

https://dspace.org/

Why do people walk on this street?: comparing quantitative and qualitative measures of imageability and their association with pedestrian patterns

Msingaphantsi, Mawabo

2024

https://hdl.handle.net/10539/37359

Downloaded from a DSpace repository. https://dspace.org/

University of the Witwatersrand, **Dec, 2022**

School of Architecture and Planning

Why do people walk on this street?

Comparing quantitative and qualitative measures of imageability and their association with pedestrian patterns

Mawabo Msingaphantsi
mawabo.msingaphantsi@wits.ac.za

Abstract

Imageability, the quality of a place that makes it distinct, recognisable, and memorable, is traditionally considered to make places pleasant and attractive to pedestrians. The use of primarily qualitative (rather than quantitative) descriptions to discuss the concept of imageability poses a challenge for the application of this concept in physical designs in practice, where designers work with environmental features that have specific dimensions and where they must decide how much of each feature (building height, number of courtyards, number of trees etc.) is necessary to make the environment imageable. There is also wide disagreement in urban design theory and practice about what factors contribute to imageability. Quantitative models attempt to address these challenges by producing operational definitions of imageability with strictly defined variables (factors) that are based on the mathematical relationships between physical environmental features (such as building shape or street length) and the occurrence of imageability. The chief benefit of these models for urban design is their potential use as a means to measure and describe the presence of imageability in a given place. However, the drawback of models is the limited number of verification studies to test their applicability in different contexts.

The Ewing model is a street-based statistical model that uses a street audit to describe how imageable a place is from the point of view of a pedestrian on a street. The model identifies eight variables that have a statistically significant correlation (R>0.6) with imageability (Ewing, Clemente, Handy, Brownson, & Winston, 2005). In this study I apply the Ewing model to a low-density environment to measure the imageability of part of Diepkloof (Zone 5), a former black township in Johannesburg, South Africa. I use sketches and qualitative descriptions to validate measurements taken on 30 streets. The purpose of the study is to determine the extent to which environmental features such as imageability can explain pedestrian patterns in a neighbourhood. I tested for correlation between pedestrian activity and imageability and then created a linear regression model to predict pedestrian volume on a given street based on the level of imageability on that street. My conceptual framework, however, demonstrated that imageability has three key aspects (*structure, identity and meaning*) and that different quantitative models have in-built assumptions that privilege one or more of these aspects and may affect how the resultant measurements should be interpreted. I use mapping to illustrate other potential factors of imageability (as described in the literature and in other models) and argue that these represent conceptual gaps in the Ewing model that should be considered when interpreting the model's outputs and their correlation to pedestrian patterns.

The results of applying the Ewing model in Diepkloof Zone 5 show low levels of imageability, which is consistent with my qualitative assessment of the site, as lower densities reduce the potential for composition because the environment has fewer elements. Bivariate linear regression was found to be an inadequate measure of the correlation between imageability and pedestrian activity. These simple linear regression models had R^2 values of less than 0.65 and had many outliers, which suggested that there were factors outside of the model that had a significant effect on pedestrian activity. When multiple regression is used to account for other neighbourhood conditions, correlation increased and the R2 value (which describes the models' predictive capacity). There are three statistically significant variables (with p-values less than 0.05): *street length*, *street integration* and *imageability*.

Faculty of Engineering and the Built Environment

Private Bag 3, Wits 2050, South Africa * Telephone (011) 717 – 7007 * Fax: (011) 717 7009 * Email: febe.pg@wits.ac.za

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Mawabo Msingaphantsi (Student number: 0614712x) am a student registered for the degree of Doctor of Philosophy (TRP) in the academic year 2022.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this in not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: _____ Date: 2022-12-05

ACKNOWLEDGEMENTS

I dedicate this work:

To my wife, Palesa, for bringing clarity and peace to my life. To my mother, for nurturing a love for knowledge and supporting my dreams. To my brothers (Mandisi, Lungisa, Xola and Bongani), for being the best men I know and my life-long friends. To my father, for providing stability and discipline and for protecting us from the dangers in the ghetto in our formative years.

TABLE OF CONTENT

Chapter 1: Introduction 1
1.1 Problem statement: 2
1.2 Rationale and project objectives 3
1.3 Contribution to knowledge 3
1.4 Main research question: 3
1.4.1 Sub questions 3
1.5 Research methods 4
1.5.1 Limits of study 6
1.6 Site selection 6
CHAPTER 2: LITERATURE REVIEW 8
2.1 Introduction 8
2.2 Background 8
2.3 WHY DOES URBAN DESIGN THEORY TAKE ON A LAYERED FORM? 11
2.3.1 How do later theories relate to Lynch's imageability? 14
2.3.2 "A city is not a tree" but "a pattern language" spoken by those who know "the timeless way of building" 15
2.3.3 Trancik's theories of figure-ground and linkage 17
2.4 CONTEMPORARY APPROACHES FOR MEASURING IMAGEABILITY 24
2.4.1 Space syntax as a measure and representation of imageability 25
2.4.2 GIS-based cognitive mapping 28
2.4.3 The influence of Gestalt psychology 30
2.4.4 Cognitive mapping 31
2.4.5 The information approach: why we remember some environmental features and not others 33
2.4.6 Reflection on the approaches discussed above 35
2.4.7 Ewing model: a count-based model of imageability 36
2.5 CONCEPTUAL FRAMEWORK 39
2.5.1 Structure 40
2.5.2 Identity 41
2.5.3 Meaning 41
2.6 Conclusion 42
Chapter 3: Research methods 43
3.1 Introduction 43
3.2 Ontological and epistemological considerations 43
3.2.1 Empiricism, logical positivism, and the scientific method 45
3.2.2 The problem of induction 48

3.2.3 Karl Popper's problem of demarcation: science as conjecture and refutation 49
3.2.4 "Normal" science and research paradigms – post-Kuhnian philosophy of science 52
3.3 Site selection 54
3.4 Measuring the physical characteristics of streets (model variables) 55
3.5 Application of Ewing model to derive imageability scores 57
3.5.1 Developing a scale of imageability 58
3.5.2 Correcting measurement errors 59
3.6 Deriving qualitative descriptions of imageability 60
3.7 Field observations of pedestrian patterns 60
3.8 Statistical analysis – correlation between imageability and pedestrian patterns 61
3.8.1 Linear regression and correlation 61
3.8.2 Modelling in R-studio, identifying outliers and making scatter plots on MS Excel 62
3.9 Limitations 64
3.10 Conclusion 65
Chapter 4: Research findings 66
4.1 Introduction 66
4.2 Site context 66
4.2.1 Historical background 67
4.2.2 Neighbourhood structure and movement 69
4.2.3 Development trends and topological qualities 76
4.3 MODEL CALIBRATION – DEVELOPING A SCALE TO UNDERSTAND THE MAGNITUDE OF IMAGEABILITY SCORES 79
4.4 IMAGEABILITY IN DIEPKLOOF 83
4.5 PEDESTRIAN ACTIVITY 88
4.6 NEIGHBOURHOOD FEATURES ASSOCIATED WITH PEDESTRIAN ACTIVITY 90
4.6.1 Land use pattern 90
4.6.2 Grain and texture 91
4.6.3 Intersection density 92
4.6.5 Street integration 93
4.6.6 Block permeability 94
4.6.7 Street length 95
4.7 Conclusion 97
Chapter 5: Analysis 98
5.1 Introduction 98
5.2 Calculating the correlation between imageability and pedestrian volumes and developing a linear regression model for predicting pedestrian volumes 99

5.3 MULTIPLE REGRESSION: CALCULATING CORRELATION BETWEEN MULTIPLE NEIGHBOURHOOD CONDITIONS AND PEDESTRIAN ACTIVITY AND DEVELOPING A REGRESSION MODEL FOR USING THESE NEIGHBOURHOOD CONDITIONS TO PREDICT PEDESTRIAN VOLUMES 104
5.4 THEORETICAL IMPLICATIONS 107
5.4.1 Structure, identity and meaning 107
5.4.2 Affordance and Shannon's measure of information 108
5.4.3 Path continuity and angular betweenness 108
5.4.4 Neighbourhood conditions: destination, density, and diversity 108
5.5 Conclusion 109
Chapter 6: Conclusions and recommendations 110
6.1 The relationship between imageability and pedestrian patterns in Diepkloof Zone 5 111
6.2 Limitations 112
6.2.1 Comparability and replicability 113
6.2.2 External validity: A process [rather than a tool] for measuring imageability 113
6.3 Contribution to knowledge: potential applications and recommendations for future research ... 114

Chapter 1: INTRODUCTION

Imageability refers to that quality of a place that makes it visually striking or memorable (Lynch, 1960). Quantitative models of imageability have emerged in the last twenty years in an attempt to provide an empirical basis for the association between certain physical features of urban environments and the occurrence of imageability. Such quantitative descriptions of traditionally abstract theoretical concepts may also be of value for urban design practice, where designers work with environmental features that have specific dimensions and where they decide how much of each feature (building height, number of courtyards, number of trees etc.) is necessary to achieve an intended urban design quality, such as imageability. Quantitative models provide operational definitions of imageability with strictly defined variables (factors) that are based on the mathematical relationships between physical environmental features (such as building shape or street length) and the occurrence of imageability. Some of these models use space syntax technology to define the physical features to be used as model variables (Kim and Penn, 2004), while others use Geographic Information Systems (GIS) (Filomena, Verstegen and Manley, 2019). Others use street audits to identify and measure features from site visits, videos, or photographs (Ewing and Clemente, 2013). Certain of these models are street-based in that they describe urban design qualities from a pedestrian perspective on a given street (Stamps and Smith, 2002; Ewing and Handy, 2009; Ewing and Clemente, 2013) whereas others describe the overall image of a neighbourhood based on cognitive mapping (Sharmin and Kamruzzaman,2017; Filomena, Verstegen and Manley, 2019). The chief benefit of these models for urban design is their potential use to measure and describe the presence of an urban design quality, such as imageability, in a given place.

The Maryland Inventory of Urban Design Qualities (MIUDQ) protocol is a street-based quantitative model of urban design qualities that (among other things) uses a street audit to describe how imageable a place is from the point of view of a pedestrian on a street. For brevity, the MIUDQ protocol is referred to in this report as the Ewing Model, so named after Reid Ewing who was part of the research team responsible for developing it and is the lead author in the first journal article describing the model (Ewing et al, 2006). In a subsequent book, Ewing and Clemente (2013) describe the process of developing the model, its applications as a measurement protocol and its validation in five case studies in New York City. The model identifies eight variables that have a statistically significant correlation (R>0.6) with imageability. In this model, imageability is defined by using a panel of 10 experts to rate 200 street scenes to develop a distribution of *high* and *low* ratings (Ewing et al, 2005). Correlation in this model describes the relationship between the presence of certain environmental features and the perception of imageability, where perception is measured by the ratings that the expert panel gives to each street (Ewing and Handy, 2009; Ewing and Clemente, 2013). The Ewing model has been implemented by researchers at Columbia University's Built Environment and Health project in a study of 588 block faces, with a stratified sample that included various densities and land use mix (Ewing and Handy, 2009).

In this study I apply the Ewing model to a low-density environment to measure the imageability of part of Diepkloof (Zone 5), a former black township in Johannesburg, South Africa. I use sketches and qualitative descriptions to validate measurements taken on 30 streets. The purpose of the study is to (a) validate the applicability of the Ewing model in a new context[1] and to (b) determine the extent to which environmental qualities such as imageability can explain differences in pedestrian patterns in a neighbourhood. I use linear regression to create a model that can describe the amount of pedestrian activity on a street based on three factors: *street length*, *street integration* and *imageability*.

[1] Previous validation study was conducted in New York City (Ewing and Clemente, 2013)

1.1 PROBLEM STATEMENT:

Imageability is associated with pedestrian activity, in urban design literature, but this relationship is traditionally described in qualitative terms, which limits the possibility of using imageability as a measure of walkability. For example, Lynch (1960: 10) describes it as "that shape, colour, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment". This description has at least three predictor variables (shape, colour, arrangement) and it is not particularly clear if they equally influence imageability or if a change in one of them for that matter could solely make a place more or less imageable.

Yet the benefit of less ambiguous descriptions of imageability (and other desirable environmental qualities) extends beyond the urban design profession. Urban environments in South Africa are increasingly being created and controlled by large corporations with less expertise of and dedication to the area (Cote-Roy and Moser, 2018). Regardless of socioeconomic or geographic character, large multi-national businesses leave their standardized stamp across the country. Everything is laid out without respect for context: from the signage and brand name logos to the building shape and site design. In the residential sector, large tracts of land are being packaged and developed by a few large property firms into gated enclaves – with no sense of neighbourhood or identity – and managed as *sectional title schemes* by body corporates with a very narrow public interest. (Motlhabane, 2014). The expectation seems to be that what works in Johannesburg or Cape Town must likewise work in East London or Knysna. Artists, architects, and other designers have had significantly less influence on city shape in recent years. Arguably, even urban planners' influence in the development process is limited due to skills shortages in many municipalities (Koelble and LiPuma, 2010; Davids et al, 2012). This threatens to make municipal planners either dependent on private developers when it comes to assessing design quality or overly dogmatic in their regulation of urban development, unleashing a seemingly endless stream of banality and conformity. This trend is potentially compounded by the vagueness of urban design descriptions and the fact that determining a place's urban design qualities often requires a discipline-specific in-person assessment by a practitioner. As professions in the built environment become increasingly specialized, they may lack a common language to describe desirable environmental qualities and nuanced qualitative descriptions that require familiarity with urban design literature may be useful for guiding designers in their work but they fail them in communicating their ideals to a broader professional audience (Cockburn et al, 2016). A shorthand is necessary to develop a common language. Because the built environment is complex and has many parts to it, quantitative descriptions can be useful because of their specificity insofar as they can point to the most significant variables to look at. In this way, having a model can highlight the list of key ingredients for creating imageable places.

Imageability can create more desirable places (Lynch, 1960; Southworth, 1985). The expansion of the historic preservation movement, as well as widespread appreciation for "antiques" that are only a few decades old, demonstrates the need for tangible roots and a feeling of place. Tourism thrives in locations that have retained their uniqueness or produced new environmental forms that are fascinating. The environment also affects human wellbeing (Ewing and Handy, 2009). Obesity, injury, and psychopathology are just a few of the health markers that can be influenced by neighbourhood circumstances (Mooney et al, 2017). Walking is a relatively egalitarian means of access that also offers the benefit of exercise and a growing body of literature is accumulating evidence of a relationship between the built environment and active living (National Research Council, 2005).

1.2 RATIONALE AND PROJECT OBJECTIVES

A variety of quantitative models for measuring and describing imageability have emerged in the past two decades. Some approaches use space syntax analysis to explore how street configuration relates to people's ability to form mental representations of their environment (Dalton and Bafna, 2003; Kim and Penn, 2004). Other scholars have looked at the use of automated computer models (Rousell and Zipf, 2017) and GIS (Filomena et al., 2019) to create cognitive maps. The use of such models allows researchers to establish a quantitative description of the relationship between imageability and pedestrian behaviour that ultimately be used to develop a field instrument for measuring walkability in environmental assessments or project proposals. **The first objective in this study is therefore to determine if measurements from the Ewing model can be used to establish correlation between pedestrian activity and imageability.**

Models of imageability differ in the methods they use to identify and measure features to be used as variables. Methods such as GIS, space syntax and site visits have been used in different models, which has implications for the accuracy of measurements on the one hand and the versatility of the model on the other. For example, highly technical models such as GIS can be very accurate in information-rich contexts; but they may be difficult to adapt in situations where there is spontaneous change and uncertainty. Given this, such a model may be better suited for measuring relatively fixed elements such as building footprints or street layouts. Models also differ in terms of scale and perspective: some focusing on the street and what the pedestrian can see, while others consider the neighbourhood and pedestrian perceptions. This in turn limits what aspect of imageability is likely to feature in the models' measurements. Research is necessary to understand the suitability of each model for application in different contexts. **The second objective of this study is thus to assess the suitability of the Ewing model by situating the results of the study within the context of alternative explanations of the pedestrian pattern on site – other than the measured correlation with imageability.**

I selected Diepkloof Zone 5, a neighbourhood in Soweto (in the southwest of Johannesburg), as the site for the study. It contains 30 streets and spans 90ha. Its location in the former black township of Soweto makes the site comparable to many places in South Africa, which increases the relevance of the study, and sets it apart from previous quantitative urban design studies, which often look at places in the Global North.

1.3 CONTRIBUTION TO KNOWLEDGE

By conducting a verification study of Ewing and Handy's (2009) model I will be contributing to the literature by establishing the external validity of existing knowledge. By determining the extent to which a residential context might necessitate a different model for walkability than that proposed by Ewing and Handy (2009), in so doing I will also help to inform the direction of future research in this area of urban design theory, This research will also identify variables that may behave differently from what the model predicts and it can also identify factors that may not have been considered in the previous model.

1.4 MAIN RESEARCH QUESTION:

To what extent can a quantitative description of imageability (the Ewing model) be used to predict pedestrian activity in Diepkloof Zone 5?

1.4.1 Sub questions

(a) What is the level of imageability in each street on site, as measured by the Ewing model?
(b) How does the level of imageability, as measured by the Ewing model, compare to qualitative assessments of imageability (validation)?
(c) What is the number of pedestrians in each street on site?
(d) What is the correlation between the level of imageability and the number of pedestrians?

(e) To what extent do other factors, such as land use, density, street length and connectivity explain the pedestrian pattern on site?

1.5 RESEARCH METHODS

The table below shows how the research question has been subdivided into five questions that can be answered by applying a set of research methods:

Main research question	
To what extent is there a correlation between imageability (as measured by the Ewing model) and the distribution of pedestrian activity in the streets of Diepkloof Zone 5?	
Sub-questions	**Research methods**
(a) What is the level of imageability in each street on site, as measured by the Ewing model?	**Field observations** - Apply Ewing and Clemente's (2013) measurement protocol on comparable streets, in order to generate a prediction of imageability. Measure physical attributes associated with imageability in selected residential streets.
(b) How does the level of imageability, as measured by the Ewing model, compare to qualitative assessments of imageability (validation)?	**Qualitative assessment** - Use sketches and verbal descriptions to demonstrate the physical features that make each street distinct, recognisable, and memorable - Give each street a rating of *high* or *low*
(c) What is the number of pedestrians in each street on site?	**Field observations** - Observe pedestrian patterns on streets where measurements were taken
(d) Is there correlation between the level of imageability and the number of pedestrians?	**Statistical analysis** - Use linear regression to measure correlation between imageability predictions and observed pedestrian patterns.
(e) To what extent do other factors, such as land use, density, street length and connectivity explain the pedestrian pattern on site?	**Mapping** - Use satellite imagery and GIS to measure and illustrate urban features.

Table 1: research questions and corresponding research methods

The methods employed in this report fall into seven categories: (a) measurement of physical features; (b) application of Ewing model to derive imageability scores; (c) qualitative descriptions of street scenes; (d) field

observations of pedestrian patterns; (e) mapping; (f) statistical analysis of the relationship between imageability scores, pedestrian patterns, and physical features; and (g) interpretation of results.

I began by conducting site visits and using the measurement protocol described in Ewing and Clemente (2013) to count eight kinds of environmental features associated with imageability: 1. number of courtyards, plazas, and parks; 2. number of major landscape features; 3. proportion historic building frontage; 4. number of buildings with identifiers; 5. number of buildings with non-rectangular shapes; 6. presence of outdoor dining; 7. number of people; 8. noise level. This was done by dividing the 30 streets on site into 200m segments, to only capture features within a pedestrian's field of vision, thereby more accurately mimicking the experience of walking. I inputted the measurements of the physical features into the Ewing model, which is an excel spreadsheet provided by Ewing et al (2006)[2], which in turn added a constant and a multiplier to each measurement and produced an "imageability score". I conducted qualitative assessments of each street to validate the imageability scores produced by the model by sketching the street scenes and reflecting on whether they had a strong sense of place, if they had any striking features and if they were memorable. I made notes of my reflections and gave each street a score out of 10, which is a protocol employed by Ewing et al (2006) when they developed the model, wherein they also asked an expert panel to rate the street scenes and provide descriptions.

The purpose of this qualitative assessment was to give myself a frame of reference for how accurately the model scores reflected what I (and potentially other pedestrians) perceived on site. As a further point of reference, I used Google Street View to measure the imageability of 70 international streets (in addition to the 30 on my site), which gave me a sense of where my site fits within a wider distribution of possible scores. The sample of international streets included streets from the areas sampled in the University of Columbia validation study. The 130 measurements (30 from my site, 50 from NYC, and 50 other streets) were then made into a box-whisker distribution. The logic here was that if my measurements of New York City streets were too different from those found in the Colombia study, then perhaps this would indicate that I am not applying the model correctly. If the 50 measurements for the NYC sample were similar to the average score from the Columbia study but the other 80 measurements (including those of my site) were either too high or too low, then perhaps this would indicate that the contexts are too dissimilar and the model has limited application outside of NYC.

Once I had descriptions of the level of imageability, I then turned my focus to measuring the level of pedestrian activity on each street. Using a camera mounted on my car, I drove across the site recording the activity on each street. I used a geo-location app on my phone to track the route that I was travelling at any given point in time, to allow me to reference my location against the time lapse in the video. I could thus map the number of people captured by the camera against the particular segment of the given street that I was travelling on at the time. I also used satellite imagery and GIS (geographic information systems) to map environmental features such as land use, block permeability, street connectivity, grain and texture and street length, given that these were also likely influences on pedestrian activity.

Using the imageability scores and the number of pedestrians, I created bivariate linear regression models to measure correlation. I then made multivariate linear regression models that also included data gathered from mapping on features such as land use. Finally, I used my conceptual framework (described in chapter 2) to explain differences between the models as well as to determine the accuracy of their description of the relationship between physical environmental features and pedestrian activity.

[2] The MIUDQ "measurement instrument" is available on: https://activelivingresearch.org/measurement-instrument-urban-design-quantities-related-walkability

1.5.1 Limits of study

The Ewing model was developed by looking at "commercial streets in urban or 'main street' settings—all places with sidewalks and other pedestrian amenities such as landscaping, pedestrian lighting, street furniture, and businesses or public spaces within view" (Ewing et al, 2006: 227). A later validation study carried out by the University of Columbia demonstrated that the model was applicable in more diverse environments by looking at 588 city blocks across the five boroughs of New York City. The data points for this study ranged from quiet streets in the suburbs of The Bronx and Staten Island to those in the dense commercial areas of Manhattan. My study builds on this initial validation by testing the extent to which the model is applicable in a low density environment in a different country. By comparing model measurements of imageability to pedestrian patterns my research aims to determine if there is a significant relationship between imageability and walkability.

1.6 SITE SELECTION

The study area is located in Diepkloof Zone 5. It has a low density (112.6 people per ha (Frith, 2013)) and is characterised by low rise buildings. It is also primarily residential. This makes it sufficiently different from the sites of the original (Ewing et al, 2006) study, such that a comparison between the Ewing model and the site is likely to yield novel insights. The site also has a high amount of observable pedestrian activity, which makes it suitable for collecting data on pedestrian patterns.

Diepkloof is a neighbourhood in the township of Soweto, Johannesburg. According to the 2011 census Soweto has the largest population of any area in Johannesburg, with 1,271,628 people, which accounts for 28.7% of the population of Johannesburg (STATS SA, 2011) and 12% of its workforce (Simpson et al, 2012). The racial composition of Soweto is overwhelmingly black – a legacy of segregationist policies – and more than 20% of the population subsists on less than 4,800 Rands (334 USD) per month (STATS SA, 2011). More recent demographic figures are unavailable as the 2021 census has been postponed due to the COVID-19 pandemic. However, the 2020 mid-year projections estimate that the Gauteng population has increased by 20.7%, between the year 2001 and 2011[3] (STATS SA, 2020). Soweto's population grew by 48% in the same period. Diepkloof, on the other hand, has experienced a progressive decrease in population since 1996, falling by 2%, between 1996 and 2001, and then by 7% between 2001 and 2011 (Weakley and Bickford, 2015).

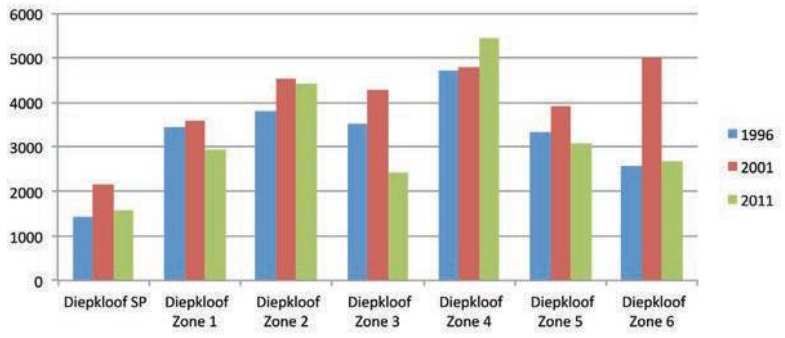


Figure 1: Population changes in Diepkloof (number of households per zone), from 1996 to 2011 (Weakley and Bickford, 2015:34)

[3] Gauteng's population is projected to have grown from 12,272,263 (2011) to 15,488,137 between 2011 and 2020, at a rate of 20.7%. The growth rate between 2001 (8 837 178) and 2011 was 38.8%.

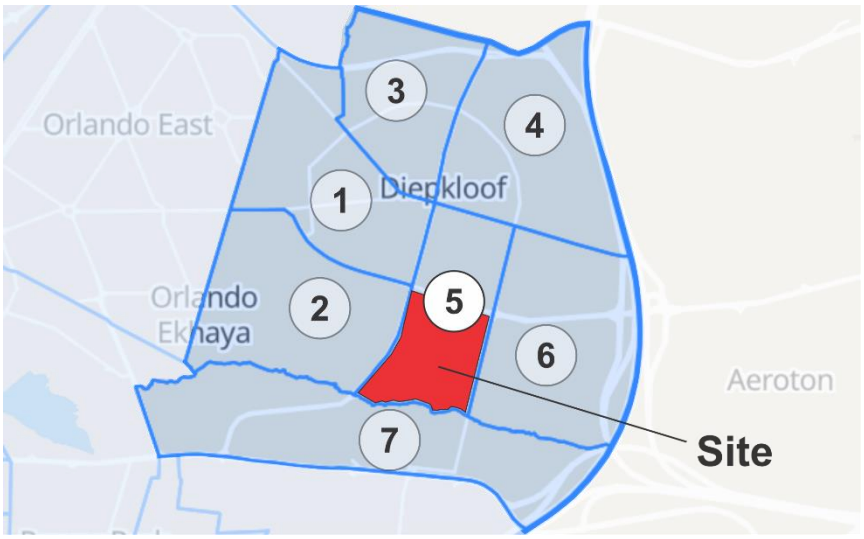


Figure 2: The seven zones of Diepkloof, with other parts of Soweto to the west and the industrial area of Aeroton to the east. Industry served as a buffer between the townships collectively known as Soweto and the suburbs to its east.

The population of Diepkloof is unevenly distributed between seven areas (fig.2), with Zone 5 being the densest (table 2). Diepkloof Zone 5 has a population of 14,681 people, in 3,052 households, and an area of 0.9km (Frith, 2013), which translates to a density of 146 people per hectare.

Zone	Population	Area (km_2)	Density (people/km_2)
Diepkloof Zone 5	14681	0,9	16312,22
Diepkloof Zone 2	19899	1,3	15306,92
Diepkloof Zone 4	20029	1,39	14409,35
Diepkloof Zone 1	13241	1,19	11126,89
Diepkloof Zone 3	9897	0,91	10875,82
Diepkloof Zone 6	11417	1,71	6676,608
Diepkloof SP	5903	1,42	4157,042
	95067		

Table 2 Population, area and density of each zone in Diepkloof (after Frith, 2013)

By looking at Zone 5, this research considers the extent to which a neighbourhood's physical features make it imageable and the extent to which certain physical features associated with imageability correlate with pedestrian activity.

Chapter 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is divided into four sections. The first section introduces Lynch's theory of imageability and the three claims made therein. Lynch argued that people form mental images of urban environments that his experiments showed to be relatively consistent across individuals. He further claimed that these mental images were constituted by five elements: paths, nodes, edges, districts, and landmarks. Finally, because imageability affects people's experience of place he argued that it can be a normative basis for design. Although Lynch's theory has been widely accepted, some follow up studies challenged his three claims and raise questions about the universality of the theory. Some theorists even question its scientific basis (Raynsford, 2011; Marshall, 2012) and the accuracy of cognitive mapping as a tool for describing imageability (Stein, 2022). Yet Lynch's theory continues to be influential in urban design education and in practice, despite there being other theories that also holistically describe urban form and its relationship to human perception without referring to Lynch (Raynsford, 2011). Therefore, when compared to fields such as the natural sciences, urban design is an incompletely theorized field (Verna, 2011) insofar as it seems to be a layered collection of theories rather than a coherent systematic explanation of phenomena.

The second section of this chapter considers why urban design theory takes a layered form and what implications this has for the validity of the profession's knowledge base. The fact that urban design theory is layered rather than integrated, that it sometimes contains contradictions, and that practice can often proceed without it, opens the discipline to criticism and even to the charge of being a pseudoscience – in the same vein as astrology (Marshall, 2012). The chapter identifies three perspectives from which the concept of imageability has been discussed in urban design literature: structure, identity and meaning. These three perspectives represent layers of the same phenomenon. This section discusses the work of two theorists (Christopher Alexander and Roger Trancik) in relation to Lynch's theory of imageability to demonstrate how, even though each of these scholars discuss urban form and human perception, their theories nonetheless diverge rather than forming an integrated system of knowledge.

The third section of this chapter discusses contemporary theories of imageability, which are grouped under the three themes of structure, identity and meaning, based on the aspect that each theory mostly focuses on. After reflecting on the strengths and weaknesses of each theory as an approach for measuring imageability, the section presents the Ewing model as an alternative measure of imageability that nonetheless also has a narrow scope and its own set of advantages and disadvantages.

The chapter concludes by providing a conceptual framework that is premised on the understanding that urban design knowledge is layered and not necessarily scientific. The conceptual framework acknowledges the Ewing model as being primarily concerned with structure and it draws insights from other theories discussed in this chapter as potential explanations for phenomena that may lie outside the scope of the model.

2.2 BACKGROUND

Lynch's book *The Image of the City* is primarily concerned with two qualities of the built environment: *legibility*, 'the ease with which [an environment's] parts can be recognized and can be organized into a coherent pattern' and *imageability*, 'that quality in an object which gives it a high probability of evoking a strong image in' the observer' (Lynch, 1960: 60). According to Haung et al (2021), Lynch's thesis makes three important claims. The first is that a city has a public image that is formed when people experience the city and is relatively consistent across different individuals. Secondly, the elements that form a city's image can be conveniently classified into five elements: "path", "node", "edge", "district" and "landmark". Thirdly, *imageability*, the ability of the urban environment to evoke mental images, creates a sense of emotional security and an intensity of human

experiences that can serve as a normative basis for good urban design. To arrive at these conclusions Lynch conducted multiple studies of Boston, Los Angeles, and Jersey City where he asked participants to draw maps to describe their city to him. He found that individuals' drawings could be overlapped with each other to form a community map comprised of features that were frequently repeated by numerous individuals. These frequently repeated features fell into five categories, which became the five elements of the image of the city. Finding that different individuals repeatedly drew the same group of features when describing a place suggested that they remembered it in the same way, that there was a commonly shared cognitive map of the city that correlated with physical attributes of the city (Lynch, 1960). This was significant because, firstly, it demonstrated that the image of the city, the cognitive map formed in people's memories, was not merely subjective but could be objectively demonstrated with mapping. Secondly, the image of the city was based on tangible elements of the physical city and could be improved or hindered by changes to these elements. Lynch's theory has been widely cited in the fields of urban planning, social science, and environmental psychology (Banai and Rapino, 2009; Morello and Ratti, 2009; Pocock and Hudson, 1978) (table 3).

Web of Science Category	Citations % of Total	Web of Science Category
Urban studies and planning	677	23.5
Environmental studies	495	17.2
Geography	452	15.7
Computer science and information systems	351	12.2
Psychology (multidisciplinary and experimental)	341	11.8
Architecture	292	10.1
Other	271	9.4
Total	2,879	100.0

Table 3: Citations of The Image of the City across disciplines (Mondschein and Moga, 2019: 264)

There were several follow up studies after Lynch's book (de Jonge, 1962; Gulick, 1963; Goodey, 1971; Francescato and Mebane, 1973; Evans, Marrero, and Butler, 1981). De Jonge looked at the central areas of six cities in the Netherlands and provided verification of Lynch's claims (by testing his cognitive mapping approach in a wider variety of areas) and found a potential psychological basis for the phenomenon of imageability in the work of Gestalt psychologists who noted that people have selective perception processes and a predilection for simple patterns (de Jonge, 1962). In a study of cognitive representations of large-scale environments in adults, Evans et al (1981) found that people use landmarks as initial anchor points in the environment and that path structures were subsequently elaborated within the initial landmark network. They also found that the basic ordinal accuracy of landmarks did not shift with experience, whereas exact location in space improved. That is to say, the role of the landmark in the hierarchy of the image did not change but research respondents were better able to identify its location as they became more familiar with the area. This finding was borne out in later studies on cognitive mapping (Blades, 1990; Lopez et al, 2020). Whereas de Jonge (1962) and Evans et al (1981) found evidence for the universality of imageability and the prominence of landmarks in cognitive maps, Gulick's (1963) study of 35 residents of Tripoli (Lebanon) argues that socio-cultural associations are as important as visual cues in the formation of the image of the city because respondents in that study emphasized districts and minimised landmarks or individual buildings. Gulick draws a connection between his findings and Arab culture, but the sample of the study is comparatively small and is likely insufficient to refute Lynch's emphasis on visual cues.

There is debate regarding the relative importance of the five elements in Lynch's image of the city. Some researchers rank landmarks as being the most important, whereas others place more emphasis on paths and districts (Haung et al, 2021). Appleyard (1970) found that there were differences in the cognitive maps of the

cities in Lynch's study: "the inhabitants of Boston usually organized it as a set of loosely related districts, Los Angelenos tended to organize their downtown by its gridiron street system, while the people of Jersey City used the main roads and the view of Manhattan" (Appleyard, 1970: 100). This casts doubt on the objectivity of the image of the city and its consistency across individuals (the first claim in Lynch's theory). Raynsford (2011) is dubious of the novelty of Lynch's findings and argues that the five Lynchian elements predated his now famous empirical studies and can be traced back to terms such as "avenue," "intersection," "precinct," "wall," and "monument", which were already popular concepts in civic art traditions. This criticism challenges the validity of Lynch's second claim, that the five elements were how people in the public saw cities, rather than how architects and planners had always conceptualised urban environments. Moreover, some scholars question the widespread acceptance of the theory of imageability and they caution that more studies are needed to improve its external validity: that the finding of imageability in Lynch's case studies does not make the theory applicable to other contexts. Marshall (2012) notes with concern that urban designers use imageability a-priori and conveniently switch to a different theoretical basis when confronted with contradictions to this theory, instead of using their findings to validate it or establish its limits. Therefore, the third claim – about imageability's potential role as a normative basis for design – also faces scrutiny.

Contemporary scholars directly critique the relevance of *The Image of the City* in the Digital Age. Offenhuber and Ratti (2013) argue that legibility in urban settings is today provided by information technology, rather than the built environment. They argue that imageability should be achieved through digital design to affect virtual environments and the actual environment's experience. Thus, the "sense of security" and "intensity of human experiences" that Lynch (1960:5) ascribes to imageability can be achieved through technology, thereby negating the need for imageable environments. Proponents of this digital approach cite the role that navigation services, such as Google Maps, play in guiding people's movement through the city as evidence that Lynch's emphasis on environmental cues for wayfinding may have been overstated or, at least, that it is outdated (Offenhuber and Ratti, 2013; Al-Ghamdi and Al-Harigi, 2015; Wohl, 2019). Yet, the fact that, in some cases, Google Maps include the main features of an area on the map suggests the continued importance of physical landmarks despite technological navigation aids. There is also evidence to suggest that virtual spaces, such as social media, can influence the perception of a place.

In a study using text-mining, image processing and other data science methods, Haung et al (2021:1) concluded that "*Instagramability*, the frequency of a place captured on Instagram, was linked to its perception as an architectural landmark and tourist attraction, while *Twitterability*, the frequency of a place mentioned on Twitter by name, was linked to its perceived niceness and relevance to everyday life of communities". However, the ability of technology to replace environmental cues may be overstated. Huang et al (2021) concede that social media presents a distorted image of the general population as it overrepresents young people with access to digital resources and knowledge and because participants may be prone to exaggerated behaviours. Their study also carried out a survey and sketch mapping (similar to Lynch's) to validate their findings. Haung et al's (2021) study is thus not a rejection of Lynch's findings but it builds on them by adding new technologies as a means of describing imageability. Offenhuber and Ratti's (2013) assertion that Lynch's emphasis "on the pedestrian experience is inconsistent with the way most individuals move" (Mondschein and Moga, 2019: 265), while true on the face of it (because of the pervasiveness of cell phones), also overlooks the experiences of the majority of people in cities, those who walk rather than drive through the city, since even motorists are pedestrians for at least part of most journeys. Although pedestrians can also use GPS for navigation, it is a very different experience because people engage with a widely more diverse range of aspects of their environment when walking, as compared to when they drive (Wagner et al, 1981). It has been observed in the in the literature that, whereas motorists' eyes look straight ahead for most of the trip (Appleyard, Lynch and Meyer, 1964), pedestrian's eyes move more frequently and across a wider field of vision (Wagner et al, 1981). Thus, a smaller share of pedestrian's attention can be dedicated to checking their GPS. This means that, even when additional information is provided by technologies such as GPS, the physical environment is likely to remain a significant informant of the image of the city.

2.3 WHY DOES URBAN DESIGN THEORY TAKE ON A LAYERED FORM?

The preceding background demonstrates how Lynch's theory of imageability has had a far-reaching impact across several disciplines but also that the wider body of work within which it is set is "an incompletely theorized project" (Verna, 2011:57). In this chapter I argue that the discourse on imageability can be broadly arranged under three themes. There are scholars who approach the topic by looking at the city itself, to find out what makes it imageable. They are primarily concerned with the physical artifacts that make up the environment, the dimensions of these items and their arrangements. In this chapter, scholars in this category are referred to as being concerned with *structure.* In the second category there is that portion of the literature that looks at the human mind as the subject of study in trying to understand imageability. These scholars are concerned with the psychological processes that underpin the phenomenon of imageability and many of them draw from Gestalt psychology – a subdiscipline that studies how people form, recognise, and respond to patterns. In this chapter, this section of the literature on imageability is referred to as being concerned with *identity*. Lastly, a comparatively smaller section of the literature looks at imageability as a socio-cultural phenomenon by which places attain an identity of their own (a sense of place) that transcends their physical structure and what is consciously perceptible in terms of identity. From this perspective, the elements that make up the image of the city are not merely artifacts with dimensions and arrangements that lend themselves to human cognition. They are not things to be seen but symbols to be understood, with the implication being that the same arrangements of urban elements may have different meanings in different contexts. This section of the literature is referred to here as being concerned with *meaning*. This thematic categorisation of the literature (in terms of structure, identity and meaning) is admittedly one of several possible ways to organise the literature on imageability and it reflects my own understanding rather than an objective universal truth about everything that has been written on the subject. However, as I hopefully demonstrate in the following discussion, this framework is useful as a means of arranging the more than 50 years of scholarly work on the topic of imageability into a coherent discourse that is layered rather than fragmented.

> "An imageable city is one whose landmarks, centers, districts, and routes are differentiated yet well-connected - forming a larger unit we can picture mentally, where we are well-oriented and can move about confidently without fear of becoming lost. Besides locating us in space, the truly imageable environment also positions us in time, providing an overall sense of historical roots, the present, and even of the future. At a deeper level, it allows its users to attach their own meanings to its parts."
>
> Southworth (1985: 52)

Lynch argues that "An environmental image may be analysed into three components: identity, structure, and meaning. It is useful to abstract these for analysis, if it is remembered that in reality they always appear together" (Lynch, 1960: 8). The above description of imageability by Southworth (1985) demonstrates the layered treatment of this concept in urban design literature after Lynch's book. At the most readily apparent level imageability is about the things that form the image of the city, the Lynchian elements that Southworth lists at the beginning of his passage. A place becomes imageable because of how these elements are "differentiated yet well-connected", because of its structure. The second interpretation of imageability is that it is a cognitive process, and this is demonstrated in Southworth's assertion that the structure of urban elements must form "a larger unit we can picture mentally" and that the result of this mental picture is a better sense of orientation. Finally, at a deeper level, imageability is understood to be a prerequisite for people to "attach their own meanings" to a place (although the literature is still not clear regarding the extent to which other phenomena play the same role). But why do urban design theorists present such a layered (and perhaps even fragmented) description of imageability? Given the breadth of such a description (encompassing physical form, user perception and symbolic meaning), why do other broad theories (such as Alexander's conception of the city as a semi-lattice) not align with Lynch's theory, even though they are supposedly

theories about the same phenomena, the urban environment and human perception? Why have such contradictions not been resolved in the more than 50 years since these ideas were first introduced? Lastly, why has such little attention been paid to the association between imageability and the meaning that users ascribe to places, even though there is consensus about the existence of such meaning and wide acceptance of the theory of imageability? This section attempts to make sense of these questions before proceeding to discuss *structure*, *identity* and *meaning* in more detail.

Carmona (2014) argues that "a reading of the literature on public space demonstrates how partisan and polemical much of it is, but also that particular views about public space—either negative or positive—are often espoused on the basis of remarkably little evidence, with the evidence that does exist sometimes distorted to fit a particular thesis" (Carmona, 2014: 2). It could be argued that, although urban design literature is characterised by an abundance of theories, there has not been any serious effort to establish a knowledge base for urban design and, as such, its theories "seldom amount to anything more than statements of beliefs put forward by leading practitioners and academics in the field" (Bahrainy and Bakhtiar, 2016: 29). Cuthbert argues that Without the foundation in social theory that would allow critical self-reflection to grow, urban design practice is dangerously near to becoming little more than a social technology – a veiled instrument for social control. To understand the relevance of this critique, we have to consider its basis and what urban design theory's "partisan and polemic" nature is being compared to. More broadly, the comparison is being made to other disciplines that use theory, with regards to considerations such as what constitutes a theory and what ought to be the relationship between theory and practice. However, more specifically, comparisons are made to scientific theories to consider the extent to which urban design theory constitutes a science; and the extent to which the treatment of theory in urban design through its application and validation in practice adds rigor to the theory. A theory is "a systematic explanation for the observations that relate to a particular aspect of life" (Babbie, 2016: 10). Rigor refers to "strict application of the scientific method to ensure unbiased and well-controlled experimental design, methodology, analysis, interpretation and reporting of results" (Cahill, 2021:50). In a provocative paper titled *Science, pseudo-science and urban design*, Marshall (2012) assesses the scientific rigor of three seminal urban design texts – including Lynch's (1960) *The image of the city*. He outlines four reasons why a discipline or its theories may be considered to be pseudo-scientific:

> "First, it may be disingenuous, fraudulent or deliberately manipulative, trying to pass itself off as science... Second, its underlying theories may be far-fetched or fundamentally implausible, flying in the face of known evidence... A third way of being pseudo-scientific is where the treatment appears to be scientific, where it may involve a method, approach or general mindset that 'appeals to observation and experiment', but which 'nevertheless does not come up to scientific standards... Fourth, a pseudo-science may be used as a sort of post hoc justification for a form of practice that could proceed even without the theory"
>
> (Marshall, 2012: 259)

Marshall (2012) concludes that the charge of pseudo-science, on the first two counts, is unfounded since urban design does not appear to be deliberately deceitful and its claims appear somewhat grounded. However, the discipline's treatment of theory is more pseudo-scientific (in terms of Marshall's third reason) because having a theoretical basis makes it seem as though the discipline derives its knowledge from observation and experimentation, whereas there is in fact very little validation and falsification of urban design theories and contradictory theories sometimes continue to exist alongside one another for decades. According to Sommer (2009) a professional or academic discipline's worth is that it advances and curates a critical body of ideas, distilling them into a variety of methodologies and approaches that question established assumptions and change practices. The purpose of theory in this regard is to enable the discipline's reflexivity by acting as a repository of the discipline's knowledge, memory, and experience whereby things happening in research, practice and training are made available to members of the discipline as a coherent body of ideas that they can critically engage with to determine the best methods for their practice (Bahrainy and Bakhtiar, 2016).

Thus, urban design may be considered pseudo-scientific in terms of Marshall's fourth reason as well. Through limited validation and falsification and by allowing contradictory theories to coexist, urban design now finds itself in a position where practice can proceed without theory or – more specifically to the situation in urban design – the discipline finds itself in a position where practitioners can choose whatever theory supports their current project and ignore the rest.

Some scholars lament urban design's nebulousness, describing it as "an ambiguous amalgam of several disciplines" (Inam, 2002: 35) while others argue that it is characterised by an intellectual "anarchy" because it lacks a theoretical core of its own (Cuthbert, 2011: 94), or they deride it as being excessively banal and orthodox, preoccupied with the timeless validity of its prescriptions rather than their broader social and environmental ramifications (Sorkin, 2009). For many of these critics the solution is to see urban design as a sub-discipline within something larger, such as: architecture (Koolhaas 1995); urban planning (Gunder 2011); urban studies (Arabindoo, 2014); or spatial political economy (Cuthbert 2006). However, other scholars see urban design's broad knowledge base, with its imprecise boundaries, as a strategic advantage and a deliberate effort to straddle and integrate different pre-existing silo-based disciplines (Bentley, 1998) and they argue, therefore, that there is no need for a distinct body of urban design theory. Given the breadth of the discipline's knowledge base "science has no monopoly on knowledge production in urban design" (Dovey and Pafka, 2016:7). Marshall, himself an urban design scholar, seems acutely aware of this reality in making his cautiously worded conclusion that "urban design is *at least in part* pseudo-scientific" (Marshall, 2012: 267). He argues that many of the foundational works of urban design are scientifically sound in and of themselves, but there has been a tendency to accept them blindly into the discipline's fabric without fully verifying their validity in other situations or against alternative hypotheses. The problem is not the extent to which urban design theory is broad but in the way the discipline decides what constitutes valid conceptions of urban design knowledge. The danger of such uncritical assimilation of externally derived knowledge is that urban design risks having theories being generated on its behalf by disciplines that have little regard for its core objective, the creation of good public places. Marshall's remedy for this is "not just for more and better science, but more specifically [for] more systematic verification and critical assimilation of scientific knowledge within urban design theory" (Marshall, 2012: 267). That is to say, "urban design needs to be fortified from within, rather (as others have argued) than effectively abandoning urban design to more developed knowledge fields outside the discipline which may have little to say about its primary preoccupation, how to better shape place for future use" (Carmona 2014: 3)

The above critique is prefaced on the notion that urban design should be scientific. Verna (2011), however, asserts that it is neither theoretically possible nor practically desirable for urban design to be a scientific discipline. He argues that urban design occupies a unique niche between physical science and the social **sciences** and that its flexibility and amorphousness are a necessary adaptation for managing the tension between these two modes of thinking: "the dialectical positioning of urban design within science and design suggests a preference for 'low theory' over 'high theory'" (Verna, 2011: 58). The ethos of low theory varies from that of high theory. It has a precarious relationship with its subject-matter and is contingent, complex, and imperfect. High theory, however, seeks certainty and law-like statements and, as a result, reduces its subject matter to the point of being emotionally empty. As with Marshall (2012), Verna (2011) determines that some parts of urban design knowledge have more in common with science than others but, unlike Marshall, Verna's prescription is to embrace the ambiguity of urban design knowledge, as an incomplete synthesis of low theory and high theory. Taking the middle ground between Verna (2011) and Marshall (2012), I argue that the objective should not be for urban design to be scientific but for urban designers to recognise and distinguish those parts of their knowledge that are scientific from those that are not and to treat them accordingly. From this perspective, urban design theory tends to present knowledge in a layered form because much of it is low theory, which "is not and cannot be empirical science but is based in the detailed observation of cities using multiple logics" (Dovey and Pafka, 2016:1). Thus, if some parts of urban design theory cannot be made scientific or be tested empirically, whereas others can, then the discipline's knowledge base

necessarily takes a layered form whereby some claims cannot be directly compared, tested against one another, or integrated and instead they may only continue to exist in parallel. However, a responsibility remains on the part of urban design scholars to identify those parts of urban design knowledge that indeed can be made more scientific – in the same vein as Karl Poper's *problem of demarcation*[4] – and to actively attempt to validate them against empirical experience. To this end, in the following sections I sift through the layers of urban design knowledge to find works that are comparable to Lynch's theory of imageability (either in terms of their subject matter, their scale or their methods of study) and consider if they form the same layer of urban design knowledge and the extent to which their claims can be compared and reconciled.

