 4
VARIABLES	Y	Y	Y	Y
(Log) X_{4b}: Angular Segment Analysis	-0.0117	-0.150*	-0.0100	-0.0233
	(0.0628)	(0.0820)	(0.0904)	(0.0744)
X6: Average Income		0.677***		-0.155
		(0.206)		(0.195)
X7: Population density			-0.00114***	1.42e-05
			(0.000253)	(0.000274)
X8: Ethnic composition Native	0.430***			0.462***
	(0.0506)			(0.0812)
Constant	0.614**	1.143***	0.924***	0.691**
	(0.254)	(0.349)	(0.332)	(0.290)
Observations	71	71	71	71
R-squared	0.587	0.267	0.345	0.591

Standard errors in parentheses Source: Author, 2016
*** p<0.01, ** p<0.05, * p<0.1

Similar tests were performed with second measure of connectivity, X_{4b}: Angular segment analysis. X_{4b} is seen to have no significant effect on neighbourhood satisfaction, when controlling for ethnic composition and population density.

From the observed results, it can be deduced that measures of connectivity on their own do not provide any significant effects on neighbourhood satisfaction. Of the two measures, angular segment analysis (X_{4b}) is seen to have no relationship with the dependent, with a coefficient value of -.023. While axial integration (X_{4a}) shows mild statistical significance with the dependent when not controlling for population density and ethnic composition. Hence in the following steps, only the first measure- Axial Integration (X_{4a}) is taken forward.

Model B – Overall Effects

The model on overall effects takes into account both, neighborhood features and control measures within a single model. As neighborhood satisfaction is the sum of satisfaction with neighborhood features (Marans and Stimson 2013), it can be assumed that including neighborhood features is not only necessary but an important variable to control for when assessing neighborhood satisfaction. From the previous conducted analysis (4.2.1), three neighborhood features were identified to best influence neighborhood satisfaction for Rotterdam city- social objective Features, social subjective features and safety subjective features. The three neighborhood features are compared alongside three control variables: population density, ethnic composition and average income and, measure of connectivity X_{4a} and X_{4b}.

The focus of Model B is to study the influence of connectivity measures when controlling for other factors. Hence the six, above discussed, variables all play the role of control measures. Table 36 provides a detailed interpretation of this analysis. Robust standard errors were conducted to dismiss bias in results.

Table 36. Model B: Overall influence of variables on Neighbourhood satisfaction

	Model 1
VARIABLES	Y
(Log) X4a: Axial integration	-0.0686
	(0.0705)
X2a: Social Index (objective)	-0.0195***
	(0.00442)
X2b: Social Index (subjective)	0.0296***
	(0.00697)
X3b: Safety Index (subjective)	-0.0107***
	(0.00396)
X6: Average Income	-0.246*
	(0.127)
X7: Population Density	5.49e-05
	(0.000179)
X8: Ethnic composition native	0.0324
	(0.0736)
Constant	0.925***
	(0.0790)
Observations	71
R-squared	0.842

Robust Standard errors in parentheses Source: Author, 2016
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 36 describes 7 variables influencing neighbourhood satisfaction for the measure of 71 observations of 71 different neighbourhoods for Rotterdam city. The result of the analysis indicate neighbourhood objective and subjective features to significantly influence neighbourhood satisfaction. Social and safety features are seen to have a negative effect while social subjective features to have a positive. Apart from neighbourhood features the model also discusses the influence of control measures such as population density, average income and ethnic composition. Of the three average income is seen to mildly determine satisfaction albeit negatively. This attests that with increase in percentage of residents maintaining average income, satisfaction with neighbourhood decreases. Lastly the model describes, influence of the first measure of connectivity X4a: axial integration. The measure determines level of street integration at the local scale of 3 turns/steps. It is observed to have no significant influence on neighbourhood satisfaction when controlling for other factors with a coefficient change of -0.0686 points. The model variance explains 84% with a root mean square value of 0.046, indicating a good fit and minimal errors within the model.

A couple of statistical tests were further conducted to grasp the overall status and strength of the model. To understand the strength of model prediction, predicted values were generated and compared along dependent variable. Figure 13(a) shows the relation between Y – Neighbourhood satisfaction (y axis) and Yhat or fitted values (x axis), and from the observation the model seems to perform well.

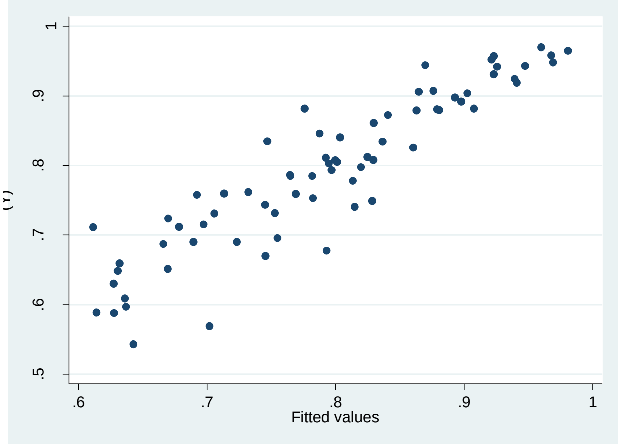
Testing for homoscedasticity

"The error term [e] is homoscedastic if the variance of the conditional distribution of [ei] given Xi[var(ei|Xi)], is constant for i=1…n, and in particular does not depend on x; otherwise, the error term is heteroskedastic" (Stock and Watson, 2003, p.126) . To test for homoscedasticity both Bursch Pagan test and scatter plot were performed.

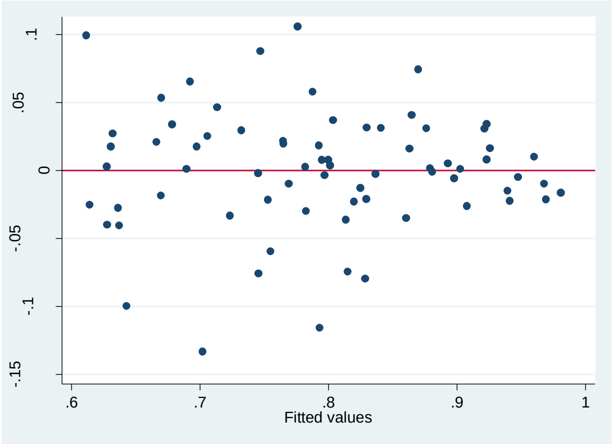
Figure 13(b) depicts a scatter plot between residuals and fitted values. For this model there seems to be a slight contraction of residuals at higher fitted values.

Figure 13. Assumption testing for model strength and accuracy

(a) Scatter plot of predicted values



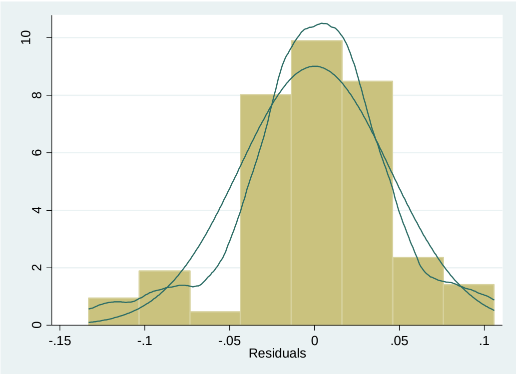
(b) Scatter plot of residuals and predicted values



Source, Author 2016

Testing for normality: Using the Kernel Desity test, normality is observed in figure 14.

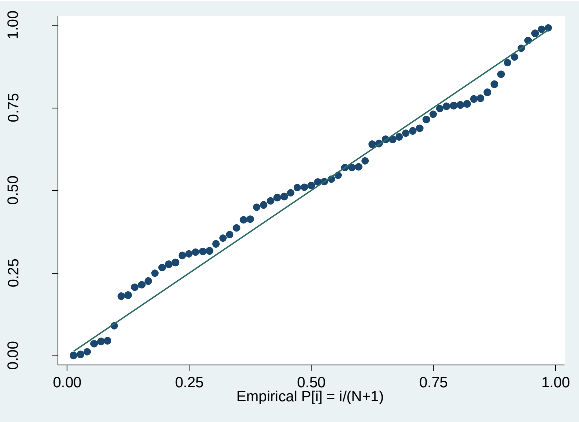
Figure 14. Kernel density plot with histogram of residuals



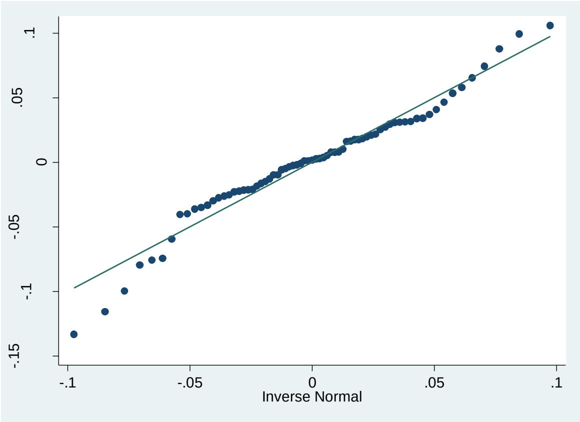
Source, Author 2016

Figure 15. Testing normality at different ranges of the residuals

(a) Standardised normal probability plot



(b) Quintile normal plots



Source, Author 2016

Figure 15a is a depiction of "P norm" test that checks for non normality within midranges. From the observed figure the residuals look slightly off the line but pretty much normal. Figure 15b is the "Q norm" test for measuring normality at extreme values. As observed in 15b the edges seem to waver off the normal.

