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Influence of visual variety of streetscape on the preference of pedestrians

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Summary

With rapid urbanization of all the existing cities and development of new cities in certain parts of the world, it has become utmost important to create good urban spaces. Spaces that are used to the optimum level economically, that do not harm the environment, and are attractive and pleasing to the pedestrians and other users. This study delves into the area of urban design and environmental psychology to find out relationships between the physical aspects of street and the reaction of the pedestrians to those physical aspects.

The main aim of this research is to understand the relationship between urban design qualities together with visual complexity on the visual preference of the pedestrians for the streets or Rotterdam. Relationship between visual complexity and preference has been studied by various researchers by employing fractal dimension as a measurement of visual complexity. The relationship between urban design quality and visual preference has also been explored earlier but this research based on the extensive study done by Ewing and Handy (2009) in which they have operationalized subjective urban design qualities through measurable physical characteristics of streets. Thus these characteristics have been studied and rated to come down to single number representing urban quality of each street. Visual complexity has been computed by taking out the fractal dimension of each street using binary images of those streets. For the visual quality perception, a preference survey was carried out and 100 responses were taken for each street.

The statistical correlation and regression between fractal dimension and preference of pedestrians revealed significant positive relationship. It also confirms the research by Cooper and Oskrochi, (2010) to find significant positive relationship between fractal dimension and visual preference. Urban design measurement was then qualitatively compared with the fractal dimension and preference of each street. It was then established that those streets that had scored higher in urban design qualities had also scored higher in fractal dimension and were preferred more than the other streets. This research can be taken forward by quantifying all the three variables using the same base data of static images or videos of the streets. Urban designers can use this study to employ fractal dimension as a tool to achieve attractive and vibrant streets.

Keywords

Fractals, fractal dimension, urban design quality, visual variety, urban streetscape, pedestrian, perception, preference survey

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Abbreviations

IHS	Institute for Housing and Urban Development
VQM	Visual quality measurement
UQM	Urban quality measurement
FD	Fractal dimension

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Chapter 1: Introduction

Chapter 1 gives a background of the study and gives an overview of the framework of research related to human perception of built spaces. Two areas of study from where the focus towards human perception comes are highlighted. The background also gives an overview of the relationship between external stimuli and human perception thereafter resulting in preference. Research gap known through literature study has been explained in the problem statement to establish the significance of the study. The main research questions and objectives have been clearly stated and the chapter concludes with taking cognizance of the limitations owing to time and other factors and clearly demarcates the scope of research.

1.1 : Background

Our urban environment is continuously being constructed, expanded, formed and reformed by actions and preferences of the population, be it a common pedestrian or an urban designer. The urban design practice has sought to make “good places”(Cooper and Oskrochi, 2008, p.349) by altering the form and clustering of built structures. These good places as described by Cooper (2008), are those that are economically viable, environmentally sustainable, aesthetically pleasing and are secure, comfortable spaces. Human perception can easily assess what is aesthetically pleasing and places that are secure and comfortable. Discerning the critical elements of a space that gives it an aesthetic appeal or renders it safe and secure for human consumption is what makes a space user friendly. Thus it is imperative that urban designers understand “how a place is perceived by users and to practice applied psychology” (Cooper and Oskrochi, 2008, p.349).

With the re-emergence of walking environments in twentieth century, we need to delve deeper into the characteristics of environments that give priority to the pedestrians above other transportation modes. It has been highlighted by Zacharias(2001, p.3) (2001) that “a unique set of behaviours and perceptions can be associated with the walking environment” .Most of the push towards the expansion of pedestrian districts have been due to economic reasons of the distribution and activities of people spread in space. The views of various urban designers such as Ewing and Handy (1992 and 1996 in Ewing and Handy, 2009)concur with the line of thought that numerous perceptual qualities may affect the walking environment. They also encourage the study of other contributors such as environmental psychology, visual preference and visual assessment literature (Ewing 2000 and Ewing et al, 2005a in Ewing and Handy, 2009). A list of perceptual qualities was studied by Ewing and Handy (2009), out of which they pointed out that there was a gap in measuring the subjective qualities of the walking environment. Towards this, they tried to rationalize and correlate the urban design elements that contribute to such qualities and measure it for some streets within cities.

The visual preference is governed by cognition and aesthetic effect of the content of a scene being viewed. Kaplan (1987)refers to the visual preference as aesthetic reflections. According to him aesthetic reactions by human beings are not causal or trivial aspect of their personality but they inherently guide human behaviour. These day to day behaviours have significant visible results on the use of our built environment, on how they are modified according to the needs. “Even in patterns of thought, avoiding certain directions and approaching others may be based as much on feelings of mystery, coherence, and the like, as on the specific content involved. Aesthetics could thus be seen as a set of inclinations, however intuitive or unconscious, which might influence the direction people choose not only in the physical environment but also in other domains.”(Kaplan, 1987, p. 26))

The content of a particular scene (physical features of a streetscape in this case) together makes up the visual quality (urban design qualities as a resultant of the physical features) which is constantly assessed by a number of pedestrians. This preference of pedestrians may be based on their individual reactions based on the physical features of urban environment or the quality of urban design which invokes certain sense of safety, comfort or interest. Thus the purpose of this research is to explore this relationship between the visual variety of streetscape (that lies in the domain of urban design) and the preference of pedestrians. It can then be concluded if streets with certain qualities and certain physical features are more visually preferred by pedestrians.