2.3.1 How do later theories relate to Lynch's imageability?

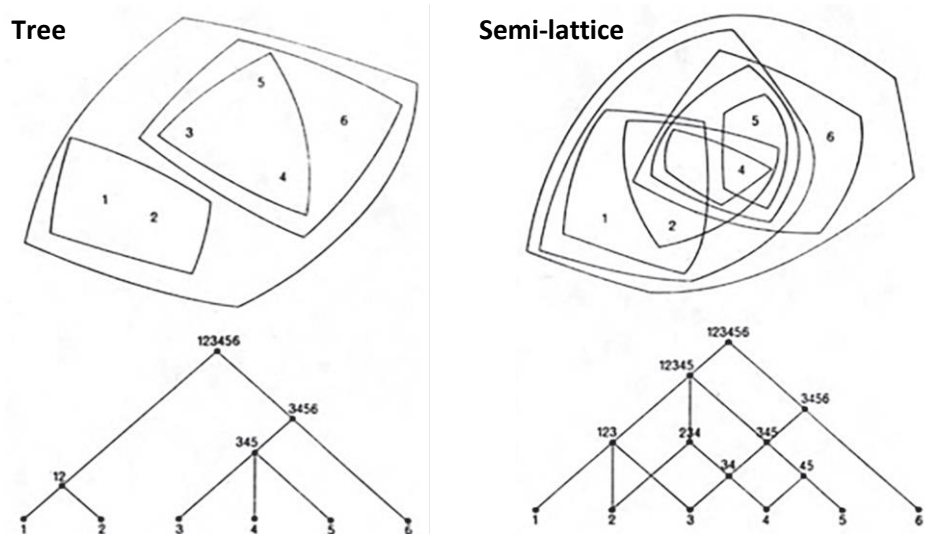
Urban design is often described as operating within a relatively modest scale, within a neighbourhood or even "between buildings" (Gehl, 2011: 15). Lynch's theory of imageability is thus comparatively unique in its scale. This may account, in part, for the paucity of directly comparable theories since – despite its widespread acceptance – Lynch's conception of imageability is beyond the scope of most urban design projects. Few other authors have attempted to posit theories at such a general scale and received a similarly prolific reception as Lynch. One of these is Christopher Alexander, who published two notable works that warrant discussion in this section: his essay, "A city is not a tree" (1965), and his book "A pattern language" (1977). In the former, Alexander theorises about the overall structure of the city and, in the latter, he organises the city into individual parts (which he calls patterns) and contemplates their meaning. However, these theories do not coherently link to Lynch's work or even make significant reference to it. Reading these two authors, the titular urban design student may be left with some questions: are semi-lattices more imageable than trees; does a good pattern language create more legible environments that are cognitively more fit to be recognised as nodes, landmarks, paths and so forth? Similar questions could be asked of Roger Trancik's (1986) three theories of urban design since they are broad enough to be comparable to Lynch's imageability and they also make claims that are specific enough to be empirically tested against Lynch's. In figure ground theory, Trancik describes the constituent parts of urban form as solids and voids; in linkage theory, he describes three types of combinations of solids and voids; and, in place theory, he describes the role that culture and social activity play in adding meaning to such combinations through symbols and spatial customs[5]. Thus, we may ask: are some urban elements – in Lynchian terms – made up of more solids than voids? Are some combinations of urban elements (linkage) more likely to result in lost space than others? How does the presence of lost space affect imageability? In both these cases, the result of a literature review is usually a layering of knowledge (where urban phenomena are explained from a Lynchian perspective or through Alexander's or Trancik's theories) rather than a consensus on the questions raised above, where there is potential for alignment between these theoretical perspectives. Moreover, the objective in presenting the following discussion of Alexander and Trancik's theories is not to bridge the gaps between them and arrive at a consensus as that task requires its own problem statement and fieldwork (that are beyond the scope of this research) and such an approach is arguably at odds with the ethos of a design profession – a discipline where knowledge has a heuristic value because it works even if we do not understand why it works yet (Verna, 2011). Instead, by discussing these theories in this chapter, I wish to demonstrate how urban design knowledge takes on such an unreconciled and layered form, before turning to theories that directly build on Lynch's thesis. The rationale for doing this is to develop an appreciation for design as something distinct from science, where it may be necessary to simultaneously hold two or more divergent versions of the truth while pragmatically working towards an acceptable final product or design.

[4] 'The problem of demarcation' is discussed in more detail in Chapter 4

[5] An example of a spatial custom could be if a society determined that there should not be noise or excessive activity near a religious site or, in the case of Diepkloof, if it is a trend that houses have a brick wall and an iron gate

2.3.2 "A city is not a tree" but "a pattern language" spoken by those who know "the timeless way of building"

Alexander (1965) distinguishes between two kinds of urban form: what he calls the "tree" and the "semi-lattice". The tree and the semi-lattice are both ways of thinking about how a large number of little systems come together to form a huge and complicated system. In a broader sense, they're both names for set structures. A set is a group of elements that we believe belong together for some reason (ibid). Insofar as everything that exists can, when looked at in detail, be seen to be composed of smaller parts, it could be argued that each set, in turn, comprises other sets. The city is no exception. Thus, for Alexander, "whatever picture of the city someone has is defined precisely by the subsets he sees as units" (Alexander, 1965:4). The distinction between a tree and a semi-lattice then, is in the units that compose these forms. More specifically, the distinction is that the semi-lattice is composed of overlapping sets whereas the tree is more restrictive in its structure. As seen in figure 3, a tree or semi-lattice's overall structure is determined only by the subgroups' selection. A semi-lattice is defined as a structure that fits specific criteria. It is referred to as a tree when it meets other more stringent requirements. Thus "[a] collection of sets forms a semi-lattice **if** and only **if,** when two overlapping sets belong to the collection, then the set of elements common to both also belongs to the collection" (Alexander, 1965: 4). However, "[a] collection of sets forms a tree if, and only if, for any two sets that belong to the collection, either one is wholly contained in the other, or else they are wholly disjoint" (ibid: 4). When we have a tree structure, it means that no unit is ever connected to another unit within that structure except through the medium of the structure as a whole. In figure 3, unit 3 does not overlap with unit 1, 2 or 12 and the only time they connect is at the very highest level (in 123456). Some contemporary interpretations of the tree/semi-lattice distinction have placed emphasis on how "artificial" tree-like environments and "traditional" semi-lattice urban forms differ in terms of densities, street network connectivity and land-use accessibility (Simons, 2021:1). From this perspective, the tree and semi-lattice are descriptions of integration in urban form more than they are descriptions of perception and experience, whereas Lynch's imageability places more emphasis on the latter.



(a) In a tree the units are either wholly contained within the set or they are wholly separate from it. For example, 1 and 2 belong to 12. Similarly, 1,2 and 12 belong to 123456. However, 3 does not overlap with 1,2 or 12 and the only time they connect is at the very highest level (in 123456).

(b) In a semi-lattice there is overlap between the sets. 3 features in all but one of the eight sets in this diagram.

If 3 was a land use or a mode of transport, it would be present in 80% of the city.

Figure 3 the distinction between the tree and the semi-lattice (after Alexander, 1965:3)

Alexander (1965) is dubious of the human cognitive capacity to grasp and accept complexity and argues that our tendency is to try and form a pattern. The patterns that we form are usually out of sync with the realities of how we would like to live because life is messy – perhaps messier than we are comfortable with seeing. As evidence of this cognitive limitation, he cites experiments by Sir Frederick Bartlett, where people were shown a pattern for a fraction of a second and then asked to redraw the pattern. The experiments found that many of the respondents, unable to comprehend the complexity of the pattern they had observed, simplified it by removing the overlap (Alexander, 1965). When confronted with a complicated organization, people have an innate inclination to cognitively reorganize it into non-overlapping components. The semi-lattice's intricacy is replaced by the tree's simpler and more intuitive shape. “You cannot bring the semi-lattice structure into a visualisable form for a single mental act. In a single mental act, you can only visualise a tree” (Alexander, 1965: 17). The problem faced by designers then is not unlike that faced by any other person attempting to comprehend a complex pattern since it is a problem of humans having limited cognitive capacity. Many places are designed as trees because “the tree” lends itself more readily to the human mind. This idea is further elaborated on in this book, *The synthesis of form*, where Alexander postulates that the reason why preindustrial design tended to create better products (including cities), even with more limited technology and resources, is precisely because of the multiplicity of technologies and methods available to contemporary designers due to the complexity that this abundance brings (Alexander, 1973). When faced with such complexity, it may be tempting to resort to simplification.

While Lynch’s (1960) *Image of the city* is by no means reductive, the conceptual framework that it introduces – with 5 distinct elements – lends itself to a simplistic interpretation. It may be tempting to think of a “node” as a discrete item that is separate from a “path” or a “landmark”. Paths pass through nodes and landmarks are located within nodes and along paths. There is overlap between the elements. Moreover, there are foundational connections between them since a node can draw its vitality and activity from the presence of a concentration of paths in or around it. Similarly, the character, distinction, and attractiveness of a node may be influenced by the location of landmarks within it. This tendency towards reductivism is not true of Alexander’s semilattice, which emphasizes overlap and makes no attempt to distil or categorise the units that make up a city. “Each unit in each tree... is the fixed, unchanging residue of some system in the living city. A house, for instance, is the physical residue of the interactions between the members of a family, their emotions, and their belongings. A freeway is the residue of movement and commercial exchange” (Alexander, 1965: 9). However, a tree includes relatively few such units, thus only a few of its systems may have a physical counterpart in a tree-like city. In such cities, thousands of critical systems are devoid of an overlapping physical equivalent that can support the residual meanings and functions of each system. The poverty of the tree-city takes the form of houses with no schools, shops with no resident markets and streets with no destinations along them.

In keeping with the garden symbolism of trees and lattices, Galle (2020: 360) argues that “a recurrent theme in Alexander’s writings is the metaphor of architectural and urban design and construction as the ‘unfolding’ of an embryo through a process of “differentiation” of (things in) space, involving what he later called ‘adaptation’”. Beyond the physical differences between tree cities and semi-lattice cities, Alexander’s conception of the urban development process (as unfolding) also suggests the role of time. Urban planners conceive trees as cities in part because they attempt to perform the mental effort of imagining a very complex system in a relatively short time. Historically, cities developed over decades and even hundreds of years. Most planners invariably fail in this endeavour because of the limits of human cognition. Yet, Alexander also rejects the modernist quest for simpler forms, famously championed by intellectuals such as Le Corbusier’s CIAM and the Bauhaus School of Design, because he is equally doubtful of the human ability to imagine beauty where none (or very little) exists. Whereas Bauhaus philosophy of functionalism censured ornamentation of buildings as a bourgeois concern (Trancik, 1986), and while Le Corbusier lauded the cube as the ideal form (what became known as the international style), Alexander argues that, for the most part, beauty and meaning cannot be created by removing material and simplifying form. Nor can beauty and meaning be distilled into a single ideal

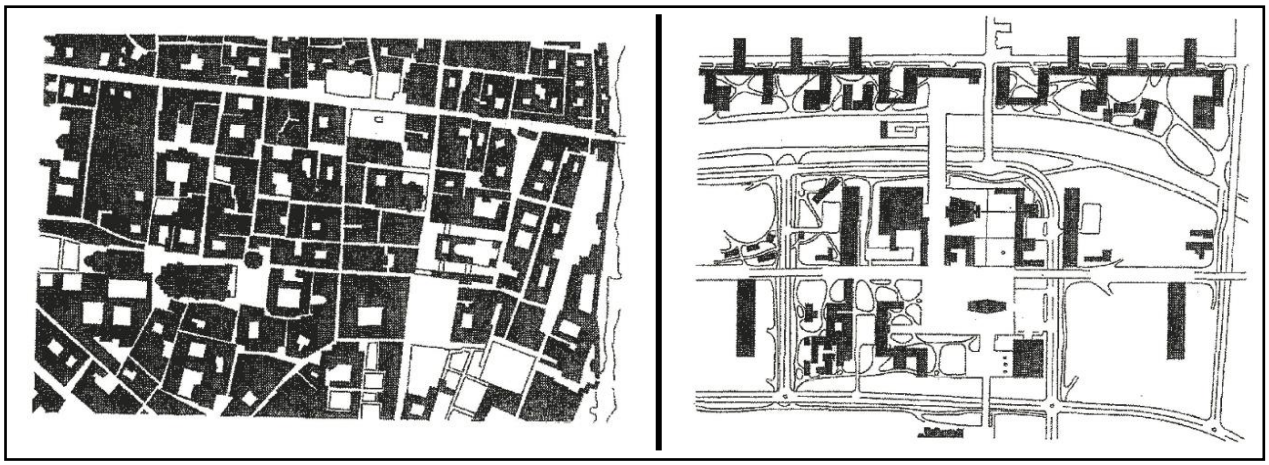
form. A decade after his essay[6], Alexander addressed the issue of cognition in his book "A pattern language", where he argued that the function and experience of places is informed by the patterns that make them up. The book presents over 1000 of these patterns. Here, the simple schematic descriptions of the semi-lattice form (fig.20, discussed earlier) are elaborated into broad examples of places, such as a shopping street (pattern 32) and the numbers in the semi-lattice diagram are patterns that can be fit together to form a set, such as a street café (pattern 88), a bus stop (pattern 92), row housing (pattern 38) and the neighbourhood (pattern 14). Not only is the ideal city (the semi-lattice) made up of patterns but the patterns themselves are made up of patterns. For example (if we consider the four patterns mentioned above), the shopping street, which is made up of a street café, bus stop and row housing, is also part of a larger pattern, the neighbourhood (pattern 14). A less charitable interpretation of Alexander's body of work, which I am presenting here for perspective, is that his faithlessness in people's cognitive ability, combined with his attempt to codify hundreds of possible environments into patterns, suggests that he is weary of the idea that the human mind can create and find meaning wherever it wants. Thus, he has proposed his own list of patterns to prescribe how others must live. However, Alexander was concerned by the fact that most people in contemporary societies do not build their own environments and they do not know how to. Moreover, the professions that build urban environments (for reasons discussed earlier in this chapter) do not have a rigorous body of knowledge about what ought to constitute a liveable place. Alexander's patterns were intended as a contribution towards the creation of such a normative basis for how urban places are designed and built, with the expectation that future designers would contribute to the vocabulary of patterns and that – through validation in practice – they would further clarify which patterns worked best in each context.

2.3.3 Trancik's theories of figure-ground and linkage

By far, Roger Trancik's most significant contribution to urban design theory was his 1986 book, *Finding Lost Space,* in which he described the causes of the urban fragmentation that characterised the downtown areas of many post-industrial cities. The book traces the origins of these lost spaces to the historical evolution of different architectural styles and artistic movements – such as functionalism (of the Bauhaus School) and De Stjyl – and to the work of influential practitioners such as Le Corbusier. As a remedy for and a preventative measure against lost space, Trancik (1986) puts forward three theories of urban design: figure-ground theory, linkage theory and place theory. The premise of figure-ground theory is that the urban fabric essentially consists of two (binary) components: solids, which are the built-up structures (mostly buildings); and voids, which are the unbuilt space. The theory argues that in good design the solids frame and give shape to the voids and that when such framing does not take place, the voids become lost spaces (fig.4). Lost spaces are defined as "the undesirable urban areas that need redesign (anti-spaces), making no positive contribution to the surroundings or users. They are ill-defined, without measurable boundaries, and fail to connect elements in a coherent way" (Trancik, 1986: 3) Linkage theory expands on the premise of the urban fabric being made up of solids and voids to consider how these two elements come together (how they are "linked") to form the urban fabric. Trancik (1986) identifies three kinds of linkages. Compositional form, the first, is how individual buildings and spaces are arranged in relation to one another at the most local scale. A simple example of composition is how the façade of a building relates to the space in front of the building in a way that both fulfils both the functional requirements of use (such as being able to enter the building and being able to guard the space) and the aesthetic requirement of the combination of the building and the space being pleasant to look at. The term composition thus refers to the sum of the two parts of the urban fabric, the building, and the space. From this perspective Trancik's (1986) critique of the lost spaces of modern cities is that they lack composition by either being so poorly shaped that they cannot perform their necessary social functions or by forming aesthetically unappealing or cognitively incomprehensible combinations of solids and voids. Compositional form is not strictly limited to a single building and a single space, but it often occurs as two or

[6] "A city is not a tree" (Alexander, 1965)

three buildings with spaces (and sometimes statues or landscaping) between them. Figure 5(A) shows an example of such compositional form in Michelangelo's Campidoglio.



(A) Parma, Italy

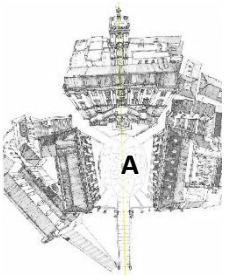
1. "buildings as elements in a generalized, highly connected mass… which defines the streets and squares"
2. "Buildings are generally low rise and of similar height. Taller buildings are exceptions, and usually have civic significance"
3. "The street pattern consists of a grid, the cells of which are relatively small"

(B) Saint-Die, France

1. Buildings are shown as "free-standing pavilions"
2. The urban fabric is coarse
3. The road network consists of very large (2-3 sq. km) "super blocks" and has low integration

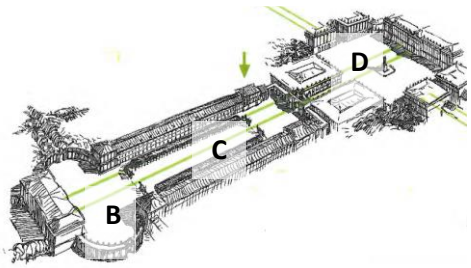
Figure 4: In (A) we see an example of figure-ground, where the buildings (solids) give structure to the spaces around them. (B) shows a neighbourhood designed on modernist principles, where buildings "sit" in space rather than framing it, consequently creating lost space (*Carmona et al, 2003: 62)*

Compositional form



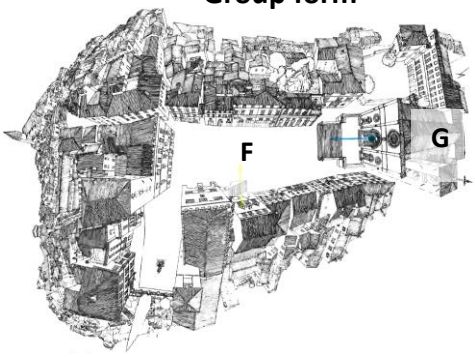
A group of buildings frame the spaces between them. The square (A) is the focal point of the composition from the public perspective but the courtyards are also compositions in their own right.

Mega form



A large building frames what seems like a single continuous space around it, creating an enclave. This is especially clear in (B), where there is a single building with colonnades extending around the space. In (C) two buildings frame a corridor but they are identical and symmetrical, acting as a single mega form building.

Group form



Group form is a combination of multiple instances of compositional and mega form. In the above image different sized buildings frame streets, courtyards and the large public space (F), creating multiple compositions. On the right, a large building frames an enclave (G), creating mega-form.

Figure 5 Three types of linkage, according to Roger Trancik's linkage theory (Bacon, 1967:)

The second type of linkage is what Trancik calls *mega form*. While the scale of mega form may be similar to that of compositional form, in this linkage type a single very large building is used to organize the space, whereas compositional form uses a group of smaller buildings. As such, mega form may be associated with the expression of power. A single entity, the building, shapes space in a manner traditionally associated with a group of buildings and potentially controls the activities of the people around it. Early examples of mega form can be seen in the Baroque architecture of the renaissance period, where large palaces and temples seem to have dominion over large amounts of space (fig. 5). More contemporary examples of mega form may be seen in government buildings, such as the Union Buildings in Pretoria. In the Johannesburg context, shopping centres are an even more ubiquitous application of mega form (fig. 6). In such cases it can be argued that, rather than an expression of power, the structure of the shopping centre employs mega form as an exertion of control, by restricting access and confining movement to the internal spaces of the building. It should be noted that the exaggerated scale of shopping malls is a historical outlier that would have been infeasible in societies without cars. Buildings such as shopping centres (especially large ones) exceed the scale of compositional form and conventional mega form. They functionally act as streets rather than buildings. From this perspective, linkage theory argues that very large buildings such as shopping malls create lost space because it is impossible for a single building to organise large amounts of space. Since any building has a limited amount of surface area that can act as street frontage (and a portion of its perimeter must be the back, to be used for more private functions), freestanding mall structures necessarily turn their backs on some spaces around them thereby causing them to be lost spaces. In addition to this, the functional objectives of shopping malls, as securitized commercial spaces, contradicts the requirement for effective mega form that characterise historical examples, such as palaces and public buildings, which have long well-adorned frontages. Thus, except for public buildings – which do not have a back, by virtue of their public status – mega form is ill-suited for application at a large scale.

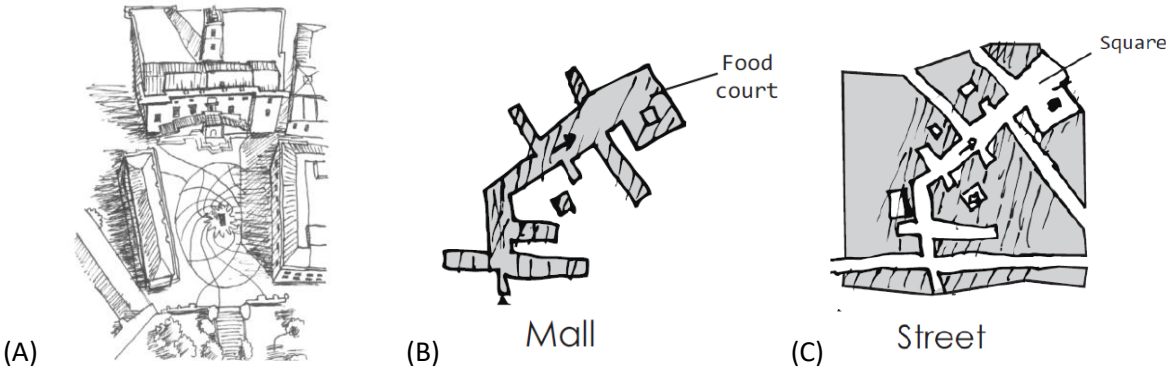
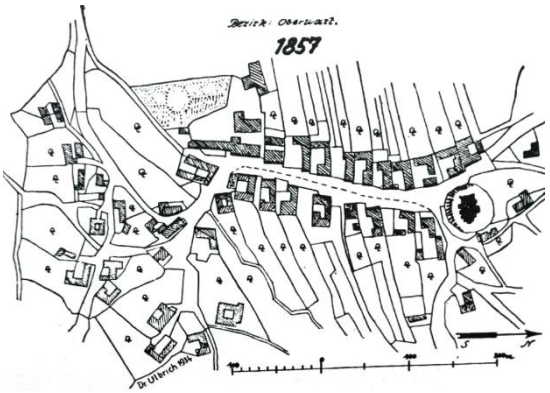


Figure 6 (A) Michelangelo's Campidoglio uses the buildings, the square, a statue, and a pattern on the ground to form the composition (Bacon, 1967) (image by Author); (B) The mall (shopping centre), as an example of mega form, is in fact an inversion of the street (C), which is an example of group form (Msingaphantsi, 2015: 41)

The third type of linkage, group form, is how space is framed at the scale of the street and the district. Fig. 6 shows how a shopping mall has the same fundamental structure as a street, with two exceptions: (a) in the mall space is organised by a single enormous building whereas in the street numerous groups of buildings (compositions) work together to organise the space; and (b) in the street the focal point – the space being organised by the buildings – is public space and it is external but in the mall the focal point is internal to the building which results in the spaces outside becoming lost space. Group form is the type of linkage employed at the largest scale – what could be called the urban scale – and it encompasses both compositional form and mega form within it as groups of buildings are arranged together along channels of movement (Fig. 7).



Japanese village - Trancik (1986)



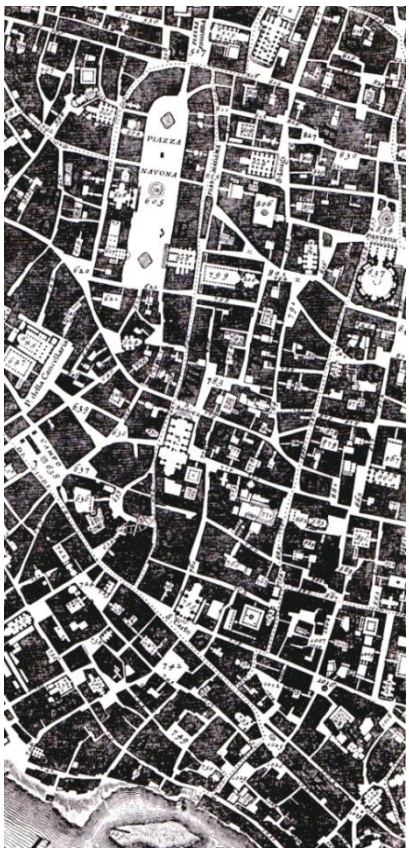
Scandinavian village - Gutkind (1965)

Gutkind (1965) postulates that the premodern form of towns, with its characteristic focus on channels of movement, was influenced by the demands of agrarian societies. In this image of Mariasdorf (Austria) long narrow plots of farming land permeate from the cluster of buildings along the main road. This suggests that what Trancik describes as "Group Form" may have been a natural adaptation to balance urbanization with the need to preserve agricultural land close to urban centres to ensure self-reliance in a time before modern logistics

Figure 7: The agrarian origins of group form (Gutkind, 1965: 118) (Trancik, 1986: 109)

Although Trancik's (1986) *Finding Lost Space* has had a substantial impact on urban design literature (with more than 1700 citations on Google Scholar[7]) most subsequent authors have given attention to Trancik's figure-ground theory than his other two theories. One possible explanation for this trend is that Trancik is often cited as the basis for site analysis studies, for identifying lost spaces, rather than as a basis for design intervention (Hebbert, 2016; Eu and Jen, 2018; Huimin et al, 2019; Jordan and Syafitri, 2021). Figure-ground theory is well suited for this task because of its emphasis on mapping – especially the use of Nolli diagrams (Eu and Jen, 2018) – which allows designers to view the urban fabric from a perspective similar to the medical use of X-rays, to identify spaces that are excessively large or poorly shaped (fig.8). However, an exceptionally small amount of the literature investigates the hypothesized relationship between channels of movement and prevention or repair of lost space, which is described in linkage theory. This suggests that theory is more often used as a means of analysis than as a guide for intervention. However, this discrepancy may also reflect the tendency for urban design problems (and theories for seeing and explaining problems) to be published in academic journals whereas urban design interventions tend to be exhibited or submitted in project proposals.

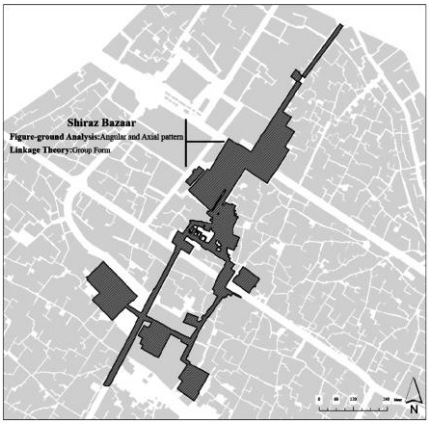
[7] 1784 citations; but this is still very small when compared to the Lynch's (1960) *The image of the city*, which has 24044 citations (checked on 2021-10-12).



Giambattista Nolli's map of Rome, Italy (1748) (Trancik, 1986: 99)



George Town, Penang, Malaysia (Eu and Jen, 2018: 214)



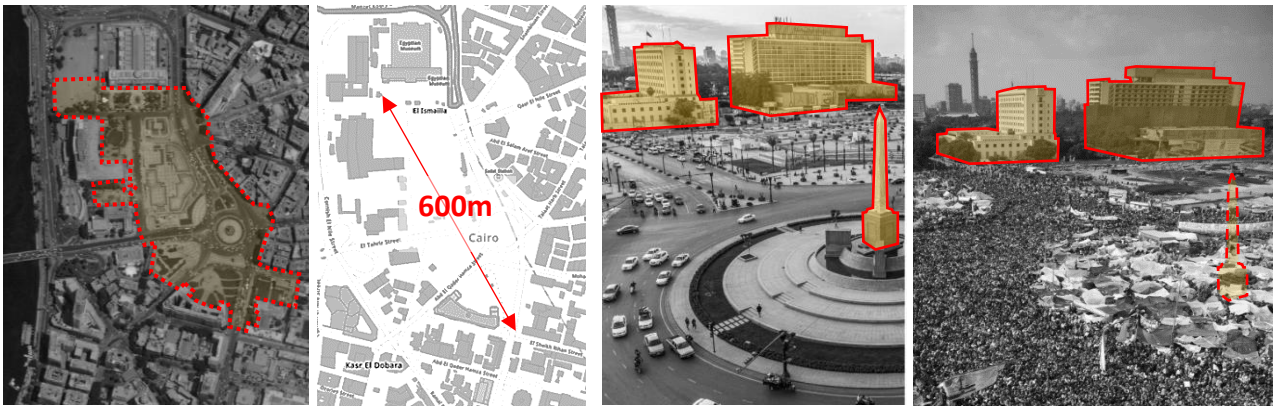
Shiraz, Iran (Lak and Hakimian, 2018: 214)

The emphasis on mapping in figure-ground theory allows for an anatomical ("X-ray") approach to urban environments. Designers can evaluate how parts of the urban fabric fit together.

Figure 8

From an ontological perspective, if Lynch and Trancik's theories describe the same phenomenon (urban form), there are some salient points where it is reasonable to expect overlap between the theories but there are few examples of this in the literature. Trancik (whose book was some two decades after Lynch's) merely cites *The image of the city* as one of the influences of his Place Theory and describes the five Lynchian elements. Given the title of Trancik's book, the most obvious question may be: if some spaces are lost, to whom are they lost or from whose perspective are they lost? There are countless examples of spaces whose morphology qualifies as lost space when looked at from the perspective of figure-ground theory and linkage theory, but which nonetheless are given structure by cultural or aesthetic practices (such as planting trees) or by the social activities that happen in them. For example, Tahrir Square in Cairo (fig.9) is an enormous space with a 600m diameter[8] that cannot be appropriately framed by the buildings around it. Figure ground analysis shows that this is a lost space. However, the character of the space was completely altered in 2011, during the "Arab Spring" when large crowds gathered in the space. Besides changing the content of the space (the void), by filling it up with crowds (solids) and making it feel less empty, this event also suggested that there are functional and perceptual dimensions to the space (its purpose and meaning) beyond its morphology. This is a rather drastic example, but it demonstrates the role that the presence of people and the purpose attached to a space may play in determining whether it is a lost space, beyond its physical dimensions. In this regard, the theory of imageability could provide a different interpretation of large oddly shaped spaces by considering how they are perceived by their users.

[8] 600m at its longest part



Tahrir Square (Cairo, Egypt) is too large to be effectively framed by the buildings around it. From a figure-ground perspective, it should be a lost space (After ESRI, 2021)

During the "Arab Spring" (2011) the occupation of Tahir Square by large crowds changed the perceptual experience the space's enormous size (After Middle East Eye, 2020)

Figure 9 Tahir Square (Cairo, Egypt)

Another example of the potential overlap between imageability and Trancik's theories can be seen in a study by Lak and Hakimian (2018). In their application of Trancik's linkage and figure ground theories to Iranian Bazaars, they recognise the perceptual qualities of these spaces, but they do not make an explicit theoretical connection between how these qualities are measured and how the presence of symbolic meanings or cultural associations relate to the morphological qualities that are measured in their mapping. There are three other potential links between imageability and Trancik's theories, which again have not received adequate treatment in the literature. The first is the relationship between linkage theory and Lynch's conception of paths. Since linkage theory proposes group form as the ideal linkage type for streets, is there a correlation between presence of group form along a street and the likelihood for that street to be recognised as a path in cognitive maps measuring imageability? The second point to consider is the relationship between Trancik's concept of the mega form (a large building that organises the space around it) and Lynch's concept of the landmark. Does mega form correlate with buildings being perceived as landmarks? Finally, epistemological comparisons could also be drawn between Lynch and Trancik in their respective approaches to studying morphology and perception. Lynch's approach begins by asking what people perceive and then, using cognitive mapping, arrives at his categorisation of urban elements. However, Trancik begins with a study of the urban fabric (the study of solids and voids), in his figure ground theory. Then he proceeds to consider how movement at different scales connects these elements of the urban fabric, in linkage theory. Then, finally, in place theory he considers how meaning is added to space through cultural practices, symbolism and aesthetics. For both authors, space exists first and its structure shapes human perception but their approaches to study this process proceed from opposite directions – either perception first... or form first.

The absence of explicit theoretical links in the literature does not necessarily prove that designers are unaware of the relationship between perceptual theories and physical theories of design. They may accept it as a forgone conclusion that such a connection exists and they do not see the need to test its validity, instead opting to test out the application of a design solution based on a combination of perceptual and physical theories – regardless of the validity of such a combination. From this perspective, the content of theories is validated based on whether it produces a design that works rather than its logical coherence or its alignment with other theoretical claims. As discussed above, this weak theoretical alignment and lack of validation weakens urban design's scientific rigor (Marshall, 2012) but it may also allow designers to be more pragmatic and experimental in their practice (Verna, 2011). Surprisingly, Roger Trancik himself makes little reference to his theories despite having continued to be a practicing designer and a professor for decades after publishing his seminal book. He did not publish follow up articles or validation studies of his theories, despite their proliferation within the literature. His plan for Yates County (New York State, USA), which was published a

mere four years after his book, makes no reference to his theories (Trancik 1990). Again, I would argue that this points to the absence of a culture of theory validation in urban design scholarship; as well as, perhaps, an implicit expectation that design work should be experimental and pragmatic – without the dictates of theoretical suppositions – even when it is performed by an acclaimed design theorist. Kevin Lynch also continued to publish and practice extensively after writing *The Image of the City* but his work branched off to other topics such as site planning (Lynch and Hack, 1984) and developing a general normative theory of good city form (Lynch, 1981).

Christopher Alexander is a notable exception to this trend of theory becoming separate from practice since there is a consistent logical thread between his publications and his practice. In *Notes on the Synthesis of Form* (1973) he describes what may be considered the problem statement of his body of work: that the abundance of methods and resources in contemporary society creates a computational problem for design (not just in architecture but also in fields such as textile design, for example) because it is difficult to determine what combinations of elements and methods fit together and which contexts, they are appropriate for. In *The Oregon Experiment*, Alexander et al (1975) use the University of Oregon campus (in Eugene, Oregon, USA) to test their hypothesis that it is possible to organise a design process that allows a community to plan their own environment by capitalising on the abundance of ideas, methods and resources while codifying these ideas and methods to negate the confusion that may result from their profusion. This "experiment" culminated in Alexander's two best known publications, *A Pattern Language* (1977) and *The Timeless Way of Building* (1979), which organise different ideas and methods of design for architecture and urban planning into a set of patterns and propose a general normative theory of how to arrange these patterns in the "timeless way" that precedes the confusion of contemporary architectural practice and hopefully addresses what Alexander sees as the discipline's theoretical bankruptcy. Despite this relatively strong internal validity, it could be argued that Alexander's body of work lacks external validity and, in this regard, exemplifies another trend in urban design theory that also undermines the discipline's theoretical rigor insofar as insufficient connections are made to other contemporaneous theories. For example, despite the potential overlaps discussed above, Alexander's major works do not cite Lynch's work. In this way, Alexander is comparable – albeit to a very limited extent – to many urban design practitioners who may attain professional success and proliferate their ideas through their practice rather than by publishing their work in an academic platform where they are presented coherently and open to critical reflection. Such practitioners may present portions of their work on websites, in public participation forums and even at conferences but, because of the nature of such platforms, the emphasis of these presentations is often on the "product", how it is implemented in practice and how it works after construction rather than the idea behind the project and its relationship to the wider theoretical frameworks within the urban design discipline. For example, Douglas Farr (founder of Farr Associates Architecture and Urban Design, Inc.) is the vice chair of the Congress of the New Urbanism (CNU), which is the intellectual counterpart of Le Corbusier's CIAM. His firm has undertaken myriad urban design projects and received many awards from their work (Farrside, 2021). From these two positions, it could be argued that Farr has significant influence on urban design ideas despite not primarily working in the realm of theory[9].

The discussion above points out two major reasons why urban design knowledge tends to be layered rather than theoretically integrated. The first reason is that the urban design discipline does not place high value on the process of validating theories and subsequent authors have a tendency of relating their work to only a few previous works, without attempting to reconcile their ideas with other existing theories in the field. Urban design tends to view knowledge as a heuristic for identifying urban design problems (in site analysis) and deriving solutions to them (in design). Rather than seeing knowledge as an objective universal reality with a high external validity, this heuristic view of urban design knowledge is more pragmatic: a good theory is one

[9] Doug Farr and Christopher Alexander are inadequate examples of this trend of urban design scholarship being separate from practice because we are nevertheless aware of them by virtue of the fact that they made considerable attempts to publish work from their practice.

that does the work; one that identifies problems on a site and guides the development of design solutions that work when implemented. The second reason why urban design knowledge tends to take a layered form is the separation of theory and academic scholarship from practice. Not all urban design ideas take the form of theories, in the strict sense of the word. Many influential ideas exist as design precedents and professional conventions that may be widely disseminated and popularly accepted but are nonetheless never presented in a discursive format that can be readily related to existing theories and critiqued based on their theoretical rigor. Furthermore, a large amount of design knowledge is not produced by design theorists but by practitioners who may put considerable effort into refining their ideas and methods but nonetheless never attempt to formulate these as theories, perhaps because of a fear of becoming dogmatic and overly prescriptive. Thus, although Lynch's theory of imageability has had widespread influence in urban design literature, many potential areas of overlap with other major theories in the field (and their implications for practice) remain unexplored. The background of this chapter has already discussed the enormity of Lynch's influence across several disciplines. Thus, the objective in this section was not to describe every comment that has been made on his theory of imageability over the decades, although the sections below will provide a more detailed discussion of how the concepts of *structure*, *identity*, and *meaning* (as aspects of imageability) have been conceptualised, represented and sometimes measured by later authors. Similarly, the overarching argument in this section (that Lynch's imageability fits somewhat oddly with other theories about urban form and about its relationship to human perception) does not discount the currency of Lynch's theory but, rather, comments on how urban design theory tends to create layers of knowledge rather than critically synthesizing and assimilating ideas.

2.4 CONTEMPORARY APPROACHES FOR MEASURING IMAGEABILITY

One of the consequences of the theoretical shortfalls discussed above is that the concept of meaning (as a dimension of imageability) is ubiquitously accepted as a critical part of the urban environment but is simultaneously also less explored in studies of imageability, when compared to structure and identity. The third claim of Lynch's theory of imageability was that imageable places create a sense of emotional security and an intensity of human experiences. The inverse is also true, and people can project their own preconceived meanings to the image of the city: "Every citizen has had long associations with some part of his city, and his image is soaked in memories and meanings" (Lynch, 1960: 1). Lynch (1984b) was critical of how later studies (and the application of his work in practice) focused on the environment and did not consider how people saw, experienced, or remembered it. So, why is meaning so small, even though Lynch himself considered meaning to be an important aspect of imageability? The most likely explanation is that we know so little about the physical city relative to the human capacity to derive meaning. What set of questions could we ask about meaning without the risk of generating innumerable false positives? We must begin from testable hypothesis. Urban design is not short of claims about meaning but these are sporadically scattered within the literature, with too few connections between them to form a theory (Norberg-Schulz, 1979; Madanipour, 1996; Nas, 2011). Many of them rely on anecdotal evidence, based on detailed observations and common-sense expectations of human nature, rather than experiments (Dovey and Pafka, 2016). At most these claims can be considered principles rather than theories about meaning. The difference here being that it suffices for a principle to exist if it successfully guides practice whereas a theory must explain the relationships between phenomena or between concepts (Babbie, 2016). I argue as the rationale for the present research project that it is necessary first to establish a rigorous foundation of knowledge about the physical structure of urban environments and its relationship to human cognition in order to clarify the appropriate path for effective research into how people attach meanings to places. This rationale seems to be in keeping with literature on contemporary approaches for measuring imageability, whereby most measures describe the structure of urban form and the next largest group of approaches describe human cognition but relatively few approaches propose a way to measure meaning.

Since cities are physical entities, one dimension of imageability necessarily entails their physical structure. In an imageable environment the myriad things (shapes, colours, sizes, and arrangements) that compose that environment evoke a vivid image in the mind of the person experiencing the environment (Lynch, 1960). At this level imageability seems to be about a generalized impact that the sum of the environment has on the human psyche. This is the sense in which imageability is understood in Gehl's (1987) analysis of the experience of *sense of place* in the public squares of old Italian towns. Rather than any one physical feature, he argues that the imageability of these spaces is the result of their having a sense of place: what he describes as "an unforgettable total impression" (Gehl, 1987: 183). Notably, for Gehl (1987) the ingredients for making such places are relatively vague and perhaps even completely abstract. He speaks about the "life" in the spaces, the "climate" of the space and the architectural "quality", without establishing an objective rather than subjective or artistic standard of quality (ibid: 183). For Gehl (1987) imageability is essentially a measure of how memorable a place is, and the creation and recollection of memories is not necessarily linked to any one physical feature. This notion is at odds with the importance placed on landmarks by Lynch (1960) and by later authors, such as Rousell and Zipf (2017). Proponents of the space syntax approach are among the most notable detractors from the holistic conception of structure. While still recognising the role of topology (that the whole is more than the sum of its parts), this computer-based approach reduces the environment to a few key elements (lines, points, and configuration).

2.4.1 Space syntax as a measure and representation of imageability

Space syntax is a set of theories and techniques "for the representation, quantification and interpretation of [the] spatial configuration of buildings and settlements" (Hillier, Hanson, and Graham, 1987:363). It describes "what degree of choice each space represents for its immediate neighbours as a space to move to" (Hillier and Hanson, 1989: 109). In urban design this form of analysis is performed by modelling settlements (or parts of them) as a set of lines and points of intersection between the lines (nodes). This creates a framework in which the "topological properties of degree, closeness and betweenness are usually computed employing a dual graph representation, wherein street segments are represented by vertexes and junctions by links" (Filomena, Verstegen and Manley, 2019: 16). Thus, a space syntax model has three components: lines, points, and configuration (fig.10) (Lee, Yoo and Seo, 2020). Such a model can be used to describe the relationship between external space and social phenomena (Filomena et al (2019). The most common application of space syntax in this regard is the use of the number of intersections on a street to calculate its *integration* into the urban fabric and thereby describe the extent to which pedestrian activity is likely to occur along it relative to other streets in the area (fig.10) (Paksukcharern, 2006). However, there have been attempts to use space syntax to describe more visual qualities of urban environments, such as imageability. This section will discuss two key developments in space syntax theory with regards to describing imageability. The first is Dalton and Bafna's (2003) model, which adds polygons called isovists to the geometry of space syntax models and uses them to account for the visual qualities of urban environments. The second development Is Jiang's (2013) assertion that space syntax must account for *the scaling law of artifacts*, whereby concentrations of elements are fewer than dispersions. Therefore, cores or places with high integration (as shown in fig.10) are always fewer relative to their wider context.

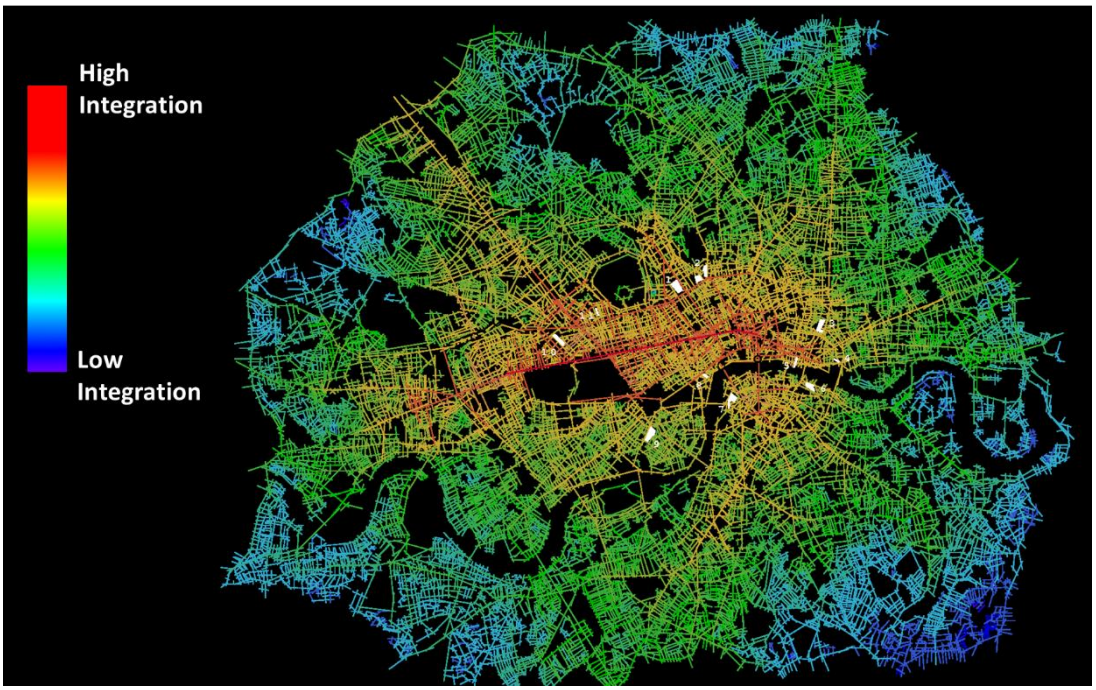


Figure 10 Space syntax analysis of London (United Kingdom) showing high street integration in urban core (after Paksukcharern, 2006)

Kim and Penn (2004) found that the ability to form mental representations is significantly impacted by the street layout and configuration of an area, which are the two spatial elements that space syntax is concerned with. What sets space syntax apart from the intuitive expectation that a long street is likely to be easier to recognize (and therefore more imageable) is the fact that this analysis does not only consider the properties of the street itself (the line) but also considers that street's relationship to the overall network (its configuration) (Filomena et al, 2019). To use space syntax to represent Lynch's five elements Dalton and Bafna (2003) adapt the space syntax framework of lines, points, and configuration by adding *isovists*. The addition of isovists is necessary because traditional space syntax models present a flat plane and thus do not account for the vertical dimension of space (Benedikt, 1979; Morello and Ratti, 2009). Put another way, people see in three dimensions, but conventional space syntax maps are only two dimensional. An isovist is the volume of space that can be seen from a vantage point in space, together with a specification of the location of that point (Morello and Ratti, 2009). The use of isovists thus adds a visual dimension to how imageability is understood in terms of space syntax (fig.11).

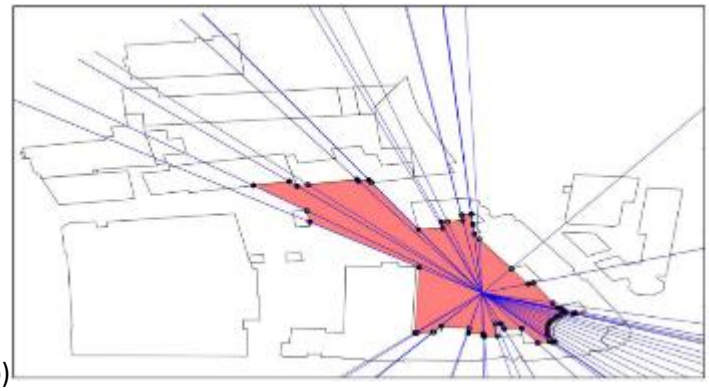
(a)  (b) 

Figure 11 Isovists are polygons that represent field of visions. They are used in space syntax to emulate and quantify the experience of walking in urban environments, by mapping the termini of sight lines. In image (b) the visual elements, shown as dots, are made significant by the structural elements, the configuration of the buildings, shown as the red space. These structural elements are more ubiquitous and may often be overlooked when considering imageability (Yin and Carswell, 2013: 148)

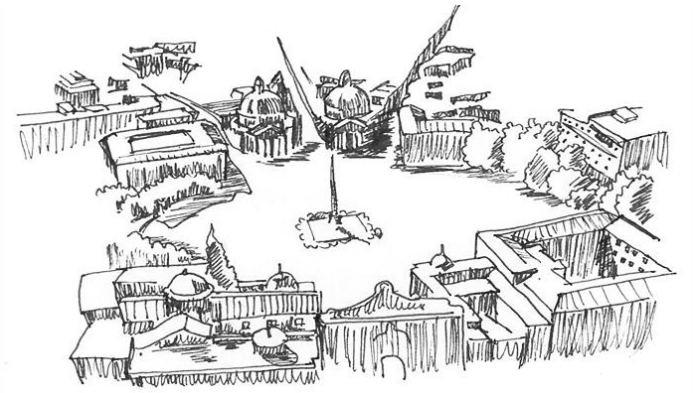


Figure 12: From the perspective of structure, imageability is determined by the shape of the physical environment and the arrangement of urban elements (by author)

Dalton and Bafna's (2003) adjusted model, which includes isovists, determines that imageability is predicated on two categories of urban elements: a set of first order (spatial and structural) elements and a second order set of visual elements. The ordering of the elements in this model is significant. The spatial and structural elements are more numerous, and they give shape to the mental representation whereas the visual elements (the vantage points) are fewer, and they serve to enrich the image. Thus, although an imageable place may be associated with its visual qualities (2nd order elements), their impact is grounded in their location within the broader structural (1st order) elements of the place (fig. 12). This is consistent with Jiang's (2013) conclusion that settlements tend to contain more less-connected streets and fewer well-connected streets, even though the latter are more closely associated with imageability. This is the case even in highly imageable places (ibid). Similarly, there tend to be more *visual landmarks*, which are small and dispersed throughout a settlement, and fewer *structural landmarks*, which are large and have prominent locations (Jiang, 2013; 2017). This phenomenon is referred to as *the scaling law of artefacts* (Jiang, 2011).