Chapter 5: Conclusions and recommendations

This research explored the potential of spatial factors in determining quality of life in urban regions. It particularly focused on connectivity of urban networks (streets, pedestrian walkways and roads) as a factor influencing quality of life in neighbourhoods, taking Rotterdam city and its 71 neighbourhoods as a case study. To assess quality of life in neighbourhoods the research adopted neighbourhood satisfaction as a reliable measure, while connectivity of urban networks was measured using the tool Space syntax. Both concepts were measured grounded on theories and literature reviews and facilitated in the development of the conceptual framework, based on which three important relations were observed:

- ❖ The first and main relationship explores the concept of neighbourhood satisfaction and factors that determine neighbourhood satisfaction specific to Rotterdam city. The relation focused on factors related to "place", hence analyses three place based neighbourhood features: physical, social and safety features.
- ❖ The second relation investigates the association between connectivity of urban networks and the identified neighbourhood features. From theory on cognitive access and space syntax, two measures that best represent connectivity of urban networks were recognised and exercised for this assessment.
- ❖ The third and final relation analysed the overall association between neighbourhood satisfaction and connectivity of urban networks, through the approach of multiple linear regressions. This final model incorporated the identified neighbourhood features as control measures to ensure complete representation.

5.1 Reflections of Research Results

Overall the research results illustrated connectivity of urban networks to have no statistical significance with neighbourhood satisfaction, and surprisingly even instigated a decrease in satisfaction levels. However connectivity of urban networks were seen have a stronger association with shaping neighbourhood features and satisfaction with neighbourhood features. In some cases it was seen stimulate a positive influence. As satisfaction with neighbourhood features affect neighbourhood satisfaction, a plausible mediating relationship was assumed. Nevertheless, the effects noted were relatively weak and in some cases, negligent. A detail account of research results are described in the following three relations. The three relations are reflections of the three research questions, starting with sub-questions 2 that address individual effects of neighbourhood features and connectivity of urban networks, and concluding with answering the main research question that analyses overall effects on neighbourhood satisfaction.

Sub-Question 1: Neighbourhood satisfaction and neighbourhood features

Research findings assert neighbourhood features to act as significant predictors of neighbourhood satisfaction. Both objective and subjective measures of neighbourhood features are seen to be important in influencing neighbourhood satisfaction, with subjective measures having a greater impression. Of the features, neighbourhood *Social features and Safety features* are seen to have the strongest association, while Physical features have no statistically significant impact in determining neighbourhood satisfaction. However the relationship between the features and dependent variable vary. Social features represent measures of interaction, bonding, sense of familiarity and trust, hence S*ocial subjective features* were seen to predict an increase in neighbourhood satisfaction. However *social objective features* were surprisingly seen to cause a decrease in satisfaction, but this form of contrasting effect can be explained by ruminating individual indicators that form the indices. The index on social objective features comprises of accounts of social relations *like contact with neighbours, residents that practice weekly sports and visit religious events.* Of the list of indicators residents with low household income and residents that visit religious events are seen to enforce a, statically significant, negative effect on satisfaction (table 12), thereby generating an overall decreasing effect for the index. This is surprising that

Spatially distributing this result indicates a clear divide between the north and south, with the northern half of the city expressing greater satisfaction with social measures of the environment (annex 2, map 13). This implies that northern parts of the city are more conducive to spaces that encourage social processes like neighbours helping each other and participating in gatherings.

Safety subjective features are seen to instigate a negative association with satisfaction implying, with increase in negative accounts of safety a decrease in satisfaction is observed. When spatially distributing this result for Rotterdam city (Annex 2, Map 15), it is observed that the least safe neighbourhoods concentrate in the southern belt of the city with the exception of a few central neighbourhoods.

Sub-Question 2: Neighbourhood features and connectivity of urban networks

From the observed analysis connectivity of urban networks, specifically measure X_{4a} (Axial Integration) is seen to significantly influence 2 of the 6 set of neighbourhood features- physical subjective features and safety objective features. The negative association between connectivity on physical subjective features indicate that better integrated spaces seem to instigate a sense of dissatisfaction with the physical environment. When spatially distributing the information (Annex 2, Map 11) the least satisfied with physical subjective features are seen to originate from largely central and southern neighbourhoods of Rotterdam city. Such neighbourhoods are seen to be high dense comprising, less, of green spaces and more of roads and infrastructure. Though it is seen to concentrate access to facilities and amenities, the trend observed indicates that lack of green spaces and over concentration of street infrastructure to negatively impact satisfaction. Even while controlling for average income, ethnic composition and population density.

The positive association of connectivity of urban networks and safety objective features is one of the most surprising results observed in this analysis. It implies that with increase in better integrated spaces, increases the negative account of safety. This result is a reflection against theoretical arguments, that state better integrated neighbourhoods to depict less accounts of theft and crime. Theoretically better integrated urban network structures are seen to encourage through movement acting as the ideal routes for pedestrian and vehicular traffic (Hillier 1996; van Nes 2009b). This constant presence of people disadvantages the plausibility for occurrences of vandalism (Jacobs 1961; Leslie and Cerin 2008). However, for Rotterdam city the results seem to indicate otherwise.

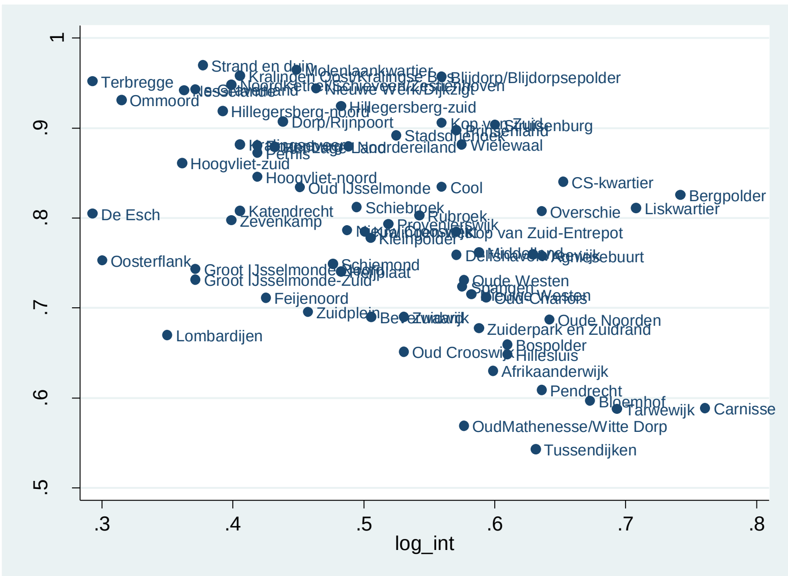
Spatially projecting this result (Annex 3, Map 15), highlights neighbourhoods largely centred around central and southern parts of the city that seem to comprise of type 4- dense housing districts, largely housing non-native ethnic residents with a low average income. A plausible explanation for this result, can be explored by studying existing land use typology in the neighbourhoods that indicate negative accounts of safety. An over concertation of mono land use (type 4 – dense housing) leaves less opportunity for spaces of commerce and leisure to develop. This reduces the chance for social gathering and active street life, often leaving streets isolated and barren- encouraging disreputable activities (Jacobs 1961; Jackson 2003). To test for this assumption requires pursuing another study on land use analysis and level of neighbourhood activity, but as this falls out of the scope of this research, the author only suggests plausible reflection of existing conditions.

Main Research Question: Effect of connectivity or urban networks on neighbourhood satisfaction, when controlling for neighbourhood features and connectivity of urban networks

Overall it is observed that connectivity of urban networks seems to have no significant influence in determining neighbourhood satisfaction, especially when controlling for neighbourhood features and control measures. From the assessed relations in 4.2.3, it is observed that neighbourhood satisfaction for Rotterdam city is largely a reflection of ethnic composition and population density, more than measures of connectivity, with population density influencing the neighbourhood satisfaction negatively.

In dwelling deeper into the analysis, it is observed that native ethnicities are seen to score on average higher values of neighbourhood satisfaction as compared to non-natives, and also lower with respect to negative accounts of safety. Likewise native ethnicities are seen to concentrate in less integrated neighbourhoods with more green spaces located towards the periphery. While highly integrated neighbourhoods like city centres, and some of the south are seen to concentrate non-native residents. This form of division though is seen to significantly mould levels of neighbourhood satisfaction and satisfaction with neighbourhood features. However, to obtain a fair account of the distribution of neighbourhoods along both satisfaction and connectivity (X4a: Axial Integration) a scatter plot graphs were generated.

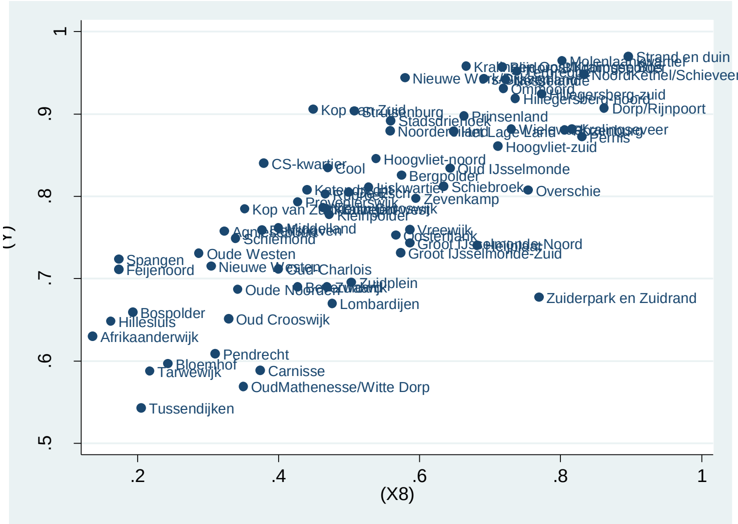
Figure 16. Distribution of Neighbourhoods along neighbourhood satisfaction and Axial Integration (X4a)



Source: Author, 2016

Figure 16, is an appropriate representation of the distribution of neighbourhoods along level of satisfaction and level of network connectivity (axial integration X4a, in this case). The figure depicts clearly a negative association of neighbourhood satisfaction with an increase in connectivity. Highly integrated and connected neighbourhoods Carnisse, Tussendijken, Witte Dorp, etc are seen to report very low levels of satisfaction. While least integrated neighborhoods such as Terbregge and Strand en duin, De Esch indicate significantly high levels of satisfaction, hinting at spatial structure of the neighbourhoods in determining satisfaction. However some exceptions like neighbourhoods Bergpolder, Overschie, Liskwartier and CS-Kwartier exhibit moderately higher levels of satisfaction even when depicting well connected urban network structure. In order to understand the differences, further comparisons with control measures population density and ethnic composition were processed.