> "Scaling, in the context of geography, implies that there are more small things than large things, or far more low-density locations than high-density locations" (Jiang, 2013: 1553).

The fact that elements associated with imageability are always in the minority suggests the importance of context in creating the necessary conditions for imageability to occur. Increasing the number of landmarks or nodes for instance may not necessarily result in a more imageable place. Instead imageability may be more significantly affected by how these elements fit into their context and how they relate to it (by, for example, being larger or more articulated than other elements in the context). The main criticism against the application of space syntax in studying imageability is that it represents the environment as a flat plane (by excluding metrics such as building height) and it neglects the impact of land use (Ratti, 2004). This is addressed by isovists in Dalton and Bafna's model. Another criticism is that space syntax only partially represents the phenomenon of imageability. Jiang (2013) distinguishes between two approaches to the study of imageability and argues that one approach looks at the city, to see what urban elements constitute imageable places, whereas the other looks at the human mind, to understand the cognitive processes that allow people to form an image of a place. From this perspective, cognitive mapping (the method used in Lynch's (1960) studies) tells us some insights about what is happening in the human mind and how it relates to the physical environment, but it is not an accurate representation of either human cognition or the physical environment. In comparison, space syntax is a highly accurate representation of the physical environment, but it does not have a strong basis for explaining spatial cognition. For example, space syntax cannot account for why some urban elements tend to have an exaggerated significance in the image of the city, relative to their real size and coordinate

positioning, which is a phenomenon observed in studies of cognitive mapping where respondents were noted to place more emphasis on places and urban elements that they are familiar with (Blades, 1990). Lastly, space syntax software is ultimately an unautomated instrument for measuring space and depends on human interpretation to give meaning to the patterns generated by its maps. For example, space syntax can show if a street has high integration (fig.10) or that a square has a large isovist (fig.11) but human interpretation is still needed to determine if the street is a significant path or if the square is a node.

2.4.2 GIS-based cognitive mapping

Several studies have explored the potential for generating maps to represent imageability using automated computer models, instead of the conventional method of cognitive mapping which relies on participant interpretations of the environment (Raubal and Winter, 2002; Elias, 2003; Winter, Tomko, Elias, and Sester, 2008; Rousell and Zipf, 2017). These studies draw on Sorrows and Hirtle's (1999) definition of landmarks, which differentiates three kinds of landmarks: *visual landmarks*, used as reference points; *cognitive landmarks*, which are notable to the observer because of their meaning or rare occurrence; and *structural landmarks*, which are significant because of their prominent location. The Filomena model is an example of a computer-generated cognitive mapping approach. The model is based on Lynch's original 1960 cognitive map of Boston. Using GIS maps of the city, the researchers developed an algorithm that can identify the five elements of Lynch's cognitive map by using quantitative operational definitions of each element. These definitions are based on aspects such as distance, centrality, size, connectivity, and continuity (Filomena et al, 2019). Figure 13 compares a map of Boston (MA, USA) produced by Filomena et al (2019) to one produced by Lynch (1960) through his studies of cognitive mapping. There are remarkable similarities, despite the very long period between the two studies and the associated morphological changes that are likely to have taken place.

Much of the theory informing the Filomena model makes the same prepositions as those already discussed in the preceding sections of this chapter, particularly those raised with regards to space syntax analysis. However, one operational definition is of particular interest for the purposes of my research. Filomena et al (2019) argue that, when a neighbourhood has low legibility (when it has many repetitive elements and few distinct ones, the continuity of paths plays a significant role in the occurrence of imageability.

> "In low-legibility contexts, when a path is not characterised by vivid activities or peculiar properties, perceptual continuity comes into play: people rely on this functional quality to successively travel across the city. The concept of continuity recalls the idea that people tend to choose routes that minimise angular change rather than distance. In this sense, angular betweenness is described as the best predictor of pedestrian and vehicular movement when only the street network is at disposal of the researcher… major paths are those which minimise angular change in travels across the city" (Filomena et al, 2019:16).

Differences in methodology limit comparability between the Filomena model and the Ewing model. Because the Filomena model relies on GIS to measure imageability, its application is city-wide or neighbourhood wide, as elements are evaluated in terms of their relationship to one another. Thus, the measure is more topological, describing Lynch's 5 elements in relation to one another and to the overall context, rather than giving a measure of the imageability of any one place. Given this, the output of the Filomena model is a map, similar to Lynch's (1960) cognitive map, whereas the Ewing model produces a score for a single particular element, the path. As such the Filomena model cannot be used to calculate correlation between imageability and pedestrian behaviour since it does not quantitatively rank the imageability of different parts of the city.

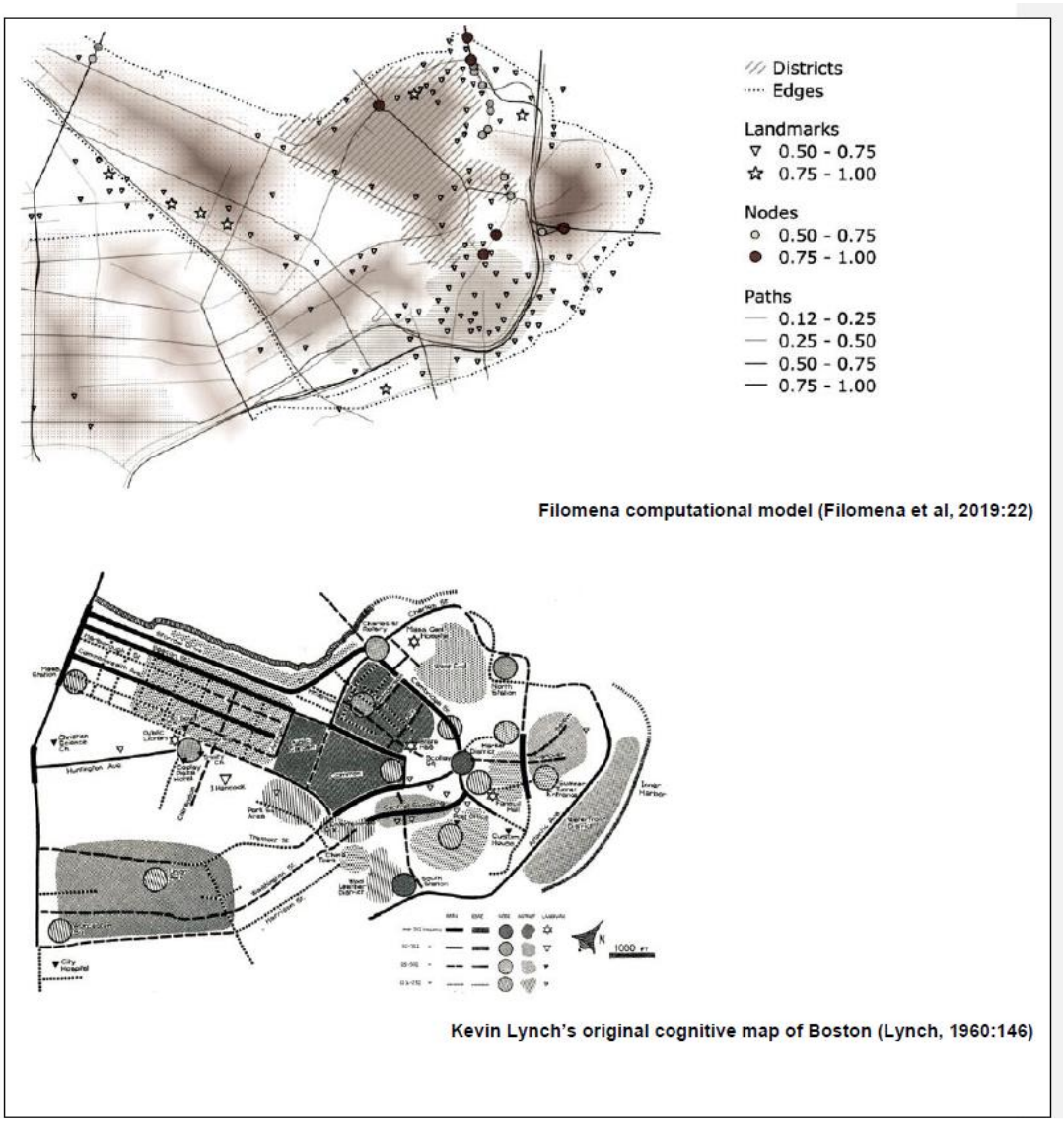


Figure 13: When compared to Lynch's 1960 cognitive maps, the Filomena model has three key characteristics (a) a larger number of landmarks, (b) fewer nodes, and (c) a less differentiated but more connected path network.

A notable limitation of the Filomena model is that, when compared to conventional cognitive mapping techniques, it lacks the hierarchy of urban elements that would be expected, based on Scaling Law and Hirtle and Sorrow's classification of landmarks (discussed above[10]). It has a larger number of paths, nodes and landmarks when compared to Lynch's (1960) cognitive maps. This suggests that the model overestimates the significance of certain urban features that may not necessarily possess the qualities to make them significant or memorable when viewed by pedestrians. A computer's ability to identify a feature on a map as a path depends on the parameters set by the researchers as part of the definition of "path". Thus, for example, if there are no additional parameters to further narrow this definition, then the pool of features identified as paths is likely to be larger than it would be with a narrower definition. However, when cognitive maps are drawn by people, they may consider the length and size of a street as well as frequency of use, in determining that it is a path worth including in their sketch. They may also consider experiences of the space, something that may have more to do with land use rather than the path itself. Perhaps this may explain the tendency in Lynch's map for paths to coincide with districts (fig.13).

Haung et al (2021) present an alternative GIS-based approach for cognitive mapping and attempt to correct for the shortcomings discussed above by using social media as an indicator of meaning. By using Location-

[10] It also contradicts the *information approach*, which is discussed in 2.3.5 below

tagged images, Text-Mining, Image Processing, Clustering Analysis, Kernel Density Estimation, and Sentiment Analysis they created a model that associated places with people's perceptions of them as reflected on social media. The model describes landmarks as places associated with "Instagramability, the frequency of a place captured on Instagram", and nodes as being places that are associated with, "Twitterability, the frequency of a place mentioned on Twitter by name" (Haung et al, 2021:1) (fig.14). Districts were identified using density-based clustering, which grouped nodes according to the spatial relationships to form districts. Paths were measured by the density of mobile phones detected along them by using GSM[11] density (admittedly, there are gaps in this research methodology as it exclusively considers people travelling with mobile phones) (ibid). Edges, on the other hand could not be identified and they were also found to be absent in social media.

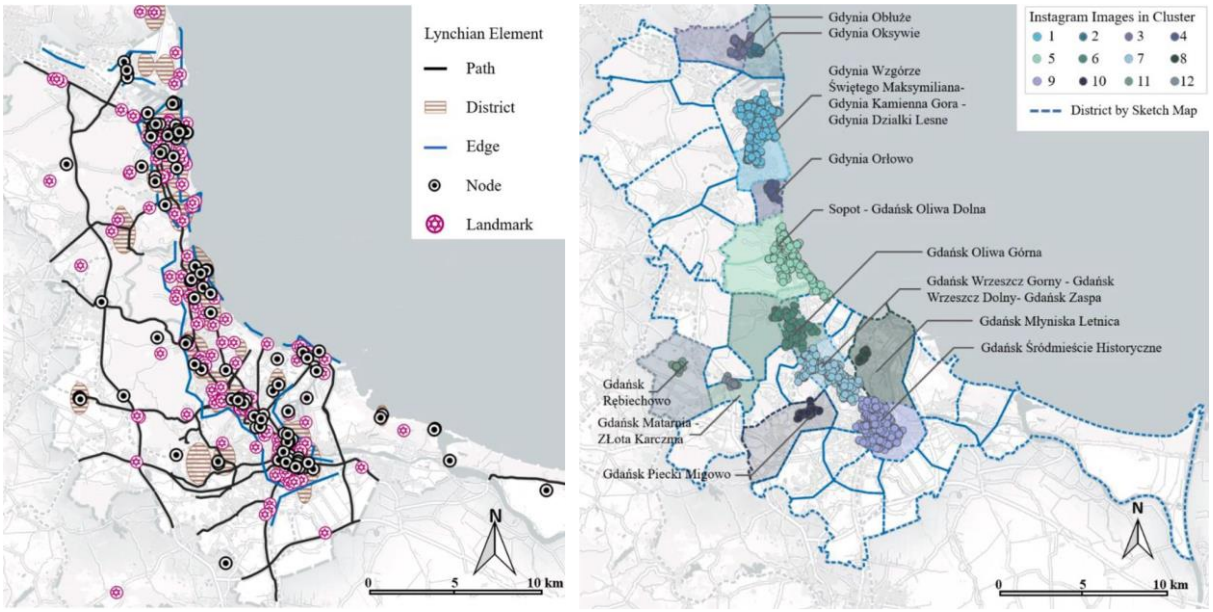


Figure 14 Computer generated maps attempt to simulate the imageability described in cognitive mapping by using data from social media (Haung et al, 2021: 5, 6)

2.4.3 The influence of Gestalt psychology

So far, the descriptions of imageability discussed in this chapter primarily focus on *structure* rather than *identity* and *meaning*. Now we turn to look at theories where the nature of human cognition precedes the composition of the environment. Authors such as Wilson (2002) argue that imageability is about the human ability to organize observations of the environment into groups of things rather than a holistic heterogeneous sum. Lynch is quite explicit in asserting that an imageable environment is made up of distinct parts (paths, nodes, districts, edges, and landmarks). Much emphasis is placed on the notion of distinctiveness and Lynch (1960) stresses the role of edges in forming the ends and beginnings of places, establishing what is "in" as distinct and relatively separate from what is "out". In cognitive terms, the many items that constitute the urban environment must be able to be formed into a pattern. Whereas in discussing structure we understood imageability as the result of the spatial layout of the environment, when viewed from the perspective of cognitive science, imageability and other "cognitive processes are rooted in the [human] body's interaction with the world" (Wilson, 2002: 625). The development of hierarchies (with things that are larger and smaller) serves to describe our relationship to the environment in a process known as *cognitive off-loading*, which is a response to cognitive limitations when the human mind is under high pressure or must process large amounts of information (Wilson, 2002). For example, to process complex information such as a street scene or the route to a place, the mind can "off-load" some of this work to the environment by only remembering key points (such as landmarks) because of the large amount of information contained in the scene. Landmarks often

[11] GSM (Global System for Mobile Communication) is a digital mobile network widely utilized in Europe and other areas of the globe by mobile phone users.

standout from their surroundings because of their large size and distinct shape (Rousell and Zipf, 2017). Winter et al (2008) postulate that this size differential is necessary for the development of cognitive hierarchies that are used in human communication. They note that "when communicating routes or place descriptions people refer typically to landmarks. These landmarks are cognitive anchors of the learned environment that are assumed to be shared with other people, or at least with participants of a particular conversation" (Winter et al, 2008: 382). However, landmarks are not always large and they can be as small as a house with different colour from the rest (Lynch, 1960). However, they are always distinct from their surrounding and are thereby set apart from other elements in the cognitive hierarchy of spatial elements.

Lynch thanks his mentor and research supervisor, Gyorgy Kepes, in the foreword of *The Image of the City*. Kepes was a painter and art theorist who argued for a universal "language of vision" and was heavily influenced by German *gestalt* psychology (Dovey and Pafka, 2016). The Gestalt had emerged in the 20th century as a counter movement to the prevailing structuralist school at the time which maintained that all perceptions, including abstract concepts, are built entirely from lower-level sensations that are linked merely by their proximity in space and time. Instead, Gestalt psychologists argued that seeing psychological events as organized, structured wholes was the most beneficial way to view them (Sternberg & Sternberg, 2012). The gestalt is a pattern or total that emerges as more than the sum of its components, where parts and wholes are intertwined — we don't just observe an objective reality; we arrange pieces to create wholes (ibid). Dovey and Pafka (2016) argue that the Gestalt influence can be seen in the methodology of Lynch's study. He employed mapping of topic regions by trained observers and in-depth semi-structured interviews with locals. Interviewees were asked to name elements of the city and describe where they begin and end, and their answers were categorized into landmarks, pathways, edges, nodes, and districts. This typology appears to be a framework for study rather than a finding gleaned from the interviews; it is a theory backed up by facts. To put it another way, the elements are mostly derived from gestalt theory as wholes that emerge from pieces, figures against the urban fabric's ground. Thus, according to Dovey and Pafka (2016) the five Lynchian elements exist *a priori*, as foundational psychological elements that are frequently used – albeit in slightly different forms – to perform the cognitive work of recognising patterns even in other areas of life. Lynch's framework is thus rooted in *identity* first before *structure*. The Lynchian elements "all draw upon gestalt perceptual tendencies to construct identities out of differences (Dovey and Pafka, 2016: 3). His studies of human perception sought to draw out what happens when the human mind, with its pre-existing cognitive anchors, interacts with what people see in the built environment. He used cognitive mapping to translate these mental images into sketches that could be studied and compared to one another.

2.4.4 Cognitive mapping

Cognitive mapping, sometimes referred to as sketch mapping, is a research method that uses simple hand drawings to describe people's perception of the environment. This may be done to determine the relationship between people's perceptions and the physical features of the environment (Lynch, 1960); to understand the extent to which an environment is identifiable (De Jonge, 1962) or the extent to which it is memorable (Appleyard, 1969); or to determine how people navigate their environment (Kim and Penn, 2004). Cognitive maps are characterised by distortions whereby sizes and distances may be exaggerated and whereby some features are omitted. Distortion may be affected by factors such as the scale of the area being mapped and the respondent's familiarity with the area (Costa and Bonetti, 2017). Local cognitive maps are modest in scope and acquired by first-hand experience but "as the area represented by the cognitive map increases (e.g., a city or a geographic region), first-hand experience is supplemented by secondary sources of information such as cartographic maps" (Costa and Bonetti, 2017:53). However, previous studies on the role of secondary information in reducing geometric distortion were inconclusive (Devlin 1976; Devlin and Bernstein 1995). Furthermore, distortion may not necessarily be a bad thing. Kim and Penn (2004) found that exaggerated features often corresponded with configurations that were more conducive to wayfinding, such as continuous paths or place identifiers. In his famous studies of Boston, Jersey City and Los Angeles Lynch (1960) found that

cognitive maps were made up of five elements that corresponded to physical aspects of the urban environment: nodes, paths, districts, landmarks, and edges (fig.15).

> "Nodes are the strategic foci into which the observer can enter, and which are the intensive foci to and from which he is travelling. They may be primarily junctions, places of a break in transportation, a crossing or con- vergence of paths" (Lynch, 1960: 47).
>
> "Paths are the channels along which the observer customarily, occasionally, or potentially moves. (..). People observe the city while moving through it, and along these paths the other environmental elements are arranged and related" (Lynch, 1960: 47).
>
> "Districts are the relatively large city areas which the observer can mentally go inside of, and which have some common character (Lynch, 1960: 66). The characteristics that determine districts are thematic continuities which may consist of an endless variety of components" (Lynch, 1960: 67).
>
> "Landmarks are point references considered to be external to the observer. They are more easily identifiable, if they have a clear form; if they contrast with their background; and if there is some prominence of spatial location" (Lynch, 1960: 78).
>
> "Edges are linear elements not considered as paths: they are usually, boundaries between two kinds of areas. They act as lateral references. Those edges seem strongest which are not only visually prominent, but also continuous in form and impenetrable to cross movement" (Lynch, 1960: 62).

Figure 15: Definitions of the 5 elements of the image of the city (Lynch, 1960)

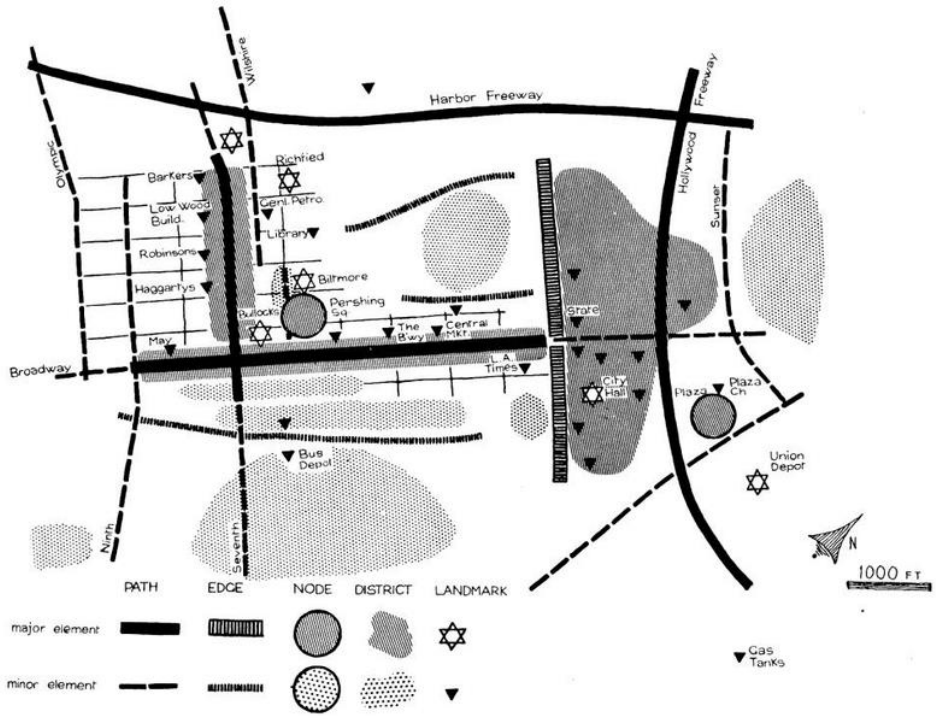


Figure 16: Cognitive maps are characterized by the absence of many elements (mostly structural elements) and the exaggeration of others (mostly visual elements). This can be seen in the above cognitive map of Los Angeles, USA (Lynch, 1960: 33)

Experiments by Blades (1990) found that cognitive maps have high test-retest reliability, which means that, unless additional secondary information is given, a research respondent is likely to redraw the map with the same level of accuracy. This suggests that the image of the city has a very high degree of internal consistency

and that changes to the image are likely to be in response to external stimuli, which can include changes to the physical environment but may also include access to additional information such as maps. Finally, although cognitive maps have inaccurate scales with a tendency to exaggerate the sizes of urban features (fig.16), experiments by Lopez et al (2020) found that as familiarity with spatial layout increases mapping accuracy also improves. However, the accuracy of cognitive maps in these experiments was nonetheless very low, when compared to actual map coordinates, and thus these representations of imageability cannot be directly translated into physical design (Lopez et al, 2020).

Dovey and Pafka (2016) argue that Lynch's framework of five elements also has flaws that create ambiguity regarding what respondents mean when they classify a part of town as being a particular element. Upon closer inspection, the lines between 'components' blur and cross, distorting the distinctions between them. A node is an intersection of pathways that is sometimes also referred to as a district. A main path might become a district or a district's perimeter. Through the effects of scale, certain features transform into others, for as when a road (freeway) at the metropolitan size becomes into an edge at the neighbourhood scale. “There is no objective sense in which this is a complete set of elements” (Dovey and Pafka, 2016: 3). Yet, why should it be so? The answer to this question (and the extent to which we are comfortable with ambiguity) depends on whether we expect to use cognitive maps (or the theory of imageability) as a scientific basis. On the one hand, as expressed in the problem statement for this research, urban design might become easier and more effective if ideals such as imageability had a scientific and potentially more predictable basis. On the other hand, being easier and more effective says nothing about the quality of the end product. It is equally possible to be effective in the wrong direction. Additionally, the validity of how we measure an ideal such as imageability is a matter of positive theory and says nothing about its suitability as an ideal. That is a normative question. As discussed in the section on why urban design theory tends to be layered, there are arguments against planning a city with the expectation that it should be readily apprehended by the human mind (Alexander, 1965). Gordon Cullen’s (1961) principle of serial vision suggests delight at the prospect of an illegible urban layout, “or at least the joys of discovering the city one street and place at a time” (Dovey and Pafka, 2016: 3). Lynch also concedes that “there is some value in mystification, labyrinth, or surprise … but only where there is no danger of long-term disorientation” (Lynch, 1960: 5-6). This then leads to a question regarding the extent to which cognitive maps describe imageability or if they tend to describe legibility instead. For Lynch (1960) the two concepts are related but nonetheless distinct. Legibility refers to the ease with which pieces of the environment can be identified and ordered into a logical structure, whereas imageability refers to an object's ability to elicit a powerful image in the observer. Perhaps then, what cognitive approaches fail to capture is the meaning behind places, beyond their classification as nodes, paths and so forth.

2.4.5 The information approach: why we remember some environmental features and not others

The third level on which imageability may be understood is as an inextricable extension of the human capacity to form, learn and read language. Lev Vygotsky’s theory of socio-cognitive development maintains that a person’s culture passes on to them “cognitive devices and procedures with which we communicate and explore the world around us” (Snowman and McCown, 2014: 49). Written language, for example, depends on our ability to form symbols from initially random combinations of lines and spaces. These combinations form patterns, and language depends on our ability to remember and recognize these patterns as distinct entities that are resolutely different from other lines or markings that we may consider to be arbitrary nonsense. To perform this work, the human mind uses shortcuts by interpreting new data through existing cognitive devices (ibid). Perhaps this may also explain the phenomenon of *Pareidolia*, the propensity to construct a meaningful interpretation on an ambiguous stimulus, generally visual, resulting in the perception of an object, pattern, or meaning where none exists (fig.17) (Nield, 2021). The mind is using a pre-existing cognitive device (in this case, one associated with human faces) and producing a meaning for the pattern being observed.



Figure 17: These random objects seem to have faces (with human expressions) due to a cognitive phenomenon known as Pareidolia (Nield, 2021)

We may consider an edge, as described by Lynch (1960), to be a simple pattern composed of a line with space on either side of it. The line could be a street, railway tracks, a river or the shoreline. This pattern of a line with space on either side of it has a pre-existing meaning to humans: the space on the one side of the line is "in" something (perhaps inside a district) whereas the space on the other side is "outside" of that same something[12]. From a socio-cognitive perspective, the reason why such seemingly inherent meaning is possible is that the concept of the edge utilizes pre-existing cognitive devices, everyday notions about "in" and "out". The pattern of what Lynch's respondents recognise as an edge and the patterns of all the Lynchian elements are meaningful because "they resonate so well with the urban phenomenology of everyday life" (Dovey and Pafka, 2016: 3). They draw on pre-existing understandings of patterns to read the city. A similar notion has been discussed earlier in this chapter, Alexander's pattern language. Yet, for such an interpretation to occur – even in the case of *pareidolia* – there must be something there (a stimulus) to interpret in the first place. Scholars in the information approach contend that places become imageable if they are containers of meaning.

Proponents of the information approach argue that "some elements, including those that compose the face of the city, are quantitatively and qualitatively more informative than others and are therefore more legible and better perceived and remembered" (Haken and Portugali, 2003: 385). The concept of *affordance* (Gibson, 1979) explains how this is possible. Some urban configurations have characteristics that 'afford' them the ability of being readable and memorable (legible and imageable) (Haken and Portugali, 2003). That is, "legible cities are composed of informative and significant artefacts or urban configurations. City nodes, paths or districts are 'information carriers' that shape the mental image" (Filomena et al, 2019: 15). In this regard then, affordance describes those properties of an urban element that allow it to contain and convey information to the observer. The information approach attempts to quantify this phenomenon by using Shannon's measure of information, which is a measure of the "unexpectedness" of an event. In this regard information (like the

[12] As described above (pg.41), Lynch's respondents were asked to name elements of the city and their boundaries

symbolic kind contained in urban elements) is an event that reveals to us something that we would not know or expect otherwise. Shannon's measure of information is a form of entropy in that, each time an event reoccurs, it becomes less unexpected and thus less informative (Shannon and Weaver, 1949). Haken and Portugali (2003) adapt Shannon's calculation of information by adding a variable for *semantic information*, which is information with meaning. This adaptation improves the theory's applicability to urban environments and to imageability. Thus, on a visit to the site, 'the first house we see provides lots of information about its style, origins, socio-cultural references, climate and so on. But then as we see another and then another one, row upon row of similarly styled houses, each additional piece of repetitive detail reduces the richness of the content' (Ganis, 2014: 58)

In keeping with *scaling law* and with Jiang's (2013) findings (discussed above), the information approach finds that most urban elements repeat information and only a few present novel information (e.g., landmarks). Similarly, most elements have a low density of information and only a few present a concentration of information (Haken and Portugali, 2003). In other words, most of the physical features in any given environment have comparatively low affordance. Moreover, according to Shannon's *measure of information*, increasing the information density (affordance) of such elements would not necessarily increase the overall imageability of the place if no novel information is being conveyed by the increase in affordance. Comparatively unique elements, those with new information and those with concentrations of information (such as landmarks and nodes) are more likely to take a prominent position in the observer's mind and become more recognisable and memorable. The image of the city, the cognitive map, is formed by these "informative" elements that people recognise, remember, and associate with meaning.

Filomena et al (2019) argue that the shortfall of the information approach is that, while it provides a suitable measure of entropy for a city or a district, the measure is ultimately not suitable for quantitatively evaluating individual elements. However, a potentially more restrictive challenge for applying the information approach in urban design might be that the theory is still too foreign to the discipline and may be impossible to employ by researchers without formal training in advanced mathematics. Although good descriptions of how it might be applied to cities are provided (Haken and Portugali, 2003; Ganis, 2014; Filomena et al, 2019), there are still no examples of its practical applications to inform research methods for urban design projects. Nonetheless, the central thesis of the information approach is still applicable to my study: According to Shannon's measure of information, the impact of affordance decreases in proportion to the number of times an element occurs within the environment. The more ubiquitous and element is, the less likely it is to be memorable or meaningful and thus the less it contributes to imageability.

2.4.6 Reflection on the approaches discussed above

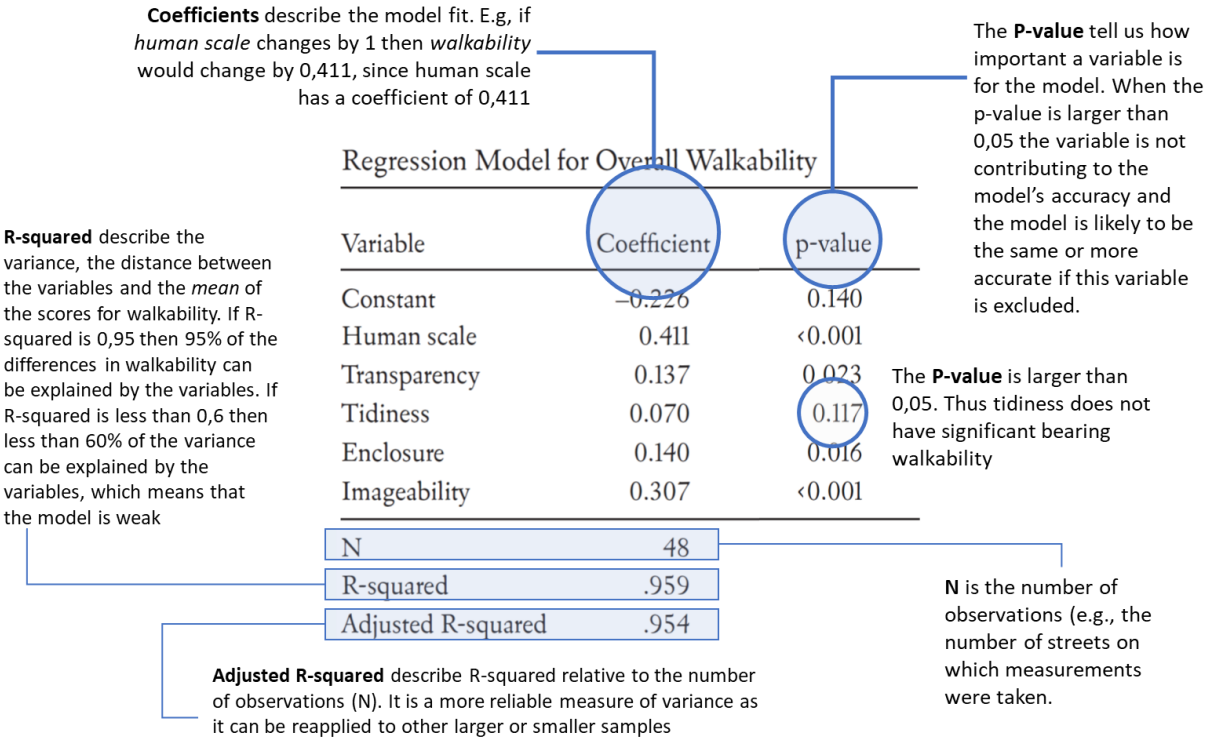
This chapter has discussed five approaches to the problem of describing and measuring imageability, which have been broadly categorised as the themes of *structure*, *identity* and *meaning*, based on the aspect of imageability that they address most effectively. Space syntax and GIS have been successfully used to describe the physical dimension of imageability (referred to here as structure) by mapping the configuration of urban space. Dalton and Bafna (2003) use the addition of isovists to adapt the two-dimensional space syntax platform and account for the visual experience of space. However, their model does not account for the impact of land use. Filomena et al (2019) map imageability with GIS, which has in-built functions for land use, building heights and street properties – such as length and continuity. Their model defines nodes and districts based on land use, and accounts for height when identifying landmarks but, since the model is automated and generated by a computer, it lacks the ability to account for what people see in an environment. Ultimately, the Filomena model is a replication of Lynch's (1960) study by other means (through a computer instead of responses from actual people), and it is based on Lynch's descriptions of what people see, but it is not a verification of Lynch's findings, since it assumes as its premise the validity of Lynch's descriptions. Haung et al (2021) also use GIS to describe imageability but they use social media to account for how people see and experience space. While notably increasing the ability to relate GIS mapping to aspects of spatial cognition, their findings however have

limited external validity because of the demographic differences in the use of social media amongst the general population. All of the above studies resorted to cognitive mapping (through sketches by respondents), as a means of validating their findings. Cognitive mapping is the traditional means of describing imageability and it is the method used in Lynch's original studies. However, sketches made by respondents in cognitive mapping studies tend to have low spatial coordinate accuracy, as they are drawn from memory, and they do not provide a quantitative description of imageability. There is also ambiguity as to whether cognitive mapping describes legibility or imageability because of the close interaction between these concepts. To definitively distinguish between the two, descriptions of imageability have to describe the distinctiveness of the place. Thus, the discussion turns to the concept of meaning. Proponents of the information approach suggest that meaning is imbued onto objects (and places) that have the quality of *affordance,* which is the ability to carry and convey new information. Haken and Portugali (2003) propose a method to calculate affordance that is based on the novelty of the information being conveyed by an object but, yet there are no applications of this method in urban design or planning.

The objectives of this research report are to measure imageability on a site and to determine if there is correlation between imageability and pedestrian activity on the site. The models presented above provide descriptions of imageability and have strengths in different respects. For example, space syntax and GIS provide detailed descriptions of urban spatial configurations, with a high degree of coordinate accuracy, while cognitive maps provide better descriptions of user perceptions of space albeit with lower accuracy. However, except for the information approach, these models do not provide a quantitative value for imageability that can directly associated with a space (such as a street) and therefore their descriptions of imageability cannot be correlated with pedestrian activity in that space. The final model to be presented in this chapter is from studies by Ewing et al (2005; 2006; 2013). Because the Ewing model describes imageability as a numeric value, it is best suited for my research objectives.

2.4.7 Ewing model: a count-based model of imageability

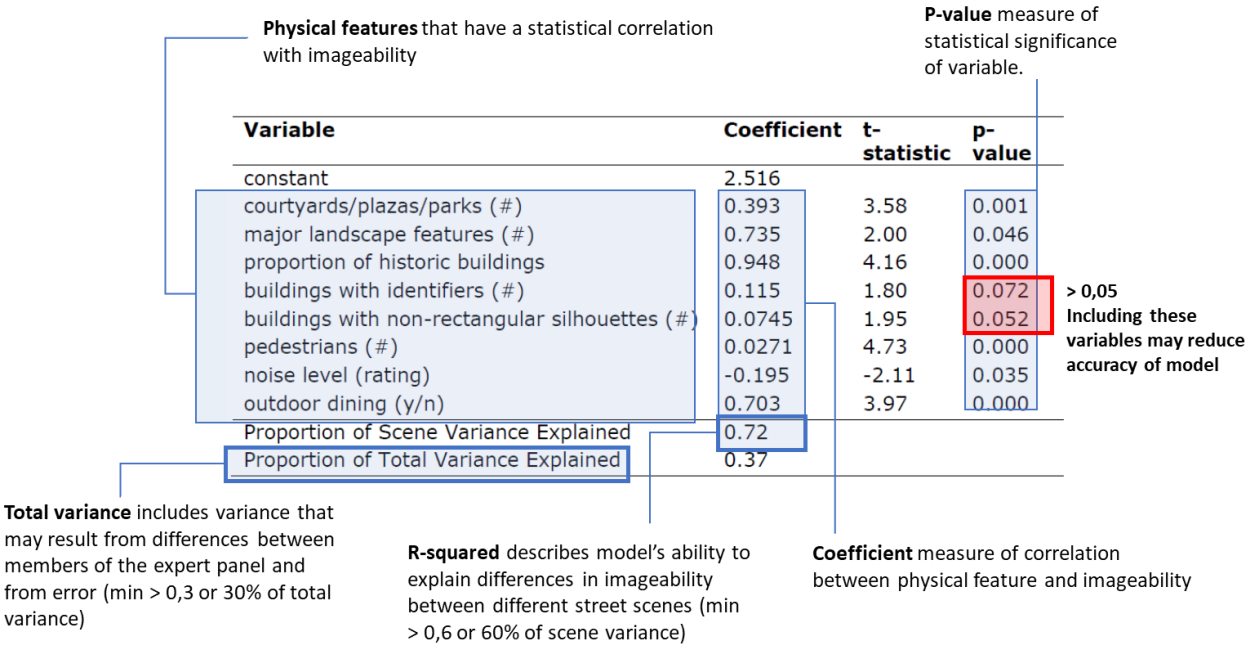
Reid Ewing, along with his colleagues at the Active Living Research centre, conducted several studies attempting to develop operational definitions of aspects of urban design that are associated with walkability (Ewing et al, 2005a; Ewing et al, 2005b; Ewing, 2006; Ewing and Handy, 2009; Ewing and Clemente, 2012). These studies make three significant contributions to urban design literature. The first is a literature review that considers 51 perceptual qualities of urban environments that urban design theorists associate with good walking environments. The second contribution made by Ewing et al (2005a) is a statistical model (referred to here as the Ewing model) that describes the correlation between five perceptual qualities (imageability, enclosure, human scale, transparency, and complexity) and the physical features associated with them (Fig.18). This model describes imageability as being significantly correlated to eight physical features: *number of people*; *proportion of historic buildings*; *number of courtyards, plazas and parks*; *presence of outdoor dining*; *number of buildings with non-rectangular silhouettes*; *noise level*; *number of major landscape features*; and *number of buildings with identifiers* (Fig.19) (Ewing and Handy, 2009). The third contribution made by the Ewing studies is a survey instrument (Appendix A) that can be used to measure perceptual qualities (such as imageability) by counting the number of times that the physical features associated with them occur within an environment and using a multiplier to adjust for the statistical significance of each feature (Ewing and Clemente, 2012).



Regression Model for Overall Walkability

Variable	Coefficient	p-value
Constant	–0.226	0.140
Human scale	0.411	‹0.001
Transparency	0.137	0.023
Tidiness	0.070	0.117
Enclosure	0.140	0.016
Imageability	0.307	‹0.001
N	48	
R-squared	.959	
Adjusted R-squared	.954	

Figure 18 How to interpret the results of a multivariate linear regression where walkability is the dependent variable (After Ewing et al (2006: S235))



Variable	Coefficient	t-statistic	p-value
constant	2.516		
courtyards/plazas/parks (#)	0.393	3.58	0.001
major landscape features (#)	0.735	2.00	0.046
proportion of historic buildings	0.948	4.16	0.000
buildings with identifiers (#)	0.115	1.80	0.072
buildings with non-rectangular silhouettes (#)	0.0745	1.95	0.052
pedestrians (#)	0.0271	4.73	0.000
noise level (rating)	-0.195	-2.11	0.035
outdoor dining (y/n)	0.703	3.97	0.000
Proportion of Scene Variance Explained	0.72		
Proportion of Total Variance Explained	0.37		

Figure 19 The Ewing model: Eight physical features have correlation with imageability (after Ewing et al, 2005a: 23)

The Ewing model is comparable in some respects to the information approach in that it attempts to describe imageability as a quantitative measure of the number of times particular urban features occur within an environment. However, whereas the information approach is more general (attempting to quantify the uniqueness of every urban element relative to other elements in the environment) the Ewing model is more conservative and instead restricts the number of relevant features by developing strict operational definitions

that describe which urban elements are relevant to consider when describing imageability. To do this, Ewing et al (2005a) rely heavily on inputs from urban design experts and on urban design literature to define imageability and to describe what physical features are associated with them. Whereas Lynch's (1960) study relied on pedestrians to describe their perception of the city and based on this, concluded that cities possess a perceptual quality that may be described as imageability, Ewing et al (2005a) begins with the premise that imageability exists and that it is possible to determine when it is present. This is consistent with the literature review presented in this chapter and therefore my research begins from the same premise. Their study showed 200 video clips of streets to a panel of 10 urban design experts, where they were asked to say whether they thought a street had high or low imageability and to describe what physical features informed their assessment (Ewing, 2006). The features described by the panel were cross-referenced with those described most frequently in urban design literature and then the researchers took on the task of counting the number of instances that each feature occurred within the 200 video clips reviewed by the panel. Finally, by using regression analysis, Ewing et al (2005b) were able to determine the correlation between the number of instances that a particular feature was present on a street and the number of panel experts that ranked the street as having either high or low imageability. This correlation formed the basis for the values in the scoring sheet shown in figure 20, which can be used as a field survey instrument to measure imageability by counting the number of features along a street.

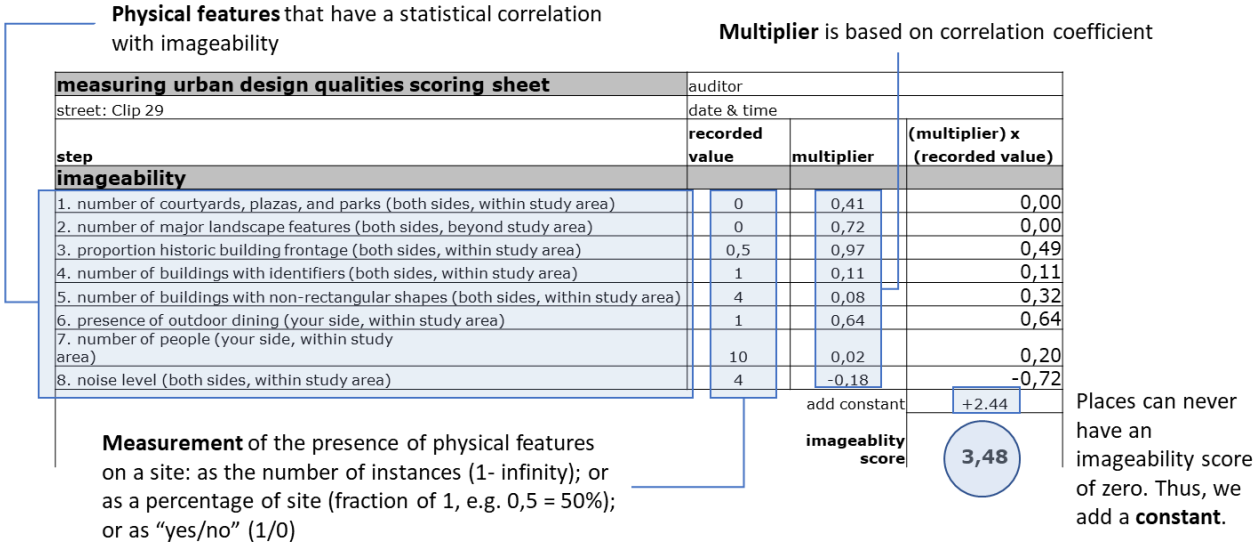


Figure 20: Survey instrument for measuring imageability using the eight physical features identified in the Ewing model (after Measurement Instrument Database for the Social Sciences (MIDSS), 2006)

There are two key differences between the Ewing model and the other measures of imageability discussed in this chapter. The first is that, by using video clips, the study can simulate the experience of walking more accurately, taking pedestrians' limited field of vision and the impact of motion (both on the part of the pedestrian observing the scene and other elements on the street). As discussed earlier, one of the limitations of approaches such as the Filomena model is that they tend to overestimate imageability because they fail to consider pedestrians' inability to accurately observe urban elements, even those that theoretically possess the qualities that should make them significant and memorable. The second aspect that sets the Ewing model apart is that it uses people (the expert panel) to determine the presence of imageability. This is a similar approach to that taken in Lynch's (1960) study, with the exception that Lynch's respondents were residents rather than experts. In theory, using human respondents, should make it less likely that the model would emphasize a feature that a person would not recognise as being significant because the model's definition of what is significant is based on what a person (the expert panel) is able to see. However, a potential weakness of the Ewing model in this regard is the small sample size of the expert panel (10 respondents). For comparison,

Lynch (1960) conducted his experiments in three cities and the sample size for Boston alone has 30 respondents. Lastly, the output of the Ewing model is a score, a measure of how imageable a street is. Because each street is evaluated independently, it is possible to rank them in terms of their imageability and, as a result, to measure the extent to which the imageability score on each street correlates to the amount of pedestrian activity in that street. This way, imageability can be used as a measure of walkability.

The Ewing model also has two shortcomings. The most readily apparent of these is that the model describes urban form (structure) rather than an individual person's perception (identity) of that form and it cannot account for historical experiences or symbolism associated with the form. It is for the most part what Jiang (2013) describes as an *external representation* of imageability. It is possible, when using such a measure, to overlook some aspects of imageability. Secondly, in practice scores generated by the Ewing model may only describe a portion of a street, since the model is based on the assessment of street scenes and is limited to a distance of about 200m in front of where the pedestrian viewing the scene is standing. Thus, for example, it may be possible for a long street to have the same number of features – and thus the same score – as a shorter street but the longer street may in fact be scored as less imageable because the features are not experienced in the same scene. Notably, according to the Filomena model, the length and continuity of a street is expected to positively contribute to imageability.

2.5 CONCEPTUAL FRAMEWORK

The preceding sections have discussed key debates in the literature around the concept of imageability. In this section these arguments, which are broadly categorized under the three themes of structure, identity and meaning are formulated into a conceptual framework that describes the expectations of urban design theory with regards to imageability (fig.21). In terms of composition, imageability is expected to be subject to the scaling law of geography (Jiang, 2013) whereby small elements are more numerous than large ones and dispersed elements are similarly more numerous than concentrations of elements. The environment is therefore composed of 1st and 2nd order elements (Dalton and Bafna, 2003) and some of these 2nd order elements (those that are well-located or that are large relative to their context) are expected to act as *structural landmarks* (Sorrows and Hirtle, 1999). In terms of identity, we can distinguish between two kinds of studies of imageability: those that focus on external representation and those that focus on internal representation. The former is concerned with the presence of *affordance* (Haken and Portugali, 2003), which is the ability for environments to act as containers of information (Ganis, 2014) that provide "clues" to pedestrians (Jacobs, 1993). Studies on internal representation emphasize the human cognitive ability and tendency to organize observations into perceptual patterns, such as those described by Lynch's five elements. From this perspective, it is expected that some places are likely to have high imageability and become *visual landmarks* (Sorrows and Hirtle, 1999) because of the concentration of visual clues within them. Finally, in terms of meaning, it is expected that some of the information that makes a place symbolically or socially significant (such that it becomes imageable) may not be inherent in the physical space or the objects within it but may in fact be contained in people's minds, especially in cases where the meaning of the space is based on an experience or a historical event that may be captured in people's memories. Such places then may be described as *cognitive landmarks* (Sorrows and Hirtle, 1999).

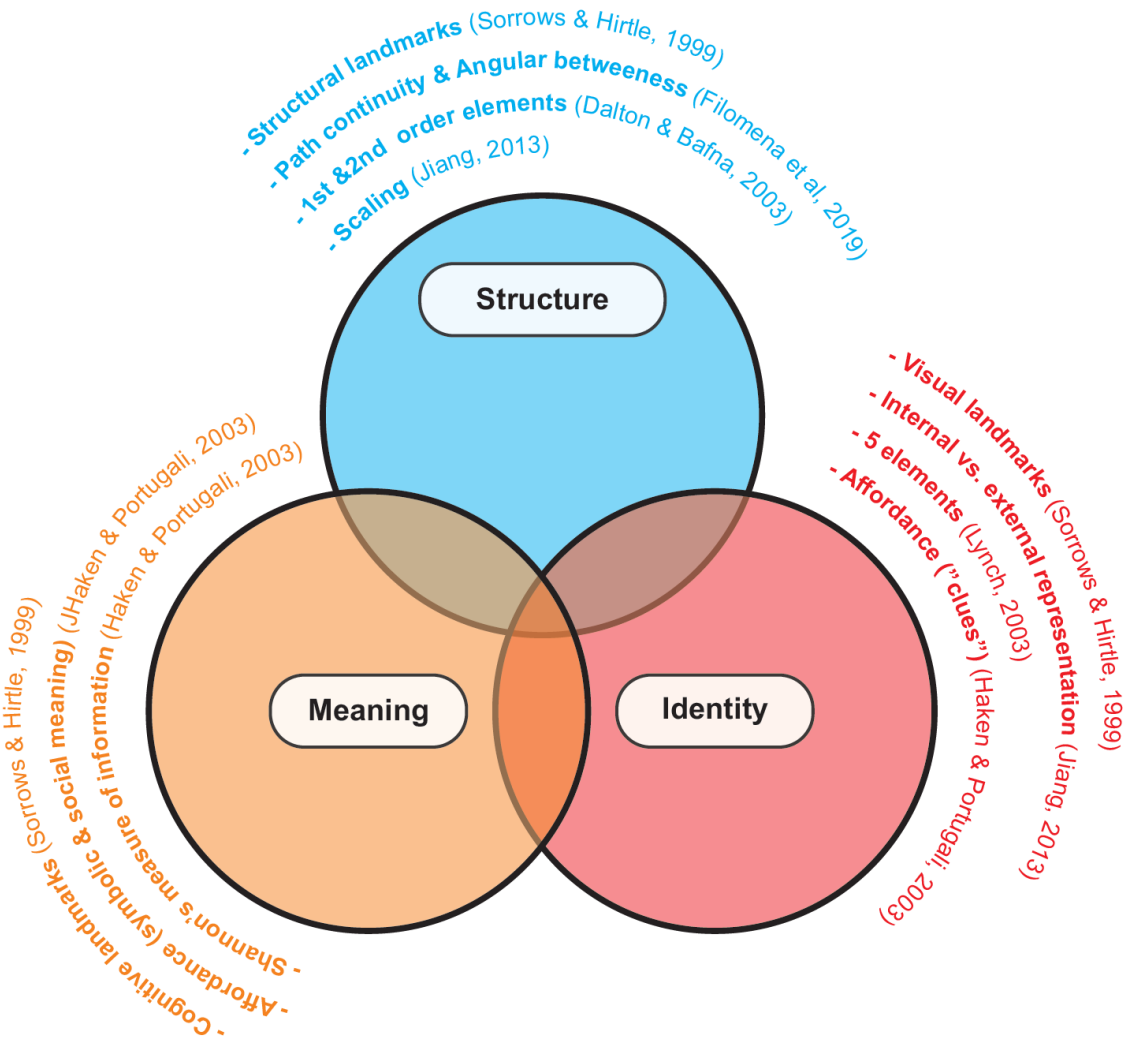


Figure 21: Conceptual framework

2.5.1 Structure

Dalton and Bafna's (2003) model determined that imageability is predicated on two categories of urban elements: a set of first order *structural elements* and a second order set of *visual elements*. Thus, although an imageable place may be associated with its visual qualities (2nd order elements), their impact is grounded in their location within the broader structural (1st order) elements of the place. The literature therefore suggests that the most significant urban elements on a site – the ones that most contribute to its imageability – should be distinguishable as either structural elements or visual elements. Furthermore, based on the principle of scaling (Jiang, 2013), structural elements are likely to be more numerous. Structural elements frame how visual elements are perceived by limiting the pedestrian's field of vision, as shown using isovists in space syntax models (Benedikt, 1979; Morello and Ratti, 2009). Filomena et al (2019) suggest street length to be positively associated with imageability. Because Diepkloof Zone 5 has low legibility, *path continuity* is thus likely to be more important for navigation. The most continuous paths and those with the least angular change are expected to be most imageable and would be most significant in cognitive maps. Since the Ewing model is applied at 200m intervals (the pedestrian's immediate field of vision), the model is likely to underestimate the imageability of long streets. Finally, the literature suggests that certain features act as *structural landmarks* (Sorrows and Hirtle, 1999). These are features that are recognisable and memorable because of their location or their size relative to surrounding elements,

rather than for what they are, how they are shaped, or how they are used. Thus, the presence of objects (not necessarily buildings) that are tall relative to their context may result in higher imageability. For example, streetlights may act as structural landmarks in an environment such as Diepkloof because they are taller than most other objects and they are found in relatively few streets. Continuous elements that are not immediately conspicuous may also appear as significant structural elements in people's mental images (perhaps as what Lynch would describe as edges). This may be due to their role in regulating movement on the site and thereby influencing people's experience of the place. Thus, for instance, a railway line, a river or a long street may become prominent features in the image of the city even if they are not visually striking. This is another reason why the Ewing model may underestimate the imageability of long streets.

2.5.2 Identity

The literature suggests that the experience of imageability can be represented graphically using *cognitive mapping* and that physical features of the urban environment can be broadly categorised into five kinds of elements: paths, nodes, landmarks, edges, and districts (Lynch, 1960; de Jonge, 1962; Haung et al, 2021). However, Jiang (2013) distinguishes between two approaches for studying imageability (internal representation and external representation), which both have their respective limitations. Cognitive mapping is a subjective representation of the environment, and it can be inaccurate because it relies on a person's mental ability to see, recognise, and remember aspects of the environment. To this extent, it is an *internal representation* of imageability (Jiang, 2013). On the other hand, the Ewing model may also be inaccurate because it focuses on environmental features rather than mental processes and is therefore an *external representation* of imageability (ibid). This means that cognitive mapping may be necessary as a means of validating measurements from the Ewing model. There is precedent in the use of cognitive mapping as a means of validating previous studies that used external representation to measure imageability (Filomena et al, 2019; Huang et al, 2021).

Certain urban physical features, such as signs, are more prone to trigger the cognitive processes responsible for *internal representation* but they are also distinct enough to be mapped or quantified and therefore they can also feature in *external representations* such as maps and models. These urban features possess the quality of *affordance* because they are information carriers (Haken and Portugali, 2003). Sorrows and Hirtle (1999) suggest that *visual landmarks* are characterised by high levels of affordance. Visual landmarks will have "clues" (Jacobs, 1993: 30) (such as signs, permeable facades, or distinct shapes) that convey information about them. However, the significance of these clues will be higher on streets with few visual landmarks and lower in streets that have many visual landmarks, in keeping with the entropy value in *Shannon's measure of information* (Ganis, 2014). A quantitative measure of imageability, such as the Ewing model, is likely to underestimate entropy if it does not adequately account for sameness and monotony.

2.5.3 Meaning

Shannon's (1948) measure of information describes the uniqueness of the information contained in an urban element as a contribution to the meaning of a place. As the physical feature that contains this information is repeated, the significance of that feature as a conveyor of that information marginally decreases (Haken and Portugali, 2003). However, this measure assumes that the person observing a physical feature (such as a window) is a receiver of information: that they are aware of the information contained in the feature; and that they are not themselves generating information and associating it with the window. Since cognitive maps are characterised by variance between respondents and inaccuracy when compared to geographical coordinates (Lopez et al, 2020), one explanation for this may be that imageability is a subjective experience. It is thus theoretically possible for the information about a space to be retained inside the person observing the space – as a memory – but to not have any physical representation in the space. This could be the case, for example if a significant historical event has occurred on the site without changing the space. However, because

imageability (in cognitive mapping) has high test reliability (Blades, 1990) subjectivity is not expected to cause fluctuations in measurements[13] but it suggests that there may be occasions where spaces contain immeasurable qualities that should be explored through qualitative methods. Therefore, the literature suggests certain aspects of imageability are impossible to represent quantitatively because sometimes the affordance of physical features is based on symbolic and social meanings. Certain features may act as *cognitive landmarks* (Sorrows and Hirtle, 1999), whereby they are significant because of what they represent and their social function, rather than their location, spatial configuration, or visual qualities.

2.6 CONCLUSION

This chapter has presented debates on the concept of imageability and its association with pedestrian behaviour. Classical urban design scholars describe imageability in less tangible terms, as a sense of place or the spirit of a place. It is the quality that makes a place striking, distinct or memorable. Designers such as Gehl (1987) understand imageability as a holistic experience that results from the arrangement of spatial elements. However, some scholars place special emphasis on the qualities of urban features, such as height or path continuity, as factors of imageability. Authors such as Winter et al. (2008) argue that differences between urban features are necessary for the creation of cognitive hierarchies, similar to those in human communication, and that these hierarchies can allow us to perform cognitive tasks such as orientation and remembering places. Lastly, scholars such as Alexander (1977) draw a direct parallel between the cognitive hierarchies contained in urban environmental patterns and those contained in human language patterns. Certain patterns are important, not only because of the mental activities they enable us to do, such as orientation, but they are also important because of what they mean to us, in a symbolic sense. Thus, there are three definitions of imageability: as *structure*; as *identity*; and as *meaning*.

In this chapter I have also discussed five approaches to measure and describe imageability, including the Ewing model. The preceding discussion shows that each approach is limited by its definition of imageability (as either structure, identity or meaning) and that none of the approaches adequately account for more than two ways of interpreting imageability. This suggests that imageability models are inherently incomplete and that their results must be interpreted with an understanding that other dimensions of imageability may not be measured using a given model, even when they are present.

[13] Measurements are taken as an average of what individual respondents are likely to find to be imageable, since the Ewing model is based on the weighted average of scores from an expert panel. This is the equivalent of Lynch (1960) layering the cognitive maps of his respondents.

Chapter 3: RESEARCH METHODS

3.1 INTRODUCTION

The research methods discussed in this chapter fall into seven categories: (a) measurement of physical features; (b) application of Ewing model to derive imageability scores; (c) field observations of pedestrian patterns; (d) mapping; (e) qualitative descriptions of street scenes; (f) statistical analysis of the relationship between imageability scores, pedestrian patterns, and physical features; and (g) interpretation of results, with reference to the conceptual framework discussed in chapter 2.

3.2 ONTOLOGICAL AND EPISTEMOLOGICAL CONSIDERATIONS

In John Creswell's framework of research approaches, shown in table 4 (Groat and Wang, 2013), quantitative and qualitative research are distinguished from one another in terms of ontology, epistemology and methodology. Quantitative research assumes an objective reality and views the subject of inquiry as being independent of the researcher. Conversely, in qualitative research, reality is assumed to be subjective and the researcher is seen as interacting with and potentially influencing the subject of enquiry. In terms of methodology, quantitative research is described as a deductive process, seeking explanations of cause-and-effect, while qualitative research is inductive and sees phenomena as being shaped by multiple factors.

Question	**Quantitative**	**Qualitative**
Ontology: What is the nature of reality?	Reality is **objective** and **singular**, apart from theresearcher.	Reality is **subjective** and **multiple** as seen by participants in a study.
Epistemology: What is the relationship of the researcher to that being researched?	Researcher is **independent** from that being researched.	Researcher **interacts** with that being researched.
Methodology: What is the process of research?	Deductive process: cause and effect.	Inductive process: Mutual simultaneous shaping of factors.

Table 4: Qualitative and quantitative research approaches differ in terms of ontology, epistemology and methodology (Groat and Wang, 2013:71)

From the perspective of Creswell's framework, my study may be described as follows. (a) Since the objective of the study is to *measure* an aspect of cities, then cities are an objective reality. Otherwise, it would not be possible to develop a consistent metric to measure cities if they were subjective. Although cities are built by humans, once they are created, their physical form is independent of human perception or expectations. A street that is 200m long is the same length regardless of what a person sees or experiences when looking or walking on it. (b) Imageability is a quality of cities that – by virtue of being part of cities – is similarly independent of human perception and exists regardless of our awareness of it. Thus, if a blind person walks on an imageable street but sees nothing and does not experience imageability, the city is still imageable regardless of the individual user's experience. (c) Imageability is created by the existence of physical elements in the city that can be broadly classified into five categories (paths, nodes, edges, landmarks and districts). If these elements exist, then so does imageability, regardless of what any one individual experiences. These initial three points describe the ontology of the study from the perspective of Cresswell's framework. In terms

of epistemology, (d) imageability is traditionally described through cognitive mapping, where people describe what they find striking or memorable about the city that they are mapping and the image of the city emerges as the points of overlap between how each individual experiences, perceives and recalls the physical features of the city. If the researcher asks a large enough sample to describe what they find remarkable or memorable about a place, there will be some points of deviation but most respondents will share common perceptions and experiences of physical aspects of that place. Furthermore, their perceptions will generally be classifiable into five categories (channels of movement, *paths*; places of concentration, *nodes*; boundaries that modulate movement, *edges*; significant points that stand out and are useful for orientation, *landmarks*; and places that are characterised by similarities in use or structure, *districts*). This overlap between individual perceptions and the tendency for perceived urban features to be grouped into five types of elements will occur regardless of the researcher's own perception of the city and therefore it is a reality that is independent of the researcher. (e) The propensity for particular aspects of the physical environment to be perceived as striking or memorable can be described statistically by using value-neutral mathematical tools such as the Ewing model. In terms of methodology, Creswell's framework would classify my research as being deductive, as can be seen in the following two points. (f) The study proceeds from the physical structure of the city (the *cause*) to the respondents' perception of five categories of urban elements, which confirm imageability (the *effect*). (g) Finally, once imageability is measured (and thereby described quantitatively) it is possible to compare it to other measurable phenomena such as the number of pedestrians on a street. Thus, linear regression can be used to measure the correlation between imageability and the number of people walking on a street. Figure 22 outlines the above description of my research in terms of Cresswell's framework.

(a) Since the objective of the study is to *measure* an aspect of cities, then cities are an objective reality. Otherwise, it would not be possible to develop a consistent metric to measure cities if they were subjective. **[Ontology -> Objective reality]**

(b) Imageability is a quality of cities that – by virtue of being part of cities – is similarly independent of human perception and exists regardless of our awareness of it. **[Ontology -> Objective reality]**

(c) Imageability is created by the existence of five types of physical elements in the city. If these elements exist, then so does imageability, regardless of what any one individual experiences. **[Ontology -> Objective reality]**

(d) Imageability is traditionally described through cognitive mapping, Cognitive maps are characterized by overlap between individual perceptions and the tendency for perceived urban features to be grouped into five types of elements. Since overlap and the categorization of elements into five types occur regardless of the researcher's own perception of the city, imageability can be studied independently of the researcher. **[Epistemology -> Independent]**

(e) The propensity for particular aspects of the physical environment to be perceived as striking or memorable can be described statistically by using tools such as the Ewing model. **[Epistemology -> Independent]**

(f) The study proceeds from the physical structure of the city (the *cause*) to the respondents' perception of five categories of urban elements, which confirm imageability (the *effect*). **[Methodology -> Deductive]**

(g) Once imageability is measured, it is possible to compare it to other measurable phenomena such as the number of pedestrians on a street. Thus, linear regression can be used to measure the correlation between imageability and the number of people walking on a street. **[Methodology -> Deductive]**

Figure 22 Description of present research in terms of Cresswell's framework

3.2.1 Empiricism, logical positivism, and the scientific method

Research projects that faithfully subscribe to the rigid boundaries of Cresswell's framework are examples of positivism (Groat and Wang, 2013). The positivist view of research is characterized by the belief "that scientific truths could be positively verified through empirical observations and the logical analysis of what was observed" (Babbie, 2016: 35). Thus, positivism has two prongs: empiricism (experiential data) and logic (a system of thinking that evaluates the relationship between premises and conclusions). Logic significantly predates empiricism. Greek philosophy valued logic but often used idealism as the premise of their logical deductions, although there were many notable exceptions[14]. For example, Aristotle created the earliest known systematic classification of organisms but used the concept of "Telos" (an ideal purpose) to determine why things are what they are. From the premise of telos, a bird is a bird because it either wants to be a bird or it is meant to be a bird. Because of this faulty premise, the logic in this statement is self-referential and weak. Empiricism came about in the 16th century, beginning with Francis Bacon's formulation of the scientific method, which paired empirical observation (and experimentation) with rational analysis (and mathematical modelling). Bacon replaced idealism with empiricism but retained logic as a key ingredient in the creation of knowledge. He reasoned that idealism required either incredible intelligence or luck for a researcher to land on ideals that were correct enough to always remain true regardless of the circumstance. However, with empiricism, a researcher could patiently use careful observation and experimentation to find something that works (what we might call a principle) and then use logical deduction to infer other instances where it might work.

In general, we build theories that are simplifications or abstractions of the most important aspects of how the system works, and we may make predictions based on these abstractions. For such generalizations, we frequently use mathematics as a foundation. We develop trust in the theory if it repeatedly predicts the system under a variety of situations; finally, this confidence may be so great that it achieves the status of a law. The finest examples of this process are those of classical mechanics, in which we discovered laws of motion that describe how things move when forces are applied to them under a variety of situations that we can create in our immediate experience (Batty, 2017). The scientific method refers to how we come up with these hypotheses, as well as any rules we may infer from them. This is made up of two interconnected processes known as induction and deduction. The basic mechanism to derive theory is to start with a series of observations that appear to suggest some degree of regularity in the system of interest (Babbie, 2016). As a practical example, we may consider the development of explanations of how urban populations are distributed. Batty (2017) notes that several authors in the 20th century had noted that the density of city population decreases as distance from the city centre increases. By the middle of the century, there was enough data gathered to evaluate the possibility of fitting well-defined regular functions of density against distance to such events. From this baseline of existing data and experience, in 1951 Colin Clark was one of the first to successfully demonstrate that if such a function could be fitted to a metropolis, it could be used to forecast future population densities. This example is illustrative of how the accumulation of previous empirical experience allows theorists to logically infer generalizations that lead to discoveries such as that made by Clark. This is the process of induction (Batty, 2017).

The combination of logical analysis with (positive) empirical evidence laid the groundwork for the emergence of logical positivism as the prevailing approach to scientific discovery in the early 20th century. The Vienna Circle was a group of philosophers in this period who epitomised logical positivism (Uebel, 2020). The two main ideas of logical positivism were the analytic/synthetic distinction and the verifiability theory of meaning (Russell, 2001). In terms of the first idea, logical positivists argued that knowledge claims fall into two categories. Analytic propositions are ones that are true or false by virtue of their meaning alone. For example, the sentence "a home is where a person lives" is true as a matter of convention based on the meanings of words: "home", "where", "person" and "to live". The value of analytical propositions for logical

14

positivism was that it allowed them to explore the validity of mathematical claims independently of empirical evidence. For example, the claim "2+2=4" is an analytic proposition and it is true in abstraction, independent of the real world. The logical positivists further argued that propositions that are true or false by virtue of how the world is fall into the category of *synthetic propositions* (ibid). For example, the sentence "this home is old" or "this person does not have a home" are synthetic propositions because their validity depends on the nature of the world, on the amount of time that a home has existed or on whether a person has a place to live.

a. Imageability is associated with walkability. It creates positive experiences for people and thereby encourages people to be outdoors and to walk **[synthetic]**
b. Imageability is created by the existence of physical elements in the city that can be broadly classified into five categories **[synthetic]**
c. Imageability is traditionally described qualitatively or through cognitive mapping **[synthetic]**
d. Ewing et al describe imageability through a statistical model **[synthetic]**
e. The Ewing model can be used to describe imageability in a different context **[contains analytic statements: Ewing model; imageability]**
f. Correlation can describe the relationship between imageability and walking **[contains analytic statements: Correlation; imageability]**

Figure 23: Description of present research project in terms of the analytic/synthetic distinction

Figure 23 illustrates six points that can be made to describe my research. Let us consider how they can be interpreted in terms of the analytic/synthetic distinction. (a) "Imageability is associated with walkability" is a synthetic statement because validating it requires either observations of imageable places and the number of people walking in it or a literature review that describes how other people have associated imageability with walkability. Therefore, the truthfulness of this statement is contingent on the nature of the world. (b) "Imageability is created by the existence of physical elements in the city" is also a synthetic statement because it similarly requires empirical evidence. In this case, evidence would be to observe imageable places and to identify the elements in them as being responsible for the imageability in these places. (c) and (d) are also synthetic propositions because they require a literature review as proof of their truthfulness. These first four statements employ inductive reasoning by basing their validity on experience. However, (e) and (f) are analytic statements. They assume the validity of previous statements. For example, in statement (e) ("The Ewing model can be used to describe imageability in a different context") statements (b) and (d) are assumed to be true. Otherwise, statement (e) cannot be made without first asking "is it possible to describe imageability statistically" and "what variables should be measured", questions that are dealt with in statements (d) and (b) respectively. From this exercise we can see how logical positivism attempts to shift from an inductive mode of thinking into one that is deductive. It does this by taking empirical observations and inferring "laws" based on these observations about how future observations will behave (fig.24).

If ***M*** is a model that describes a place

If ***x*** and ***y*** are both places

If ***M*** can describe ***x***,

Then ***M*** can also describe ***y*** (because ***M*** describes places and ***y*** is a place)

M ~ ***x***

x = ***y***

thus... ***M*** ~ ***y***

Figure 24

The use of prior experience to infer laws about future observations requires some way of verifying that the statements about prior experience are comparable to statements about future observations. In the case of the example in fig.24, to infer that M has a relationship with y, based on the fact that M has a relationship with x, we need a way of verifying the sameness of x and y. We need to verify that x and y "represent the same thing". This could be demonstrated in another example, in terms of language. The IsiZulu sentence "*igazi libovu*" means the same thing as the English sentence "blood is red". Yet how do we determine that these indeed mean the same thing? In the *verifiability theory of meaning*, the logical positivists argued that statements can only have a meaning if they can be empirically tested (Alston, 1955). That is to say, "blood is red" is only meaningful if we can look at blood and see that it is red and therefore this statement is equivalent to its IsiZulu counterpart insofar as if we verified "*igazi libovu*" we would again look at the concepts therein and find empirical evidence of the same thing. The verifiability theory of meaning effectively excluded discussions of poetry, ethics, and theology from being forms of knowledge insofar as these are not empirically verifiable.

Quine (1976) challenged the foundations of logical positivism, describing the analytical/synthetic distinction and the verifiability theory of meaning as "the two dogmas of empiricism" (Quine, 1976: 41). He argued that testing and meaning were holistic (an idea known as *holism*). It is impossible to test ideas in isolation; when you test one idea, you test every idea connected to it. Therefore, the analytic/synthetic distinction does not make sense. From Quine's perspective, any test of synthetic claims also involves testing some analytic claims. For example, when we test a sample of 4 observations, we are not only testing the content of the observations but are called to question 'what it means to be "4"; of if the observations are sufficiently similar to constitute "4" of the same thing' However, "4" is an analytic statement and is supposed to be true by convention, without testing. If we refer to our previous example in figure 3, the practical implication of this is that, if we test statement (e) "The Ewing model can be used to describe imageability in a different context" and find that we are unable to describe imageability, we do not necessarily know as yet if statement (e) is false, even though we have tested it. Perhaps there may have been a mistake in the way that the test was run. We would have to ask what we mean by "the Ewing model" (statement (d)), what we mean by "describing imageability" and what we mean by "different context". In chapter 5, I discuss how the first set of measurements had an error because some of the features counted in the street audit did not match the definitions of the Ewing model's variables. Therefore, one of the steps involved in the research is establishing operational definitions of the model variables and thereby testing if they make sense rather than assuming the model as an analytic statement. In terms of asking what we mean by "describing imageability" and what we mean by "different context", I experienced a challenge in interpreting the resultant scores from using the Ewing model to measure imageability in Diepkloof insofar as determining what constitutes a valid description of imageability. Since the average score described in Ewing and Clemente (2013) is 3, if I find a score of 1.9 on my site, would this be a valid score or a measurement error? Would it be an abnormally low score, or does that depend on the context (that some places just tend to have lower imageability)? Again, rather than assuming "describing imageability"

and “context” to be analytic statements, it is necessary to test what this means. In chapter 4, I describe how I developed a scale to contextualise the Ewing model’s descriptions of imageability across a varied sample of international streets.

3.2.2 The problem of induction

The logical positivists attempted to construct a scientific inductive logic that resembled deduction as closely as possible. This approach proved to be infeasible. Figure 25 illustrates an example intended to show why induction cannot be reduced to deduction. To put it another way, when we formulate hypotheses, test them, and generalize based on the results, it's not just a matter of form (how we do these steps), but the content of each step (what kind of hypothesis we formulate, how we test it) has an impact on the truthfulness/validity of the knowledge derived from the process.

A. “This piece of copper conducts electricity”

- This confirms (increases the credibility of) the hypothesis ‘all pieces of copper conduct electricity’
- This is clearly a legitimate example of confirmation

But what about...

B. “This person is a third child”

- This confirms the idea that all people are third children.
- This is clearly ridiculous. But what, exactly, is the difference between these two statements?

Figure 25

How can we tell the difference between the two types of confirmation shown in (A) and (B) (fig.25)? In both circumstances, the syntactic structure is the same: "This *X* is a *Y*, hence all *X*'s are *Y*'s". As a result, confirmation cannot be only a consequence of science's logical framework. There needs to be something about the theories that differentiates them. Since statement (A) is 'law-like' (and so can be verified) and (B) is just 'accidental', what is required is a mechanism to distinguish between 'law-like hypotheses' and 'accidental hypotheses'. Inductive reasoning attempts to use confirmation to make this distinction. Statement (A) is considered a valid knowledge claim because it has many instances of confirmation. If Kevin Lynch’s claim that the image of the city is made up of elements is borne out in subsequent studies that also find that people tend to perceive the city as being made up of the five elements, then these findings add validity to Lynch’s claim. However, the notion that scientific knowledge can become “law-like statements” is at odds with the position of empiricists, such as David Hume. They would counter that we can only know what we observe. Yet we cannot observe law-like statements; we can only observe individual instances that confirm the statement but not the statement itself. Since the future is under no obligation to be the same as the past, we cannot know with certainty that any statement is a law of nature. This is the problem of induction. Betrand Russell (2001) illustrates this problem using a story about a chicken (fig. 26)

- **According to the chicken, every time the farmer shows up, he pours grain into the enclosure and the chicken gets fed. This is consistent with inductive reasoning and the chicken may reasonably conclude that there is a ‘law of nature’ that when the farmer shows up it gets food. But then one day the farmer shows up and kills the chicken for dinner!**

Figure 26 the parable of Russell’s chicken (adapted from Russell, 2001: 35)

Russell’s example points to the potential danger of induction creating an unrefined view of reality. Therefore, while confirmation can be helpful in distinguishing between statements (A) and (B) (fig. 25), confirmation

alone is not sufficient to determine the validity. Nelson Goodman's "New riddle of induction" points to a second problem with confirmation, that it is possible for the same data to confirm two mutually exclusive statements

Consider these two statements:

1. All emeralds that we see before time (T1) are green (*e.g., before 1999*)
   - Up to time T1, all observations confirm the hypothesis 'all emeralds are green'
2. But imagine another predicate, 'grue', where something is grue if:
   - It is observed before T1 and is green or
   - It is observed after T1 and is blue

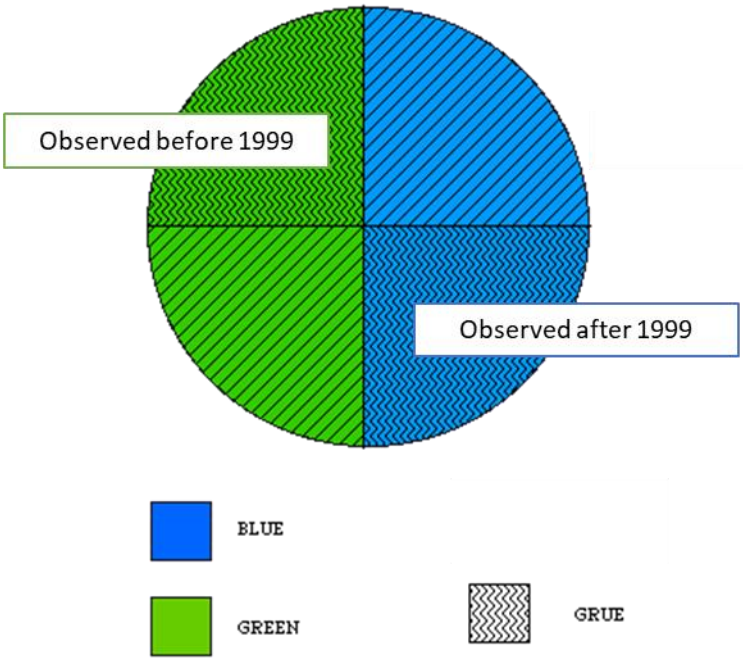


Figure 27: "Grue" – Nelson Goodman's New Riddle of Induction: theories can suffer from underdetermination because the same set of data can provide confirmation for mutually exclusive claims (after Elgin, 1997: 88)

In figure 27, Statement 1 and Statement 2 are both true and supported by the same evidence, even though they are mutually exclusive. Something cannot be both green and blue at the same time because of how those categories (colours) are defined. However, it is possible for something to be both green and *grue* at the same time because of how those categories are defined, even though the category of *grue* contains the mutually exclusive categories of green and blue within it. Because both arguments have the same form, we must conclude that inductive validity is not inherent to the formal structure of arguments. However, because both arguments are backed by identical evidence, inductive validity is not a substantive feature of arguments. Goodman's riddle has implications for how scatter plots would be interpreted before performing linear regression. For any graphable dataset, there are an infinite amount of mutually exclusive equations that fit the data. Thus "given a set of data points on a graph, which might be connected by countlessly many different curves, which is the best curve that might be drawn through these points, recognizing that each point in the curve selected (other than those points originally obtained as data points) constitutes a prediction about unexamined cases?" (Elgin, 1997: 109). The purpose of Goodman's concept of *grue* is to demonstrate that the same facts can support different and sometimes mutually exclusive statements (Elgin, 1997). Thus, while confirmation is helpful in distinguishing between statements such as "copper conducts electricity" and "all people are third children" (fig. 25), this is only possible because the data for verifying one claim is very different from that of verifying the other. However, in cases such as the social sciences there are often cases where the same data is open to multiple interpretations and with a big enough sample it is possible to find confirmation for almost any claim.

3.2.3 Karl Popper's problem of demarcation: science as conjecture and refutation

Popper's main concern was the question of how we decern the difference between valid science and non-science (or 'pseudo-science'). This became known as the problem of demarcation. Popper concedes the points discussed in the previous section, regarding the problem of induction, but argues that science is not founded on induction. Induction, according to Hume, is a "psychological habit" with no rational basis. This implies that

science lacked a logical foundation. In terms of the induction problem: We learn to believe that there is a 'necessary relationship' (a scientific law) between X and Z if we witness X followed by Z enough times. However, we never perceive this 'essential link,' and the future is under no obligation to repeat the past. As a result, science has no way of knowing if such a link/law exists. Unlike Hume, who argued that the problem of induction represented a crisis for science since there cannot be confirmation of scientific laws[15], Popper argued that "the fundamental feature of a scientific theory is that it should be falsifiable" (Okasha, 2016: 11). Thus, for Popper, genuine science is also immune to the underdetermination of theory (as described in Goodman's New Riddle of Induction), whereby the same data confirms multiple theories. This is because science is not concerned with finding confirmation but, instead, all good scientific research projects are attempts to falsify a theory and good scientific theories are those that have not yet been falsified. Thus "human knowledge is based not on unchallengeable, rock-solid foundations, but rather on a set of tentative conjectures that can never be proven conclusively, but only disproven" (Bhattacherjee, 2012: 11).

An earlier section of this chapter (3.2.1) discussed Quine's (1976) refutation of the logical positivists' distinction between analytic and synthetic propositions. Quine argued that testing a sample of 4 observations necessitates first asking what it means to be "4" and thereby testing the notion of "4", which is an analytic statement. To observe a sample of four things, we have to have some *a priori* expectation. However, empiricists, such as Hume cannot explain how we come to see four events as being repetitions in the first place, since they think expectations only come from observation. For Popper, to say two events are "the same" we need to interpret the data. Making such an interpretation requires a frame of reference, a best guess of what to expect. The role of induction then is to provide this baseline expectation through prior experience or existing theories – what Popper calls conjectures. Phenomena or observations are never just 'similar' or just 'different'. Instead, they are only similar or different in certain regards, in certain respects. Unless those regards are specified in advance, then you cannot say whether things are similar or different. Thus, before we can even observe a phenomenon, we need a theoretical context in which that observation can display itself. This is called "the theory ladenness of observation" (Kordig, 1971: 1).

a. Imageability is associated with walkability. It creates positive experiences for people and thereby encourages people to be outdoors and to walk **[theoretical framework]**
b. Imageability is created by the existence of physical elements in the city that can be broadly classified into five categories **[theoretical framework]**
c. Imageability is traditionally described qualitatively or through cognitive mapping **[theoretical framework]**
d. Ewing et al describe imageability through a statistical model **[theoretical framework]**
e. The Ewing model can be used to describe imageability in a different context **[hypothesis]**
    - Can this model be used to describe imageability in a different context **[research question]**?
f. Correlation can describe the relationship between imageability and walking **[hypothesis]**
    - Can the association between imageability and walking be demonstrated through correlation **[research question]**?

Figure 28: Description of present study from a Popperian perspective

[15] there cannot be empirical confirmation of scientific laws because the laws themselves are not observable

Figure 28 shows a description of my research project from a Popperian perspective. The structure is similar to that described earlier, from the logical positivist perspective (fig. 23). The first difference between these two perspectives is that, whereas logical positivists divided knowledge claims between analytic statements (which are assumed to be true by convention) and synthetic statements (which are empirically verified), in the Popperian perspective all knowledge claims are conjectures and open to testing and potential falsification. This boundless openness to testing is a point that other philosophers of science, such as Kuhn (2012) and Feyerabend (1993), critique about Popper's view of science. In figure 28, the first four claims (a – d) have more confirmation than the last two because there have been previous studies exploring their validity. These statements are the theoretical framework, and they provide the inductive basis for the claims that the research aims to test. However, it is important to note that for Popper all of these claims are conjectures and – since past experience has no bearing on the future – even claims that have been confirmed before are open to potential falsification. Thus, the second difference between the Popperian and logical positivist perspectives is in the objective of scientific enquiry. While logical positivists sought empirical confirmation of claims, Popper argues that the true test of scientific rigor is falsification. To this end, Popper makes ten key points in response to the problem of demarcation, for distinguishing science from non-science (fig. 29):

1. Scientists believe in induction because they mistakenly thought it was an answer to the problem of demarcation
2. Induction is an insufficient demarcation
3. Inductive inference is a myth
4. Confirmations for any theory are everywhere if you look for them
5. Science actually operates by conjecture and refutation
6. Experiments are tests of hypotheses and attempted refutations
7. Every scientific theory prohibits some things from happening
8. Every genuine test of a theory is an attempt to falsify it
9. A theory that is not falsifiable is not scientific. Unfalsifiable theories are not necessarily false or worthless. They are just not science.
10. You can rescue a falsified theory by retooling it, but this may weaken its falsifiable status.

Figure 29: Demarcation: What make a theory 'scientific'? (Okasha, 2002)

A key criticism of Popper's framework is that it does not provide a distinction between anomalies and counterexamples and therefore can lead to invalid claims of falsification. If a scientist tests a piece of copper, to see if copper conducts electricity. If they find that there is no conduction on that particular piece of copper does that mean they have falsified the claim that 'copper conducts electricity'? It seems far more likely that there may have been an error in the way that their test was set up (mis-calibrated instruments, contaminated sample, etc.). As stated earlier (3.2.1), any attempt to test a claim implies a test of other claims underlying the claim that is the subject of study (Quine, 1976). In this case, testing if copper conducts electricity involves

questions about what constitutes copper, about the sample size necessary for conduction and about how electricity works. It is far more likely that the scientist in our example is not properly cognisant of any of the underlying claims or that they made an error. The finding is an anomaly. This does not necessarily mean that the finding is wrong but that it does not decisively meet the standard of falsification, given that there may be another explanation for it. A*nomalies are not counterexamples*. If they were, then all theories would be falsified. The Popperian framework does not give clear guidance for how to distinguish anomalies from counterexamples. Having falsification as the objective of research also has the unintended effect of creating perverse incentives for researchers to be inadequately critical of their findings. It could also create *white noise*, whereby having a large number of new research that mistakenly claims to have falsified existing theories undermines the reliability of scientific knowledge. This is because a theories longevity and its popularity increase scientific interest in it and therefore (if all scientists are approaching it from a Popperian perspective) there is more chance of anomalies.

3.2.4 "Normal" science and research paradigms – post-Kuhnian philosophy of science

The philosophy of science can broadly be divided into two categories. The perspectives discussed thus far fall in the first category, concerned with the "context of justification". They looked at how scientific theories attain their validity. Thomas Kuhn focuses on the historical development of science and how theories come into existence. This is known as the context of discovery (Kuhn, 2012: 46). In his book, *The Structure of Scientific Revolutions* (which was first published in 1962), Kuhn is concerned with the conditions that affect the conception, maturation and acceptance or rejection of scientific ideas. He notes that most history and science textbooks tended to portray science as written from the perspective of the enlightenment. Science is framed as a totally rational undertaking that begins in the ancient world and incrementally progresses in a more-or-less straight line to the present day. Kuhn argues that this is an unrealistic vision: the history of science is littered with dead ends, false beginnings, and inconsistencies. There are bogus hypotheses, failed experiments, and a lot of 'going back to the drawing board'. Instead of this vision, Kuhn (2012) proposes that the history of science is characterised by long periods of "normal science" that are interrupted by paradigm shifts (2012: 47). As opposed to Popper's characterization of every legitimate scientific project as being a daring attempt at falsification, for Kuhn the majority of everyday science is tranquil, uneventful problem-solving – "normal science". Normal science operates based on a set of unchallenged assumptions that regulate (among other things): the kind of questions posed, how those questions are researched, and how the findings are interpreted. A "paradigm" is a framework that describes the mode of thinking in a given period of normal science. Examples include the Aristotelian, Newtonian and Einsteinian paradigms in physics or the Aristotelian and Darwinian paradigms in biology. From this perspective, the frame of reference that allows observations (either by identifying relevant data[16] or establishing 'natural kinds'[17] or by creating a proto-hypothesis[18]) is provided by the paradigm (the kind of normal science) that exists at a particular point in history.

A scientist's day-to-day practice isn't nearly as heroic as Popper portrays it to be. In the lab, a typical day consists of sluggish, monotonous, repetitive work. Kuhn (2012) argues that, in a period of normal science, research focuses solving 'puzzles' with the belief that a solution does exist, just as there is a solution for a crossword puzzle[19]. As long as there are no significant threats to the paradigm, normal science will continue but anomalies will inevitably emerge. These take the form of Results or observations that do not fit within the prevailing paradigm or cannot be immediately explained. They may have many different causes, such as poorly

[16] The hypothetico-deductive method

[17] Nelson Goodman's "new riddle of induction"

[18] Karl Popper

[19] This part of Kuhn's argument is objectionable because it assumes not only that a discoverable reality exists but also that the human mind is an adequate tool to comprehend such a reality. In his allegory of the Cave, the Greek philosopher Plato asks whether the human mind has constraints that prevent it from ever being able to see the world as it is (Wright, 1906).

constructed experiments. In the course of normal science, the errors are often found, and the anomaly ceases or experiments from different disciplines usually provide new information that explains the anomaly. However, Kuhn further argues that, as anomalies accumulate, they push the scientific paradigm into a state of crisis. Yet this does not result in the immediate rejection of the paradigm, contrary to what Popper suggests should happen. Instead, it is seen as inadequate but continues to persist.

At this point we can see a key distinction between how Popper and Kuhn each describe science. Popper's perspective is normative, describing how scientists should act when they do science whereas Kuhn, taking the historical perspective, is describing how scientists have tended to act. In practice, scientists may have good reason to continue working within a paradigm (or an individual theory) despite recognizing it as inadequate. One reason may be the lack of an alternative explanation for observations, that the present paradigm explains enough other things even if it cannot explain them all. Another reason may be its heuristic value. That is, even if a theory is demonstrably false, it may continue to be useful as a practical tool if it is effective (this was the case for the Ptolemaic geocentric model, which continued to be a useful means of navigation even after it was an accepted truth that the sun does not revolve around the earth) (Kuhn, 2012).

Popper and Kuhn disagree regarding how open science should be criticisms and claims of falsification. According to Popper, a 'good scientist' is one who is (a) innovative and (b) open to criticism. Kuhn accepts the former but rejects the latter. During a time of normal research, scientists are fairly closed-minded. They can only view facts in terms of their paradigm. Kuhn claims that if scientists were as open as Popper desires, science would cease to exist. Science necessitates collaboration and unanimity, which in turn necessitates the cessation of debates about established fundamentals. For Kuhn, accepting a paradigm requires a certain amount of faith and, to that extent, a good scientific education (within a paradigm) is in fact a form of indoctrination. Whereas Popper believes that open-mindedness is what enables scientific progress, by preventing dogmatic thinking, Kuhn argues that science works by striking a balance between open-mindedness and paradigm-specific focus. Very little progress would be made if the bulk of scientific research was spent on testing and retesting established knowledge. While he recognises that the status of any knowledge as 'established' is questionable and that paradigms and theories become inadequate, Kuhn rejects Popper's attempt to use logic to resolve this problem. As discussed above, there are often rational reasons to maintain inadequate paradigms as well as good reasons to be dubious of claims of falsification. Whereas Popper sees all scientific change as stemming from conjecture and refutation, Kuhn distinguishes between two kinds of change. The first is change within a paradigm, wherein there are clear standards for what counts as progress because there is a pre-existing theoretical framework that sets the 'context of justification'. The second type of change is what Kuhn calls "revolutionary change" or a paradigm shift, which is a gradual process that involves uncertainty because of the accumulation of anomalies and contradictions and the erosion of the standards necessary to decisively determine between competing paradigms.

Given the preceding discussion, which contrasts Popper and Kuhn's approaches, we can describe my research project as (a) primarily working within the existing paradigm to make incremental changes within it but also (b) aware of the potential limitations of the existing theory and the role that my research plays as either providing conjecture or refutation of the existing theory. Specifically, my research expects that imageability exists and that it can be measured and demonstrated to have a relationship with pedestrian activity. This hypothesis is consistent with contemporary and classical urban design theory, which is the discipline's paradigm. The objective of the research is to solve the puzzle of how accurately the Ewing model can describe imageability and the extent to which measures of imageability can be statistically associated with pedestrian activity. In the Popperian sense, if the research findings show that imageability and its associated pedestrian activity cannot be described using the Ewing model, my hypothesis will have been refuted. I will then have to take a closer look at the theory and contextual conditions informing my hypothesis, in order to determine the extent to which they have been appropriately replicated in my study. For example, since previous studies of

imageability looked at highly urban, central, areas whereas my study looks at a suburban environment[20], are there important differences between these contexts that may affect the accuracy of my measurements? If so, perhaps I can calibrate the Ewing model in order to account for these differences and this may produce different results.

3.3 SITE SELECTION



Figure 30: Division of site into four quadrants (by Author)

The site was selected for its relatively self-contained structure. Since the study is looking at the relationship between two variables (imageability and pedestrian patterns), it was important to limit the number of external factors that could influence pedestrian patterns. During my site visits I found that the site could be further subdivided into four quadrants based the street network. For example, it is impossible to move from the north-west quadrant to the north-east without exiting the site and joining the main road. Thus, the quadrants are also relatively self-contained and can be studied independently and compared to one another. The self-contained nature of the quadrants informed the method of observing pedestrian patterns. It was possible to arrange the observation process as three phases: (1) around the perimeter of the site; (2) around the perimeter of the quadrant; and (3) within the internal streets of the quadrant. This limited the possibility of observing the same pedestrian more than once (fig. 30). This reduced the likelihood of double-counting during pedestrian observation.

[20] And in a developing country? With particular history

3.4 MEASURING THE PHYSICAL CHARACTERISTICS OF STREETS (MODEL VARIABLES)

The street characteristics to be measured as variables for imageability are described in Ewing and Clemente (2013). Data was collected on eight kinds of physical features: (a) number of parks, plazas, and courtyards; (b) number of major landscape features; (c) proportion of historic building frontage; (d) number of buildings with identifiers; (e) number of buildings with non-rectangular shapes; (f) presence of outdoor dining; (g) number of people; and (h) noise level. The measurements of physical environmental features were taken between July and October 2020.



Figure 31: Each street on site was divided into 100m segments. This ensures that the physical features measured are within the pedestrian's immediate field of view.

Unlike other approaches discussed in chapter 2 (such as space syntax or cognitive mapping) the Ewing model does not measure overall imageability of the neighbourhood. Instead, it simulates the experience of walking on a street and measures the imageability of a segment of that street, a distance within the pedestrian's immediate field of vision (about 100m). The site has 28 streets, which have been subdivided into 88 street segments of less than 100m (fig. 31). Initial measurements were taken using the measurement protocol described in Ewing and Clemente (2013), with a handheld camera, walking slowly through each street, and panning across:

- *start about 20 feet from the beginning of the block on the outside of the sidewalk*
- *walk slowly forward in the direction of adjacent traffic at a speed of approximately 1 mph*
- *as you move forward, pan slowly and continuously following the same sequence*
- *looking straight ahead, pan down 30 degrees, pan up 30 degrees, back to level*
- *pan 45 degrees right, pan up to the top of adjacent buildings or trees, and back to level*

- *pan 135 degrees left to the opposite side of the street, pan up to the top of opposite buildings or trees, and back to level*
- *pan 90 degrees right, to straight ahead*
- *repeat the sequence for a total of two complete pans*

Figure 32: Ewing and Clemente's (2013: 27) video recording protocol, which will be adopted in my study

Use of the prescribed protocol was intended to maintain consistency between my study and the Ewing and Clemente (2013) study, but use of this method proved unfeasible on site due to two main reasons. The foremost challenge was that the odd practice of walking through the neighbourhood with a camera drew unnecessary attention to me, which interfered with the behaviour of pedestrians and made me vulnerable to attempts to steal my research equipment. I often encountered people who were interested in what I was doing, and I had to pause to explain but there were also incidents of being followed, which interrupted the site visits. The second challenge was that the site encompasses more than 8km of street length, which would take several weeks to complete. The use of a hand-held camera was important in the Ewing studies as a way of simulating the pedestrian experience of a street, so that it could be communicated to the expert panel who were the respondents for the studies (Ewing et al, 2005a; 2005b; 2006). However, since the objective of taking videos in my study is to capture the physical features on the site, it is possible to achieve the same effect with a wide-angle lens mounted inside a car. I recorded the videos using a Canon video camera[21], which was mounted on a tripod in the backseat, and a cell phone[22] that was mounted on the windscreen.

Once the data is collected, it is entered into an excel spreadsheet that has the parameters of the Ewing model preloaded onto it. Measurement errors may occur if the person doing the measurements misunderstands Ewing and Clemente's description of the appropriate variables to measure. For example, one of the variables is landscape features. How large does something have to be for it to be considered a landscape feature? Does it have to be naturally occurring (such as a lake or mountain) or can it also be man-made? Ewing and Clemente (2013) provide descriptions for each variable to help the observer determine if an aspect of the environment qualifies as a variable that should be measured. However, since there are eight variables that have to be measured across 85 street segments, there is still room for error. Thus, how do we know if we have performed the steps correctly and that the data, we captured is accurate? More generally, how do we know if a score of 4.3, for example, represents high or low imageability?

> **Some urban design qualities are related primarily to what is in your immediate surroundings, while other urban design qualities depend more on the entire environment you can see. Consequently, for some measurements, you will be instructed to count elements only on the same side of the street, whereas for others you will count on both sides of the street. Sometimes you will be instructed to count only elements that are physically located within the study area, and sometimes you will count elements that you can see from the study area.**
>
> **Pay close attention to the specific instructions for each element. Instructions and scoring sheets will indicate which sides of the street you should measure ("your side" or "both sides") and also whether you should consider objects beyond the space you walked ("within study area" or "beyond study area"). Consider "within study area" to be anything within the area you walked or anything that is no more than 50 feet ahead of the area you walked. Consider "beyond study area" to be anything that is no more than 500 feet from the area you walked.**

Figure 33: Instructions on how to determine which aspects of the environment to measure as part of a variable of the Ewing model (excerpt from Ewing and Clemente (2013: 101))

21 Canon Legria HF R86

22 Huawei P20

3.5 APPLICATION OF EWING MODEL TO DERIVE IMAGEABILITY SCORES

The Ewing model can be described as follows:

Let:-

$E_m = 2.44\ (static\ constant)$

$x_1 = number\ of\ courtyards, plazas, and\ parks\ (both\ sides, within\ study\ area)$

$x_2 = number\ of\ major\ landscape\ features\ (both\ sides, beyond\ study\ area)$

$x_3 = proportion\ historic\ building\ frontage\ (both\ sides, within\ study\ area)$

$x_4 = number\ of\ buildings\ with\ identifiers\ (both\ sides, within\ study\ area))$

$x_5 = number\ of\ buildings\ with\ non-rectangular\ shapes\ (both\ sides, within\ study\ area)$

$x_6 = presence\ of\ outdoor\ dining\ (your\ side, within\ study\ area)$

$x_7 = number\ of\ people\ (your\ side, within\ study\ area)$

$x_8 = noise\ level\ (both\ sides, within\ study\ area)$

$m_1 = 0.41\ (multiplier\ for\ x_1)$

$m_2 = 0.72\ (multiplier\ for\ x_2)$

$m_3 = 0.97\ (multiplier\ for\ x_3)$

$m_4 = 0.11\ (multiplier\ for\ x_4)$

$m_5 = 0.08\ (multiplier\ for\ x_5)$

$m_6 = 0.64\ (multiplier\ for\ x_6)$

$m_7 = 0.02\ (multiplier\ for\ x_7)$

$m_8 = -0.18\ (multiplier\ for\ x_8)$

Thus imageability is thus given by: -

$$Im = \sum_8^1 x_i m_i + E_m \qquad (1)$$

From the above should x_{1-7} be kept at zero, and there is only noise in the street, it is noted that then the imageability will be below the static constant.