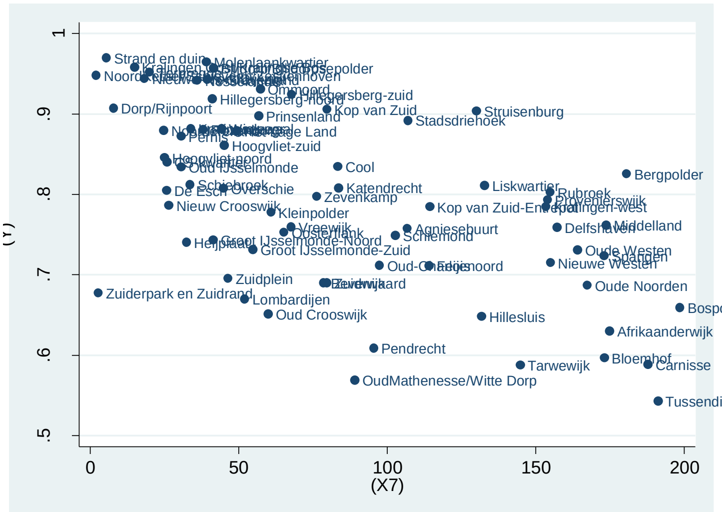
Figure 17. Distribution of Neighbourhoods along neighbourhood satisfaction and Ethnic composition - native



Source: Author, 2016

In figure 17, it is evident that most satisfied neighbourhoods are the one concentrating high percentage of native ethnicities. Neighborhoods Carnisse, Tussendijken, Witte Dorp all indicate a larger percentage of non-natives, and this clearly states a pattern in the influence of ethnic composition influencing satisfaction.

Figure 18. Distribution of Neighbourhoods along neighbourhood satisfaction and population density.

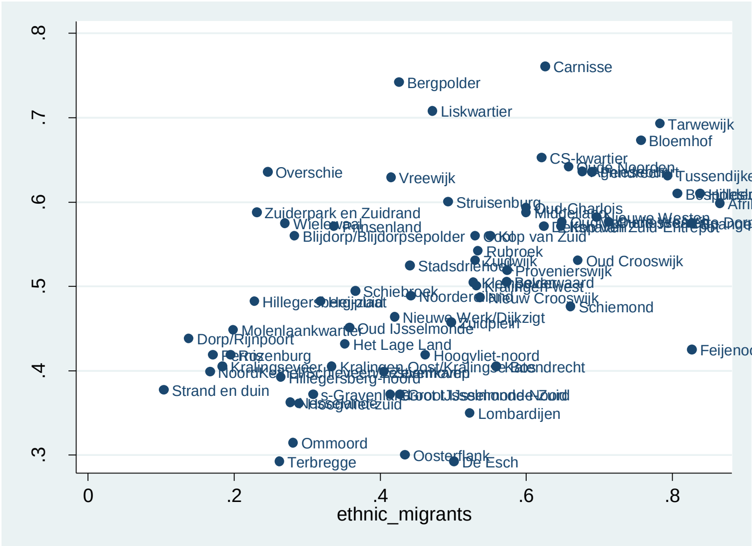


Source: Author, 2016

Similar is the effect of population density. Figure 18 describes also indicates the neighbourhoods that are highly populated to depict low levels of satisfaction, but with variance as observed for neighbourhoods Witte Dorp, Oud croowijk and Prendrect, which are relatively less populated but still indicate low levels of satisfaction.

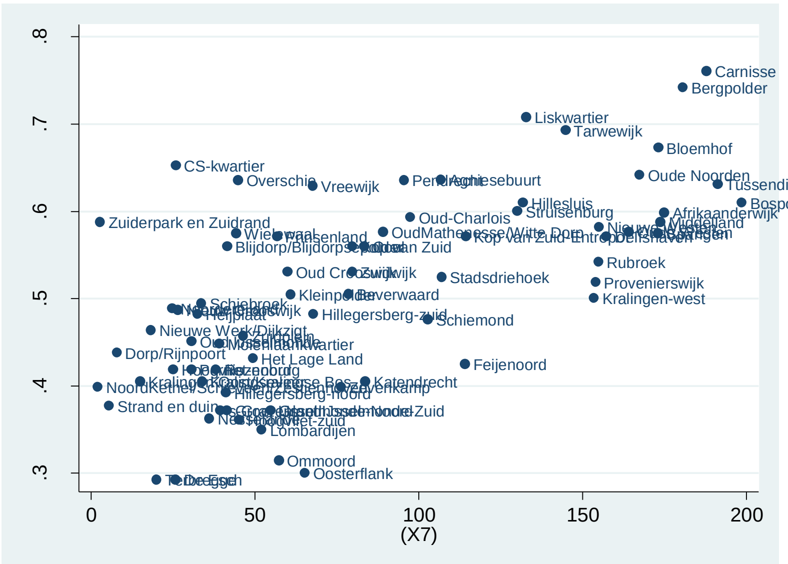
Similar comparisons were execute with level of connectivity (x4a: Axial Integration) in place of neighbourhood satisfaction (figure 19 and 20). The results further establish the strong divide within the city of Rotterdam, along patterns of population and ethnic divide. But further research is required to understand spatial difference within the neighbourhoods that seem to influence satisfaction.

Figure 19. Distribution of Neighbourhoods along level of connectivity (X4a Axial integration) and ethnic composition – non-natives/ migrants.



Source: Author, 2016

Figure 20. Distribution of Neighbourhoods along level of connectivity (X4a Axial integration) and population density.



Source: Author, 2016

5.2 Limitations in Research Methods

Limitations of Research Tool- Space Syntax: Practical limitations

A major limitation in the scope of this research is in the methodology incorporated to assess connectivity of urban networks- Space syntax analysis. The technique used by space syntax to assess connectivity and generate the two measures- Axial integration and Angular segment analysis runs on a fundamental element called “Axial lines”. Axial lines are abstract line representations of urban street structure and pedestrian walkways, generated by the researcher with reference to open sources map projections – such as Google maps, Openstreetmaps (OSM). They do not exist in reality and the subjectivity of generating axial lines lies in the knowledge of the researcher on the context and area of study (Xiaolin and Jiang 2013). “The axial line has been shown to produce a specific representation of the city that is closer to the cognitive representation that people use to navigate the city (Hillier, 2003; Penn, 2003). Due to this it has been extended into many other domains such as crime science (Chih-Feng, 2000; Hillier, 2004) and spatial cognition (Conroy Dalton and Bafna, 2003)” (Dhanani et al. 2012).

However the process of generating axial lines follow tedious and time consuming steps, requiring the researcher to hand draw the entire street network of a city as a line representation. This method often leaves space for errors and variance based on representation, leading to variance in results as well. An example of this condition is described figure 17.

Figure 21. Bad representations of axial lines, (a) urban network as represented by OSM, (b) urban network as represented by axial lines in space syntax.

(a) (b)

Source: A Comparison Study on a Set of Space Syntax based Methods, (Xiaolin and Jiang 2013)

With the advent of new technology and access to open source mapping data, alternate methods have been suggested, such as OSM datasets, natural streets, transport street datasets. However, from the suggested, axial lines and axial maps are still preferred technique used for space syntax analysis. OSM datasets are seen to be problematic for space syntax analysis they include non-road networks and pedestrian routes that are unofficial leading to over representation of urban network routes.

Limitations of Research Tool- Space Syntax: Theoretical limitations
Space syntax runs on the concept of cognitive access and angle of change– topological measures that suggests residents and movement takes place through the cognitive assessment of the urban network, unlinked to distance and metric measures. However, this form of assessment has been criticised by many theorists indicating metric measures as pivotal in determining movement, especially in complex urban conditions (Ratti 2004). Similarly space syntax is seen to disregard geographic conditions of space, such as change in elevation of land, which are inevitable determinants in enabling movement, access and there in connectivity (Sevtsuk and Ratti 2010).

Another limitation of the space syntax and axial map is that it does not take into account land use and diverse land allocations. This observations has been the highlight of many critics, stating that, "though space syntax measures provide indices associated with forecasting trip volumes, they do not incorporate the differences in land uses, which are seen to simulate process of movement and patterns of pedestrian cognitive movement (Batty et al, 1998, p.3)". (Ratti 2004)

5.3 Recommendations for further Research

As this research is a preliminary attempt to understand the influence of connectivity of urban networks on neighbourhood satisfaction, the following recommendations reflect largely on the need for further research exploring methods to assess and measure the concept of connectivity, through alternate techniques and tools.

Future research needs to look into assessing the different relations by which connectivity influences urban living, apart from the method in this research which has largely followed linear relations, between neighbourhood satisfaction, neighbourhood features and connectivity. However, there is a need to assess at what aspect connectivity participates or contributes to shaping aspects of urban living. Theory has suggested urban network connectivity to influence street activity and there in level of social interaction (Jacobs 1961; Marans, Robert W.; Stimson 2013; Leslie and Cerin 2008), but how consistent is the process at different contexts of the environment, is an area that needs investigation. It has been noted that well connected networks that link dysfunctional spaces, can lead to the paradox of unused and isolated environments (van Nes et al. 2013). Hence future research should look into addressing connectivity of urban networks from the perspective of diverse spaces that they connect.

Future research should also try to understand difference in neighbourhood satisfaction for Rotterdam City, by addressing the different categories of neighbourhood types to procure clearer perception of the influence of contextual factors, such as the green spaces.