The result of measuring imageability on a street with the Ewing model is a score, a number between 2.44 and "something" (an as-yet-unknown upper limit). The low end of the distribution is limited to around 2.44 because, although places can have low imageability, it is not possible for them to have no imageability. Thus, the Ewing model adds a constant of +2.44 to each score. The purpose of the constant is to account for the fact that all places have some image and the imageability score cannot be absolute zero. However, there is no upper limit to the distribution, which means that we know how low imageability can be (around 2.44) but we do not know how high it can be. This poses a difficulty for interpreting a score, such as 3.5 for example, because we do not know if it is very high or only marginally higher than 2.44, since we do not have an upper limit to compare it to. To develop an upper limit for the Ewing model I decided to compile a distribution of 100 measurements (scores) made using the model. This would form a scale, with a value of 2 on the low end and another value (the highest observed score in the distribution) would form the upper limit of the scale. I refer to this process as "calibrating" the model. The starting point for developing this scale was to look at the imageability scores described in Ewing and Clemente (2013) of the streets in New York City, where the model was initially validated by measuring over 500 street segments. Ewing and Clemente (2013) found that imageability in New York City ranged between 3.36 and 3.87 (fig. 34).

	Bronx	Brooklyn	Manhattan	Queens	Staten Island
Urban design qualities					
Number of block faces	101	173	78	186	50
Imageability	3.36	3.74	3.87	3.45	3.43

Figure 34 (After Ewing and Clemente, 2013: 75)

3.5.1 Developing a scale of imageability

In order to understand whether a score generated by the Ewing model is "high" or "low" I developed a scale to contextualise the scores. The scale was developed by measuring 100 other streets in different contexts. The first 60 streets in this sample were taken from the same neighbourhoods in New York City where the Ewing Model was first verified (Ewing and Clemente, 2013). I determined the accuracy of my application of the model by the extent to which the average score for my measurements for each neighbourhood was consistent with the averaged reported in the verification study.

I took a random sample of 60 streets from Ewing and Clemente's (2013) study and, using online images and videos, I made sketches of scenes from these streets to get a qualitative sense of what these scores entail. It is notable that suburban areas such as Bronx and Staten Island had lower scores than more urban areas such as Manhattan. I expanded my scale by looking at streets in other cities (Barcelona, London, Johannesburg, Paris, and Rome). I purposely sampled suburban and inner-city streets to ensure that my understanding of the upper and lower limits of imageability scores was not restricted by the suburban context. The results of these measurements were made into the box-whisker plot shown below (fig.35), which was used to set the upper limit for measurements in the study. The highest scores in the scale were on La Rambla (Barcelona) and Borgo Pio (Rome), both with a score of 6.0. The five lowest scores were in Diepkloof (my site), ranging between 2.0 and 2.3. These low scores are reasonable, however, because of the suburban character of the site. The highest score in Diepkloof was 3.9, which is similar to the average score of streets in Manhattan. Certain scores were extremely high, such as Piazza di Spagna (Rome), with a score of 8.7. I used a boxplot to determine that these were outliers within the distribution and excluded them from the scale. Based on these scores, I was satisfied that model predictions were consistent with my qualitative impressions of the streets (based on my sketches) and that differences in context could be explained by the location of the streets relative to urban centres. "High" imageability can thus be defined as a score between 4.3 and 6.0, based on the scale that I have developed. A more detailed discussion of the scale is presented in chapter 4.

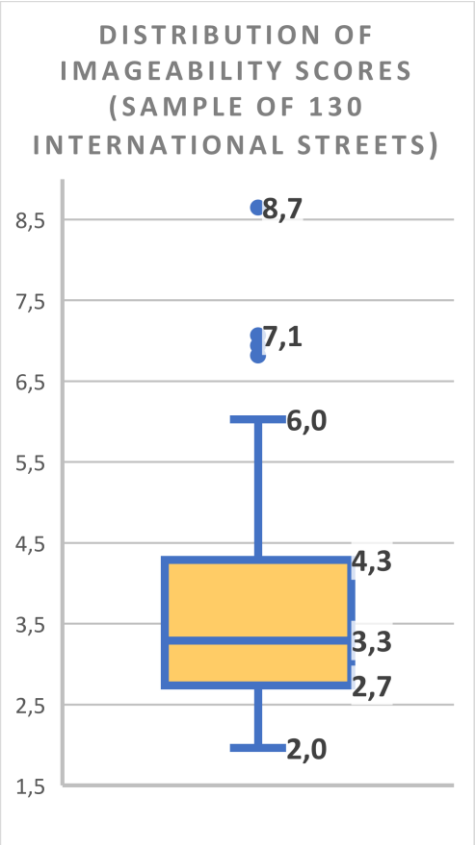


Figure 35: This box-whisker plot was used as a scale to evaluate the relative magnitude of scores generated by the Ewing model. With a scale, it is now possible to classify scores above 4.3 as being high and those below 2.7 as being low. Crucially, the scale allows for the identification of statistical outliers (values above 6), which are potential measurement errors.

The box plot in fig.35 shows that the median score for street imageability is 3.3. This means that half of the streets measured had scores on or below this point and the other half had scores on or above this point. The upper limit of imageability is a score of 6. Higher scores do exist (such as the Piazza di Spagna, in Rome (8.7), 5th Ave, in Manhattan (7.1), and Joubert Street, in the Johannesburg CBD (6.9) but these were rare in the sample of 100 streets (only 5) and they are considered to be statistical outliers. This does not mean that streets in Diepkloof cannot have scores higher than 6 but that, if they do, special attention must be given to why they are more imageable. High scores can suggest measurement errors or variables that are not consistent across contexts. They can also, of course, be an indication of high levels of imageability that, according to my hypothesis, should also have high pedestrian activity. Scores in Diepkloof range between 2 and 3.8 (very low to medium) and there are no scores in the 4th quartile (high).

3.5.2 Correcting measurement errors

Initial measurements were based on incorrect definitions of model variables. For example, views of landmarks, such as the Soweto Towers and the ridge on the horizon, were considered major landscape features. This was an error as the Ewing model only considers features that occupy at least 20% of the screen (Ewing and Clemente, 2013:140). I was able to determine this to be a measurement error by two methods. Firstly, I compared the measurements to the imageability scale (ch.4), to see whether they were low or high. Since the measurements had an average score of 5.76, they were very high and fell into the upper quartile of the scale. Secondly, I qualitatively assessed the scenes to determine if they possess imageability. This was done by noting the presence of striking features in the scene; and assessing whether the scene was memorable (if I could vividly recall the contents of the scene without looking at it).

Once I had identified that the scores were too large and probably represent an error, I corrected them by reviewing Ewing and Clemente's (2013) definitions of model variables and comparing them to how I determined which aspects to measure for each variable. I concluded that there were no significant "landscape features", although I had initially included the Soweto Towers and the ridges in the distance as part of this variable. I further concluded that the streets were too narrow to meaningfully distinguish between pedestrians on one side of the street as opposed to another when taking measurements for the variable of "number of pedestrians on your side of the street". This was because people generally walked in the middle of the street since most streets did not have sidewalks or lane markers (with the exception of the four main roads).

3.6 DERIVING QUALITATIVE DESCRIPTIONS OF IMAGEABILITY

Sketches are a useful technique for engaging with urban space as they require detailed and prolonged awareness of the contents of a scene. The process of sketching can also reveal intuitive aspects of the space that the observer may only experience subconsciously as they become aware of these aspects when drawing them (Richards, 2013). Prior to sketching a scene, I asked myself two questions to assess whether a street was imageable: (a) what is most striking about this scene; and (b), when I close my eyes, what do I remember about this scene (fig.36). I did not sketch every scene but, if I thought that what I remembered about the scene was unexpected, I made a sketch to explore where the elements are in the space. I also used sketches to explore scenes in cases where I found it difficult to remember their contents, where the space might have poor composition or the elements in the space have weak affordance or no apparent meaning. I then gave the scene a rating out of 10 to reflect my opinion of its imageability and wrote a short description explaining my opinion. Although the ratings were not used in any quantitative computation, they allowed a better comparison between the scores generated by the Ewing model and my experience from walking in the streets.



Immink Drive,
Diepkloof,
Johannesburg
(site)

Boston Post Road,
Bronx,
New York

Figure 36: using sketches to explore the spatial elements that make street scenes imageable. I asked myself: (a) What is striking about this scene; and (b) What is memorable about this scene? (By Author)

3.7 FIELD OBSERVATIONS OF PEDESTRIAN PATTERNS

I used video recordings to record pedestrian behaviour on the site in three stages. As mentioned, the site is divided into four quarters, based on its street layout. In the first phase of recording, I would drive around the entire site, using the main roads (Marius Smuts, Baragwanath, Immink, and Ben Naude). In the second phase, I would enter a quarter and drive around its outermost street (shown in black in fig.37). Then, finally, I would record the internal streets (shown in red in fig.37). Recording the entire site often took 40min, an average of

about 1min per street. This limited the chances of recording a pedestrian twice but, when tallying up the pedestrian counts for each street, I still looked out for potential repeated encounters.

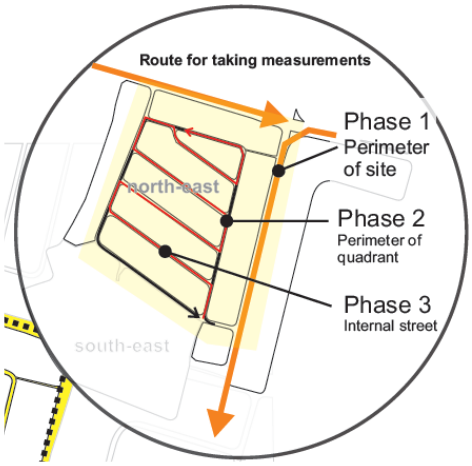


Figure 37 Route for taking measurements in the north-east quadrant. Similar routes were created for each quadrant: Main roads (1), loop street inside quadrant (2), linear streets from end of the block to the other (3). Starting outward and moving in limited the potential for double-counting pedestrians (by Author)

Recordings were done using a cell phone camera mounted on the windscreen. Unlike when recording physical features and building details, a single camera angle was sufficient to record pedestrian activity as both street edges were visible from a distance and I could pause the video to verify the exact location of pedestrians. Pedestrian data was collected for three times of the day (07:00-8:00, traffic to work and school; 14:00-15:00, traffic from school; 17:00;18:00, traffic from work). Recordings were done on weekdays, on Monday 28 Sep, Tuesday 29 Sep, and Wednesday 30 Sep. However, due to unfavourable weather conditions the recordings for the Thursday and Friday were taken on the next week, on 08 Oct and 09 Oct.

Pedestrian activity was mapped by using dots to show the pedestrian pattern, a single dot per pedestrian. This method has the benefit of more accurately representing quantity and clustering. Because I used video recordings rather than audit sheets (used in manual counts) it was possible to determine the exact position of pedestrians by pausing the video and representing the position accordingly on a map. Due to the large amount of work that this process entails mapping was only done for one set of pedestrian recordings (14:00-15:00, Monday, 28 Sep) to illustrate the general distribution of pedestrians.

3.8 STATISTICAL ANALYSIS – CORRELATION BETWEEN IMAGEABILITY AND PEDESTRIAN PATTERNS

A correlation analysis of imageability and pedestrian activity was performed. By testing for correlation, the study merely seeks to establish whether a relationship exists between variables. The existence of such a relationship is not sufficient to prove causation – that one variable is responsible for causing the other. For instance, a positive correlation between the proportion of historic buildings along a street and high pedestrian traffic would not mean that the historic buildings encourage walking (although some urban design theory does argue this to be the case). Rather, correlation serves as evidence that the two variables tend to occur together, even though we may still not know why this tends to be the case. This section explains the method used for calculating correlation and describes how this was performed using R-Studio software.

3.8.1 Linear regression and correlation

Linear regression was used to check for correlation between recorded pedestrian numbers per street with measurements of imageability per street. Correlation describes the linear relationship between two variables. By testing for correlation, the study merely seeks to establish whether a relationship exists between variables. The existence of such a relationship is not sufficient to prove causation – that one variable is responsible for causing the other. For instance, a positive correlation between *the proportion of historic buildings* along a

street and high pedestrian traffic would not mean that the historic buildings encourage walking (although some urban design theory does argue this to be the case). Rather, correlation serves as evidence that the two variables tend to occur together, even though we may still not know why this tends to be the case. This study will use a type of correlation known as *sample correlation*, which I have chosen because it controls for unknown potential variables, unlike the alternative *population correlation*. In a controlled setting (such as a factory, for example) it may be possible to account for the population but in a setting such as a street any correlation involving pedestrians would necessarily be derived from a sample. Sample correlation coefficients can be determined using Pearson's correlation coefficient (fig. 38).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2]\,[n(\sum y^2) - (\sum y)^2]}}$$

r = sample correlation coefficient
n = sample size
x = independent variable
y = dependent variable

Figure 38: Formula for calculating sample correlation coefficient (Wiseman, 2014)

3.8.2 Modelling in R-studio, identifying outliers and making scatter plots on MS Excel

Since pedestrian data was recorded on five different days at three different times of the day (15 data sets), linear regression was performed on the average of all the data sets. The linear regression model was built and run in R-Studio and the "summary" call was used to inspect the results. Figure. 39 shows a similar exercise for calculating the correlation between valentine's gifts and marriage (using fictional data).

```
Call:
lm(formula = Valentine's gift ~ Marriage, data = VLT_MRG)

Residuals:
    Min      1Q  Median      3Q     Max
-1.08672 -0.20325 -0.07426  0.32139  0.97846

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 2.741544   0.115237  23.790  < 2e-16 ***
Marriage 0.011269   0.003316   3.399  0.00205 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4634 on 28 degrees of freedom
Multiple R-squared:  0.4921,     Adjusted R-squared:  0.4822
F-statistic: 11.55 on 1 and 28 DF,  p-value: 0.002049
```

Figure 39 Summary call on R Studio

The most important items in the results of the summary call (fig 39) are the adjusted R-squared and the p-value. The p-value describes the statistical significance of the model results, and it must be below 0.005. An R-squared value above 0.6 indicates strong correlation. Since the R-squared value in figure 39 is less than 0.6, the independent variable explains less than 60% of the changes in the dependant variable and there is weak correlation between the variables.

In interpreting the summary call, I looked for outliers, points that were too high or too low in relation to the distribution (fig.40). By referring to my conceptual framework I could determine if the points were outliers if

the disproportionately high values at those points could be explained by factors such as land use or density. By removing outliers, I could improve the strength of correlation within the model. I took note of these outliers so that I could critically reflect on their significance for my research findings by using my conceptual framework. For example, one of the outliers in figure 40 is a street with a school. The presence of the school accounts for the higher pedestrian volumes but the large extent of the school reduces the number of other environmental variables (such as buildings with identifiers), which may reduce the imageability score generated by the Ewing model. This creates a situation where high pedestrian activity occurs in the absence of a correlating increase in imageability. However, the school may be a significant cognitive anchor, or it may hold special meaning to people familiar with the street and these may be positive aspects of imageability that are not accounted for in the model.

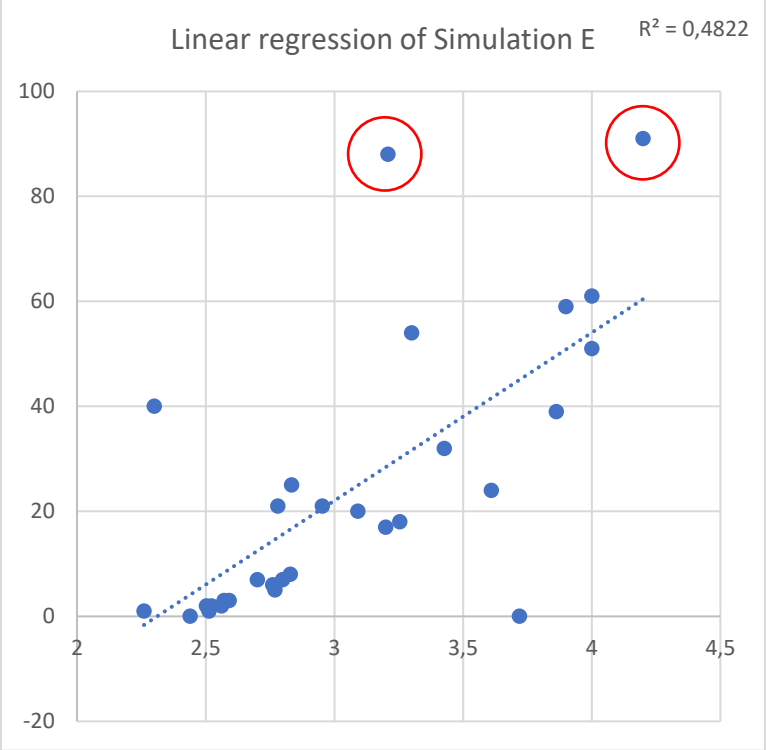


Figure 40: Example of linear regreassion scatter plot. Note the outliers circled in red. The presence of outliers is discussed in chapter 5 as the rationale for adjusting some of the variables in the Ewing model

3.9 LIMITATIONS

The scope of the study is limited in that the main method of analysis (linear regression) can only describe correlation and cannot be used to determine which environmental features *cause* people to walk on a particular street. However, since human beings have agency, it is unreasonable to presume that the environment could cause them to do something within any degree of certainty. Thus, any valid explanation of pedestrian behaviour necessarily requires a combination of quantitative methods (such as that used in this study), to describe pedestrian patterns in relation to the environment, as well as qualitative methods (such as interviews) to describe their motivations. Because of limited time, the scope of this research has been limited to (a) validating a method for measuring imageability, by interrogating its variables and comparing its results to qualitative descriptions of the concept; (b) collecting data on pedestrian patterns; and (c) determining statistical correlation between imageability and pedestrian patterns.

The method of collecting data on the physical features of streets (by driving) limits the use of the video recordings in qualitative research, as it does not adequately simulate the pedestrian experience. The

recordings are, however, an adequate reference for quantitative research as they accurately capture environmental details. Due to COVID-19 regulations at the time of recording, pedestrian patterns are very likely to be distorted as more people were at home. This fact limits the external validity of the research findings as they can only describe conditions within a relatively brief and unique period in time.

Finally, a potential challenge for the internal validity of the study stems from the fact that it is based on a model that was developed in a different context. The challenge in this regard has to do with how measurements from the model ought to be interpreted (the question of what it means for a score to be "high" or "low"), as discussed earlier in this chapter. I have attempted to correct for this by calibrating the model and developing a scale of measurements. However, this scale does not include streets in cities of the global south and thus the upper and lower limits of the quantitative definition of imageability presented in this study may be culturally biased towards European and North American contexts. The main factor behind this limitation is that, in choosing which streets to base my scale on, I relied on videos made by people walking in these streets (usually tourists), which I primarily sourced from YouTube. The popularity of the cities selected in my sample as well as language limitations on my part contributed a sampling bias.

3.10 Conclusion

This study involved seven kinds of research methods. Video recordings were used to measure physical environmental features and pedestrian patterns. The findings from this process were illustrated through mapping and tables. The Ewing model was calibrated by measuring the imageability of 100 international streets and then applied to the 30 streets on the site to get imageability scores. These scores were compared with qualitative descriptions and sketches of the streets to validate them and identify instances where model variables required modification to improve their suitability for the context and the accuracy of measurements. Statistical analysis was performed using linear regression, to determine correlation between imageability scores and the number of pedestrians observed in each street. The results were interpreted by noting the R-squared and p-values and checking for outliers. The conceptual framework developed in chapter 2 was used to explain outliers and to interpret other patterns in the data that were not explained by correlation.

Chapter 4: RESEARCH FINDINGS

4.1 INTRODUCTION

This chapter is divided into five sections. The first section discusses the context of Diepkloof zone 5 by discussing the legacy of apartheid on townships such as Diepkloof as well important topological trends in the site (such as densification and internal fragmentation) and how these affect activity. In the second section I present a scale that can be used to interpret measurements of imageability based on the Ewing model. Such a scale is necessary in order to understand whether imageability is "high" or "low" by comparing the site to measurements of other places. In the third section, measurements of imageability in Diepkloof are discussed in more detail, with drawings of site conditions. In the fourth section the pedestrian pattern is discussed with reference to mapping and time series charts, which illustrate spatial and temporal patterns, respectively. Finally, maps are used in the fifth section to discuss neighbourhood features associated with pedestrian activity, such as land use and street layout. The chapter presents several key findings. Imageability in Diepkloof ranges from medium to very low, when compared to international cases. Streets in the north of the site are usually more imageable and those in the south are disproportionately represented in the "very low" category. The pedestrian pattern is also more densely concentrated to in the north than the south. Street integration and land use show contrasting patterns between the north and south, whereas in terms of street length and block permeability the contrast is between the periphery and the core of the site. The pedestrian pattern is concentrated to the north of the site but not exclusively on the longer outer streets that connect the site to other places.

4.2 SITE CONTEXT

The planning and development of Soweto are inextricably linked to the spatial order of the "apartheid city". Soweto, like other townships around major urban centres in South Africa, was built as a physical manifestation of the apartheid ethos of racial segregation and its policies of influx control (Wale, 2013). As such, while Soweto is a "suburb" – to the extent that it is an urban area outside of the urban core – in South African parlance, it is a "township". In South African law, urban development is facilitated through the process of township establishment. This process applies to the development of suburbs as well. Thus, the distinction that has emerged between those places called suburbs and others that are referred to as townships reflects the engrained rationale of separateness that was physically manifested (in the 1950s and 60s) through a flurry of new township establishments, when the apartheid government developed a new typology of suburbs with the specific purpose of housing black people in areas that are distinctly separate from the exclusively white urban areas. When looking at Soweto today, for those familiar with the South African situation, "'suburb' implies a formerly white area or an area very similar to a formerly white area. Meadowlands, Emdeni and Orlando in Soweto are not called suburbs. Naturena, an area just east of Soweto developed for middle-class blacks near the end of apartheid, is called a suburb. Parktown North in Johannesburg is a suburb" (Ceruti, 2013:55). This section discusses three facets of this very specific site context. The historical circumstances under which townships such as Diepkloof emerged made the township into a place that is not exactly a home, too precarious and inconvenient to feel like home and yet too separate and far away to feel like the white city. The control and surveillance exerted by the apartheid regime was reflected in the urban form – especially in the control of movement by having frequent dead-ends and long streets that seldom connected with other streets – which made townships internally fragmented into enclaves, referred to as "zones"[23]. At the same time, the scarcity of places to stay for black people contradicted the high demand for cheap labour in large

[23] Zone 5, the study area, is an example of such an enclave.

cities such as Johannesburg and this promoted a trend of densification, as the small houses were expanded to create room for growing families and the influx of tenants looking for backyard rooms.

4.2.1 Historical background

Although the notion of the township as a distinct and separate entity from the suburb is intimately associated with apartheid planning, its legal and ethical basis significantly predate the National Party's assent to power (in 1948) and arguably date back to South Africa's colonial origins (Christopher, 1983). According to Wale (2013), the term Soweto (South-Western Townships) only came into general use in 1963, even though the first settlement in this area, Klipspruit, had been founded in 1904. The legal basis for the creation of segregated dormitory townships can be traced back to two pieces of legislation. The Natives Land Act (No. 27 of 1913) laid the legal groundwork for residential segregation, which was subsequently made mandatory by the Native Urban Areas Act (No. 21 of 1923), which emphasized the principle that Africans should only be permitted in cities if they were required to work for white industries. Notably, however, this legislation only came after the forced removal and relocation of black people to Klipspruit; thereby seemingly making the establishment of that settlement a naked exercise of power in pursuit of a racist ethos. The ostensible ethical motive for the forced resettlement of "natives", in the absence of an apparent legal basis, was that the multiracial working-class neighbourhoods that had emerged around the Johannesburg inner city, during the economic boom following the end of the Anglo-Boer War in 1902, had become slums and posed a serious health risk (Parnell, 1993). The 1906 Johannesburg Municipal Ordinance gave the council powers to forcibly relocate Africans to "municipally controlled compounds or locations" (ibid:126). Yet, while Africans were removed from the white city, they were nonetheless not free of the economic demands of the white city and the distant townships to which they had been relocated were not far enough to escape the authority of the white city. The natives, having been driven away to live separately in their black townships were saliently reminded by the shape of the township that even this place did not belong to them.

"So many times have I thought
about the defiant stance
of a railway station in a Location
my very first experience of
what is permissively called:
separate and equal amenities!"

Figure 41: (Pimville Station (1975), a poem by Sipho Sepamla, in Jones, 2018:10)

Apartheid planning separated places but the exploitative nature of the system also required that they remain connected. This tentative connection often took the form of a railway line that could move large numbers of people, like freight, at a minimal cost, with little consideration for comfort or integration into the local urban fabric. In the above poem Sipho Sepala remarks about the irony of the station as invasive technology that is "given" to the masses but remains intentionally inadequate, enough to control, confine and move them but not enough to empower them. In this stanza the final sentence stands out "as a direct quotation from state discourse, and the apartheid lie of 'separate but equal' is revealed as hollow and absurd" (Jones, 2018: 10). The station is "in" the township but not "of" the township and the township residents are ambivalent about their part in it. Yet it stands "defiant" as a solitary symbol of white oppression surrounded by a black area (ibid: 10). Klipspruit remained the only African location under the authority of the Johannesburg Council, itself a solitary island in what apartheid otherwise considered a white area. However, due to its remote location – on a disused sewage treatment plant – and it's appalling living conditions, it was undesirable for both its residents and the industrial employers who relied on it for cheap labour. The unreliable rail connection intended to bridge the 21km distance between Klipspruit and the white factories and mines in Johannesburg made it impossible to expect workers to arrive before 7am or leave after 6pm (Parnell, 1993). This resulted in attempts to find loopholes in the law, such as employers keeping servants' quarters in their properties or allowing workers to live on factory sites or in rooms leased by the employer in the white part of town, thereby

continuously broadening the interpretation of what the regulations meant by "employers' premises" and undermining the regulations' strict segregationist intent (ibid: 126). When Orlando was built in 1931 it was slightly less remote but still "something akin to exile" (Hellman, 1971, in Walle, 2013: 36). Yet, in the long run, this difference in proximity to the city has come to be mirrored in the emergence of class stratification within Soweto, with places like Diepkloof Extension (15km from Johannesburg CBD) resembling something like a suburb within the township: "occupied by the new middle and upper classes; it has quiet roads, big houses, well-kept gardens, high fences and expensive cars" (Wale, 2013: 51).

While Diepkloof Extension is a relatively new outlier, having been built in the 1980s, Diepkloof proper shares the same historical basis for its origin as other places in Soweto. Many of the initial residents of Diepkloof were Africans who owned property in Alexandra prior to 1959. When Alexandra was established, in 1912, it was a remote settlement on the northern outskirts of then Johannesburg, surrounded by farmland. When the developer was unable to sell the small stands, the area was declared a "Native Township" Gasennelwe (2011: 53). After 1948, this black foothold in the middle of white Johannesburg could not be tolerated and the state forcibly removed many of the residents, relocating them to Diepkloof. Wale (2013: 38) remarks that "Perhaps the most brutal outcome of apartheid's focus on the African middle classes was the programmes of forced removal of property-owning Africans from their houses in the freehold townships of Sophiatown, Martindale and Newclare to the new townships of Meadowlands and Diepkloof". Reflecting on the intent of apartheid policy, Parnell notes that "The African elite was crushed, coloureds became a distinct racial category and poor white protection from abject poverty was assured" (Parnell, 1993: 15)

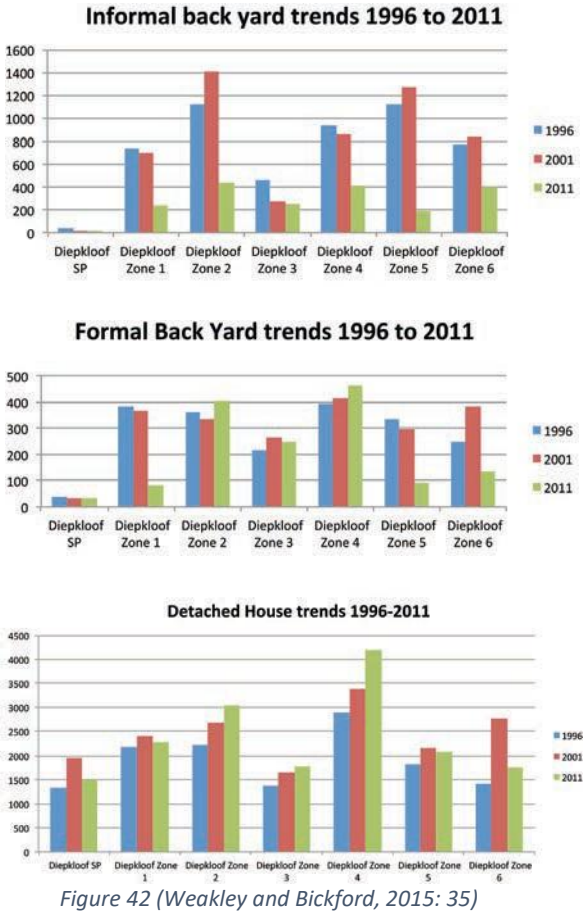


Figure 42 (Weakley and Bickford, 2015: 35)

The apartheid government built tiny three- or four-room dwellings in Diepkloof for black people who had previously lived in one-roomed cottages in Alexandra (Marx et al., 2008). In this regard – as with its proximity to economic opportunities in the white parts of town – Diepkloof was set apart from earlier settlements in Soweto from the onset and, although it has many of the same historic challenges that characterise the rest of Soweto (such as poverty and a shortage of housing (fig. 42)), it also has unique comparative advantages.

Through interviews with elderly residents, Weakley and Bickford (2015) found that the number of rooms in their homes was an important difference between the houses in Deipkloof and Alexandra to them, with many addressing it in the interviews. Household sizes tend to be large (4.8 people). Weakley and Bickford (2015) speculate that this fact may contribute to the prevailing attitude amongst residents that the houses are family homes and may explain residents' reluctance to sell. As a result, there are many residents of Diepkloof who have lived in the community since its inception. Families have grown in size over time as members of the same family have continued to live in the same house or in backyard units (ibid). Culture and financial position likely play a key role in this trend but one other contributing factor that enables backyard development emanates from the urban planning regulations. At the township's inception layout plans were approved without conditions of establishment and this allowed Diepkloof residents to build as many apartments as they choose on their land and run commercial operations there. Because there were no density or height limits, inhabitants of Diepkloof were free to build as many structures on their lots as they wanted (Marx et al, 2008). While the absence of conditions of titles was unique to Diepkloof, other factors also generally contributed to increasing densities throughout Soweto. Large household sizes have already been mentioned above but, in addition to this, the apartheid government began a strategy of developing the "native homelands", in the late 1960s, as a means of influx control, diverting housing funds away from the township, and this constricted the housing supply which created demand for backyard rentals (Ceruti, 2013). This trend has continued post-apartheid and accelerated as urbanization increased after the repeal of influx controls. Figure 42 shows how the housing supply increased most rapidly between 1996 and 2001 (Weakley and Bickford, 2015: 35). However, these charts may be misleading as they only show trends in the housing supply rather than the number of existing units. Since detached housing was the original typology of the settlement it is underrepresented in the growth trend as more people tend to build backyard units rather than new houses. The preeminent housing typology in Diepkloof remains the detached house.

4.2.2 Neighbourhood structure and movement



Figure 43 Demarcation of site into sub-areas that align with 2011 census data (by Author)

The site is in the southern portion of Diepkloof Zone 5 (fig. 43). It is bounded by three streets (Ben Naude Street to the north, Marthinus Smuts Drive to the west, and Immink Drive to the west), which act as its main

roads, and it has a stream on its southern edge. The site has a peculiar street pattern that is internally disconnected and externally misaligned. Streets within the site have very few connections to one another and there is no way to traverse from one end of the site to the opposite end without first exiting the site. All the main roads are outside of the site. Externally, the site has poor connections to surrounding neighbourhoods as the intersections tend to be staggered (or misaligned). As a consequence of this street network each corner of the site is somewhat of an enclave, where movement patterns are relatively self-contained, just as the site is itself an enclave relative to the other neighbourhoods around it, to which it has limited connections. This is in keeping with the rationale of apartheid planning to use the environment as a means of control, as discussed earlier in this chapter (Parnell, 1993). There are five alleyways that supplement the disconnected street network, and these are frequently used although they are poorly lit and often bordered by high walls (fig. 44 and 45). A 2.3Ha stretch of land to the west of the site that previously separated it from Zone 2 was converted into the Diepkloof Extreme Park in 2008. This park is one of four open spaces on the site, the other three being vacant – leftover – land rather than parks. The park is very active with children playing and commuters passing through or waiting along its edge but its location next to a busy main road impedes the likelihood of its frequent use by children from the site. Much of the playing observed on the site tended to occur in the streets and not in the other open spaces.



Figure 44: This alleyway between Mahlabathini Street and W Bombo Street (both in the south-west quadrant) is in very poor condition, with high walls, no paving, no lighting and strewn with litter (By Author)



Figure 45 School children walking out of alleyway. This path connects Mntlane street (north-west) to Nongoma Street (north-east), which has a primary school along it (By Author)

In terms of land use, the site is overwhelmingly residential, with most other uses being concentrated on the main roads on the edges of the site. The few non-residential uses in the interior of the site are a handful of taverns and spaza shops whose location is probably due to pragmatic reasons (to sell where you can) rather than in response to pedestrian flows. There are a concentration of land uses that require larger amounts of space (such as workshops) on the southern edge of the site, near the flood plain. Much of this takes place in prefabricated buildings, containers, and shacks. This is likely sporadic development that took advantage of the available land that may have been unsuitable for housing because of its proximity to the river. The site has two schools, which are located near its centre, and the street network thus curves around the core of the site – connecting outward rather than through it.

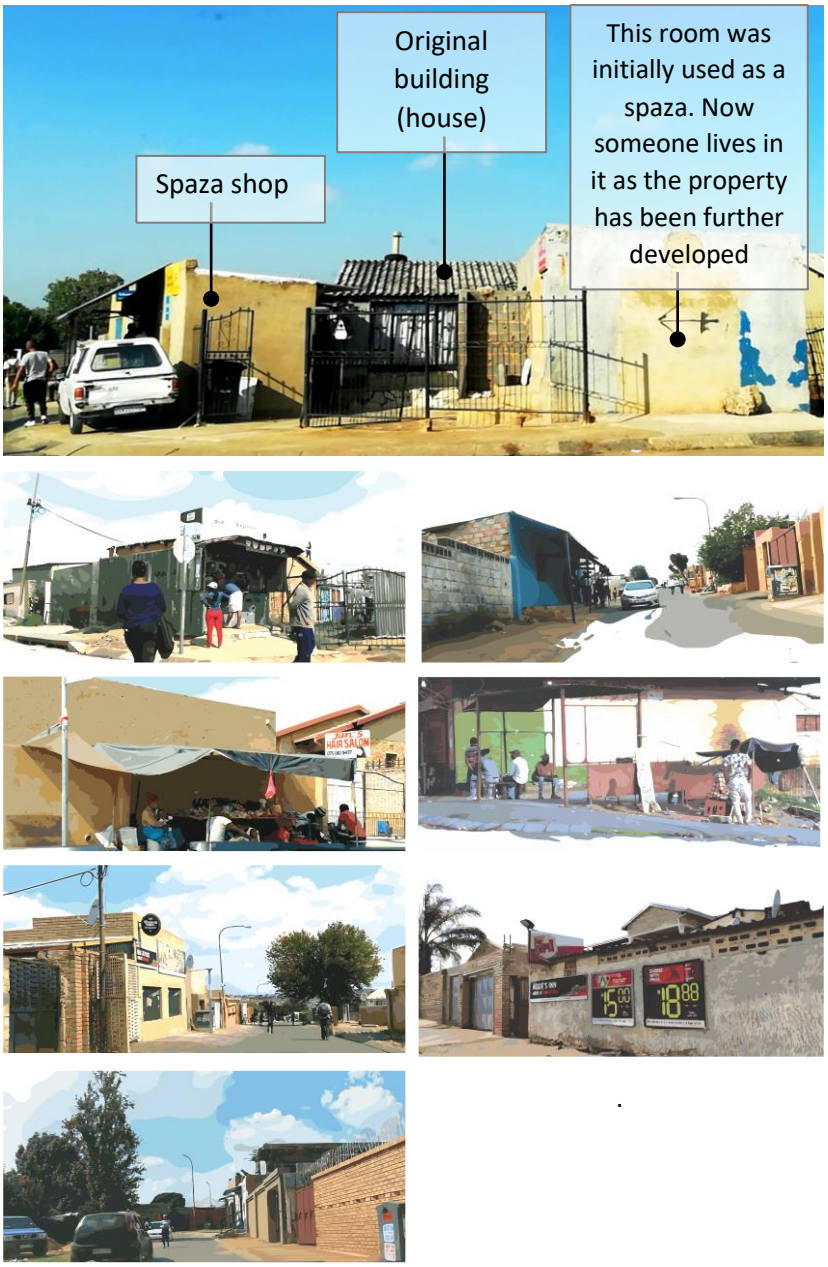


Figure 46 neighbourhood characterisitics, Diepkloof Zone 5 (By Author)

The self-contained structure of the street network informed the decision to subdivide the site into quadrants during fieldwork as this would better facilitate pedestrian observations (fig. 46). This is described in more detail in Chapter 3. In summation, the rationale for subdividing the site during fieldwork was that, because there is limited movement between quadrants, the likelihood of counting someone twice was reduced as they were unlikely to move between quadrants during the period when counting takes place. The street network together with the paucity of non-residential use also limited the number of origin and destination points for pedestrian movement. By considering each quadrant as a self-contained enclave (in addition to looking at the overall site) it may be easier to isolate cases where pedestrian flows were induced by origin and destination factors from those where the imageability of streets played a larger role.

Although the borders of the quadrants were determined with the intent of capturing the movement pattern, they also had significant overlap with the sub-areas used to capture census data (Frith, 2013). Thus, it is possible to estimate some demographic data for each quadrant. The largest quadrants, which also have the largest amount of street surface area, are to the west of the site. The north-west and south-west quadrants have the largest populations (2 386 and 2 156 respectively). The slightly smaller north-eastern quadrant has

the highest population density. The south-east quadrant is the smallest and has the least people (1254). Because the schools are located here, this quadrant has a much lower density (about 8000 people per Ha[24]) and also has fewer streets. The demographic data for each quadrant is illustrated in figures 47-50 below.

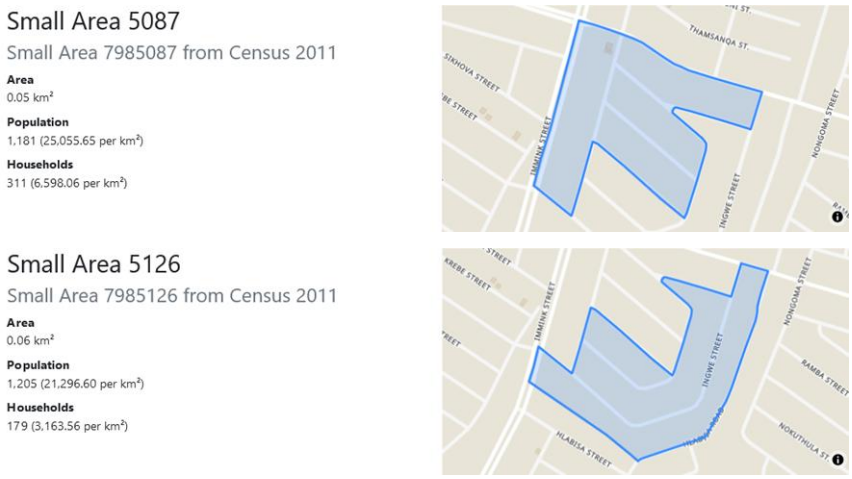


*Figure 47: North-west - **Area**: 0.11 km2; **Population**: 2 386 (21 690,9 per km2); **Households**: 490 (4 454,5 per km2) (After Frith, 2013)*

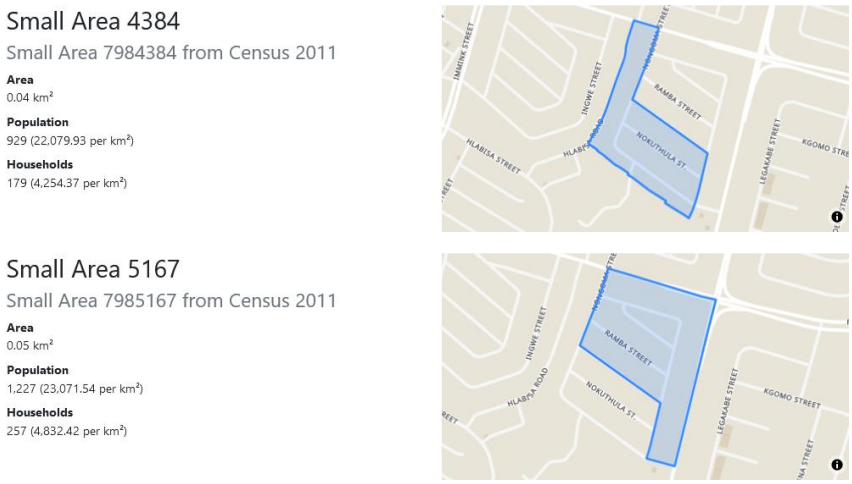


*Figure 48: North-east - **Area**: 0,09 km2; **Population**: 2 156 (23 955,6 per km2); **Households**: 436 (4 844,4 per km2) (After Frith, 2013)*

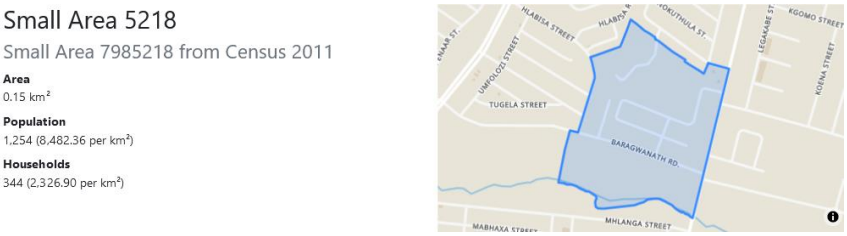


*Figure 49 South-east - **Area**: 0.15 km2; **Population**: 1254 (8482,36 per km2); **Households**: 344 (2 326,9 per km2) (After Frith, 2013)*

[24] The official statistic of about 8000 people per Ha is misleading as the calculation of land area includes the flood plain, which is uninhabitable and falls outside of the site

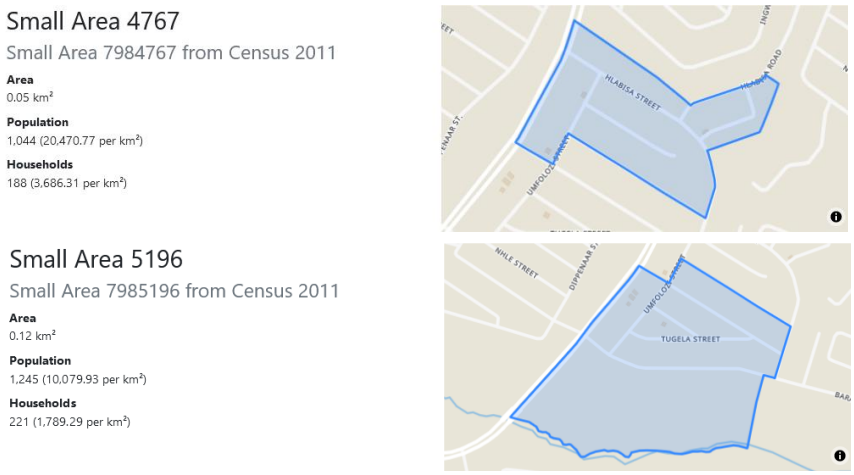


*Figure 50 South-west - **Area:** 0.17 km²; **Population:** 2 289 (13 464,7 per km²); **Households:** 490 (2 405,9 per km²) (After Frith, 2013)*

Diepkloof Zone 5 is dense with about 16,000 people per km². For comparison, other Johannesburg suburbs such as Auckland Park (1,104.34 per km²), Parktown (1,828.06 per km²) and Melville (1,954.15 per km²) have much lower densities, even though they are closer to the urban core of the Johannesburg CBD. While it is incomparable to high-rise residential areas in the urban core, such as Hillbrow (68,418.11 per km²) and Berea (42,221.41 per km²), Zone 5 rivals and sometimes even outperforms inner city suburbs such as Yeoville (19,442.93 per km²) and Jeppestown (8,083.90 per km²) (Frith, 2013). One reason for this is that Johannesburg, from its inception, was never planned as a place to live and residential land use barely made up 50% of its properties. The city sprung up from a temporary mining camp, with dusty streets, into a commercial hub with offices intended to service and benefit from the mining. Residential areas sprung up some distance away from the urban core in suburbs such as Jeppestown, Braamfontein and Bertrams as well as the affluent areas of Parktown and Kensington, which sat on the hills overlooking the urban core (Beavon, 1998). Perhaps there is no clearer evidence of this historical trend than the fact that the densities in the Johannesburg CBD (8,006.98 per km²) (which includes the multistorey buildings of Braamfontein and Marshalltown) are lower than those of some surrounding suburbs such as Jeppestown and lower than the density of Diepkloof zone 5 (Frith, 2013). A second factor that may limit densities (and which has been discussed in the background of this chapter) is that the urban core – as with all urban areas in South Africa – was an exclusively white area in terms of apartheid law and thereby prohibited the black majority from residing within it. This additional distinction between places that are dense by virtue of their proximity to the urban core and to economic opportunities (such as Hillbrow, Bertrams and Yeoville) and those places that are dense but are also homes (a family's foothold into the city) is demonstrated in the *type* of activity that such densities generate. While the streets of dense neighbourhoods in the urban core may be filled with bustling activities as young working-age people move between transport hubs, sell their wares in the streets, walk in and out of shops and socialise in restaurants, cafes and night clubs, there is often a conspicuous absence (although not exclusively) of families, and of people of different ages, most notably children. Thus, in the disconnected, destination-less and endlessly winding streets of zone 5 (as with most townships) one of the most prominent features is the abundance of children playing and people sitting outside... not really doing anything (fig. 51). Here, perhaps, we see movement and occupation of public space for its own sake and not dictated by what Gehl (2011: 9) calls "necessary activity", where people walk about even without a need to shop, to catch transport or to go to work or to school. In a case such as this, where the role of traditional factors of pedestrian activity (land use diversity, destination, and distance) are mitigated by being so few relative to the number of people (density) on the site, the physical qualities of the street may play a larger role in people's choice to gather or play in certain spaces. Zone 5 is also significantly denser than other former black townships. It is almost three times denser than the overall area of Soweto, which has a density of 6,357.29 people per km² (Frith, 2013). This

makes it an attractive site to study how design qualities such as imageability inform pedestrian activity in contexts where other factors, such as land use, are relatively absent.



A. Primary school-aged children playing in the street. One of them [left] is lying on the pavement. There seems to be no ambiguity or shame about their right to



B. Teenage boys playing a board game under the shade of a tree. The tree is in a private yard as there are very few trees in the public realm, subtly blending the distinction between



C. People like to sit on the large rocks that were left over during the construction of the township. These old "monuments" of the township are likely to play a role as landmarks.

Figure 51: The street as a playground (A. Umfolozi St; B. Ingwe St; Hlosi St) (by Author)

4.2.3 Development trends and topological qualities

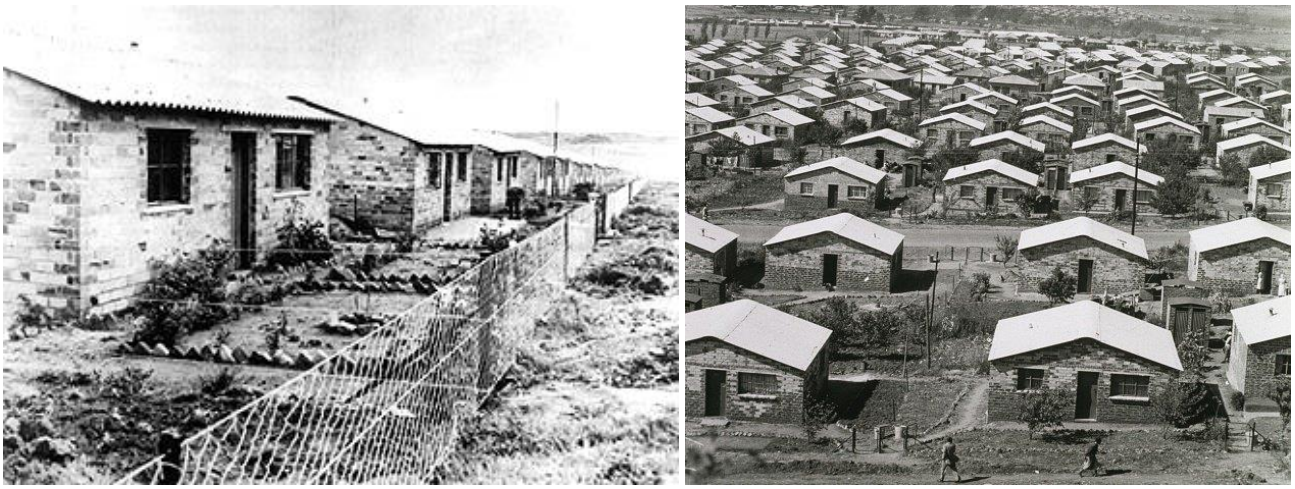


Figure 52: City council housing in Orlando. Similar units were built in Diepkloof (Mavundza, 2018)

Semi-detached: one house has been extended but is still attached to its original

Semi-detached: these two units are in their original

Detached: both units have been demolished and replaced with bigger houses.