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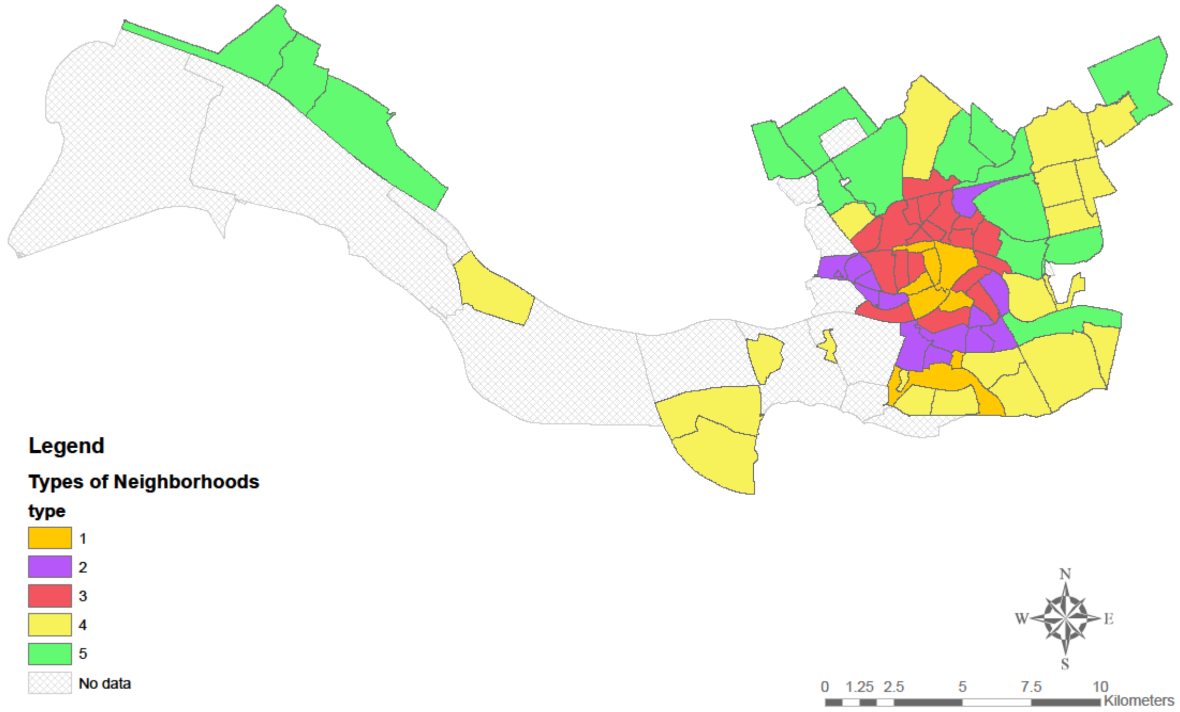
Annex 1: List of Measures of connectivity for 71 neighbourhoods of Rotterdam city (Independent Variables)

Id	Neighbourhood Name	X4a: Axial Integration	X4b: Angular segment step
1	Afrikaanderwijk	1.82	19.24
2	Agniesebuurt	1.89	19.7
3	Bergpolder	2.1	21.27
4	Beverwaard	1.658	17.32
5	Blijdorp/Blijdorpsepolder	1.75	18.42
6	Bloemhof	1.96	20.25
7	Bospolder	1.84	32.22
8	Carnisse	2.14	22.65
9	Cool	1.75	18.54
10	CS-kwartier	1.92	19.6
11	De Esch	1.34	15.58
12	Delfshaven	1.77	18.62
13	Dorp/Rijnpoort	1.55	15.61
14	Feijenoord	1.53	16.26
15	Groot IJsselmonde-Noord	1.45	14.9
16	Groot IJsselmonde-Zuid	1.45	14.9
17	Heijplaat	1.62	16.36
18	Het Lage Land	1.54	15.02
19	Hillegersberg-noord	1.48	15.4
20	Hillegersberg-zuid	1.62	17.21
21	Hillesluis	1.84	19.23
22	Hoogvliet-noord	1.52	16.2
23	Hoogvliet-zuid	1.435	14.18
24	Katendrecht	1.5	17.81
25	Kleinpolder	1.657	17.78
26	Kop van Zuid	1.75	14.65
27	Kop van Zuid-Entrepot	1.77	18.41
28	Kralingen Oost/Kralingse Bos	1.5	17.36
29	Kralingen-west	1.65	17.19
30	Kralingseveer	1.5	18.06
31	Liskwartier	2.03	21.6
32	Lombardijen	1.419	15.24
33	Middelland	1.8	19.1
34	Molenlaankwartier	1.566	16.57
35	Nesselande	1.437	15.15
36	Nieuw Crooswijk	1.628	16.7
37	Nieuwe Werk/Dijkzigt	1.59	20.76
38	Nieuwe Westen	1.79	19.6

Id	**Neighbourhood Name**	**X4a: Axial integration**	**X4b: Angular segment step**
39	Noordereiland	1.63	17.19
40	NoordKethel/Schieveen/ Zestienhoven	1.49	16.05
41	Ommoord	1.37	13.9
42	Oosterflank	1.35	13.54
43	Oud Crooswijk	1.7	17.39
44	Oud IJsselmonde	1.57	15.61
45	Oud-Charlois	1.81	18.72
46	Oude Noorden	1.9	20.03
47	Oude Westen	1.78	18.77
48	OudMathenesse/Witte Dorp	1.78	16.01
49	Overschie	1.889	18.29
50	Pendrecht	1.889	18.29
51	Pernis	1.52	15.42
52	Prinsenland	1.77	17.41
53	Provenierswijk	1.68	16.9
54	Rozenburg	1.52	13.42
55	Rubroek	1.72	16.92
56	Schiebroek	1.64	17.37
57	Schiemond	1.61	16.94
58	s-Gravenland	1.45	16.02
59	Spangen	1.7775	16.3
60	Stadsdriehoek	1.69	17.99
61	Strand en duin	1.458	16.58
62	Struisenburg	1.823	19.34
63	Tarwewijk	2	20.59
64	Terbregge	1.34	14.94
65	Tussendijken	1.88	19.34
66	Vreewijk	1.876	18.62
67	Wielewaal	1.777	20.65
68	Zevenkamp	1.49	15.74
69	Zuiderpark en Zuidrand	1.8	17.35
70	Zuidplein	1.58	15.48
71	Zuidwijk	1.7	17.31

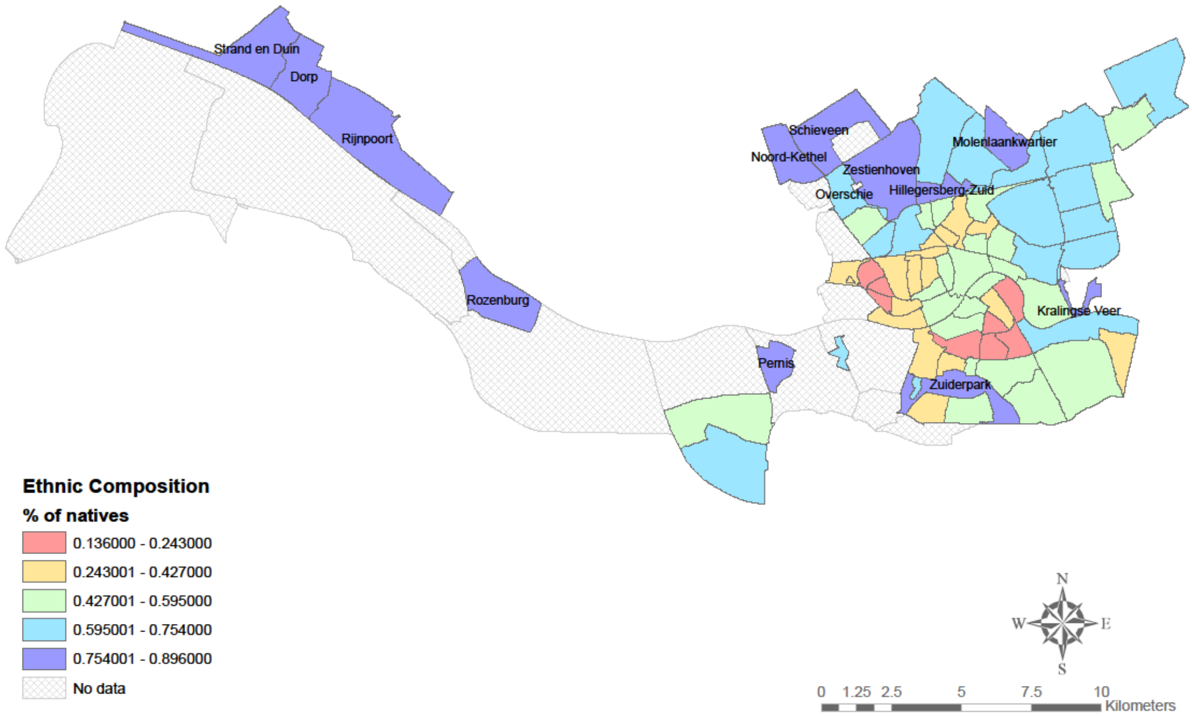
Annex 2: Spatial Distribution of Variables (List of Maps)