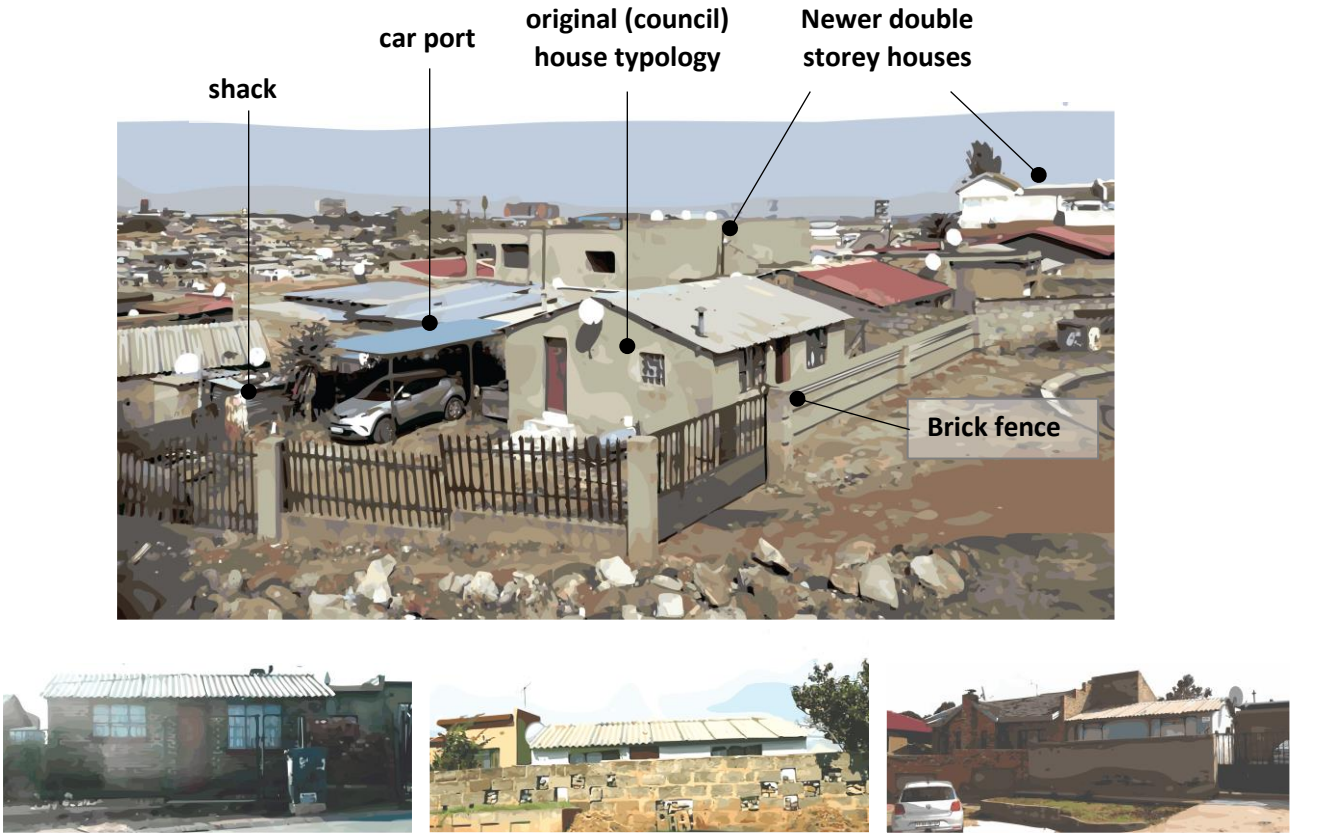
Detached: A newer house sits between its detached neighbours, which maintain their original form. The house on the left has a garage and back rooms. The one on the right only has back rooms

Semi-detached: The erven (property boundaries) are irregular. This makes it difficult to redevelop semi-detached units

Figure 53: The city council provided two kinds of detached houses when Diepkloof was initially developed, those that are fully detached and those that are semi-detached (by Author)

The first houses in Soweto had limited typological variation and thus the early settlement lacked legibility, with little distinction between its individual elements (fig. 52). The houses mostly took the form of two-room semi-detached units (two units sharing a loadbearing wall) and four-room detached units. Because people

have made improvements to their homes over the years, the housing typology has diversified further (fig.53). The newer houses are significant because of their distinctive shapes as this makes it easier to tell them apart and it gives more character to each street. This topological quality may have an impact on imageability and streets with more diverse building shapes may be more imageable. It is worth noting that semi-detached houses have irregular (non-rectangular) erven, which limit how they can be redeveloped. As such, it may be reasonable to expect more variety in building size and shape in streets that originally had detached housing than in those with semi-detached houses.



Original house, built by city council

Brick fences are usually the first external home improvement

A new house typology, next to the old one. Both have brick fences

Figure 54: Typical morphological elements in Diepkloof (council houses, brick fences, car ports, and newer larger houses) (by Author)

As discussed earlier, detached houses are the predominant housing typology on the site because Diepkloof was developed as council housing with 2-4 room units. Only 20% (470)[25] of the detached units on the site still have their original shape, without extensions, as there is a strong trend of renovations and extensions. Even in cases where the houses have not been changed higher walls made of bricks are often erected to replace the transparent fences that characterised the neighbourhood in the past (fig.54). There are two notable consequences of this trend. The first is that the higher walls limit the visibility of the building façade, especially in the case of the older council houses as these have a lower height (fig.55). A reduction of visibility may also reduce imageability. Secondly, because the original erven in Diepkloof were relatively small, development of larger buildings often entails maximising coverage and sometimes building taller buildings. The proliferation of two storey buildings in Zone 5 may increase the number of landmarks and positively affect imageability.

[25] This number is based on a manual count. However, it is likely to change slightly as there is frequent construction



Figure 55: "suburban-style" brick fences are often between 1.6-2m high with metal gates and this decreases the visibility of the buildings behind them, especially in the case of the old council houses (by Author)



Figure 56: An old man sits outside a wall, looking out at the activity in the street (by Author)

Changes in the topological qualities of Diepkloof Zone 5, through the addition of newer housing typologies and through other variations in design (such as details on walls) as well as the planting of gardens, have likely improved the imageability of the neighbourhood. However, it is difficult to assess at a glance which of these elements have had a notable impact. As mentioned, higher walls may undermine the visibility of the buildings, and downplay the role played by their shape in making the environment legible. On the other hand, given how close the front doors are to the street (with limited privacy, since the backyards are also densely built up) such boundaries may in fact be necessary in distinguishing the public from the private realm and this demarcation may give pedestrians a better sense of control over public space – as an uncontested place that they are allowed to occupy. For instance, it is not immediately apparent that the behaviour captured in figure 51 (above) of children "loitering" outside a home or shouting while playing would be tolerable or even possible without there being a sense that they are outside and therefore free to do so. In this setting, perhaps the street is more akin to a backyard than a space that is completely separated from the private realm, since the confines of the property are too crowded with back rooms and parked vehicles. Similarly, the walls – with their frequent perches and places to lean against – are more akin to balconies. On several occasions there is a grandparent or someone from the yard behind the wall sitting on a rock or a stoep in front of the wall, watching the children play in the street (fig.56). By looking at Zone 5, this research considers the extent to which a neighbourhood's physical features make it imageable and the extent to which certain physical features associated with imageability correlate with pedestrian activity.

4.3 Model calibration – developing a scale to understand the magnitude of imageability scores

In order to understand whether a score generated by the Ewing model is "high" or "low" I developed a scale to contextualise the scores. The scale was developed by measuring 100 other streets in different contexts. The first 50 streets in this sample were taken from the same neighbourhoods in New York City where the Ewing Model was first verified (Ewing and Clemente, 2013). I determined the accuracy of my application of the model by the extent to which the average score for my measurements for each neighbourhood was consistent with the averaged reported in the verification study. The scale took the form of a box-whisker plot with a median of 3.3, an upper limit of 6.0 and a lower limit of 2. This means that half of the streets measured had scores on or below this point and the other half had scores on or above this point. Scores higher than 6.0 do exist (such as Jourbet Street[26], in the Johannesburg CBD, which has a score of 6.9) but these were rare in the sample (only 5) and the box-whisker plot shows them to be statistical outliers. Table 5 shows imageability scores for 130 streets. Streets in suburban environments (with low densities, low building heights, fences, fewer pedestrians, and primarily residential use) tended to have scores in the very low to low range of the box-whisker plot. Streets in more urban environments (with higher densities, multi-storey buildings, direct street frontage and mixed land use) tended to score in the low to middle range. All the streets in the fourth quartile (those with high imageability) had high levels of retail. This does not mean that streets in Diepkloof cannot have scores higher than 6 but that, if they do, special attention must be given to why they are more imageable. High scores can suggest measurement errors or variables that are not consistent across contexts. They can also, of course, be an indication of high levels of imageability that, according to my hypothesis, should also have high pedestrian activity. Scores in Diepkloof range between 2 and 3.8 (very low to medium) and there are no scores in the 4th quartile (high).

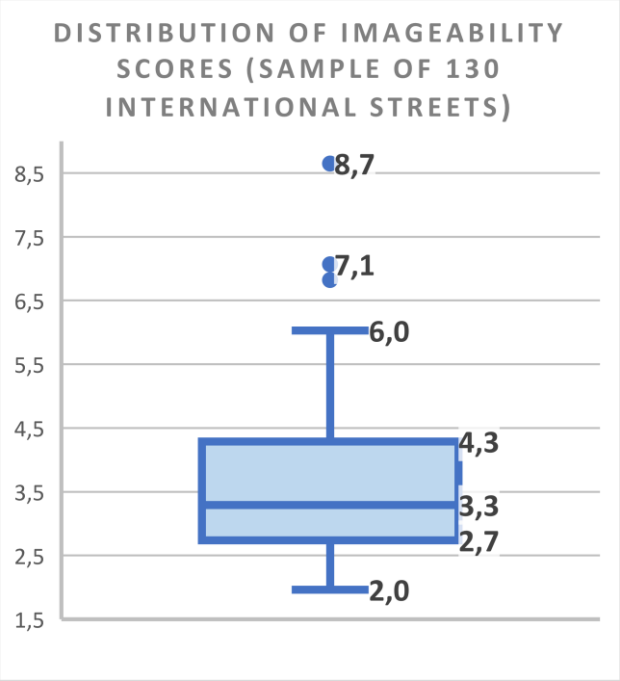
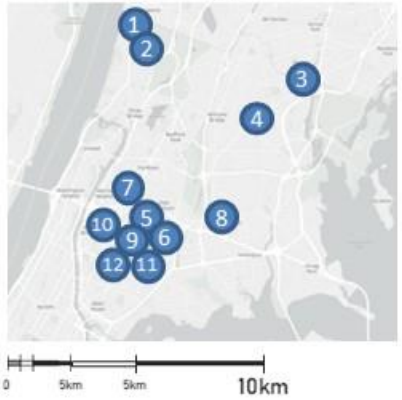


Figure 57: This box-whisker plot was used as a scale to evaluate the relative magnitude of scores generated by the Ewing model. With a scale, it is now possible to classify scores above 4.3 as being high and those below 2.7 as being low. Crucially, the scale allows for the identification of statistical outliers (values above 6), which are potential measurement errors.

[26] Street number 54 in fig. 59

Bronx, NYC, USA



Scene #	Str Name	Score
1	Goodridge Ave	2,52
2	Goodridge Ave	2,52
3	Boston Post Rd	4,34
4	Palmer Ave	2,74
5	Crotona Park	3,02
6	Crotona Ave	2,50
7	Burnside Ave	4,52
8	Tremont Ave	6,82
9	170th St	6,82
10	170th St	3,99
11	3rd Ave	3,69
12	Teller Ave	3,99





Brooklyn, NYC, USA



Scene #	Str Name	Score
13	Myrtle Ave	5,50
14	Wyckoff Ave	4,53
15	Knickerbocker Ave (1)	4,46
16	Knickerbocker Ave (2)	4,57
17	Cleveland	3,39
18	Logan	4,38
19	12th St	3,18
20	63rd St	3,31
21	2nd St	3,77
22	72nd St	3,63
23	52nd St	5,92
24	13th Ave	4,25







Manhattan, NYC, USA

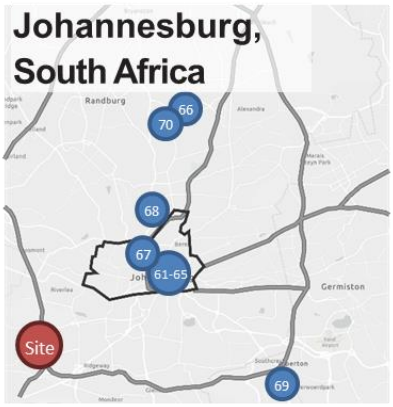


Scene #	Str Name	Score
13	Myrtle Ave	5,50
14	Wyckoff Ave	4,53
15	Knickerbocker Ave (1)	4,46
16	Knickerbocker Ave (2)	4,57
17	Cleveland	3,39
18	Logan	4,38
19	12th St	3,18
20	63rd St	3,31
21	2nd St	3,77
22	72nd St	3,63
23	52nd St	5,92
24	13th Ave	4,25





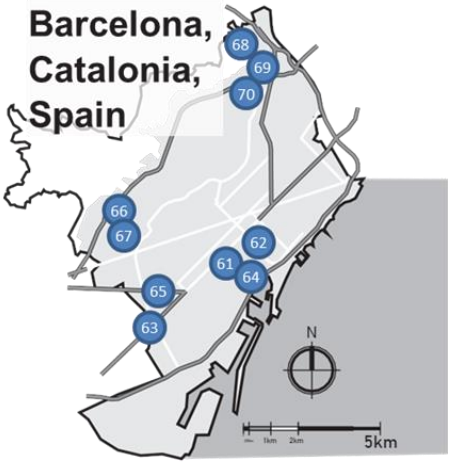
Figure 58 (see Appendix for other measurements)



Scene #	Str Name	Score
51	Main St	5,05
52	Simonds St	4,08
53	Lilian Ngoyi St	5,44
54	Joubert St	6,94
55	De Beer St	3,90
56	5th St (Sandton)	2,53
57	7th St (Melville)	4,11
58	3rd Ave (Parkhurst)	4,80
59	Voortrekker Rd	4,20
60	4th Ave	2,34



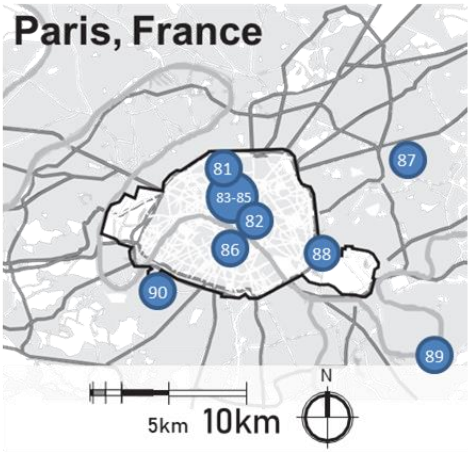




Scene #	Str Name	Score
61	La Rambla	6,03
62	Carrer de les Jonqueres	3,09
63	Avinguda de la Granvia	2,73
64	Via Laietana	4,28
65	N-340	3,91
66	Av. De Josep Vicenc Foix	2,83
67	Carrer d'Enric Gimenez	2,52
68	Carrer de Sant Feliu de Codines	2,34
69	Carrer de Platja d'Aro	2,86
70	Carrer d'Enric Casanovas	3,40



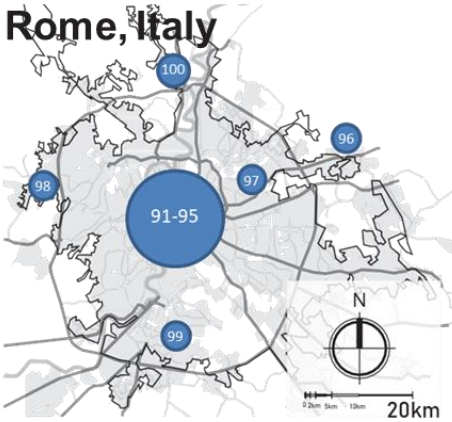




Scene #	Str Name	Score
81	Rue Norvins	5,35
82	Rue Francois Miron	5,37
83	Rue du Chevalier de la Ba	5,33
84	Rue des Abbesses	5,78
85	Rue Lepic	4,32
86	Ave Henri Barbusse	2,90
87	Ave des sciences	2,74
88	Ave du General de Gaulle	3,32
89	Rue Arthur de Montalem	3,06
90	Rue Jules Guesde	2,90







Scene #	Str Name	Score
91	Piazza di Spagna	8,65
92	Corso Vittorio Emanuele	4,47
93	Borgo Pio	5,97
94	Via Leopardi	4,90
95	Pantheon	5,17
96	Via Agosto	2,66
97	Via Castel Boverano	2,32
98	Via Giulio Clovio	2,68
99	Via dei Minatori	2,74
100	Via Adro	2,42





Figure 59 (see Appendix for other measurements)

Table of imageability scores, for 131 international streets, sorted by distribution

High (> 6,03)					Medium (3,32 - 4,28)					Low (2,8 - 3,32)					Very low (2,32 - 2,8)				
Str #	**Str Name**	**City**	**Score**	Context	**Str #**	**Str Name**	**City**	**Score**	Context	**Str #**	**Str Name**	**City**	**Score**	Context	**Str #**	**Str Name**	**City**	**Score**	Context
61	La Rambla	6,03	Barcelona	urban	64	Via Laietana	4,28	Barcelona	urban	88	Ave du General de Gau	3,32	Paris	suburban	77	Cambridge Rd	2,80	London	suburban
93	Borgo Pio	5,97	Rome	urban	29	Time Square	4,25	Manhattai	urban	20	63rd St	3,31	Brooklyn	urban	**115**	**Ramba St**	**2,79**	**Diepkloof**	**suburban**
23	52nd St	5,92	Brooklyn	urban	24	13th Ave	4,25	Brooklyn	urban	26	Greenwich	3,28	Manhattai	urban	42	Langdale	2,76	Queens	urban
84	Rue des Abbesses	5,78	Paris	urban	59	Voortrekker Rd	4,20	Johannesb	suburban	**110**	**Nongoma St**	**3,27**	**Diepkloof**	**suburban**	50	Richmond	2,76	Staten Isla	suburban
13	Myrtle Ave	5,50	Brooklyn	urban	**105**	**Ben Naude St (a)**	**4,15**	**Diepkloof**	**suburban**	**109**	**Hlungulu St**	**3,24**	**Diepkloof**	**suburban**	4	Palmer Ave	2,74	Bronx	suburban
73	Carnaby St	5,46	London	urban	57	7th St (Melville)	4,11	Johannesb	suburban	25	Washington	3,19	Manhattai	urban	87	Ave des sciences	2,74	Paris	suburban
53	Lilian Ngoyi St	5,44	Johannesb	urban	52	Simonds St	4,08	Johannesb	urban	19	12th St	3,18	Brooklyn	urban	99	Via dei Minatori	2,74	Rome	suburban
72	Piccadily	5,42	London	urban	38	College Point Blvd	4,02	Queens	urban	48	217th St	3,16	Queens	suburban	**131**	**Phumzile St**	**2,74**	**Diepkloof**	**suburban**
82	Rue Francois Miron	5,37	Paris	urban	44	Jamaica Ave	3,99	Queens	suburban	75	Tower Bridge Rd	3,11	London	urban	63	Avinguda de la Granvia	2,73	Barcelona	urban
81	Rue Norvins	5,35	Paris	urban	12	Teller Ave	3,99	Bronx	urban	39	Francis Lewis Blvd (a)	3,11	Queens	urban	98	Via Giulio Clovio	2,68	Rome	suburban
83	Rue du Chevalier de la	5,33	Paris	urban	10	170th St	3,99	Bronx	urban	**102**	**Mpumelelo St**	**3,10**	**Diepkloof**	**suburban**	**123**	**W Bombo St**	**2,68**	**Diepkloof**	**suburban**
95	Pantheon	5,17	Rome	urban	**112**	**Marthinus Smuts Dr (a**	**3,99**	**Diepkloof**	**suburban**	**107**	**Bambanani St**	**3,10**	**Diepkloof**	**suburban**	41	Union Tpke	2,67	Queens	urban
71	Oxford St	5,12	London	urban	78	Radley Rd	3,97	London	suburban	62	Carrer de les Jonqueres	3,09	Barcelona	urban	96	Via Agosto	2,66	Rome	suburban
51	Main St	5,05	Johannesb	urban	65	N-340	3,91	Barcelona	urban	**118**	**Immink Dr (b)**	**3,08**	**Diepkloof**	**suburban**	**116**	**Noqhaza St**	**2,66**	**Diepkloof**	**suburban**
94	Via Leopardi	4,90	Rome	urban	55	De Beer St	3,90	Johannesb	urban	89	Rue Arthur de Montale	3,06	Paris	suburban	**122**	**Mahlabathini St**	**2,62**	**Diepkloof**	**suburban**
58	3rd Ave (Parkhurst)	4,80	Johannesb	suburban	**103**	**Ingwe St**	**3,81**	**Diepkloof**	**suburban**	5	Crotona Park	3,02	Bronx	suburban	**106**	**Busisiwe St**	**2,60**	**Diepkloof**	**suburban**
49	Victory Blvd	4,65	Staten Isla	urban	21	2nd St	3,77	Brooklyn	urban	80	Boleyn Rd	3,01	London	suburban	**121**	**Matubatuba St**	**2,60**	**Diepkloof**	**suburban**
16	Knickerbocker Ave (2)	4,57	Brooklyn	urban	**101**	**Immink Dr (a)**	**3,76**	**Diepkloof**	**suburban**	**119**	**Umfolozi St**	**3,00**	**Diepkloof**	**suburban**	**125**	**Tugela St**	**2,60**	**Diepkloof**	**suburban**
14	Wyckoff Ave	4,53	Brooklyn	urban	35	105th St	3,71	Manhattai	urban	**120**	**Hlabisa St**	**2,99**	**Diepkloof**	**suburban**	**108**	**Dada St**	**2,55**	**Diepkloof**	**suburban**
7	Burnside Ave	4,52	Bronx	urban	11	3rd Ave	3,69	Bronx	urban	45	Francis Lewis Blvd (c)	2,94	Queens	suburban	**127**	**Msinga St**	**2,54**	**Diepkloof**	**suburban**
92	Corso Vittorio Emanue	4,47	Rome	urban	36	2nd Ave	3,66	Manhattai	urban	**128**	**Marthinus Smuts Dr (b**	**2,91**	**Diepkloof**	**suburban**	56	5th St (Sandton)	2,53	Johannesb	suburban
15	Knickerbocker Ave (1)	4,46	Brooklyn	urban	34	Amsterdam	3,64	Manhattai	urban	47	Springfield Blvd	2,90	Queens	suburban	**129**	**Baragwanath Rd (b)**	**2,53**	**Diepkloof**	**suburban**
37	Broadway	4,41	Queens	urban	22	72nd St	3,63	Brooklyn	urban	86	Ave Henri Barbusse	2,90	Paris	suburban	1	Goodridge Ave	2,52	Bronx	suburban
18	Logan	4,38	Brooklyn	urban	33	Broadway	3,62	Manhattai	urban	90	Rue Jules Guesde	2,90	Paris	suburban	2	Goodridge Ave	2,52	Bronx	suburban
76	St. Michaels Ave	4,35	London	suburban	32	57th St	3,60	Manhattai	urban	**104**	**Mntlante St**	**2,89**	**Diepkloof**	**suburban**	67	Carrer d'Enric Gimenez	2,52	Barcelona	suburban
3	Boston Post Rd	4,34	Bronx	suburban	**113**	**Ben Naude St (b)**	**3,52**	**Diepkloof**	**suburban**	**117**	**Nokuthula St**	**2,88**	**Diepkloof**	**suburban**	**130**	**Nyameko St**	**2,51**	**Diepkloof**	**suburban**
85	Rue Lepic	4,32	Paris	urban	27	Broadway	3,49	Manhattai	urban	28	9th St	2,86	Manhattai	urban	6	Crotona Ave	2,50	Bronx	urban
	Statistical outliers				**111**	**Hlosi St**	**3,28**	**Diepkloof**	**suburban**	69	Carrer de Platja d'Aro	2,86	Barcelona	suburban	**124**	**Ngwavuma St**	**2,49**	**Diepkloof**	**suburban**
91	Piazza di Spagna	8,65	Rome	urban	70	Carrer d'Enric Casanov	3,40	Barcelona	suburban	79	Plashet Rd	2,84	London	suburban	100	Via Adro	2,42	Rome	suburban
31	5th Ave	7,068	Manhattai	urban	17	Cleveland	3,39	Brooklyn	urban	**126**	**Baragwanath Rd (a)**	**2,84**	**Diepkloof**	**suburban**	46	Francis Lewis Blvd (d)	2,37	Queens	suburban
54	Joubert St	6,941	Johannesb	urban	30	56th St	3,38	Manhattai	urban	**114**	**Nkonjane St**	**2,84**	**Diepkloof**	**suburban**	60	4th Ave	2,34	Johannesb	suburban
8	Tremont Ave	6,82	Bronx	urban	43	Sutphin Blvd	3,36	Queens	suburban	66	Av. De Josep Vicenc Fo	2,83	Barcelona	suburban	68	Carrer de Sant Feliu de	2,34	Barcelona	suburban
9	170th St	6,82	Bronx	urban	74	B134	3,32	London	urban	40	Francis Lewis Blvd (b)	2,80	Queens	urban	97	Via Castel Boverano	2,32	Rome	suburban

Table 5: Imigeability scores of 130 international streets. When viewed within the context of this table, streets in Diepkloof range between very low imageability and medium imageability.

4.4 IMAGEABILITY IN DIEPKLOOF

The streets on the site were organized into four quarters (fig. 60). When measuring imageability, each street was subdivided into 100m segments, the approximate length of a pedestrian's immediate field of vision. Thus, the imageability score for a given street is the average score for each of these segments. In terms of the imageability scale presented in figure 57 (above), the site has no streets with high imageability, although Ben Naude Street (fig. 61) comes very close with a score of 4,15. The intersection of Ben Naude street and Immink Drive has two large buildings (the supermarket and the filling station), which also act as nodes. The intersection is also very busy as the two streets connect to major destinations such as Orlando, the N1 highway and the Soweto Highway. The six most imageable streets are located north of the site. Four of these are main roads (on the edge of the site), with some non-residential land uses, public transport routes and some large buildings. Ingwe Street and Hlosi Street are outliers in this regard. Ingwe Street is peculiar in that it has a high score for non-rectangular buildings. This is due to many of the properties having wire fences or low walls that allow for better views of the building shape. Hlosi Street has a park but its imageability is only marginally higher than scores in the "low" category in the above table.

Most of the streets in the "very low imageability" category have short lengths (below the site average of 287m), except for Baragwanath Road and Nyameko Street. These two streets, although long, have vacant spaces along them and this reduces their imageability. Nyameko Street is behind a school and has no street frontage on most of its norther side, except the school grounds, which are behind a fence. Part of the land south of Baragwanath Road is a flood plan and there is little formal development. However, there is a rich mix of informal activities (such as taxis, car repair shops and a scrap yard) in the flood plan and surrounding areas, which accounts for the significant amount of pedestrian activity along this otherwise sparsely developed street. Streets in the south of the site are disproportionately represented in the "very low" imageability category.



Figure 60: The arrows indicate the points at which measurements were of imageability were taken (100m intervals). The colours indicate the demarcations of the four quarters of the site (north-west = blue; north-east = pink; south-west = green; south-east = yellow)

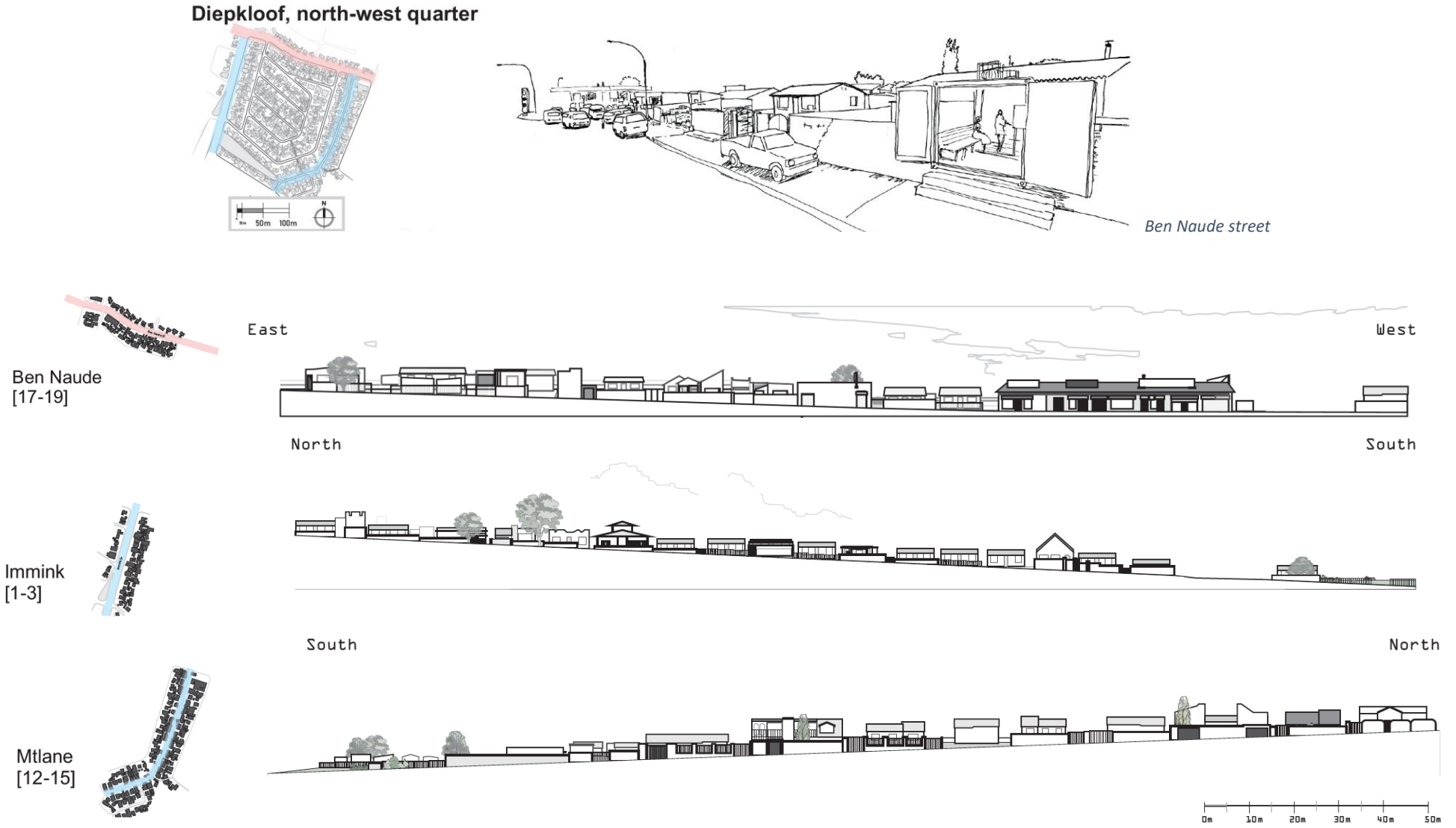


Figure 61: The north-west quarter has the street with the highest imageability score. Ben Naude Street has shops and other points of interest, such as the library and the petrol station. It is a main road, with public transport and is very busy, especially the two intersections: with Immink Drive, to the west and with Marthinus

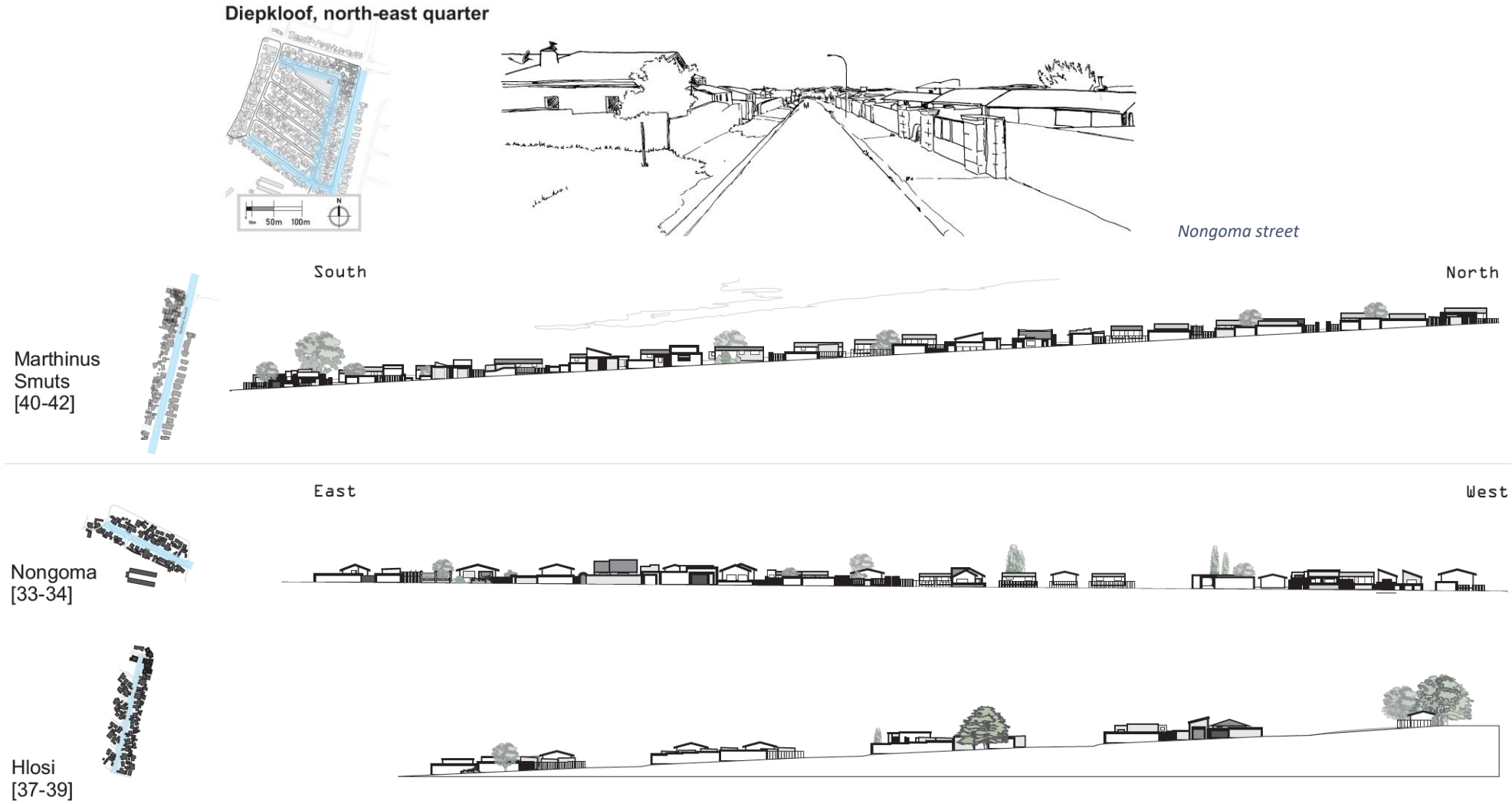

Diepkloof, north-east quarter
50m
100m
N
Nongoma street
South
North
Marthinus
Smuts
[40-42]
East
West
Nongoma
[33-34]
Hlosi
[37-39]

Figure 62

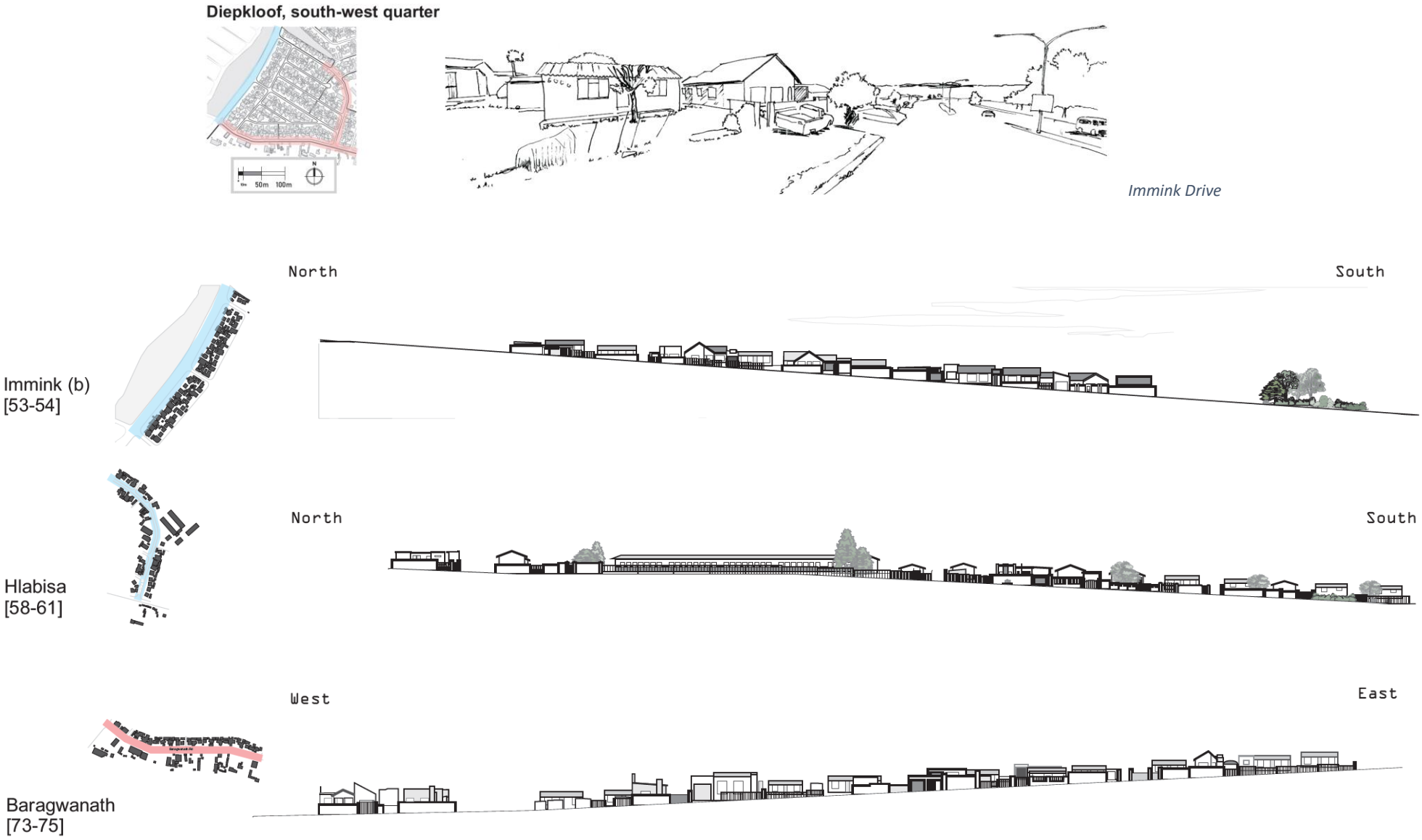

Diepkloof, south-west quarter
0m 50m 100m
Immink Drive
North
South
Immink (b)
[53-54]
North
South
Hlabisa
[58-61]
West
East
Baragwanath
[73-75]

Figure 63

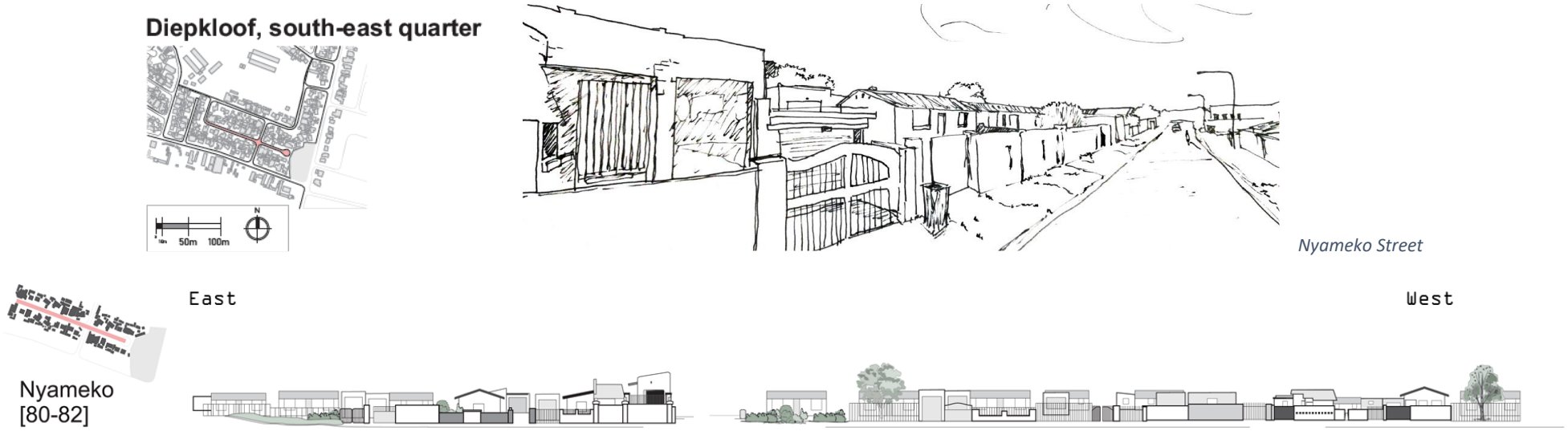


Figure 64 Nyameko Street has a cul-de-sac (dead-end) on its eastern side.

Portion of site	Medium	(3.3 - 4.2)	Low	(2.8 - 3.2)	Very low	(2.3 – 2.8)
North-west	Ben Naude St (a)	**4,15**	Nongoma St	**3,27**	Phumzile St	**2,74**
North-east	Marthinus Smuts Dr (a)	**3,99**	Hlungulu St	**3,24**	W Bombo St	**2,68**
South-west	Ingwe St	**3,81**	Mpumelelo St	**3,10**	Noqhaza St	**2,66**
South-east	Immink Dr (a)	**3,76**	Hlungulu St	**3,10**	Mahlabathini St	**2,62**
	Ben Naude St (b)	**3,52**	Immink Dr (b)	**3,08**	Busisiwe St	**2,60**
	Hlosi St	**3,28**	Umfolozi St	**3,00**	Matubatuba St	**2,60**
			Hlabisa St	**2,99**	Tugela St	**2,60**
			Marthinus Smuts Dr (b)	**2,91**	Dada St	**2,55**
			Mntlante St	**2,89**	Msinga St	**2,54**
			Nokuthula St	**2,88**	Baragwanath Rd (b)	**2,53**
			Baragwanath Rd (a)	**2,84**	Nyameko St	**2,51**
			Nkonjane St	**2,84**	Ngwavuma St	**2,49**
			Ramba St	**2,79**		

Table 6: Measurements of imageability. The colours indicate the areas in which the streets are located in the site (north-west = blue; north-east = pink; south-west = green; south-east = yellow)

4.5 PEDESTRIAN ACTIVITY

There is a noticeable difference between the north and south of the site in terms of pedestrian distribution, with the north-eastern quarter having the highest concentration of pedestrians (fig. 65). This pattern is consistent on each day at each period of the sample data. The time series of pedestrian volumes (fig. 66) shows a seasonal pattern, which is consistent with the fact that the data was collected daily. The V-shaped pattern indicates that the lowest pedestrian values were recorded in the middle of the day (2pm). The highest pedestrian volumes are in the north-eastern quadrant (orange line), where the pattern shows larger pedestrian volumes in the mornings (7am) than in the evenings (5pm). Seasonality is consistent across the four quadrants of the site (low volumes at midday) but the difference between mornings and evenings is only consistent in the north-east. The peak pedestrian count is on Tuesday at 7am but this is only marginally higher than on other days. Most pedestrian observations (63%) were in the north of the site.



Figure 65: Pedestrian activity, Mon 28 Sep, 2pm-3pmImageability scores. Pedestrian locations were mapped by using video recording. A GPS tracker (on a cell phone) was used to match the location at the time of recording with the timestamp on the video.

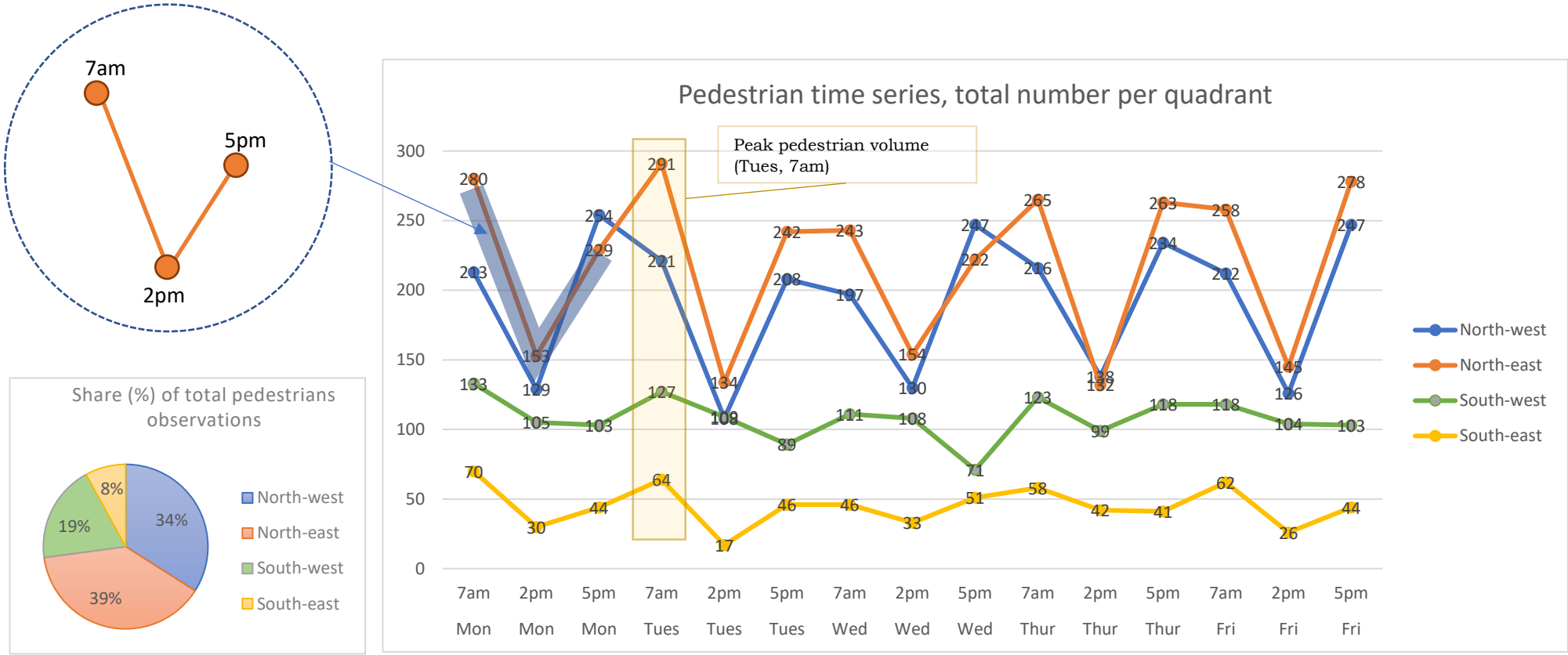


Figure 66 Average pedestrian volumes in each quarter of the site (detailed table in Appendix)

4.6 NEIGHBOURHOOD FEATURES ASSOCIATED WITH PEDESTRIAN ACTIVITY

This section presents measurements of six neighbourhood features that may impact pedestrian activity: land use, grain and texture, intersection density, street integration, block permeability, and street length. Cervero and Kockelman (1997: 199) argue that "The built environment is thought to influence travel demand along three principal dimensions —density, diversity, and design". The density dimension is described in the section with the use of grain and texture measurements. Diversity is described in terms of land use, measured through site visits, and street integration, which is measured using space syntax analysis. Lastly, the design dimension is described – at least partially – in street length, intersection density and block permeability. The selection of methods is limited by available technical skills and resources. For example, density would be more accurately measured in terms of units per hectare but, because of the number of informal dwelling structures it is difficult to calculate accurate figures for the number of units and thus "grain" is used instead to estimate the area of buildings based on their roofs.

4.6.1 Land use pattern

Certain land uses, such as shops and public facilities, attract more people than others. The expectation is that there may be more pedestrian activity in places that have intensive land uses located within them. The site is largely monofunctional, being overwhelmingly residential (fig. 67).



Figure 67 Land use map

4.6.2 Grain and texture

Grain refers to the size of the building footprint whereas texture is the distribution of buildings of different sizes. Grain was measured by calculating building area from satellite imagery. Because the form of buildings is closely related to their function, large buildings (coarse grain) may have a higher density of pedestrians around them. This is often the case with buildings such as schools and shopping centres but in such cases the correlation between building size and pedestrian activity is contingent on the building typology (e.g., a multi-storey structure) and its use. In most cases coarse grain is an indication of low building density whereas fine grain suggests higher density. It is thus more reasonable to expect a positive correlation between fine grain and pedestrian density, controlling for land use and building typology.

An uneven texture (where there is variation in building footprints) suggests a mixture of typologies and uses. Almost 80% of the buildings in the site constitute fine grain, with footprints less than 50m^2, whereas coarse grain makes up less than 1% of the site (Fig.68). Thus, the site has an even texture, which is consistent with its monofunctional land use pattern.



Figure 68: Grain and texture map. Grain refedrs to the size of buildings and texture referes to the extent to whoch different sizes are placed in close proximity

4.6.3 Intersection density

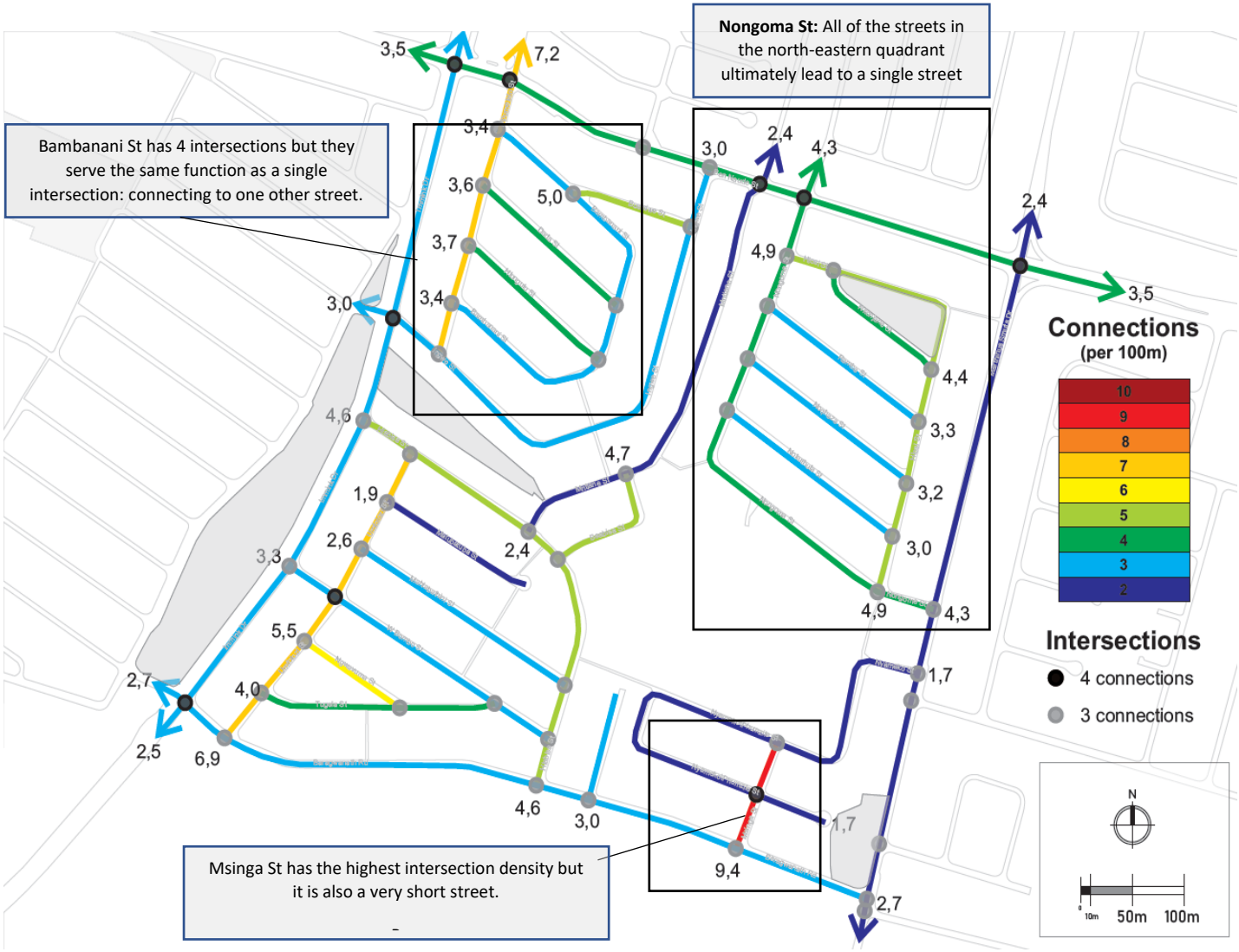


Figure 69

Intersections represent access points. It is reasonable to expect the number of intersections to be positively correlated to pedestrian flow. However, there are three other factors to consider. A very long street (such as a regional road) may have many intersections in its overall length than those represented by the portion of the street that crosses the site. Secondly, a street may have many intersections in close proximity to one another or it may intersect with streets that lead to the same destination. Bambanani Street, in the North-West quadrant (fig. 69), is a curvy street that has four intersections. However, two of the streets that it intersects with to connect to the same destination as the street itself. Moreover, because the street curves, its terminus is less than 100m from its origin. It could be argued that, although there are four intersections along this street, they provide only a marginal increase in access.

Intersection density mapping reveals that there are far more intersections on the east side of the site than on the west. These intersections, however, ultimately connect to the same street (Nongoma Street). Msinga Street has the highest intersection density, but it is also a very short street with almost no pedestrian activity.

4.6.5 Street integration

Fig.70 is a space syntax map created on depthmapX. In this software, the black parts of the map (the blocks) are vectors, and the streets are represented as empty space. DepthmapX calculates the number of times that a street is used when moving from one part of the map to another – with the assumption that no movement can occur in the blocks.

Streets with the highest *integration* (those that are frequently used to connect to other streets) are shown in warmer colours (red, orange). Yellow is medium integration and streets with low integration are shown in cool colours, green and blue.

This map shows that Ben Naude Drive is the most integrated street. Thus, we expect the highest pedestrian volumes to be concentrated on this street. Points A, B and C are likely to be outliers that possess high pedestrian volumes regardless of imageability.



Figure 70

4.6.6 Block permeability

Block permeability refers to the ease with which pedestrians can move through the site. Small blocks and a well-connected street pattern positively contribute to block permeability. When blocks are small, they have short perimeters that equate to short walking distances for pedestrians. In cases where the street pattern is not well-connected, it is possible for small blocks to be mixed with larger ones in such a way that permeability only occurs in isolated pockets (where there are clusters of small blocks) but the overall site remains mostly impermeable. This is the prevailing pattern of permeability on the site, small internal blocks, and large outer blocks. The site has a very large block (block 18) in its centre, where the schools are located. This block separates the four quadrants of the site from one another. Generally, the site is more permeable to the west and less on the eastern side.

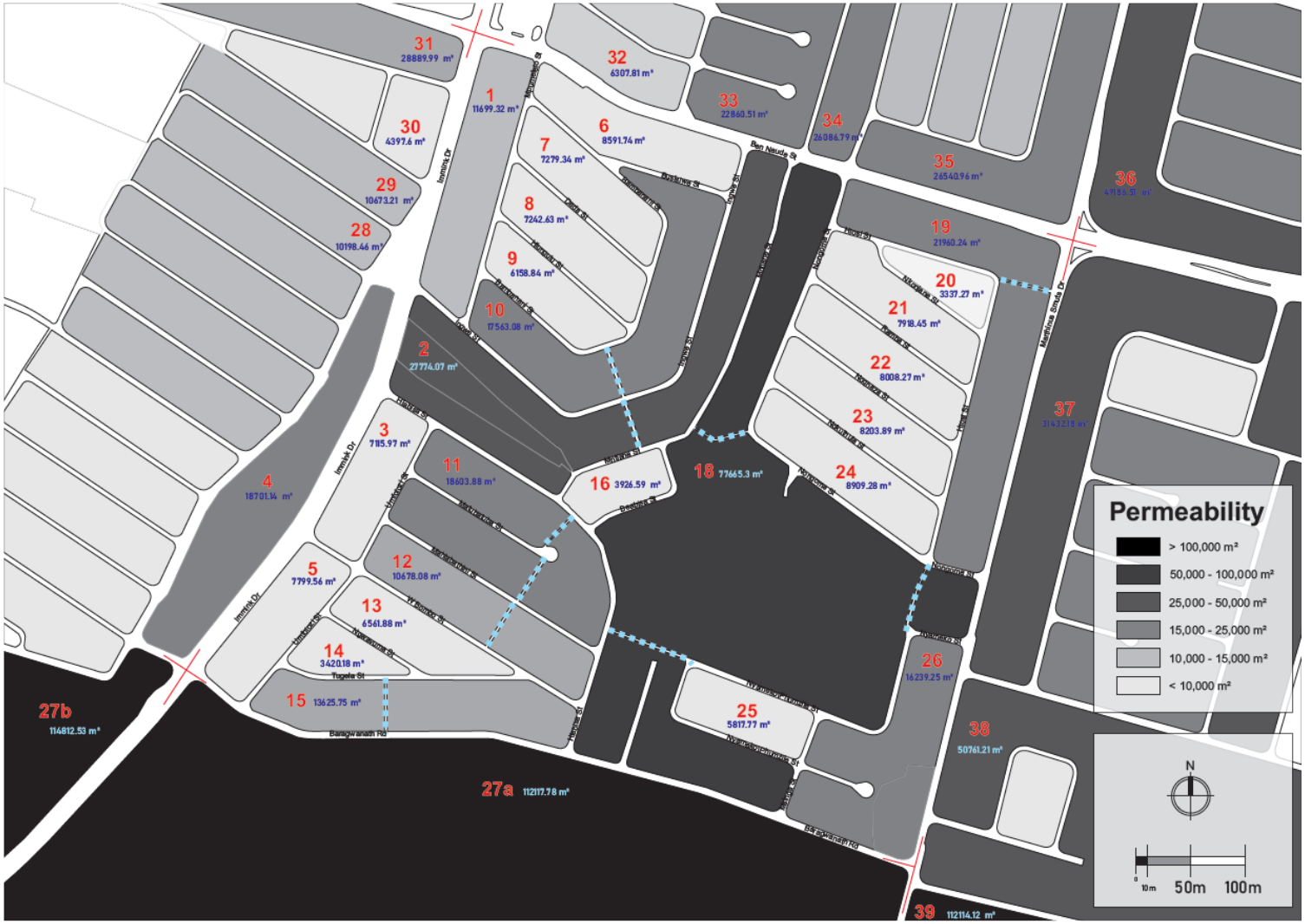


Figure 71

4.6.7 Street length

Street length is consistent with my observations of the block structure and road network connectivity in that the discontinuous nature of the road network results in many of the streets being short. Because the block structure divides the site into four enclaves (the north-east/west and south-east/west quarters referred to in ch.3), the shortest streets are within each enclave and there is a concentration of large blocks in the middle of the site separating the enclaves from one another and breaking the continuity of the internal streets. However, the longest streets are the outer roads, the main roads (fig.72), which connect the site to places outside. Consequently, as can be seen in fig.70, the site is not internally integrated. As such, it can be expected that most pedestrian activity will happen on the edges of the site.



Figure 72

Name of Str	Imageability	Pedestrians (average, Mon-Fri)	Length (meters)	Integration	Connectivity (per 100m)	Buildings (n)	Density (buildings per 100m)	Non-res uses (n)	Non-res use (per 100m)	Non-res as % of buildings	Block Permeability (block as % of street length)
Immink Dr (a)	3,8625	31	366	4	3,005464	74	20,21858	12	3,278689	16,21622	76,91257
Mpumelelo St	3,091284	17	299	3	7,35786	55	18,39465	2	0,668896	3,636364	82,25191
Ingwe St	3,9	55	559	3	3,041145	95	16,99463	7	1,252236	7,368421	88,24092
Mntlante St	2,76	4	459	2	2,396514	87	18,95425	2	0,43573	2,298851	94,79419
Ben Naude St (a)	4,2	43	333	5	5,405405	92	27,62763	12	3,603604	13,04348	75,07508
Busisiwe St	2,571757	4	118	1	5,084746	16	13,55932	2	1,694915	12,5	83,20313
Bambanani St	2,799167	21	448	1	3,348214	87	19,41964	0	0	0	91,40625
Dada St	2,561869	1	169	1	3,550296	30	17,75148	1	0,591716	3,333333	89,88095
Hlungulu St	3,253986	16	163	1	3,680982	35	21,47239	1	0,613497	2,857143	89,69697
Nongoma St	3,208	60	551	3	4,355717	76	13,7931	4	0,725953	5,263158	88,25832
Hlosi St	3,427455	28	427	2	4,918033	64	14,98829	3	0,702576	4,6875	83,68545
Marthinus Smuts Dr (a)	4	39	320	4	2,1875	83	25,9375	6	1,875	7,228916	92,25352
Ben Naude St (b)	4	64	245	5	3,265306	86	35,10204	7	2,857143	8,139535	88,77551
Nkonjane St	2,502545	4	136	1	4,411765	27	19,85294	0	0	0	92,96296
Ramba St	2,828829	10	180	1	3,333333	63	35	1	0,555556	1,587302	92,5
Noqhaza St	2,769505	8	190	1	3,157895	79	41,57895	1	0,526316	1,265823	91,79894
Nokuthula St	2,591532	7	196	1	3,061224	67	34,18367	3	1,530612	4,477612	91,87817
Immink Dr (b)	3,2	14	311	3	3,215434	62	19,93569	4	1,286174	6,451613	92,6045
Umfolozi St	3,61	24	320	2	6,875	62	19,375	4	1,25	6,451613	83,80503
Hlabisa St	3,3	33	444	3	4,504505	69	15,54054	8	1,801802	11,5942	85,61947
Matubatuba St	2,26	8	154	1	1,948052	40	25,97403	0	0	0	100
Mahlabathini St	3,72	1	232	1	2,586207	46	19,82759	1	0,431034	2,173913	93,53448
W Bombo St	2,78	8	295	3	3,389831	42	14,23729	2	0,677966	4,761905	89,21162
Ngwavuma St	2,44	5	110	1	5,454545	17	15,45455	0	0	0	81,85841
Tugela St	2,512432	2	228	1	3,947368	39	17,10526	1	0,438596	2,564103	86,80851
Baragwanath Rd (a)	2,834212	14	368	2	2,717391	113	30,70652	56	15,21739	49,55752	93,07065
Msinga St	2,52232	1	105	1	9,52381	16	15,2381	1	0,952381	6,25	73,78641
Marthinus Smuts Dr (b)	2,95286	14	272	4	5,514706	37	13,60294	2	0,735294	5,405405	75,91912
Baragwanath Rd (b)	2,3	23	334	3	2,694611	108	32,33533	59	17,66467	54,62963	91,46707
Nyameko	2,700293	6	585	1	4,273504	176	30,08547	3	0,512821	1,704545	97,87879
Phumzile St											

Table 7

4.7 CONCLUSION

Imageability in Diepkloof ranges from medium to very low with streets in the south being disproportionately represented in the “very low” category. The pedestrian pattern tends to be concentrated to in the north than the south. This distribution of pedestrians is consistent with the street integration and land use patterns. However, street length and block permeability show that the site is not only divided between the north and south quadrants but that it is also divided between the core, which contains schools that are a seasonal source of pedestrian activity, and the periphery, which has taxi routes and is where the majority of the site’s sparse non-residential land uses are located. The pedestrian pattern is concentrated to the north of the site but not exclusively on the longer outer streets. There are pockets of pedestrian activities in some internal streets such as Hlabisa Street and Nongoma Street, which are adjacent to the schools, as well as Ingwe Street and Hlosi Street, which seem to be popular with young people although without any discernible land use pattern to support this activity.

Chapter 5: ANALYSIS

5.1 INTRODUCTION

This chapter discusses the use of two statistical methods to analyse the data presented in the preceding chapter. The first is correlation, which is used to describe the relationship between the level of imageability on a street and the number of pedestrians on that street. The second method is linear regression, which is used to model and predict the number of people on a given street using environmental qualities such as imageability. Prior to performing correlation, the imageability scale developed in chapter 4 was used to identify human errors in the measurement of imageability. These errors occurred due to my initial lack of familiarity with Ewing and Clemente's (2013) survey instrument. For example, I overestimated the variable of "*major landscape features*" by including ridges in the distance, whereas the measurement protocol specifies that the feature must occupy at least 20% of the scene (Ewing and Clemente, 2013: 140). There are many other ways in which such human errors can occur, including recording incorrect values or duplicating items in a count. When I became aware of potential errors, I verified the score by checking the variable definition and the prescribed measurement protocol and then repeated the measurement.

Once I was satisfied about the accuracy of the data, correlation analysis and linear regression was then performed (at alpha = 0.05). The result was a correlation of 0.578 and an R^2 of 0.33. When outliers were removed to normalize the data, these values increased to 0.579 (correlation) and 0.859 (R^2). The presence of outliers suggests that the model was overestimating imageability, when compared to the imageability scale and to qualitative assessments of the site. Overestimation (and underestimation) occurs when items on site that should constitute model variables are either not counted or they are overrepresented in the count. This was due to the Ewing model variables not being properly calibrated to the site. An example of miscalibration is what occurred with the variable "*number of non-rectangular buildings*". While non-rectangular buildings are relatively rare in a downtown setting, they are far more common in a suburban environment such as Diepkloof and therefore have less *affordance* since they carry less novel information (as discussed in the literature review). Therefore, the imageability scale (developed in Ch.4) was used to determine when imageability scores were too high or too low when compared to my qualitative experience[27] of the site.

To correct for overestimation the theoretical framework (especially the concept of affordance) was used to translate model variables by changing how *building shape*, *number of people*, and *outdoor dining* are measured. Measurements were taken again with adjusted variables. This became Model B. The imageability scores decreased but correlation between imageability and pedestrian volumes increased. When regression was performed on the adjusted scores R^2 increased and the number of outliers also reduced. The persistent presence of outliers suggests that there are other events (outside of the data in the adjusted model) that influence pedestrian activity. The streets where outliers were observed were Ingwe, Nongoma, Ben Naude, Hlabisa, Marthinus Smuts and Baragwanath. The theoretical framework was used to determine potential explanations for the outliers, based on neighbourhood conditions such as land use mix and road hierarchy. Two of the outlier streets had schools on them. The other three were main roads that connected to places outside of the site and one of these main roads also had an above average number of non-residential uses. Ingwe Street was the only outlier that could not be explained with reference to neighbourhood conditions. Multiple regression was used to test if any of the measured neighbourhood qualities can simultaneously predict pedestrian volumes. Another two models were created, Model C (which used the prescribed Ewing model variables) and Model D (with adjustments to *building shape*, *number of people*, and *outdoor dining*). The results show an adjusted R^2 of 0.39 for Model C (statistically significant; p-value = 0,00024) and 0,70 for Model D (p-value = 1,24E-07). Model C only had one significant variable (street length). Model D, which has

[27] Qualitative experience was observed through walking in the site and then asking myself "what do I recall about this street" and "is there a striking feature about this street". I used sketching to identify striking features.

three variables (length, integration and imageability), is the better model because of its higher R^2 and lower p-value. The results demonstrate that it is possible to use these three variables to predict 70% of changes in pedestrian volumes on the site at a 95% confidence level.

5.2 CALCULATING THE CORRELATION BETWEEN IMAGEABILITY AND PEDESTRIAN VOLUMES AND DEVELOPING A LINEAR REGRESSION MODEL FOR PREDICTING PEDESTRIAN VOLUMES

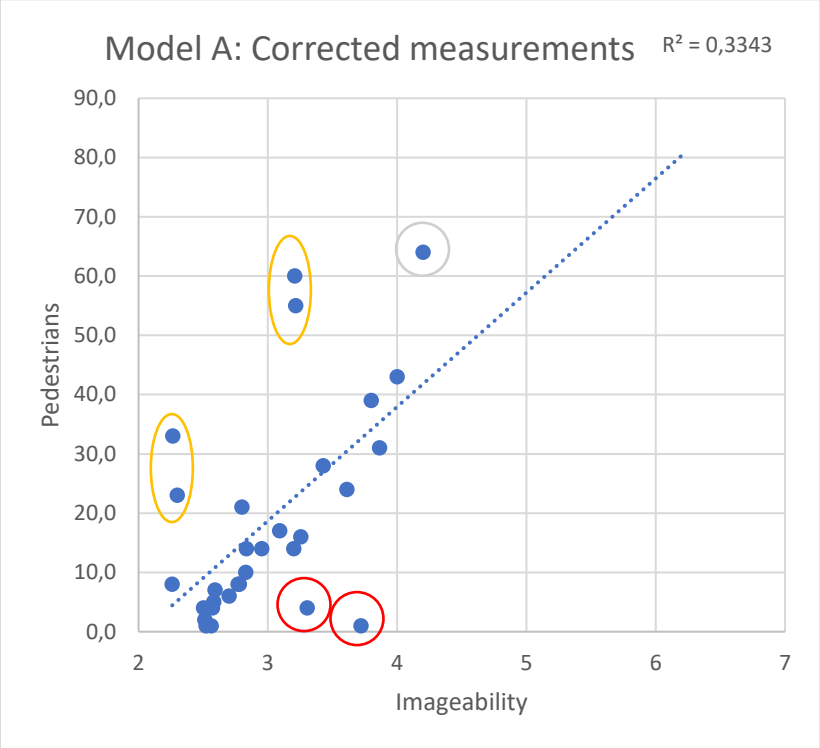
When applying the Ewing model to the site, I found that my Initial measurements of imageability were very high and possibly erroneous. These "human errors" should not be confused with standard errors, which describe the difference between the predictions of a regression and the actual values on which the regression is based. The term "human error" is used here to describe instances where an observation is called into question and found to be false because the premise of the observation does not match the operational definition of what is meant to be observed. To further explain the difference between the premise of an observation and the operational definition of what is to be observed, let us consider a hypothetical experiment. If we intended, as our experiment, to count the number of ducks in a pond, we would have to begin by defining what qualifies as a duck. This is the premise of the observation. However, if we wanted to compare this observation with observations of ducks in a previous study, we have to make sure that our observation matches the definition of what a duck is as specified in the study we are referring to (this is the operational definition). Thus, our premise must match the definition prior to making the observation. This is an example of "the theory ladenness of observation" (Kordig, 1971: 1), discussed in chapter 3 (3.2.3). In this case, I intended to observe variables such as "the number of people walking on a street" but, despite my own presumptions about what constitutes a person walking on a street, the only observations that should count – in order to maintain comparability with the Ewing model – are those that match the definitions specified in Ewing and Clemente's (2013) description of the model.

Human errors occurred because my initial measurements were based on incorrect definitions of model variables. For example, in the initial measurements, views of landmarks such as the Soweto Towers and the ridge on the horizon were considered "*major landscape features*" (a model variable). This was an error as the Ewing model only considers features that occupy at least 20% of the screen (Ewing and Clemente, 2013:140). I was able to determine this to be a measurement error by two methods. Firstly, I compared the measurements to the imageability scale (ch.4), to see whether they were low or high. Since the measurements had an average score of 5.76, they were very high and fell into the upper quartile of the scale. Secondly, I qualitatively assessed the scenes to determine if they possess imageability. This was done by noting the presence of striking features in the scene; and assessing whether the scene was memorable (asking myself if I could vividly recall the contents of the scene without looking at it). Although this measurement error occurred due to not applying the measurement protocol with sufficient care, it is noted here to demonstrate that quantitative models are prone to such errors and that their results can vary drastically depending on how well they are applied. Small mistakes such as misunderstanding what a word means can result in a variable being overrepresented and completely altering the results of the model. To put this into perspective, the R^2 value[28] from the corrected scores is 200 times larger than the R^2 from initial measurements (Appendix D).

When the measurement protocol was applied correctly, imageability scores decreased. This data was used to create Model A. Correlation between pedestrian volume and imageability in Model A was determined to be 0,5782 (moderate positive). Regression returned an R^2 value of 0.34, which means that imageability can explain about 34% of differences in pedestrian volumes. I identified outliers that could be explained by other neighbourhood conditions (circled in fig.73). When all outliers are removed correlation increased only slightly to 0,58 but R^2 increased to 0.86 (Appendix D). This R^2 represents very strong predictive capacity as 86% of changes in pedestrian volume can be explained by differences in imageability. However, removing outliers is

[28] This value describes how well the model will fit data on a new site (i.e., the model's predictive capacity)

not a genuine solution for increasing the model's predictive capacity (the R^2) as it makes the model biased and less applicable to new data. The presence of outliers indicates that there are datapoints that fall outside of the model's explanatory scope. Removing the outliers does not change the fact that there are datapoints that the model cannot explain, which would reduce the model's performance if similar datapoints are found in other sites where it is applied in the future. The fact that some outliers show high imageability (Mntlane and Mahlabathini, circled in red in fig.73) suggests that the model is still overestimating imageability.



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3149,353	3149,353	14,06227	0,000818
Residual	28	6270,813	223,9576		
Total	29	9420,167			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-39,08432646	15,68465	-2,49188	0,0189	-71,2129	-6,95578	-71,2129	-6,95578
Imageability	19,25784416	5,135466	3,74997	0,000818	8,738318	29,77737	8,738318	29,77737
			2,063899	t-critical value				

Figure 73: Model B shows an R^2 of 0.33 with 7 outliers. There are two kinds of outliers: those with high imageability and low pedestrian volumes (red); and low imageability and high pedestrian volume (yellow)

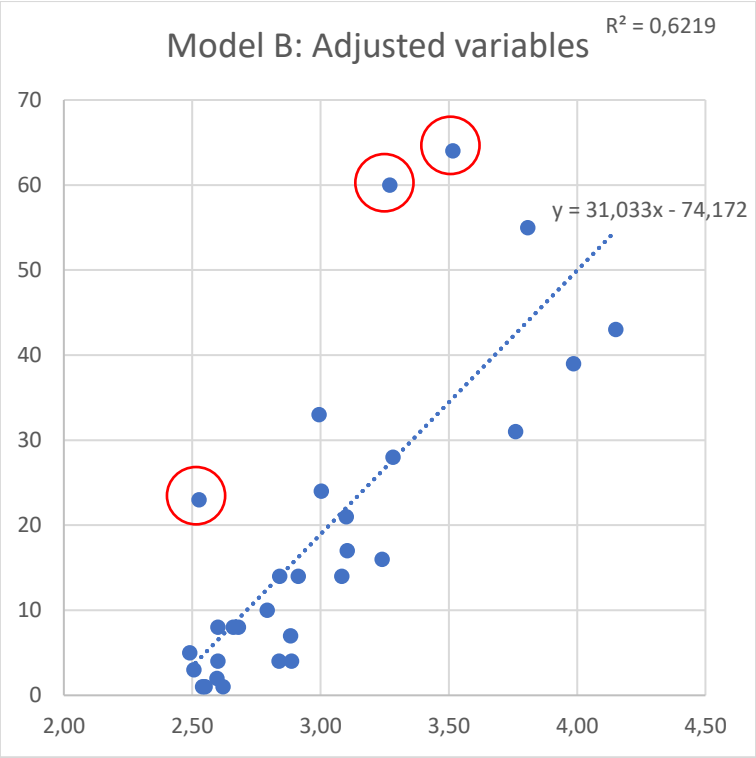
In this study, overestimation is a more noteworthy threat to the validity of results than underestimation. This is because a qualitative assessment of the imageability on site (my experience of the site as described in the sketches in Ch.4) suggests that imageability is low. In other words, the imageability scores of the two streets with outliers do not match my qualitative perception of the streets during my site visits. Thus, the high imageability scores are likely to indicate that the Ewing model is not appropriately calibrated to make measurements within the context of the site. However, it should be stressed that this is not a definitive finding of model miscalibration but, rather, an observation that the Ewing model's imageability scores do not match my own perception of imageability. It is also possible for this mismatch to be explained in the opposite direction: that the scores are accurate, and my perceptual experiences are underestimating imageability.

Perhaps, for example, I am not sufficiently skilled at identifying imageability or I am not adequately familiar with the site to notice some aspects that contribute to imageability. This seems to be an example of the persistence of theoretical paradigms (what Kuhn (2012) calls "normal science") even in the face of contradictory findings or anomalies (as discussed in Ch.3: 3.2.4). As opposed to the Popperian perspective that a contradictory finding should cause the researcher to reject a theory, in practice it is less clear to determine if the finding is a genuine counter example to the theory (demonstrating the limits of the theory) or if it is an anomaly that could be explained by shortcomings in the experiment's design. As such, I retained Model A – as a potentially valid description of imageability and its relationship to pedestrian volumes – but also developed a second model where I adjusted the Ewing variables that were the most likely causes of overestimation. If the second model (Model B) performed better than Model A (if it had a higher R^2 and lower p-value), then it would provide evidence that model calibration is necessary to improve the accuracy of the Ewing model when applying it to a South African township context.

By reflecting on the literature, especially the concept of affordance, I deduced that the likely source of miscalibration is the translation of model variables into physical features that can be observed on site. Table 8 shows how the operational definitions of *building shape*¸ *number of people*, and *outdoor dining* were adjusted in model C to ground the measure of imageability within the South African township context.

Variable	Original Definition	Adjusted Definition
Building shape (nonrectangular shape)	- Pitched roofs - Offset frontage (building not directly facing street) constitute	- Do not include single-pitched roofs (standard Diepkloof house). Only buildings with more than one pitch on their roof constitute "non-rectangular shape" - Double storey buildings constitute "non-rectangular shape" - Overlapping frontage (multiple buildings in a yard in the same line of sight) - If a solid wall covers more than 50% of a building's frontage then the building shape is considered to be rectangular.
Number of people	One side of the street	- Both sides (because the streets are narrow, and most people walk in the road)
Outdoor dining	Restaurants	- Include street trade

Table 8 adjustment of model variables to fit context



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	5429,144	5429,144	37,28879	1,37E-06	(0.00000137494704324345)
Residual	28	4076,722	145,5972			
Total	29	9505,867				

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-63,64056142	13,66835	-4,65605	7,1E-05	-91,6389	-35,6422	-91,6389	-35,6422
Imageability	27,72904198	4,54094	6,106455	1,37E-06	18,42735	37,03074	18,42735	37,03074
			2,063899	t-critical value				

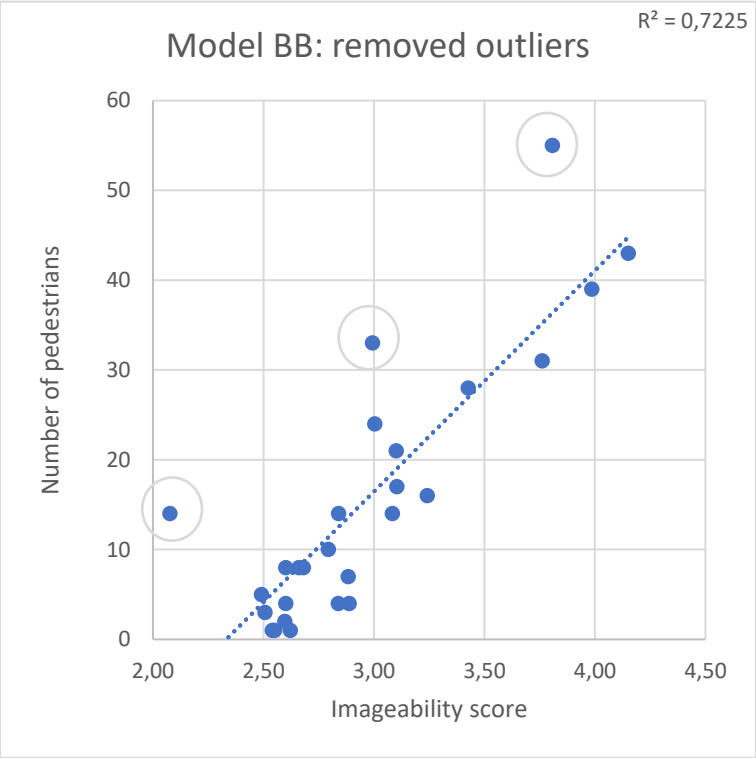
Figure 74

When the variables are adjusted, the average change in imageability scores is -0.037. The imageability scores decrease but correlation increases from 0.58 (in Model A) to 0.79 (in Model B) (fig.74). This is a change from moderate positive correlation to strong positive correlation. When regression was performed, R^2 increased from 0,34 to 0.57, which represented an increase in the model's explanatory power. Box-whisker plots were used to compare the number of outliers in Models A and B by creating a distribution of the squared residuals. Residuals are the distance between the trend line (the model's prediction of pedestrian volumes) and the observed value represented by the dots in the scatter plot. The magnitude of the sum of these residuals[29] indicates how well the trendline fits the data (the extent to which observations match predictions). The smaller this number is, the tighter the fit between the trendline and the data, which results in more accurate predictions. The sum of squared residuals for Model B (3594) is smaller than that of Model A (7482), which represents an improvement in fit. The points on a given scatter plot that have very large residuals (those that have the highest deviation from the trendline) are known as outliers. Model A had six outliers, but Model B only has three. The outliers in Model B are Ben Naude Drive (b), a main road, and Nongoma Street, an internal

[29] Technically, this is the sum of *squares* of the residuals. Some of the points are below the line and thus have negative residuals. To prevent the positive and negative values from cancelling each other out when calculating the extent that observations deviate from the trend line, the residuals are squared to ensure that they are all positive.

street with a primary school (circled in red in fig.2). Figure 3 shows that when these three points are removed R^2 increases from 0.62 to 0.72. Both models are statistically significant (at alpha = 0.05) but Model B has a smaller p-value than Model A (1,37E-06, compared to 0,000818). Based on the differences in R2, fit, number of outliers and p-values, Model B seems to be a better model for using imageability to predict pedestrian volumes.

.



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3923,487	3923,487	65,09596	2,01E-08
Residual	25	1506,809	60,27236		
Total	26	5430,296			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-57,40810251	9,143302	-6,27871	1,44E-06	-76,2391	-38,5771	-76,2391	-38,5771
Imageability	24,62167273	3,051691	8,068207	2,01E-08	18,3366	30,90675	18,3366	30,90675

Figure 75

The preceding section has presented two bivariate linear regression models (Model A and B), which predict pedestrian volumes in Diepkloof Zone 5 based on imageability scores. Model A uses unmodified variables from the Ewing model whereas Model A makes adjustments to three variables (Building shape, Number of people and Outdoor dining). There is higher correlation between imageability and pedestrian volumes in Model B than in Model A (0.79, compared to 0.58). When regression is performed, Model B has a higher R^2 than Model A (0.62, compared to 0.34). It also has fewer outliers (3, compared to 6 for Model A). Since both model A and B have R2 values below 0.65 (because of the effect of outliers), there is a moderate positive correlation between imageability and pedestrian volume. In terms of the predictive power of the models (as described by R^2), Model A can use imageability to explain 34% of changes in pedestrian volumes. This value is 62% in Model B. Since both models predict less than 100% of changes, we can conclude that there are other variables that

are not accounted for in these bivariate models and that these factors may explain the remaining changes[30] in pedestrian volumes.

When the outliers are removed from both models, Model B has a R^2 of 0.90 whereas Model A has a correlation of 0.86 (Appendix D). However, as explained above, removing outliers undermines the model's reliability and is therefore only used to normalize the data to identify streets where there may be other factors associated with pedestrian volumes that are not accounted for in the model. For example, since the outliers in Models A and B were long streets or streets with non-residential land uses, it suggests that pedestrian volumes may be correlated to street length and non-residential land use. In the next section I describe the use of multiple regression to model pedestrian activity and imageability in relation to other environmental factors.

5.3 MULTIPLE REGRESSION: CALCULATING CORRELATION BETWEEN MULTIPLE NEIGHBOURHOOD CONDITIONS AND PEDESTRIAN ACTIVITY AND DEVELOPING A REGRESSION MODEL FOR USING THESE NEIGHBOURHOOD CONDITIONS TO PREDICT PEDESTRIAN VOLUMES

Multiple regression is used in this section to remove the effect of outliers by using additional variables to account for neighbourhood conditions. The following environmental factors are modelled: *street length*; *street integration*; *connectivity score*; *intersections per 100m*; *number of buildings*; *building density*; *number of non-residential uses*; *non-residential uses per 100m*; *non-residential use as a percentage of buildings*; *and imageability*. As in the previous section, two models were created: one using variables from the Ewing model; and a second using variables that have been adjusted for the context. These are titled model C and model D, respectively. Model C returned a correlation value of 0.58 whereas Model D, which was based on adjusted variables, returned a value of 0.79 (table 9).

	Pedestrians (average, Mon-Fri)	Length (meters)	Integration	Connectivity score	Connectivity (per 100m)	Buildings (n)	Density (buildings per 100m)	Non-res uses (n)	Non-res use (per 100m)	Non-res as % of buildings	Imageability ®	Imageability (Adjusted variables)
Pedestrians (average, Mon-Fri)	1											
Length (meters)	0,62	1										
Integration	0,74	0,46	1									
Connectivity score	0,54	0,72	0,44	1								
Connectivity (per 100m)	-0,06	-0,22	0,00	0,45	1							
Buildings (n)	0,52	0,70	0,43	0,29	-0,47	1						
Density (buildings per 100m)	0,05	-0,18	0,00	-0,41	-0,44	0,53	1					
Non-res uses (n)	0,16	0,24	0,25	0,01	-0,22	0,57	0,34	1				
Non-res use (per 100m)	0,13	0,17	0,24	-0,03	-0,20	0,53	0,36	0,99	1			
Non-res as % of buildings	0,16	0,21	0,28	0,03	-0,15	0,50	0,26	0,98	0,99	1		
Model C Imageability ®	**0,58**	0,32	0,61	0,28	-0,05	0,32	0,07	-0,09	-0,09	-0,08	1	
Model D Imageability (Adjusted variables)	**0,79**	0,50	0,73	0,42	-0,07	0,43	0,02	0,00	-0,03	0,01	0,75	1

Correlation with Pedestrians

Collinearity between variables

Table 9 Correlation (shown in yellow) between physical aspects of streets and pedestrian volume. Collinearity between variables is shown in blue.

The presence of outliers in the bivariate regressions presented in the previous section suggested that other neighbourhood conditions (such as street length and land use) may be correlated to pedestrian volumes.

[30] In Model A 66% of changes in pedestrian volume remain outside the scope of the model. Similarly, in Model B, 38% of changes cannot be explained by the model.

Further analysis showed that (in addition to imageability) pedestrian volumes had correlation with four other factors: street length, street integration, street connectivity score, street connectivity per 100m, and number of buildings (table 9). Land use was found not to be a significant factor, although it had previously seemed to be a likely explanation for outliers in Models A and B. Table 2 shows that there is collinearity between several of the factors measured. Collinearity refers to when two (or more) factors are so closely correlated to one another that they could be an interchangeable measure of the same phenomenon. If two factors are highly collinear, it poses a challenge for performing regression because the model would receive information about the same phenomenon twice. In table 9, there is collinearity between *street length* and *connectivity score*. This makes sense because a longer street is likely to have more intersections. Similarly, *street length* and *number of buildings* have collinearity, which makes sense because a longer street is likely to have more buildings. Non-residential land use was measured in three different ways[31] (as number of non-residential land uses, percentage of non-residential uses and as non-residential uses per 100m), which results in multi-collinearity between those variables.

In multiple regression the "adjusted R Square" provides a more accurate indication of a model's predictive capacity as it considers how well the model can fit new data by adjusting R^2 to the sample size. It describes how likely the model is to fit the data on a new site. The adjusted R Square is the predictive capacity of the model, and it is more conservative (than the R Square used in bivariate regression) as it considers the probability that data from a new site may be more randomly distributed. When regression was performed (including the collinear variables) Model C returned an adjusted R^2 value of 0.61, with only one significant variable[32] (out of possible 10 x variables). Model D had an adjusted R^2 of 0.71 with only two significant variables[33]. As explained earlier, the accuracy of the models at this point was still compromised by the presence of collinear variables. To resolve collinearity, I identified variables with collinearity over 95% (where correlation between the variables was greater than 0.95). Three variables (*number of non-residential land uses*, *percentage of non-residential uses*, and *as non-residential uses per 100m*) were correlated with one another at a level above 0.95. As explained before, these were in fact a measure of the same phenomenon. Two of these variables were excluded from the sample and the one with the highest p-value (percentage of non-residential use) was retained to represent them. I then proceeded to perform stepwise regression on the remaining data[34].

Stepwise regression is used to select the best model by progressively identifying and removing values with the lowest significance for predicting the independent variable (in this case, pedestrian volume). This was done by running regression on the data, observing the p-values for values above the significance threshold of 0.05 and then removing the variable with the highest p-value. The process was repeated until all the variables had significant p-values. When stepwise regression is performed on Model C (unadjusted), the adjusted R^2 was 0.39 and only one variable was found to be significant, *street length*[35] (Appendix H). For Model D (with adjusted variables), the adjusted R^2 is 70, with three significant variables (alpha = 0.05). The significant variables in Model D are *street length*, *street integration* and *imageability*. Thus, Model D can be summarised as the following linear equation:

---

[31] Although correlation analysis now reveals that these three measures of land use are almost equivalent, at the time of making the measurements it was not immediately apparent that number of non-residential uses on a street would have the same impact as the percentage of non-residential uses on a street. Some streets are very short, compared to others, and it seemed reasonable that a shop on a short street could have a disproportionate impact on that street. Similarly, it seemed reasonable to expect that a concentration of shops (described as non-residential land uses per 100m) would have a larger impact than if the same number of shops were dispersed over a long distance.

[32] Street length

[33] Density (buildings per 100m) and Imageability

[34] This study identified collinearity at a level of 95%. As can be seen in table 9, if collinearity had been identified at a lower level (e.g., 60%) then more variables would have been collinear. Then PCA analysis would have to be performed.

[35] This R^2 (0.39) is the same when bivariate regression is performed on street length and pedestrian volumes.

$$Y = x_1 + x_2 + x_3 + \text{Intercept}$$

Pedestrian volume =
0,0374368848554086 (Length) + 4,24171809822996 (Integration) + 17,01934412 (Imageability) + -52,2181829930798

Model C has an adjusted R^2 of 0,36 (Appendix H) whereas this value for Model D is 0.70 (table 10). Model D also has a higher level of significance (p-value = 1,24E-07) and it outperforms Model C (0,000243). Model C also has only one statistically significant variable (integration) but Model D has three statistically significant variables: *Length, integration* and *Imageability* (table 10). Notably, street length features as a significant variable in both models. Furthermore, imageability has the highest significance in Model D but it does not feature significantly in Model C. This may have to do with the collinearity between integration and imageability, as identified earlier (table 2). This suggests that the significance of imageability may be different (perhaps lower) if explored with a more sophisticated statistical method, such as Principal Component Analysis (PCA).

Model D: Stepwise regression

Regression Statistics	
Multiple R	0,856477
R Square	0,733553
Adjusted R Square	0,702809
Standard Error	9,869946
Observations	30

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	6973,055	2324,352	23,8601	1,24E-07
Residual	26	2532,812	97,41583		
Total	29	9505,867			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	-52,2182	14,65115	-3,5641	0,001441	-82,3341	-22,1023	-82,3341	-22,1023
Length (meters)	0,037437	0,016954	2,208106	0,03626	0,002587	0,072287	0,002587	0,072287
Integration	4,241718	2,063392	2,055702	0,049982	0,000356	8,483081	0,000356	8,483081
Imageability (Adjusted variables)	17,01934	6,043375	2,816199	0,009151	4,597009	29,44168	4,597009	29,44168

Table 10: Stepwise regression of Model D shows three significant variables (Length, integration and Imageability)

Curiously, aside from imageability, two out of the three significant variables in Model D (after stepwise regression) seem to describe the street itself rather than the context within which it is located. Length describes the amount of distance a street covers (although it, admittedly, has collinearity with other variables). It thus seems reasonable that length can inform whether people walk on a street since a longer street, that connects over longer distances could have more potential destinations to attract pedestrians. Integration describes how often a street is used as a connection from one point to another within a network. It stands to reason then that a street with high integration would connect to many potential destinations and would therefore be attractive to pedestrians. Imageability thus stands out amongst these variables as it is not

immediately apparent that a street's prominence in the "image of the city"[36] describes the street itself rather than the street's role relative to a wider context. One possible explanation for this is that imageability as described in the Ewing model is in fact limited to the street: all the variables that make up the imageability score are aspects observed on that street. This is very different to how imageability is conceived in cognitive mapping, where respondents recall and draw a place (a neighbourhood or a city) holistically and the street appears as an element of the place. Another explanation for the significance of imageability alongside length and integration could be (if we accept Model D's suggestion that pedestrians prefer long and/or integrated streets) pedestrians use imageability to speculate on whether a street is likely to be long or integrated. According to this explanation, pedestrians see certain physical features (such as major landscape features, historical buildings, buildings with identifiers, and other people[37]) and deduce that the street must be long or integrated; and then they decide to walk on that street. Alternatively, imageability could be significant because it is what happens when streets are long enough or integrated enough. That is to say (again, if we accept the model prediction that long streets or integrated streets attract higher volumes of pedestrians), people will often walk on imageable streets because they are long streets or because they are integrated to their potential destinations but not necessarily because they are imageable. Yet – because they are long or integrated – these streets will develop features that make them imageable (they will develop the variables identified by Ewing and Clemente (2013)).

5.4 THEORETICAL IMPLICATIONS

In the discussion below, the results of the models presented above are considered in light of their theoretical implications. There are four key findings in this regard. The first is that the models still present an incomplete picture of imageability as they primarily look at physical qualities (*structure*) and cannot accurately account for perceptual qualities (*identity* and *meaning*). Secondly, the differences in correlation (between models with adjusted variables and those with unmodified Ewing variables) suggests evidence of the effect of *affordance* in making places imageable. Thirdly, the higher statistical significance of street length as opposed to street integration demonstrated in the regression models suggests that longer streets may play a role as a means of orientation in environments that have low legibility and few landmarks. Lastly, although the land use pattern in the site lacked diversity, density and destinations, certain key points – such as schools and main roads – nonetheless act as attractions for pedestrian activity.

5.4.1 Structure, identity and meaning

Model D, the best model presented in this chapter, has an adjusted R2 of 0.70. This means that about 70% of changes to pedestrian activity can be explained with reference to the environmental conditions captured in the model; but it also means that 30% of changes still occur outside of the purview of the model. This can be explained by the fact that imageability is only one of five urban design qualities considered to be factors of walkability in the Ewing models (Ewing et al, 2005a; 2005b; 2006; 2009; 2013). The other qualities are enclosure, human scale, transparency, and complexity (Ewing and Handy, 2009)[38]. Many of these qualities are largely perceptual and there is some overlap in the physical features used to measure them. In Model D, imageability is the only perceptual variable and its high p-value may be an indication that it is overrepresented. Overrepresentation could be because of the aforementioned overlap: that imageability is associated with

[36] In this case, "the image of a *neighbourhood*" – Diepkloof Zone 5

[37] These are the Ewing model variables (courtyards, plazas, and parks; number of major landscape features; historic buildings frontage; buildings with identifiers; non-rectangular buildings; outdoor dining; number of people; noise level)

[38] My research initially intended to test all of these factors as measures of walkability in Diepkloof Zone 5. However, since the methods for measuring them were all developed using the same process as the imageability model, the research project became infeasible. Because of the novelty of the methods, each urban design quality would have required its own international scale (to allow comparison) and adjustments would potentially have to be made to each model variable (as was done with the model for imageability) in order to fit the model into a new context.

similar physical features as other qualities (such as *human scale, enclosure, and complexity*) that are not included in Model D. Given this, an adjusted R^2 is likely to be too high and could be moderated (in future research) by including qualities such as human scale and enclosure as variables in model D.

5.4.2 Affordance and Shannon's measure of information

According to Shannon's measure of information, the impact of affordance decreases in proportion to the number of times an element occurs within the environment. The more ubiquitous an element is, the less likely it is to be memorable or meaningful and thus the less it contributes to imageability. Model A and Model C both use variables from the Ewing model to measure imageability. For example, the variable "building shape" assumes that pitched roofs positively contribute to the distinctiveness of a street. While this may be the case in urban contexts, where such roofs are comparatively rare, in suburban settings the impact of pitched roofs is diminished. This is because affordance (the quality that enables a symbol, such as a pitched roof, to convey information) is subject to entropy. Affordance diminishes as more similar symbols are observed. By successfully using adjusted variables in Model B and Model D to derive higher correlation, this chapter has provided evidence of the role of affordance in enabling imageability. When using unadjusted variables, without accounting for affordance and context, Models A and C overestimated imageability and resulted and a lower adjusted R^2 and thus a lower predictive capacity for the models.

5.4.3 Path continuity and angular betweenness

Filomena et al (2019) argue that, in low-legibility contexts, when a path is not characterised by vivid activities or peculiar properties, perceptual continuity comes into play. People tend to choose routes that minimise angular change rather than distance (Filomena et al, 2019). Thus, while space syntax theory may predict that paths become more attractive to pedestrians because of their integration into the street network, some paths may nonetheless be attractive because of their length, continuity, and lack of angular change.

Since street length (in Model D) is more significant, it suggests that – in the case of Diepkloof Zone 5 – continuous streets are more conducive to pedestrian activity than well integrated streets. This is likely because Zone 5 has low legibility. However, the lower significance of street integration may also be because, in Diepkloof Zone 5, the streets with highest integration tend to occur on the edges of the site. This makes the site externally integrated (integrated with the surrounding context) more than it is internally integrated[39]. This finding does not dispute the classical urban design principle that street networks with high integration and high legibility are more conducive to pedestrian activity; it only provides evidence for Filomena et al's (2019) assertion that, when legibility is low, street length becomes more significant than street integration because longer streets provide a better sense of orientation that can compensate for low legibility.