Map 6. Types of Neighbourhoods, for Rotterdam City



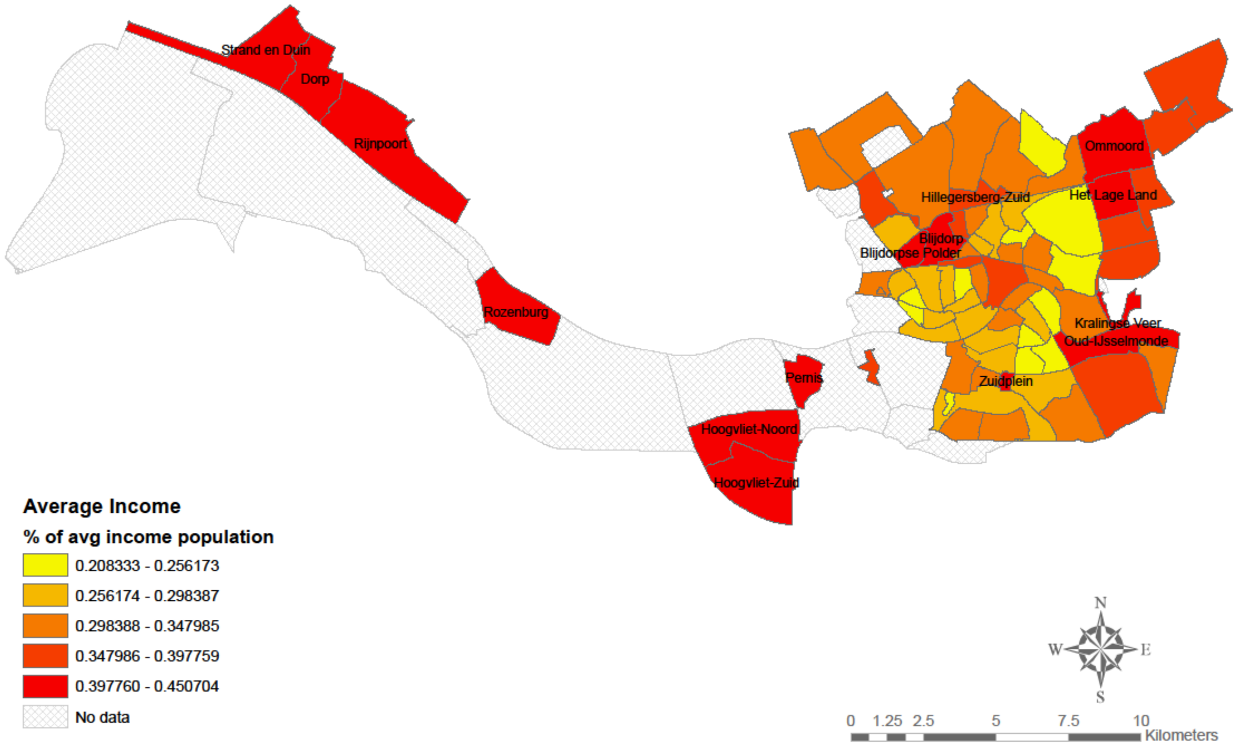
Source: Author, 2016

Map 7. Distribution of Ethnic composition- Natives, for Rotterdam city



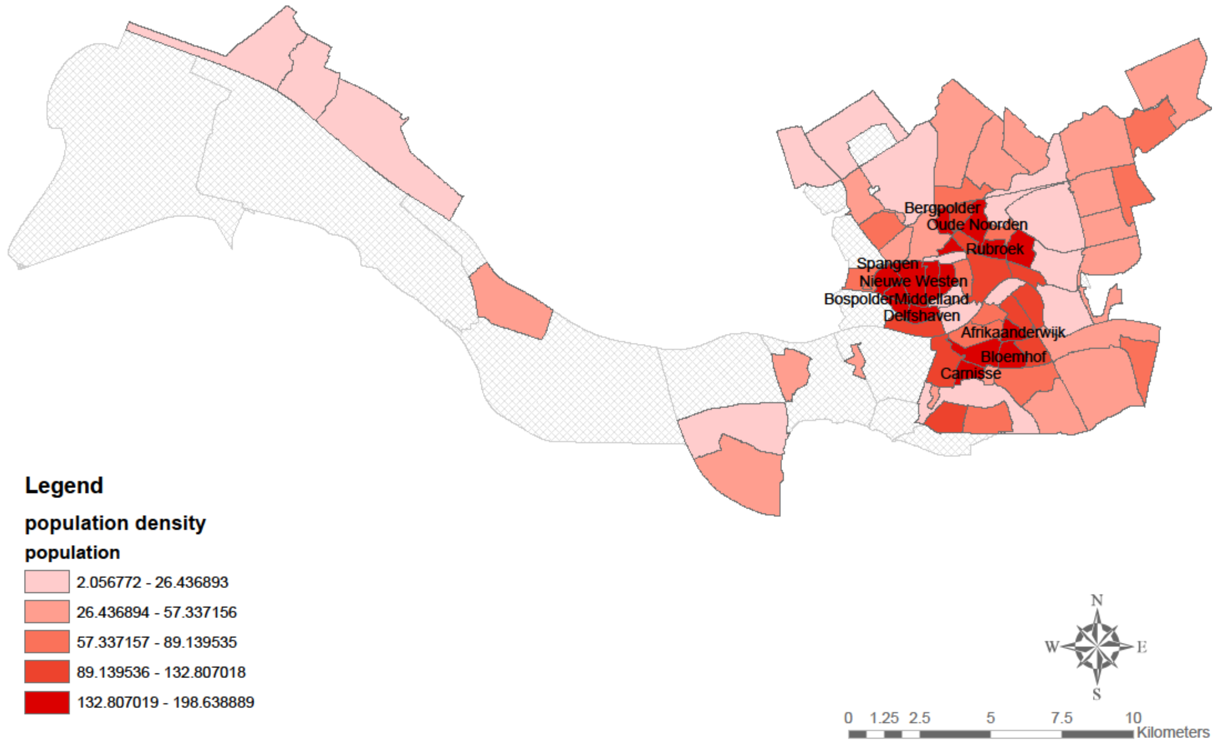
Source: Author, 2016

Map 8. Distribution of Average Income, for Rotterdam City



Source: Author, 2016

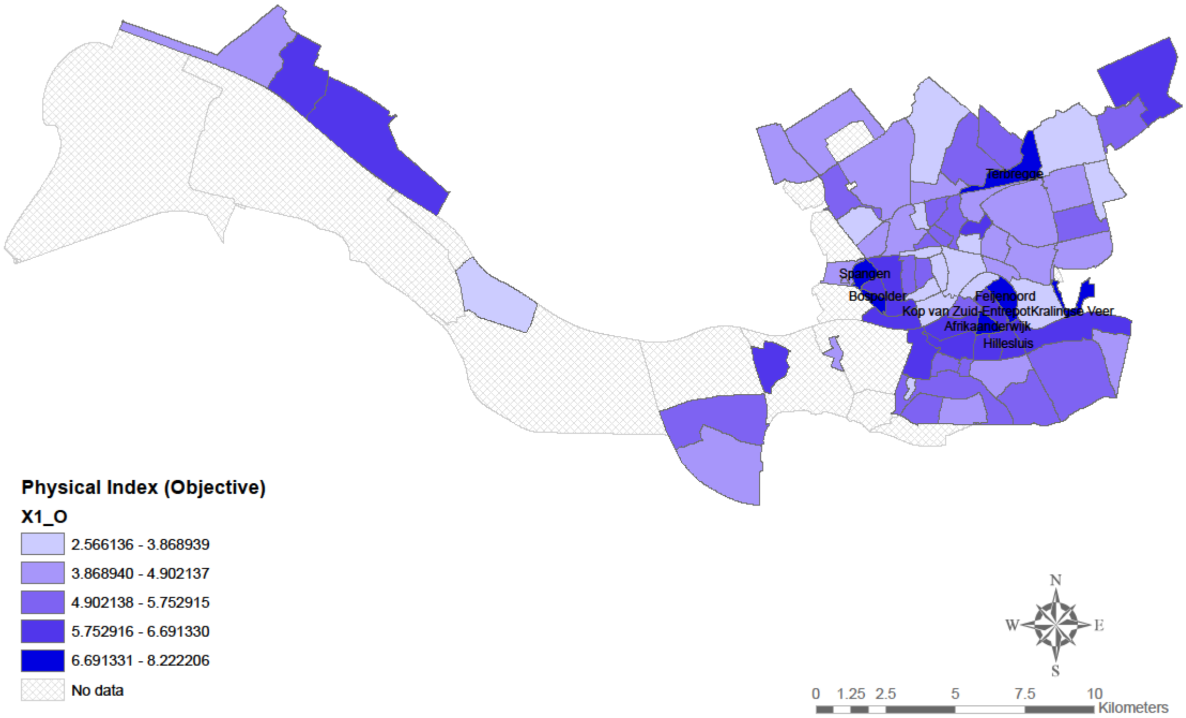
Map 9. Distribution of Population Density, for Rotterdam City



Source: Author, 2016

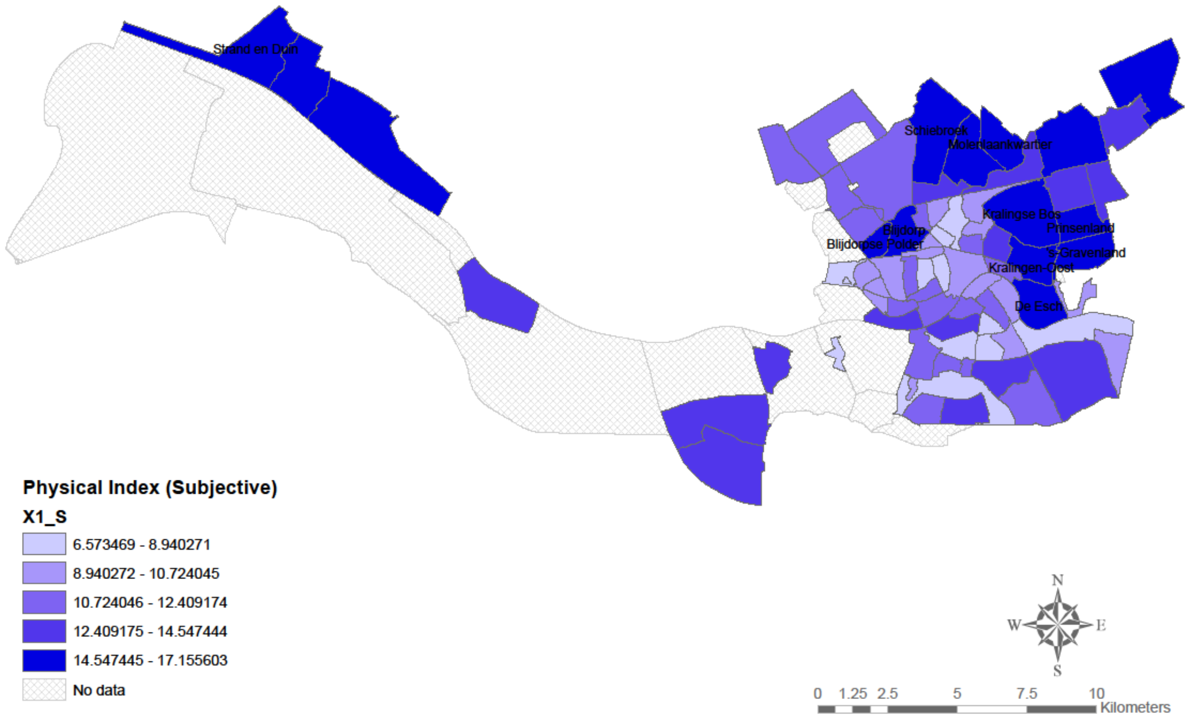
.

Map 10. Distribution of Physical Objective Index for neighborhoods, for Rotterdam City



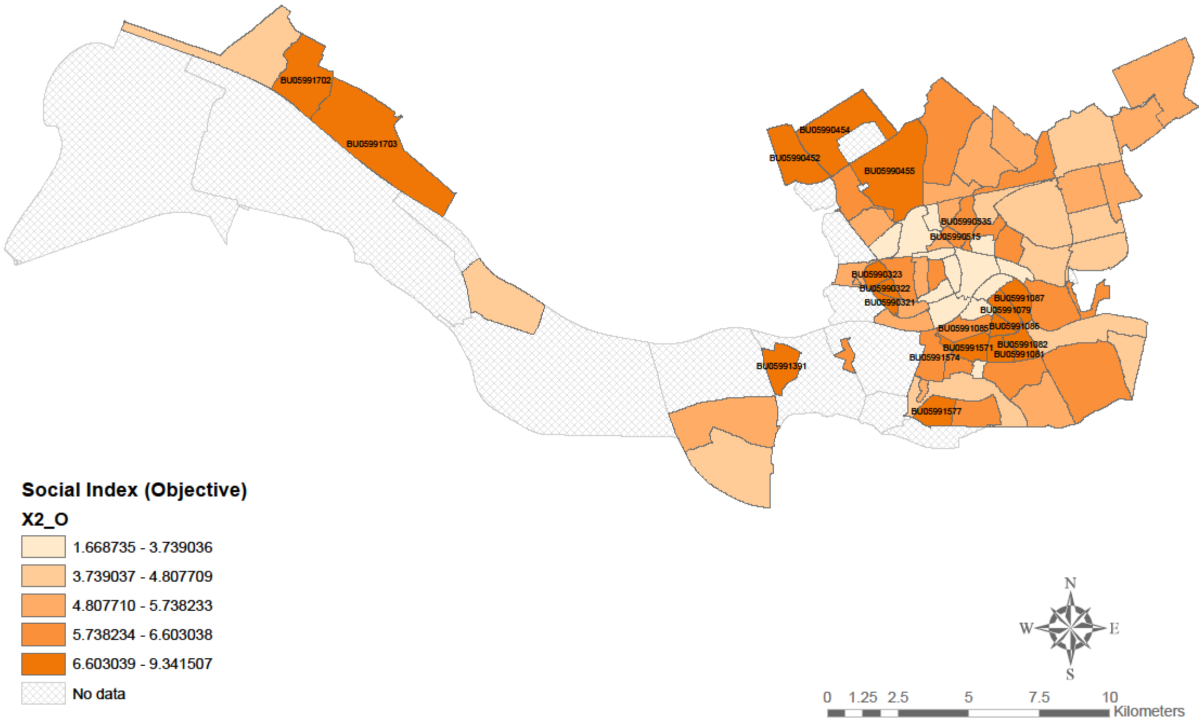
Source: Author, 2016

Map 11. Distribution of Physical Subjective Index for neighborhoods, for Rotterdam City



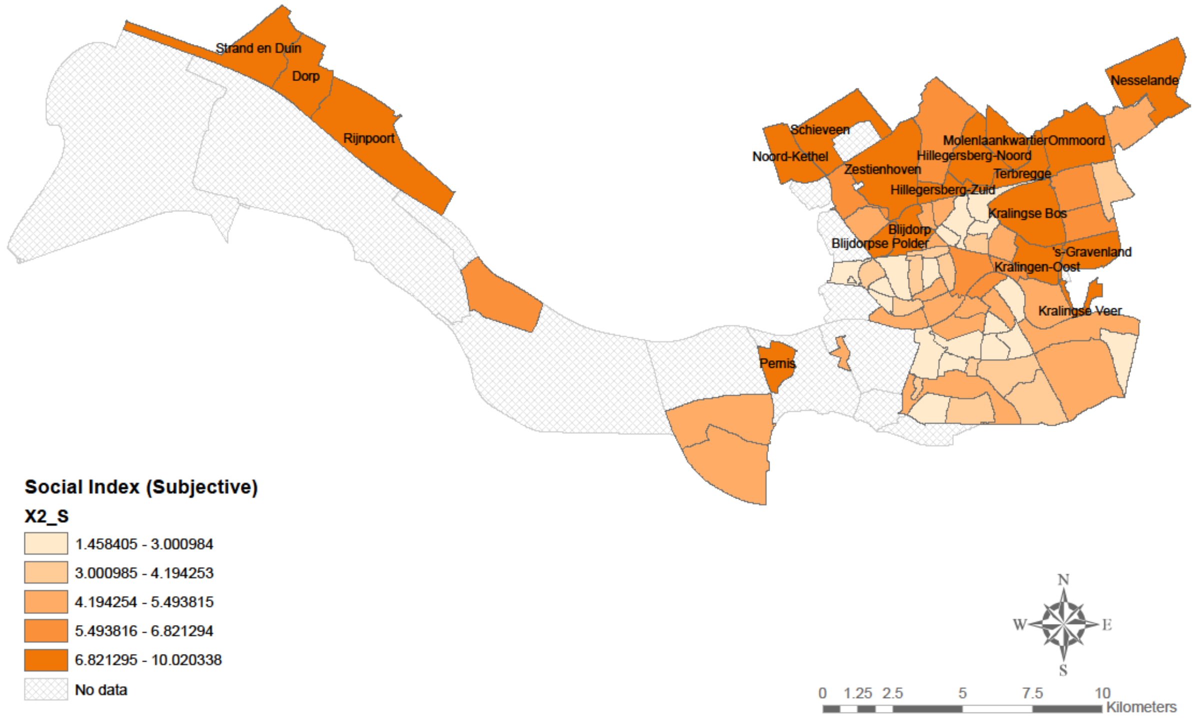
Source: Author, 2016

Map 12. Distribution of Social Objective Index for neighborhoods, for Rotterdam City



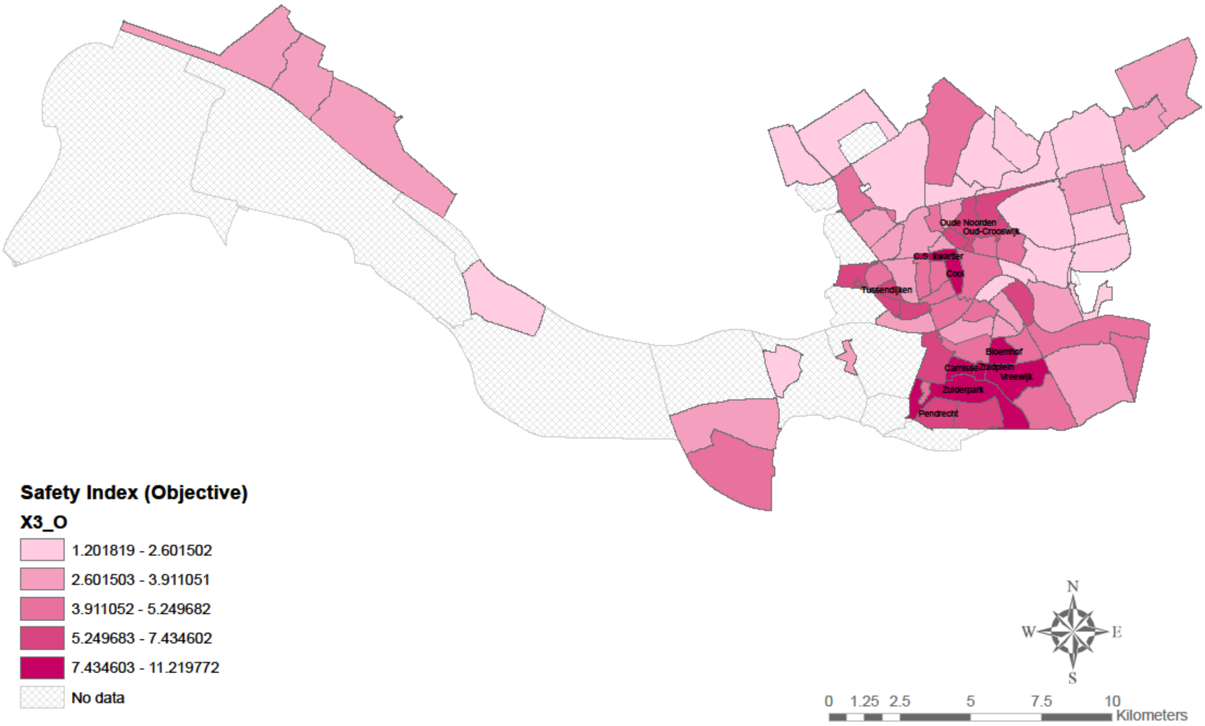
Source: Author, 2016

Map 13. Distribution of Social Subjective Index for neighborhoods, for Rotterdam City