5.4.4 Neighbourhood conditions: destination, density, and diversity

Urban features associated with destination, density and diversity did not feature significantly in the model. However, this is likely because the site has few such features. Streets with schools did appear as outliers in bivariate regression (Models A and B), which suggests that schools are prominent destinations. The same is true of main roads, which connect to destinations outside of the site. There is very low variation in densities but Baragwanath Road, which has a large amount of informal development (smaller buildings in close proximity to one another) also featured as an outlier. Main roads and places with informal development also tended to be the places with the highest variety in land use mix (see mapping in Ch.4), which accounts for diversity. However, such places were too few on the site to be statistically significant and results may be different in other sites.

[39] See detailed discussion of integration in Ch.4

5.5 CONCLUSION

Four models have been discussed in this chapter. The chapter began by discussing how quantitative models are vulnerable to human error as they depend on the researcher's interpretation of concepts to derive model variables. Model A is an application of the Ewing model to Diepkloof as a measure of imageability. The results of the model show weak positive correlation (0.58). When regression is applied Model A has an R^2 of 3.4 with seven outliers located in main roads and streets with schools. The model also demonstrates a tendency to overestimate imageability. A key reason for overestimation is that urban elements that are rare and meaningful in urban contexts are abundant in suburban and township contexts and they do not carry the same meaning in Diepkloof Zone 5 as they did in the places studied by Ewing et al when they developed their measure of imageability. Model B adjusts how urban elements such as *building shape, number of people* and *outdoor dining* are measured. This increases correlation and R^2 but the persistent presence of outliers suggests that imageability is not an adequate predictor, on its own, of pedestrian activity on the site and that there are likely to be other environmental factors that simultaneously impact on pedestrian activity but that cannot be modelled in a bivariate linear regression.

In Model C and D, multiple regression is used to simultaneously model different neighbourhood factors in addition to imageability. The results show that adjusted model variables are better suited for explaining pedestrian patterns when using imageability. Model C has an adjusted R2 of 0.39 and only one significant variable but Model D (which uses adjusted variables) has an adjusted R2 of 0.70 and three significant variables. However, since the model can only explain 70% of changes in pedestrian volumes, it is likely that quantitative modelling only captures a limited aspects of imageability (composition) and that further research is necessary to understand other dimensions of this phenomenon (cognition and meaning).

Chapter 6: CONCLUSIONS AND RECOMMENDATIONS

In the early part of the twentieth century there were attempts to make urban planning into "a science" but, to a large extent, the bounds of what constitutes scientific knowledge were narrowly defined and limited to the empiricist and positivist perspectives (Sheppard, 2014). Modernist schools of thought, such as the Bauhaus and De Stjl, attempted to separate the city from the perceived superficial misapprehensions of tradition, religion, and superstition in order to arrive at a pure form that is derived from reason and rationality (Trancik, 1986). I am guilty, to a certain extent, of trying to do the same in this study; and perhaps this could be said also of any attempt to quantitatively model urban processes. On the face of it, being scientific means establishing knowledge exclusively on verifiable truths. As shown in chapter three this definition is more closely aligned with the empiricist and positivist perspectives but is by no means the only definition of scientific knowledge. Another perspective on science is to see it as a heuristic, a means by which we arrive at *useful* information (Feyerabend, 1993). From this second perspective science may have many formidable competitors because there are already other social processes that produce such useful information. There are historical examples of demonstrably unscientific knowledge serving a practical purpose to do things that existing science at the time is unable to do, such as the continued use of the Ptolemaic system for navigation for centuries after the Copernican system demonstrated that the earth was in fact not the centre of the solar system (and that therefore the Ptolemaic view of the world was incorrect) (Kuhn, 1970). Even if we cannot verify the validity of such information, in certain cases this knowledge has retained an equivalent heuristic value as scientific knowledge (in that the information is sufficient to serve its intended purpose) despite it not being derived through the scientific method (Feyerabend, 1993). It could be argued that the epistemology of disciplines that study the urban, to some extent, necessarily includes this category of useful but non-scientific knowledge. Verna (2011) certainly makes a compelling case that design (and the design of cities) cannot be completely theorised and therefore cannot be scientific. Other examples of things that are known independently of science (and which have found validity in practical application rather than their theoretical rigor) include the notion of "home", the construction of bridges and even the development of cities themselves, since all three of these predate the scientific method. For instance, we may not be able to quantitatively verify the notion of "home" or "place" but humans have had social processes that produce these phenomena and these predate the scientific method by over thousands of years. Science itself is a social process, although it is tempting to view it as an external instrument for viewing society and its processes with the intention of identifying its working parts, quantifying them, and then optimising them. Such a positivist view of science, at its logical extreme, threatens to reduce society and cities to those things that can be counted and discarding the rest.

Today, "the spectre of positivism [still] haunts critical urban studies, distracting us from the possibilities of creative, rigorous, critically engaged scholarship beyond the obsolete dichotomies of quantitative/qualitative methodologies and positivist/post-positivist epistemologies" (Sheppard, 2014: 636). The value of quantitative models (and of science) is that they are more predictable than other heuristics. Their potential disadvantage is that they may have a narrower application. It is therefore crucial that models are not adopted uncritically and assumed to be applicable in different contexts from where they are developed. Models should not be assumed to be a replacement of qualitative and subjective human experience. Instead, because models – and science itself – are the product of human reasoning, we must accept them as being premised on human experience, with its subjectivity and its qualitative attributes. We must acknowledge that science is a social process that allows us to collate, compare and verify individual data points and observations as well as models and theories that are put forward by individual researchers. It is in this spirit that I have carried out this research to validate the Ewing model's applicability as a measure of imageability and a potential predictor of where people are most likely to walk. This report has evaluated the applicability of the Ewing model as a means to measure imageability in the context of a South African township and has tested the extent to which this measure of imageability can be used to describe the association between imageability and pedestrian patterns

in Diepkloof Zone 5. In chapter 5 I demonstrated that it is possible, with some revision of the model variables to arrive at a model that is capable of predicting 70% of changes in pedestrian volumes based on three street attributes at a 95% confidence level. However, after making so many changes to the model, one has to wonder, firstly, if it is still the same model; and, secondly, what the stated statistical significance is being compared to.

The first section of this chapter outlines the key findings of the study. This section draws out the theoretical implications of the successful use of the Ewing model as a measure of imageability; and it discusses three key lessons about the use of correlation and linear regression models to describe the relationship between pedestrian patterns and environmental qualities such as imageability. In the second section, this chapter reflects on the limitations of the study by discussing the need for urban design theory to focus on processes of deriving quantitative descriptions of theoretical concepts rather than the models that such processes produce. It points to the need for further verification studies of these relatively new models. Having considered the limitations of the study, in the final section, I outline potential areas for the application of the process described in this study and make recommendations for future research.

6.1 The relationship between imageability and pedestrian patterns in Diepkloof Zone 5

The results of applying the Ewing model in Diepkloof Zone 5 show low levels of imageability, which is consistent with my qualitative assessment of the site, as lower densities reduce the potential for *composition* because the environment has fewer elements. In order for an environment to be striking or distinct, there must be some elements within it that stand out from their context. This process is described in the literature as the presence of a hierarchical composition of elements: *first order elements*, which form the context, and *second order elements* that form visual focal points (Dalton and Bafna, 2003). Diepkloof is characterised by a lack of such hierarchy. Furthermore, in order for an environment to be memorable or to hold meaning, it must contain elements within it that have the capacity to carry and convey information. This is described in the literature as *affordance* (Haken and Portugali, 2003). However, the affordance of an environmental feature depends in part on the novelty of that feature and decreases each time the feature reoccurs in the environment. Because Zone 5 is characterised by a repetition of elements and styles, it does not have a very memorable sense of place and does not carry much meaning to a person who is not familiar with the place. The imageability scores from the Ewing model were surprisingly accurate at reflecting this qualitative experience. Ben Naude Street and Immink Drive stood out as the most easily recognisable and vibrant streets during the site visits and they were among the six highest scores. However, Ingwe Street was a notable outlier as it did not possess many striking or memorable qualities but nonetheless received a high Ewing score.

The results also show that, although most of the streets in Zone 5 have either low or *very* low imageability, there are some streets with significantly higher levels of imageability when compared to their context. This is consistent with the scaling law of artifacts, which states that concentrations of phenomena tend to be relatively rare in geography and that dispersal is the norm (Jiang, 2011; Jiang, 2013). In other words, it is normal – even in an imageable place – that there would be fewer places with very high levels of imageability relative to the context. Thus, if we refer to the scale introduced in chapter 4, the scaling law of artifacts suggests that we should expect few imageability scores above 6, just as we should expect very few scores below 2. In statistics this phenomenon is referred to as *regression to the mean*.

The application of correlation analysis and linear regression to imageability and pedestrian data yielded three key findings. The first is that quantitative descriptions (such as the scores from the Ewing model) are not a substitute for qualitative descriptions. They are only a numerical expression of the qualitative description and their accuracy and utility depend on that description. This may go without saying for individuals that are more familiar with using mathematical techniques to solve practical problems but I often found it tempting in my fieldwork to expect the field survey checklist to transform the scene I was looking at into a number that correctly described the imageability of the scene. In reality, however, I constantly had to refer back to the qualitative description in the theory to determine if an item on a particular street matched the description on

the checklist. As such, field survey instruments (checklists) or quantitative models of imageability are not likely to be feasible replacements for qualitative assessments by urban design experts as such tools rely on a good understanding of theory to determine what to note on the checklist and what to add to the model. Without such a theoretical basis there is significant room for error, as discussed in chapter 5.

The second key finding is that bivariate linear regression is inadequate for predicting pedestrian activity based solely on imageability (or based on any one of the other measured variables) (Appendix E). The literature points to multiple factors of pedestrian activity and it is difficult to isolate their effect from that of imageability. Distinctiveness, memorability and meaning (what people experience when a place is imageable) may very well be low on the list of priorities when people decide which street to walk on. Environmental conditions such as the land use mix and street network connectivity also play an important role. As a result, simple linear regression models (models B and C) had R^2 values of less than 0.65. These models also had outliers, which suggested that there were factors outside of the model that had a significant effect on pedestrian activity. In the case of Model B, the outliers were on main roads and on a street with a school. Given that Diepkloof Zone 5 has very few streets that connect outwards (and these are the main roads), the presence of outliers suggests that Model B would be less effective at predicting pedestrian volumes in a different site where the streets are better connected as there would be even more outliers. At the time of making Model B (when only bivariate regression had been performed), the notion that the outliers had something to do with differences in the length and integration of the streets on the site was only speculative. However, it was confirmed through multiple regression (in Model D), which showed that street length and integration were the only other significant variables.

Lastly, when multiple regression is used to model imageability together with other neighbourhood conditions to predict pedestrian volumes, the adjusted R^2 (which describes the model's predictive capacity) increases, which confirms that pedestrian volumes are affected by factors other than imageability. This is not surprising as it is consistent with existing literature, which identifies factors such as land use, density and destinations (Cervero and Radisch, 1996; Cervero and Kockelman, 1997; Ewing and Cervero, 2010). However, the increase in R2 is greater when three variables from the Ewing model are adjusted to consider how imageability might occur in a different place. In Models B and D three variables are adjusted. *Building shape* is adjusted because non-rectangular building shapes are more ubiquitous in a township setting. *Number of people (on your side)* is adjusted because the streets in townships are narrower and people generally walk in the middle of the street instead of a particular side. *Outdoor dining* is adjusted to include street trading because "dining" has cultural implications and suppositions about disposable income that may not apply to a township setting. Model D (the multiple regression model with adjusted values) has three statistically significant variables (with p-values less than 0.05). These are: imageability, street length, and street integration.

6.2 LIMITATIONS

'*Not everything that can be counted counts and not everything that counts can be counted*'

(William Bruce Cameron, 1963:)

The modelling approach demonstrated in this study is a highly complex exercise that requires expertise beyond the conventional scope of planning and design but it could be decried for perhaps doing little more than use numbers to describe things that we can already see with our own eyes when we go to a site. Perhaps more dangerously, if adopted without adequate scrutiny such a quantitative approach runs the risk of making designers blind to those things that cannot be enumerated and that by their very nature would not feature in a quantitative model. A quantitative model requires *known variables* and it can generate wildly erratic answers if the content of the variables change, as demonstrated by the measurement error in chapter 5. In terms of those things that we do know well as a profession, such as how to measure pedestrian flow or the lengths of streets quantitative methods perform comparatively well and they can provide deeper insights into

longstanding theories about these phenomena. The study found positive correlation between pedestrian activity and non-residential land use as well as between pedestrian activity and street length, which supports some theoretical claims by authors such as Filomena et al (2019). However, the study also found that street integration and connectivity did not feature significantly as a predictor of pedestrian patterns, which contradicts space syntax theory but may be explained by the peculiar street layout in Zone 5.

6.2.1 Comparability and replicability

With regards to whether the model presented in chapter 5 can be compared to the Ewing model, my findings suggest that the focus of urban design theory should not be on models themselves but on the process by which they are developed. That is to say theorists must focus on identifying variables that are suitable for modelling and providing context-specific definitions for these variables. Model variables require operational definitions that are based on a broader theoretical background. Without this theoretical foundation, operational definitions become too context-specific and they limit the model's external validity: such that any model would be inapplicable in a different place because its variables would be too dependent on the context within which they are derived. From this general theoretical base, it is then possible to derive operational definitions that can be further interpreted and refined to fit the context. This study is comparable to the Ewing studies to the extent that it uses the same process to determine which variables are suitable to model. However, the study deviates from the Ewing model in that it does not have a strong qualitative basis for the definitions of the variables. In the Ewing model, this qualitative basis is derived by using an expert panel to identify what physical features contribute to the imageability of a scene. In this study the qualitative interpretation was performed solely by the researcher, which leaves room for error and bias. This difference forms the foundation for one of the recommendations made in this study for future research.

6.2.2 External validity: A process [rather than a tool] for measuring imageability

The findings of this study should not be thought of as an instrument (such as a ruler) that can be applied to measure imageability and pedestrian patterns in other places. Rather than an end product, the output of this study is a process by which researchers and practitioners can: (a) derive operational definitions for physical features associated with imageability; (b) make context-specific adjustments to these definitions, in order to use them as model variables; (c) apply readily available statistical procedures, such as regression; and (d) find quantitative evidence that provides deeper insights into existing urban design theories. To this end, the application of the approach described in this study must be cognisant of three limitations. The first is that each site is different and should not be measured by the results of another place. Operational definitions and model variables must be based on what is happening on the site and, to this end, outliers must be noted when using statistical procedures as these provide indications about how well model variables match the context and the extent to which operational definitions need to be reconsidered. The second limitation is that not everything lends itself to quantitative description. The question to be considered when applying the measuring process is not "how much" imageability or correlation is present but rather "if" imageability and its correlation to pedestrian patterns on the site can be measured. The researcher must be open to the possibility that in certain cases the answer may be "no". In this study I have shown that the Ewing model can be used to measure imageability in a South African township context such as Diepkloof Zone 5; but only in terms of factors associated with environmental composition[40]. This method does not adequately account for the effects of memory and meaning in making places imageable. Lastly, quantitative models are no replacement for theory, especially if they deviate from the expected hypotheses. Exceptions to the rule do not change the rule. The paucity of quantitative research in the field of urban design necessarily means that quantitative models, at present, lack the replicability necessary to challenge any longstanding theories. Furthermore, as shown in this study, models are vulnerable to technical error, or lack of competency on the part of the researcher, and they also involve an element of interpretation that is open to subjectivity. There is a need for more verification

[40] Lynch (1960) uses the term "structure" to describe the arrangement of physical elements in a space. Later theorists, such as Trancik (1986) and Gehl (2011) use "composition"

studies. Nonetheless, quantitative models can pose insightful questions to theory by highlighting those things that we already know relatively well and providing evidence for theoretical claims, which in turn outlines the boundaries of our knowledge. This process can stimulate further research to validate and improve urban design theory.

The high statistical significance[41] of imageability in relation to walkability (when compared to other environmental factors) may be due to the fact that I spent more time thinking about how to measure imageability and less time thinking about how to measure other environmental factors. This difference in attention may have affected measurements in two ways. Firstly, I may have developed a more accurate measure of imageability. This is exemplified by the fact that, when there were measurement errors (such as when the Ewing variables did not fit the Diepkloof context), I was able to recognise these errors and to use my theoretical framework to correct them. On the other hand, the theoretical framework for other environmental factors was comparatively thinner. Secondly, I may have been predisposed to find imageability because I was subconsciously always looking for it, since it is the subject of this research. It is possible that the choice of site, being informed by an objective to find imageability, may have inadvertently optimised the potential for imageability at the cost of other environmental qualities. It is certainly true that the selection of Diepkloof Zone 5 was informed by the site's self-contained nature. I expected that the street network in Zone 5, which has few connections to the surrounding urban fabric, would make the site ideal for studying pedestrian behaviour in a relatively "controlled" setting, with limited influence from its context. However, because of this choice of site, the streets with the highest integration turned out to be on the edges of the site, which may have reduced the statistical significance of integration in my models. Thus, the external validity of any study is to a certain degree inherently limited, on the one hand, by the topic being studied and also constrained, on the other hand, by the nature of the site selected for the research.

6.3 CONTRIBUTION TO KNOWLEDGE: POTENTIAL APPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study has validated Ewing and Clemente's (2013) process for deriving quantitative descriptions of imageability. It has demonstrated how the variables of the Ewing model can be adapted to fit into the context of a South African township. When I initially conceived this study, creating a model that could describe why people walk on a street, I hoped that the model would give power to communities to determine for themselves (without intervention from urban design or planning professionals) want aspects of their public environment were of value to them – essentially what would make them want to walk on a street in their neighbourhood. I imagined, based on my experience with the implementation of the Rea Vaya (bus rapid transport – BRT) system in Soweto[42] and the suburb of Rosebank, that communities were being often being told claims about walkability that they could not verify on their own. A seemingly earnest professional could simply say that they were opting to construct an intervention on this street rather than another one because this would have a positive impact on a particular urban design quality (such as imageability) and the community would not really have any means to refute this opinion because (after a long day of work, as a plumber, mechanic or actuary for example) they do not know or have the time to find out what imageability is. In Soweto, the proposal to have the BRT system was accepted but perhaps not enough thought was given about the walkability of the streets connecting to the BRT station. In Rosebank (one of the proposed destinations of the Rea Vaya BRT), the proposal to have a route on Oxford Street was rejected without an assessment of how the system would impact urban design qualities in that neighbourhood. In each case, it seemed as though the decision was based on public perception rather than a scientific appraisal of the proposed system. The model proposed here was

[41] As described by the p-values in Model D

[42] I was involved as a research assistant in the interviews for Weakly and Bickford's (2015) study of the impact of the Rea Vaya BRT system in Soweto and, while working with Albonico Sack Metacity (ASM Architects), I performed a land use feasibility study for the Tshwane BRT.

supposed to allow interested members of a given community to input numbers onto a spreadsheet – based on observations that they could make without any formal training – and arrive at a measure of the urban design quality. However, the findings of this study suggest that we are still several steps away from such a possibility. Firstly, further research is required to validate the efficacy of Model D. Is it only an adequate description of Diepkloof Zone 5 or can it be applied in other Zones as well? Is the Ewing Model applicable in suburbs such as Rosebank or does it require similar variable adjustments as those presented in this study? Setting aside these questions for future consideration, this study has demonstrated that it is possible to model urban design qualities using the Ewing Model and that this model can be modified to work outside of downtown contexts.

There are four other contributions to knowledge that have potential application. Firstly, having an imageability model can be useful in machine learning. Regression is a fundamental step in artificial intelligence as it allows a computer to predict the consequence of changes between variables. Model D could be used as a feature of GIS systems to estimate the impact of proposed changes in street length or integration on pedestrian flows. However, competency in such a system would require urban planners and designers to also know coding in R Studio or Python to run the regression. These are not skills that are taught in most urban planning and design curricula but there is scope for change. Secondly, urban planners often have to assess urban design frameworks when approving applications from property developers. However, most urban planners are not urban designers and they are not familiar with urban design qualities and their impact on walkability. This model can give them a benchmark for estimating imageability and can aid in the appraisal of the impact that proposed projects will have on pedestrian activity. Thirdly, regardless of car-dependency in contemporary cities, most in-person shopping still occurs as a result of pedestrian activity – despite the proliferation of drive through restaurants. This model can help retailers decide on the best location for their shop if they are in a township. Lastly, the South African government's department of housing is currently building "mega projects" to accommodate people who are arguably in a similar demographic category as those currently living in the township (similar to the study area). Given that walking is one of the most egalitarian modes of transport, the regression model (model D) proposed in this report, can give organs of state a benchmark to estimate how walkable a proposed township is and – therefore – how democratic it is in terms of access.

The quantitative descriptions presented in this report are only partial measures of imageability as they rely on the *structure* of place and do not account for the effects of *identity* and *meaning*. It is likely that some part of the impact that imageability has on a site will remain outside of the scope of quantitative models because imageability is partly perceptual (rather than exclusively physical) and it is therefore difficult to innumerate. Whereas imageability has three dimensions (structure, identity and meaning), quantitative models are better suited for estimating only structure. Identity and meaning may require methods that provide for spatial representation and contextual explanation. In this study, imageability (on its own) can only account for 62% of changes in pedestrian volumes if no reference is made to other neighbourhood conditions (see Model B). However, this is still a very high degree of correlation, since imageability is only one of many urban phenomena that simultaneously exist on any site. Furthermore, correlation analysis reveals that there is some collinearity between imageability, street length and integration. This suggests that there is significant overlap between imageability and other phenomena; inasmuch as some of the features that account for imageability may also account for other urban design qualities.

When Ewing et al initially presented their model (2005a), they were looking for urban design qualities that are perceptible from the view of a pedestrian standing in a street. They used video cameras to capture data about street conditions and they used a panel of experts to identify which design qualities were present in the video clips. It is not immediately apparent that the length of a street and the extent to which it is integrated to its surrounding can be detected from a pedestrian's perspective looking down the street. It is possible, however, that some consequences of length and integration may be expressed in the variables measured by the Ewing model, such as the view of major landscape features (if the street is long enough) or the presence of outdoor dining or large numbers of people (if the street is integrated enough). Thus, the collinearity between length,

integration and imageability may indicate that they are measures of the same phenomenon and further research is necessary to determine how they are different from one another. Furthermore, to avoid confusion this report uses the term "Ewing model" exclusively to describe the method proposed by Ewing et al (2009; 2013) to measure the imageability of a street but, in reality, Reid Ewing and his colleagues propose measures for four other urban design qualities associated with street walkability (enclosure, human scale, transparency, and complexity). All five of these urban design qualities were derived from the same sample of videos using the same panel of experts. Therefore, they could jointly be referred to as the "Ewing model". Yet, since all five qualities were derived from the same research process, modelling them was infeasible within this research project as each concept would require a literature review, a comparison of international measurements and a statistical computation – each equivalent to the one presented here for imageability alone[43]. Therefore, the exclusion of these other urban design qualities in this study is premised on the anticipation that future research – similar to this one – should be performed to understand (a) the applicability of the model proposed by Ewing et al in a given context; (b) how model variables should be adjusted to fit the context; and (c) the extent to which these qualities improve our ability to predict why people walk on a given street.

This study originally intended to use a panel of experts as the source of qualitative interpretations of the fieldwork. This would have been a more faithful replication of the Ewing studies. However, the disruptions caused by the Covid-19 pandemic in 2020 (when the fieldwork was conducted) made such a workshop-based approach infeasible. As a consequence, the qualitative assessments presented in this report represent the opinion of only one urban designer and thus the findings are not directly comparable with those presented in Ewing and Handy (2009). Thus, further research is recommended to find out if a study with diverse expert opinions would recommend different adjustments (if any) to be made to the Ewing model before application to a South African township context.

[43] Inasmuch as the models presented in this report do not feature measures of these other four qualities, it is possible that street length and integration (the significant variables in Model D) have collinearity with these four qualities.

REFERENCES

Alexander, C. (1964). *Notes on the synthesis of form*. London: Oxford University Press.

Alexander, C. (1965). *The city is not a tree*. Architectural Forum, 58-62.

Alexander, C. (1979). *The Timeless Way of Building*. London: Oxford University Press.

Alexander, C., Ishikawa, S., and Silverstein, M. (1977). *A Pattern Language? Towns Buildings Construction*. New York: Oxford University Press.

Alexander, P., Ceruti, C., Motseke, K., Phadi, M., and Wale, K. (2013). *Class in Soweto*. University of KwaZulu-Natal Press.

Al-ghamdi, S. A., and Al-Harigi, F. (2015). Rethinking image of the city in the information age. *Procedia Computer Science*, *65*, 734-743.

Appleyard, D. (1969) Why buildings are known, *Environment and Behavior*, 1:131-156

Appleyard, D. (1970). Styles and methods of structuring a city. *Environment and behavior*, *2*(1), 100-117.

Appleyard, L., and Lynch, K. Meyer (1964), *The view from the road*. Cambridge: Massachusetts M.I.T Press

Arabindoo, P. (2014) "Urban design in the realm of urban studies." In *Explorations in Urban Design, An Urban Design Research Primer*, edited by M. Carmona. London: Ashgate

Arnold, H. (1993). *Trees in urban design*. New York: Van Nostrand Reinhold.

Babbie, E., M. (2016). *The Practice of Social Research*. Wadsworth: Thomson Learning Inc.

Badland, H., and Schofield, G. (2005). *Transport, urban design, and physical activity: an evidence-based update*. 10(3), 177-196.

Bahrainy, H., and Bakhtiar, A. (2016). *Toward an integrative theory of urban design* (pp. 5-29). Springer International Publishing.

Banai, R., and Rapino, M. A. (2009). Urban theory since A theory of good city form (1981)–a progress review. *Journal of Urbanism*, *2*(3), 259-276.

Baran, P.K, Rodríguez, D.A, Khattak, A.J. (2008) Space syntax and walking in a New Urbanist and suburban neighbourhoods, *Journal of Urban Design*, 13(5–28)

Batty, M. (2017). Science in planning: theory, methods and models. *Planning Research and Knowledge*, 241-254.

Beavon, K. (1998) Nearer my Mall to Thee: the decline of the Johannesburg Central Business District and the emergence of the neo-apartheid city, seminar paper presented at the Institute for Advanced Social Research

Beavon, K. (2001) *The role of transportation in the rise and decline of the Johannesburg inner city, 1886-2001*, Department of Geography and Geoinformatics, University of Pretoria

Benedikt, M. L. (1979). To take hold of space: isovists and isovist fields. *Environment and Planning B: Planning and design*, *6*(1), 47-65.

Benedikt, M. L. (1979). To take hold of space: isovists and isovist fields. *Environment and Planning B: Planning and design*, *6*(1), 47-65.

Bentley, I. (1998). "Urban Design as an Anti-profession." Urban Design Quarterly 65: 15

Bentley, I. (1998). “Urban Design as an Anti-profession.” Urban Design Quarterly 65: 15

Bhattacharjee, A. (2012). Social Science Research: Principles, Methods, and Practices. USF Tampa Bay Open Access Text books Collection. Book 3.

Blades, M. (1990). The reliability of data collected from sketch maps. *Journal of Environmental Psychology*, *10*(4), 327-339.

Cahill, N. (2021) 'Grounding dietetic research in scientific rigour/ Fonder la recherche en dietetique sur la rigueur scientifique', *Canadian Journal of Dietetic Practice and Research*, 82(2), 50,

Carmona, M. (2014). The place-shaping continuum: A theory of urban design process. *Journal of Urban Design*, *19*(1), 2-36.

Cervero, R., and Radisch, C. (1996). Travel choices in pedestrian versus automobile oriented neighbourhoods. *Transport Policy*, 3(3), 127-141.

Cervero, R.; Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity and design. Transp. Res. Part D, *Transp. Environ.*, 2, 199–219.

Christopher, A. J. (1983). From Flint to Soweto: reflections on the colonial origins of the apartheid city. *Area*, 145-149.

City of Davis (CA). (ud). Davis Downtown and Traditional Residential Neighbourhood Design Guidelines. Retrieved from Davis City: www.city.davis.ca.us/pb/design/pdfs/final-appendix.pdf, accessed 2019-09-15

City of Denver (CO). (1993). Streetscape Design Manual: 46. Retrieved 06 20, 2016, from Denver City: www.denvergov.org/admin/template3/forms/streetscape.pdf, accessed 2019-09-20

City of Raleigh (NC). (2002). Urban Design Guidelines: Raleigh Comprehensive Plan. Retrieved from Raleigh: www.raleigh-nc.org/planning/CP/Text/Chapter_03/PART%205%20URBAN%20DESIGN%20GUI, accessed 2019-09-15

City of San Jose (CA). (2004). Downtown Design Guidelines: 69. Retrieved from San Jose: www.sanjoseca.gov/planning/pdf/dg_downtown.pdf, accessed 2019-09-15

Cockburn, J., Rouget, M., Slotow, R., Roberts, D., Boon, R., Douwes, E., O'Donoghue, S., Downs, C.T., Mukherjee, S., Musakwa, W. and Mutanga, O., (2016). How to build science-action partnerships for local land-use planning and management: lessons from Durban, South Africa. *Ecology and Society*, *21*(1).

ConceptSketch. (ud). Retrieved from Tumblr: http://conceptsketch.tumblr.com/image/117947477063, accessed 2019-09-15

Costa, M. and Bonetti, L. (2017) Geometrical distortions in geographical cognitive maps, *Journal of Environmental Psychology*, 55:53-69

Côté-Roy, L., and Moser, S. (2018). ‘Does Africa not deserve shiny new cities?’ The power of seductive rhetoric around new cities in Africa. *Urban Studies*, *56*(12), 2391–2407

Cuthbert, A. (2011) Whose urban design? Review of A. Krieger and W. Saunders (eds.) ‘Urban Design’. *Journal of Urban Design* 15 (3): 443–448

Cuthbert, A. R. (2006) The Form of Cities: Political Economy and Urban Design. Oxford: Blackwell

Dalton, R., and Bafna, S. (2003). The syntactical image of the city: A reciprocal definition of spatial elements and spatial syntaxes.

Davids, B. and Esau, M., (2012). The prevailing skills crisis in South Africa: An exploration of the skills development strategy of the city of Cape Town. *Journal of Developing Societies*, *28*(1), pp.81-113.

De Jonge, D. (1962). Images of urban areas their structure and psychological foundations. *Journal of the American Institute of Planners*, *28*(4), 266-276.

Devlin, A. S. 1976. "The 'Small Town' Cognitive Map: Adjusting to a New Environment." In *Environmental Knowing: Theories, Research and Methods*, edited by G. T. Moore and R. G. Golledge, 58–66. Stroudsburg, PA: Dowden, Hutchinson and Ross.

Devlin, A. S., and Bernstein, J. (1995). Interactive wayfinding: Use of cues by men and women. *Journal of environmental psychology*, *15*(1), 23-38.

Dovey, K., and Pafka, E. (2016). The science of urban design?. *Urban Design International*, *21*(1), 1-10.

Elgin, C. Z. (Ed.). (1997). *Nelson Goodman's New Riddle of Induction* (Vol. 2). Taylor and Francis.

Elshestaway, Y. (1997). Urban complexity: toward the measurement of the physical complexity of streetscapes. *Journal of Architectural and Planning Research*, 14, 301-316.

Eu, T., B. and Jen, T., W. (2018) Figure-ground mapping to identify urban fabric characteristics of George Town . *PLANNING MALAYSIA*, *16*.

Evans, G. W., Marrero, D. G., and Butler, P. A. (1981). Environmental learning and cognitive mapping. *Environment and behavior*, *13*(1), 83-104.

Ewing, R., and Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American planning association*, *76*(3), 265-294.

Ewing, R., and Handy, S. (2009). Measuring the unmeasurable: urban design qualities related to walkability. Journal of urban design, 14(1), 64-68.

Ewing, R., Clemente, O., Handy, S., Brownson, R. C., and Winston, E. (2005a). *Identifying and Measuring Urban Design*, Maryland: Robert Wood Johnson Foundation.

Ewing, R., Handy, S., Brownson, R. C., Clemente, O., and Winston, E. (2006). Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health*, *3*(s1), S223-S240.

Ewing, R., King, M., Raudenbush, S., and Clemente, O. (2005). Turning highways into main streets: two innovations in planning methodology. *Journal of the American Planning Association*, 71, 269-282.

Farrside (2021) "Farrside Architects" https://www.farrside.com/places, accessed 2022-02-25

Feyerabend, P. (1993). *Against method*. Verso.

Filomena, J.A. Verstegen, E. Manley (2019), A computational approach to "The Image of the City", *Cities*, 89, pp. 14-25

Findlay, C. (2017). Jan Gehl: A passion for the livable city. Retrieved 01 02, 2018, from Siemens Global Website: https://www.siemens.com/customer-magazine/en/home/specials/taking-the-measure-of-the-city/jan-gehl-a-passion-for-the-livable-city.html

Francescato, D., and Mebane, W. (1973). *How citizens view two great cities: Milan and Rome*. London: Edward Arnold

Frith, A. (2013) Census 2011 sub-places, https://census2011.adrianfrith.com/place/798026039, accessed 2022-01-05

Ganis (2014) *Planning Urban Places: A Small World Network Paradigm for Dynamic Urban Placemaking*, PhD submission, The University of Queensland

Gasennelwe, P. (2011) Understanding the township property market: The case of Orlando East, Diepkloof and Orlando West Soweto, Masters dissertation, University of the Witwatersrand

Gehl, J. (1987). *Life between buildings - using public space*. New York: Van Nostrand Reinhold.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception.* Boston: Houghton Mifflin Company

Goodey, B. (1971). *City-scene: an exploration into the image of central Birmingham as seen by area residents*. Centre for Urban and Regional Studies, University of Birmingham.

Groat, L. N., and Wang, D. (2013). *Architectural research methods*. New Jersey: John Wiley and Sons.

Gulick, J. (1963) Images of an Arab City, *Journal of the American Institute of Planners*, 29:3, 179-198

Gunder, M. (2011) "Commentary: Is Urban Design Still Urban Planning? An Exploration and Response." Journal of Planning Education and Research31 (2): 184–195

Haken, H., and Portugali, J. (2003). The face of the city is its information. *Journal of Environmental Psychology*, *23*(4), 385-408.

Healy, S. D., and Jozet-Alves, C. (2010). Spatial memory. Retrieved from Academia: https://www.academia.edu/28444721/Spatial_Memory

Heath, T., Smith, S., and Lim, B. (2000). The complexity of tall building facades. *Journal of Architectural adn Planning Research*, 206-220.

Hebbert, M. (2016). Figure-ground: History and practice of a planning technique. *Town Planning Review*, *87*(6), 705-728.

Hillier, B., Burdett, R., Peponis, J., Penn, A. (1987), Creating Life: Or, Does Architecture Determine Anything? *Architecture and Behaviour* , 3 (3) 233 – 250

Huang, J., Obracht-Prondzynska, H., Kamrowska-Zaluska, D., Sun, Y., and Li, L. (2021). The image of the City on social media: A comparative study using "Big Data" and "Small Data" methods in the Tri-City Region in Poland. *Landscape and Urban Planning*, *206*, 103977.

Huimin, J., Wei, Y., and Wowo, D. (2019). An approach to describe block-based spatial configuration, http://elib.sfu-kras.ru/handle/2311/111723, accessed 2022-01-05

Inam, A. (2002) Meaningful urban design: Teleological/catalytic/relevant. *Journal of Urban Design* 7 (1): 35–58.

Jacobs, A. (1985). Looking at cities. Cambridge, MA: Harvard University Press.

Jacobs, A. (1993). Great Streets. Cambridge, MA: MIT Press.

Jiang, B. (2013). The image of the city out of the underlying scaling of city artifacts or locations. *Annals of the Association of American Geographers*, *103*(6), 1552-1566.

Jiang, B., and Jia, T. (2011). Zipf's law for all the natural cities in the United States: a geospatial perspective. *International Journal of Geographical Information Science*, *25*(8), 1269-1281.

Jones, M. (2018). The train as motif in Soweto poetry. *The Journal of Commonwealth Literature*, *53*(1), 21-42.

Jordan, N. A., and Syafitri, E. D. (2021, May). Building age profile and figure-ground image: defining the urban development pattern of Balikpapan City. In *IOP Conference Series: Earth and Environmental Science* (Vol. 778, No. 1, p. 012038). IOP Publishing.

Jung, C.H, Choi, M.H. (2010), Analysis of Traffic Volume Using Space Syntax Model Supplemented by Accessibility Factor in Downtown Daegu, *Journal of Korea Planning Association*, 45(129–140)

Kaplan, R., and Kaplan, S. (1989). The Experience of Nature - A psychological perspective. New York: Cambridge University Press.

Keppel, G. (1991). Design and analysis: A researcher's handbook (3rd ed.). Englewood Cliffs, NJ, US: Prentice-Hall Inc.

Kim, Y. O., and Penn, A. (2004). Linking the Spatial Syntax of Cognitive Maps to the Spatial Syntax of the Environment. Environment and Behavior, 36(4), 483–504.

Kitchin, R. (2014). *The Data Revolution: Big data, open data, data infrastructures and their consequences*. SAGE.

Koelble, T.A. and Li PUMA, E.D.W.A.R.D., (2011). Traditional leaders and the culture of governance in South Africa. *Governance*, *24*(1), pp.5-29.

Koolhaas, R. (1995) *Bigness and the Problem of Large*, edited by R.Koolhaas, and B.Man, S, M, L, XL. New York: Monacelli Press

Kuhn, T. S. (1970). *The structure of scientific revolutions* (Vol. 111). University of Chicago Press: Chicago.

Kuhn, T. S. (2012). *The structure of scientific revolutions* (50th Anniversary Edition). University of Chicago Press: Chicago.

Lak, A., and Hakimian, P. (2018). A new morphological approach to Iranian bazaar: the application of urban spatial design theories to Shiraz and Kerman bazaars. *Journal of Architectural Conservation*, *24*(3), 207-223.

Lawlor, V. (2015). Busy, busy, Bangkok. Retrieved from Urban Sketchers. https://urbansketchers.org/2015/10/12/busy-busy-bangkok/, accessed 2021-09-05

Lee, S., Yoo, C., and Seo, K. W. (2020). Determinant factors of pedestrian volume in different land-use zones: Combining space syntax metrics with GIS-based built-environment measures. *Sustainability*, *12*(20), 8647.

Lopez, A., Postma, A., and Bosco, A. (2020) Categorical and coordinate spatial information: can they be disentangled in sketch maps? *Journal of Environmental Psychology*, 68: 1-12

Lynch, K. (1960). The Image of the City. Cambridge, MA: Joint Center for Urban Studies.

Lynch, K. (1984b) "Reconsidering the image of the city", in L. Rodwin and R. M. Hollister (eds), *Cities of the mind: images and themes of the city in the social sciences*, New York: Springer Science and Business

Madanipour, A. (1996). Design of urban space: An inquiry into a socio-spatial process.

Maguire, A., Woollett, K., and Spiers, H. J. (2006). London taxi drivers and bus drivers: a structural MRI and neuropsychological analysis. *Hippocampus*, 16, 1091-1101.

Marshall, S. (2012). Science, pseudo-science and urban design. *Urban design international*, *17*(4), 257-271.

Marx, C., Rubin, M. and Progressus (2008) 'Divisible Spaces': Land Biographies in Diepkloof, Thokoza and Doornfontein,Gauteng. A final draft report prepared for Urban LandMark.

Mavundza (2018) "This is what Joburg looked like a century ago, compared to now", Business Insider South Africa, https://www.businessinsider.co.za/johannesburg-through-the-ages-2018-7, accessed on 2021-10-03

Measurement Instrument Database for Social Sciences (MIDSS) (ud) Measurement Instrument for Urban Design Quantities Related to Walkability, https://www.midss.org/content/measurement-instrument-urban-design-quantities-related-walkability

Meeder, M., and Weidmann, U. (2018). Measuring Neighborhood Walkability Using Detor Factor Distributions. Journal of urban development, 144(2), 1-10.

Meyer, E. K. (1997), "The Expanded Field of Landscape Architecture", In G. F. Thompson and F. R. Steiner (eds), *Ecological Design and Planning*, 45–79. New York: John Wiley and Sons, Inc

Middle East Eye (2020) "Cairo's Tahrir Square given facelift decade after Egyptian revolution", https://www.middleeasteye.net/news/egypt-tahrir-square-cairo-renovation-arab-spring, accessed 2022-02-25

Mondschein, A., and Moga, S. T. (2018). New directions in cognitive-environmental research: Applications to urban planning and design. *Journal of the American Planning Association*, *84*(3-4), 263-275.

Mooney S.J, Bader M.D.M, Lovasi G.S, Teitler J.O, Koenen K.C, Aiello A.E, Galea S, Goldmann E, Sheehan D.M, Rundle A.G. (2017), Street Audits to Measure Neighborhood Disorder: Virtual or In-Person? *American Journal of Epidemiology*, 186(3): 265–273

Morello, E., and Ratti, C. (2009). A digital image of the city: 3D isovists in Lynch's urban analysis. *Environment and Planning B: Planning and design*, *36*(5), 837-853.

Nas, P. J. (2011). *Cities full of symbols: a theory of urban space and culture* (p. 304). Leiden University Press.

National Research Council. (2005). Committee on Physical Activity Health Transportation and Land Use., National Research Council (US). *Transportation Research Board., Institute of Medicine (US). Does the built environment influence physical activity*.

Nelessen, A. (1994). Visions for a New American Dream. Washington DC: American Planning Association.

Nelson, G. (1977). How to see: A guide to reading our manmade environment. Boston, MA: Little, Brown, and Company.

Norberg-Schulz, C. (1979). Genius loci: towards a phenomenology of architecture (1979). *Historic Cities: Issues in Urban Conservation*, *8*, 31.

Norberg-Schulz, C. (1980) *Genius Loci: Towards a Phenomenology of Architecture*, New York: Rizzoli

Nunez, R., and Cooperrider, K. (2013). The tangle of space and time in human cognition. Trends in Cognitive Sciences, 220-229.

Offenhuber, D., and Ratti, C. (2013). Reading the city: Reconsidering Kevin Lynch's notion of legibility in the digital age. In B. Junge, Z. Berzina, W. Scheiffele, W. Westerveld, and C. Zwick (Eds.), *The Digital Turn* (pp. 216–224). Zurich, Switzerland: Scheidegger and Spiess

Okasha, S. (2002). *Philosophy of science: A very short introduction* (Vol. 67). Oxford Paperbacks.

Paksukcharern, K. (2006) The spatial configuration of London's railway terminus areas, https://www.semanticscholar.org/paper/THE-SPATIAL-CONFIGURATION-OF-LONDON'S-RAILWAY-AREAS-Paksukcharern/f73da6c6822ab71119cf867faefbf3fb8b5eb20c, accessed 2021-09-05

Parnell, S. M. (1993) Johannesburg slums and racial segregation in South African cities (1910-1937), PhD submission, University of the Witwatersrand

Penn, A. (2003). Space syntax and cognition or why the axial line. Environment and Behavior, 35(1), 30-65.

Pocock, D., and Hudson, R. (1978). *Images of the urban environment*. Columbia University Press.

Popper, K. (1963). Conjectures adn refutations: the growth of scientific knowledge. London: Routledge.

Quine, O. W. V. (1976). Two dogmas of empiricism. In *Can Theories be Refuted?* (pp. 41-64). Springer, Dordrecht.

Rapoport, A. (1990). History and Precedent in Environmental Design. New York: Kluwer Academic Publishers.

Rapoport, A., and Hawkes, R. (1970). The perception of urban complexity. Journal of the American Institute of Planners, 106–111.

Ratti, C. (2004). Space syntax: some inconsistencies. *Environment and Planning B: Planning and Design*, *31*(4), 487-499.

Raynsford, A. (2011) Civic art in an age of cultural relativism: The aesthetic origins of Kevin Lynch's. *Image of the City*. *Journal of Urban Design* 16(1): 43–65.

Rotondas, T. (2008). Space syntax - Global Integration - Brasilia. Retrieved from Wikimedia commons: https://commons.wikimedia.org/wiki/File:Space_syntax_-_Global_Integration_-_Brasilia.png

Rousell and Zipf (2017) Towards a Landmark-Based Pedestrian Navigation Service Using OSM Data

Russell, B. (2001). *The problems of philosophy*. OUP Oxford.

Sara. (2015). Wow references. Retrieved from Tumblr: http://viscuits.tumblr.com/post/107163200856/ipoophere-hugs-or-something

Shannon, C. E., and W. Weaver. 1949. *The mathematical theory of communication*. Urbana: University of Illinois Press

Sheppard, E. (2014). We have never been positivist. *Urban Geography*, *35*(5), 636-644.

Snowman, J. and McCown, R. (2012) *Educational Psychology* (13th edition), Cengage.

Snowman, J., and McCown, R. (2014). *Psychology applied to teaching*. Cengage Learning.

Sommer, R. 2009. Beyond centers, fabrics, and cultures of congestion: Urban design as a metropolitan enterprise. In *Urban design*, ed. Krieger, A. et al., pp. 135-152. Minneapolis: University of Minnesota Press.

Sorkin, M. (2010) Jane's spectacles. In: S.A. Goldsmith and L. Elizabeth (eds.) *What We See: Advancing the Observations of Jane Jacobs*. Oakland, CA: New Village Press, pp. xv–xviii.

Sorrows, M. E., and Hirtle, S. C. (1999). The nature of landmarks for real and electronic spaces. In C. Freksa, and D. M. Mark (Vol. Eds.), Spatial information theory. *Cognitive and Computational Foundations of Geographic Information Science*. COSIT 1999.

Southworth, M. (1985). Shaping the city image. *Journal of Planning Education and Research*, *5*(1), 52-59.

Southworth, M., (1985). Shaping the city image. *Journal of Planning Education and Research*, *5*(1), pp.52-59.

Stamps, A. E. (1998). Measures of architectural mass: from vague impressions to definite design features. Environment and Planning B, 25, 825–836.

Stamps, A. E. (1999). Sex, complexity, and preferences for residential facades. *Perceptual and Motor Skills*, 88, 1301–1312.

Stamps, A. E. (2005). Enclosure and safety in urbanscapes, *Environment and Behavior*, 37(1), 102–133.

Stamps, A. E., and Smith, S. (2002). Environmental enclosure in urban settings, *Environment and Behavior*, 34(6), 781–794.

Stats SA (2011) Census 2011, http://www.statssa.gov.za/?page_id=3839, accessed 2022-01-05

Stats SA (2020) Mid-year population estimates, http://www.statssa.gov.za/publications/P0302/P03022020.pdf, accessed 2022-01-05

Stein, E. (2022). De-imaging New York: cognitive mapping and the city symphony. *GeoJournal*, 1-9.

Tomko, M., and Winter, S. (2013). Describing the functional spatial structure of urban environments. *Computers, Environment and Urban Systems*, *41*, 177-187.

Trancik (1990) "Yates County Looking: Ahead", New York: Yates County

Trancik, R. (1991). *Finding lost space: theories of urban design*. John Wiley and Sons.

Uebel, T. (2020). Intersubjective Accountability: Politics and Philosophy in the Left Vienna Circle. Perspectives on Science, 28(1), 35-62.

Unknown. (2013, May 07). 50 Faces in Everyday Objects. Retrieved 01 02, 2018, from Twisted Sifter: http://twistedsifter.com/2013/05/50-faces-in-everyday-places/

unknown. (2018). Correlation coefficient. Retrieved June 05, 2018, from Statistics How To: http://www.statisticshowto.com/probability-and-statistics/correlation-coefficient-formula/

van der Westhuizen, D. L. (2010). Concepts of space and place: neighborhood access, pedestrian movement, and physical activity in Detroit: implications for urban design and research. University of Michigan.

Van Wyk, R. (2017). Rupert Van Wyk. Retrieved 01 01, 2018, from Offset: https://www.offset.com/artist/Rupert+Van+Wyk

Verma, N. (2011). "Urban design: An incompletely theorized project". In T. Banerjee and A. Loukaitou-Sideris (eds), *Companion to urban design* (pp. 76-88). New York: Routledge.

Wagner, M., Baird, J. C., and Barbaresi, W. (1981). The locus of environmental attention. *Journal of Environmental Psychology*, *1*(3), 195-206.

Wale, K. (2013). Historical introduction to class in Soweto. in Alexander, P., Ceruti, C., Motseke, K., Phadi, M., and Wale, K. (eds). *Class in Soweto*. University of KwaZulu-Natal Press.

Weakley, D., and Bickford, G. (2015). Transport and urban development: Two studies from Johannesburg. South African Research Chair in Spatial Analysis and City Planning.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin and review*, *9*(4), 625-636.

Winter, S., Tomko, M., Elias, B., and Sester, M. (2008). Landmark hierarchies in context. *Environment and Planning B: Planning and Design*, *35*(3), 381-398.

Wiseman, A. W. (2014). Introduction to Correlation and Regression, Part 1. Retrieved June 06, 2018, from YouTube: https://www.youtube.com/watch?v=z7kMeJQWr4Yandt=120s

Wohl, S. (2019). Sensing the City: Legibility in the Context of Mediated Spatial Terrains. *Space and Culture*, *22*(1), 90-102.

Yin and Carswell (2013) Spatial Search Techniques for Mobile 3D Queries in Sensor Web Environments