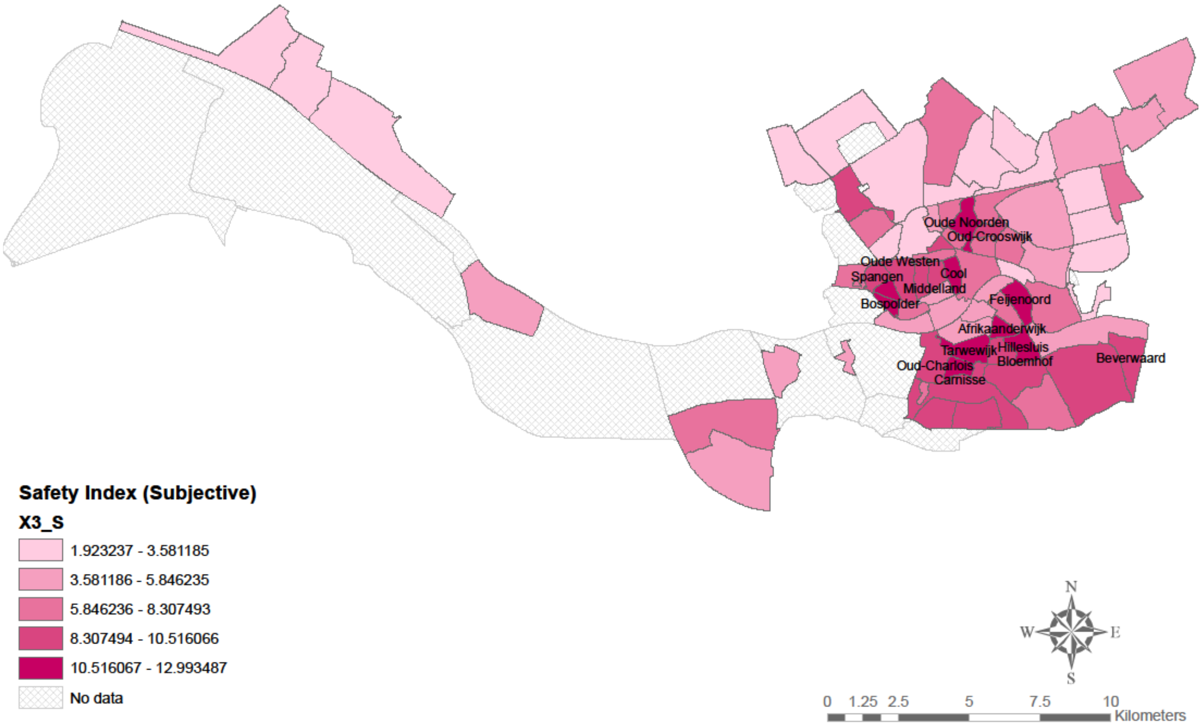
Source: Author, 2016

Map 14. Distribution of Safety Objective Index for neighborhoods, for Rotterdam City



Source: Author, 2016

Map 15. Distribution of Safety subjective Index for neighborhoods, for Rotterdam City

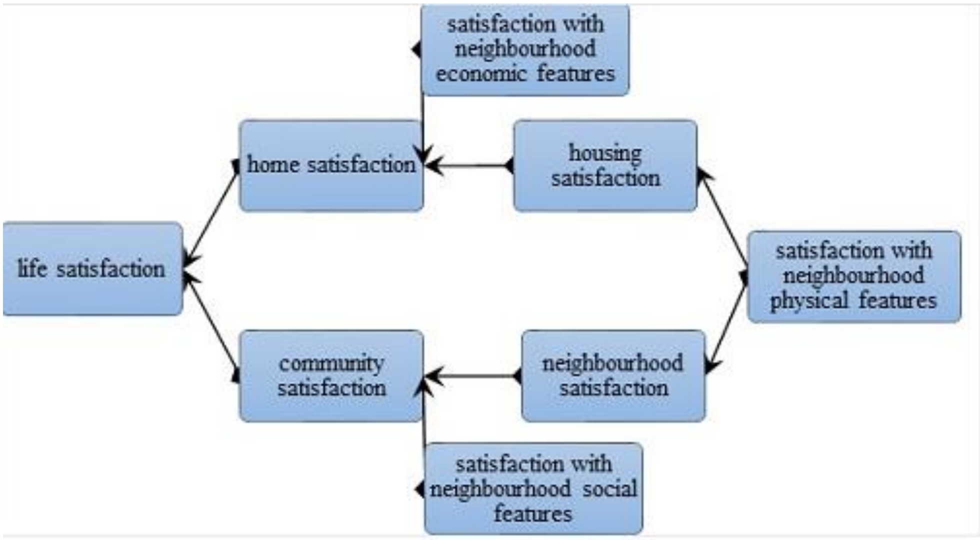


Source: Author, 2016

Annex 3: Literature extensions
Scope of Neighbourhood features

Neighbourhood features are seen to affect more than their limit to neighbourhood domain. To understand in detail the effect of neighbourhood features, Sigry and Cornwell (2002) provide an exhaustive account of the different plausible relationships between neighbourhood features and three urban domains- housing satisfaction, community satisfaction and neighbourhood satisfaction. The highlight of their research is on cross scale effects of neighbourhood features that extend beyond the limits of neighbourhood satisfaction, to impact perceptions of housing as well as community satisfaction. The authors investigate the concept using three models, progressively increasing complexity of the relationships. Of the three models, the third model depicted independent neighbourhood features with influencing all three urban domains. Satisfaction with physical features of neighbourhood predicted both neighbourhood satisfaction and housing satisfaction, and satisfaction with the social features predicted neighbourhood satisfaction as well as community satisfaction. Likewise, satisfaction with economic features were assumed to predict housing satisfaction and home satisfaction. The models depict the intricate relationship between domains and features. To assume that certain features affect certain domains would be neglecting cross scale relationships. Satisfaction with neighbourhood features is first and foremost a reflection of how these features address an individual's needs

Model 3: Neighbourhood Features Affect Life Satisfaction through a Satisfaction Hierarchy with three domains

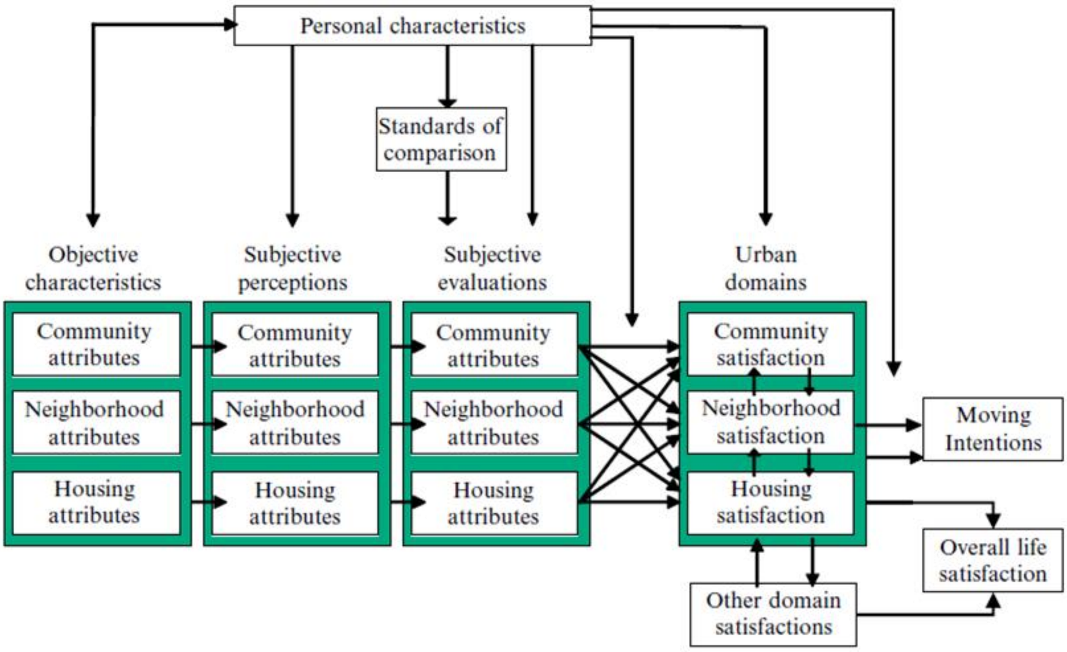


Source: "How neighbourhood features affect QOL (life satisfaction)", (2002)
Authors: The Author, 2016 based on M. Joseph Sirgy and Terri Cornwell

Each of these domains are further assessed through objective and subjective evaluations. Objective evaluations describe and measure tangible conditions of the domain, whereas subjective evaluations reflect what the objective conditions mean to its user. Empirical findings on current research in QOUL studies show that subjective evaluations have stronger correlations to satisfaction in urban domains and overall satisfaction.

To test this thought Campbell et al. (1976) experimented a model that specified a series of linkages between objective attributes of each life domain and satisfaction measures of those domains. The studies observed that the true quality of place cannot be conveyed through objective measures alone, but rather through the subjective evaluation of perceptions that people attach to the "place" (Marans and Stimson 2011). Based on this and further developed models, McCrea describes a broad conceptual framework on quality of life depicting relationships between subjective assessments as determinants of urban domain satisfaction and overall life satisfaction (McCrea et al. 2006). The model suggests satisfaction in life domains to act as a mediator between objective attributes and overall life satisfaction.

Figure 2. A broad model framework on determinants of satisfaction with the residential environment



Source: McCrea et al., 2006, derived from Campbell et al., 1976; Marans and Rodgers, 1975

The framework projects overall satisfaction to be a sum of satisfaction in individual domains, but through the subjective evaluations of that domain. Essentially stating that the objective characteristics on their own don't contribute to life satisfaction, but it is the subjective perception of those characteristics that provide better insight. Another aspect the framework accentuates is the cross scale effects of urban domains. As urban domains relate at different urban scales satisfaction in those domains can be measured through assessments of individual attributes to individual domains. In other words, it can be assumed that housing attributes influence housing satisfaction and neighborhood attributes influence neighborhood satisfaction (McCrea et al, 2011), however, the complexity of urban living is observed through crosswise effects of domain influences (also known as cross-paths) wherein attributes of one domain predict satisfaction in another domain.

For example, a neighborhood attribute like crime rate can influence housing safety conditions and thereby hosing satisfaction, and similarly the safety of the neighborhood can be determined by its proximity or connection to the larger city network which would mean neighborhood satisfaction is also dependent on city satisfaction. Through this process it is evident that different levels of urban living are closely related to each other and can affect more than themselves (McCrea et al. 2006).

Annex 5: Statistical tests

Physical Objective Features

	neighb~n	log_ov~g	log_ow~e	log_bu~r	bussto~e	underg~e	tramst~e
neighborho~n	1.0000						
	71						
log_overcr~g	-0.6897*	1.0000					
	0.0000						
	71	71					
log_ownhome	0.6508*	-0.4054*	1.0000				
	0.0000	0.0005					
	71	71	71				
log_buildn~r	0.8244*	-0.5558*	0.8134*	1.0000			
	0.0000	0.0000	0.0000				
	71	71	71	71			
busstops_s~e	-0.0187	-0.1196	-0.0273	-0.1162	1.0000		
	0.8771	0.3204	0.8211	0.3345			
	71	71	71	71	71		
undergroun~e	-0.0845	0.1153	-0.1081	-0.0502	-0.1772	1.0000	
	0.4835	0.3385	0.3697	0.6778	0.1393		
	71	71	71	71	71	71	
tramstops_~e	-0.3789*	0.3301*	-0.4379*	-0.3379*	-0.1207	0.0466	1.0000
	0.0011	0.0049	0.0001	0.0040	0.3162	0.6997	
	71	71	71	71	71	71	71
playground~e	-0.5966*	0.5249*	-0.4756*	-0.5901*	0.2258	-0.0587	0.3117*
	0.0000	0.0000	0.0000	0.0000	0.0584	0.6268	0.0081
	71	71	71	71	71	71	71
schools_st~e	-0.5872*	0.6440*	-0.4646*	-0.4734*	-0.0354	0.1452	0.2980*
	0.0000	0.0000	0.0000	0.0000	0.7694	0.2268	0.0116
	71	71	71	71	71	71	71

Physical Subjective Features

	neighb~n	satisf~n	suffic~e	Sa~ility	Sa~ality	Satisf~s	percen~i
neighborho~n	1.0000						
	71						
satisfacti~n	0.9049*	1.0000					
	0.0000						
	71	71					
sufficient~e	0.3360*	0.3676*	1.0000				
	0.0042	0.0016					
	71	71	71				
Satisf~ility	0.3418*	0.2861*	0.3313*	1.0000			
	0.0035	0.0156	0.0048				
	71	71	71	71			
Satisf~ality	0.5734*	0.5569*	0.1821	0.3568*	1.0000		
	0.0000	0.0000	0.1286	0.0023			
	71	71	71	71	71		
Satisfied_~s	0.6068*	0.6813*	0.4669*	0.1460	0.4226*	1.0000	
	0.0000	0.0000	0.0000	0.2245	0.0002		
	71	71	71	71	71	71	
percent_su~i	0.1872	0.2923*	0.7433*	0.3958*	0.1808	0.3738*	1.0000
	0.1180	0.0134	0.0000	0.0006	0.1313	0.0013	
	71	71	71	71	71	71	71
percent_Su~V	-0.2542*	-0.2284	-0.2340*	-0.2812*	-0.1482	0.1978	-0.2725*
	0.0324	0.0554	0.0495	0.0175	0.2176	0.0983	0.0215
	71	71	71	71	71	71	71
percent_Mu~e	-0.3006*	-0.2502*	-0.4447*	-0.3573*	-0.2456*	-0.3450*	-0.4250*
	0.0109	0.0354	0.0001	0.0022	0.0390	0.0032	0.0002
	71	71	71	71	71	71	71
grade_buil~d	0.8441*	0.8721*	0.3435*	0.2598*	0.6363*	0.6558*	0.2293
	0.0000	0.0000	0.0034	0.0287	0.0000	0.0000	0.0544
	71	71	71	71	71	71	71

Figure 22. Correlation Matrix

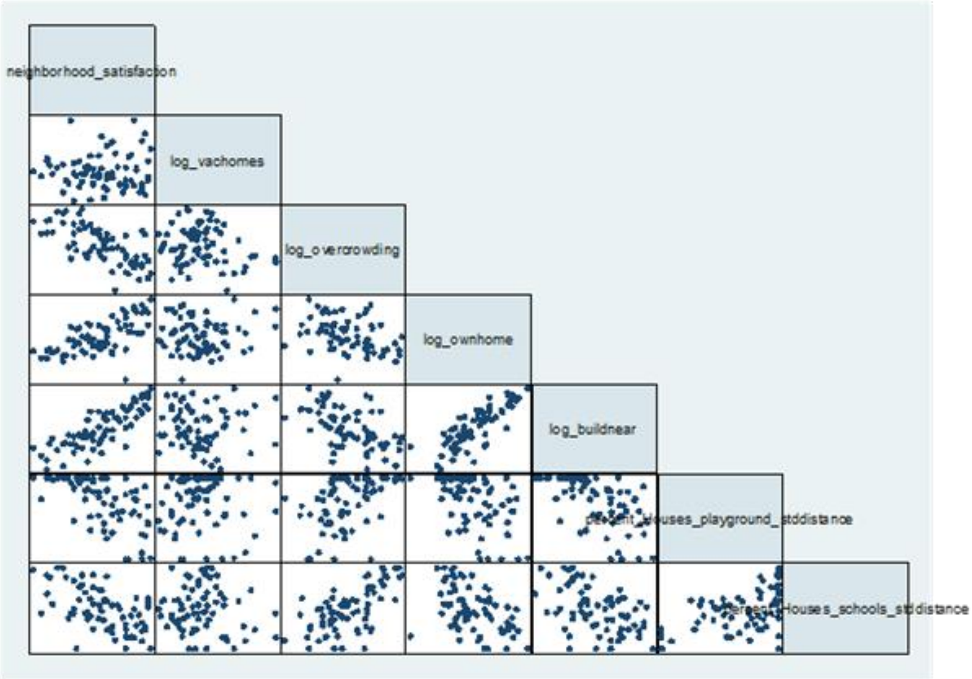
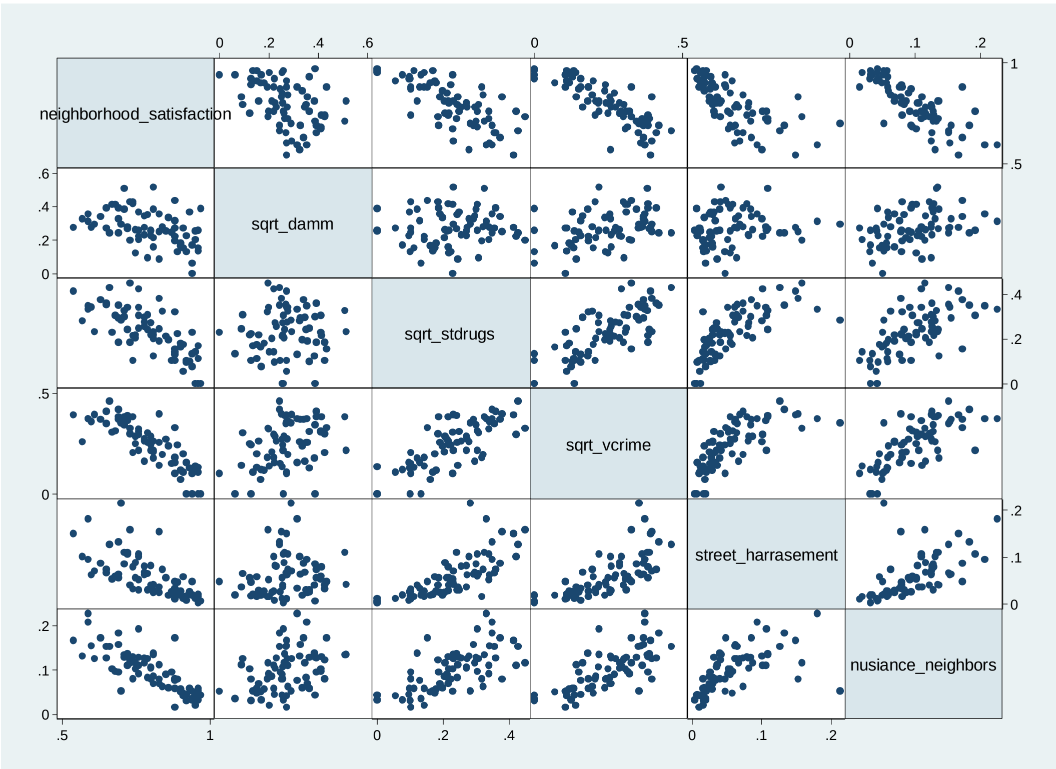


Figure 23. Correlation Matrix neighbourhood safety subjective index



A5.1: Independent Variables Indices

Table 37. Most significant Social Subjective Features

	(1)	(3)
VARIABLES	Neighborhood satisfaction	Neighborhood satisfaction
nice_surroundings	0.552***	
	(0.109)	
sqrt_noprob	0.295***	
	(0.0943)	
locas_people_help_eachother		0.263***
		(0.0771)
no_problem_neighbors		1.003***
		(0.164)
Constant	0.144***	-0.0638
	(0.0360)	(0.107)
Observations	71	71
R-squared	0.834	0.504

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Author, 2016

A5.3: Sub question 2

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	X1a: Physical index (objective)	X1b: Physical index (subjective)	X2a: Social index (objective)	X2b: Social index (subjective)	X3a: Safety index (objective)	X3b: Safety index (subjective)
(Log) X4a: Axial integration	1.190	-12.65***	-2.390	-10.14***	11.43***	17.39***
	(1.368)	(2.306)	(2.067)	(2.718)	(2.560)	(3.561)
Constant	4.544***	18.22***	9.297***	15.59***	4.593***	-0.530
	(0.713)	(1.201)	(1.077)	(1.416)	(1.333)	(1.855)
Observations	71	71	71	71	71	71
R-squared	0.011	0.304	0.019	0.168	0.224	0.257

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