1.2 : Problem statement

In the field of urban design and environmental psychology the relationship between the level of complexity of views and the human perception of visual qualities has been a prominent research topic. Authors such as Cooper and Oskrochi (2008), have done investigations to know the link between visual variety and visual quality by measuring the fractal characteristics of urban streetscapes. Hagerhall et al (2004)have looked at the relationship between human preference and landscape perception. Mansouri et al (2005, in Cooper, Su, et al., 2013) have also found out in Japan that people find those streetscapes to be attractive which have higher visual complexity when measured in terms of fractal dimension of the streetscape.

Various theories have been put forward and by researchers as to what may explain or affect the relationship between the visual variety and perception of visual quality. Cooper et al (2010, in Cooper, Su, et al., 2013)explain the link by the differences in scaling between scenes dominated by natural features and those by built environment. They point out that the difference in visual variety is due to the proportion of landscape or townscape. Hagerhall (2004) has also measured the naturalness of streetscape using fractal dimension. It was found out that the judgement of visual quality of streetscapes is influenced more by the visual complexity measured through fractal dimension than the presence of vegetation.

Research gap – It is evident from the above mentioned examples that visual variety has been tested to have relationship with the preference of people. Visual variety has been interpreted in different ways and thus measured in many ways and correlated with preference studies. It is also known through literature review that both content and complexity or visual variety of a street are affected by the larger domain of urban design qualities made up by physical features of space. It was highlighted by Ewing and Handy (2009) that perception of visual quality is affected by physical features of streets. The gap in research here lies in the fact that the effect of these urban design qualities together with visual complexity on the visual preference of people has not been studied. Taking a step further from just measuring the visual variety of streetscape, this research will try to develop further on the research of Ewing and Handy (2009) and measure the qualities as independent variables to explain visual preference of pedestrians. It will test whether the judgement of visual quality changes more with inclusion of better urban design quality.

Societal relevance of the study- This research aims to highlight the importance of urban design qualities and how it can affect the visual preference of people and thereby their behaviour in using a space. Urban designers can use the research to develop those physical features that show a higher correlation with visual preference of people to improve upon the visual attractiveness of spaces. Planners can use these physical features of streets that show a higher correlation with visual preference as a checklist in identifying problems and developing strategies to improve upon urban spaces.

1.3 : Research Question

In accordance with the problem statement given, the main question of this research is:

"How does the visual variety of street vistas of Rotterdam influence the preference of pedestrians for the streetscape?"

Furthermore, the sub-questions of research to support the main question are:

1. What accounts for visual variety of streetscape and how can it be measured?
2. What are the physical aspects of streetscape that can influence preference of people?
3. Does the urban design quality of street environment have a relationship with the preference of people of that street view?

1.4 : Research Objectives

The objective of this research is to test the theory that there is an impact of visual quality of urban spaces on the preference of pedestrians.

- To test the relationship between visual variety and preference of pedestrians
- To test the relationship between urban design qualities and preference of pedestrians
- To enumerate which physical features of streetscape affect the preference of pedestrians the most.

With the drastic shift of population happening to existing urban areas and new urban expansions happening, this research can help the urban designers in making urban spaces visually attractive to people, thereby ensuring the optimal use of urban space.

1.5 : Scope and limitations

This research is based in Rotterdam and will focus on its primary and secondary commercial streets. Since the attempt is to test the relationship between urban design qualities and visual variety of streetscape on the preference of pedestrians, the unit of study here is a street as a whole. The streets as a whole will be studied by taking periodic snapshots of it. The streets will be categorised based on different levels of urban street design from the core of the city to the peripheral areas such that distinct difference in the urban design quality is seen. This can be done by picking commercial streets from the city centre and commercial streets from peripheral neighbourhoods. It should also be noted that different levels of urban design is seen in different widths of the streets. Thus in this study the widths of the streets have not been kept constant and may bring in biases.

Since the primary data collection will be done in the month of June-July which is the holiday season in Europe, it can be a little difficult to collect data from people, especially people familiar with the field of urban design.

This research develops from the conceptual framework followed by Ewing and Handy (2009) and their Operationalization of different urban design qualities into measurable physical features of a space. Thus it is important here to highlight that only those subjective qualities of urban design will be taken up in these studies that were successfully operationalized by Ewing and Handy (2009). Also, it is important here to take note that urban design qualities have a much broader meaning in urban design literature and it can be argued whether these qualities can be fully measured by the variables included in this research.

The assessment of urban design qualities of streetscape will be done by physical survey of the streetscapes chosen for study. Thus the degree of human error possible in such a physical survey is high but can be reduced by test surveys being conducted by different researchers such that the results are similar. Due to time and financial constraint the validation of urban design quality scores cannot be done by adequate number of professionals in the field of urban design as it was done in the research of Ewing and Handy (2009).

It is also important here to note that Ewing and Handy use videos to capture the streetscape and thereby assess the parameters of urban design which allows more in depth assessment than what is available for fractal dimension measurement and preference survey of visual variety. By this means it has been left to the readers to refine the methodology of capturing the streetscape which remains same for all assessments, be it the calculation of fractal dimension or the urban design quality or perception of visual variety.

The analysis of the results will be done quantitatively using SPSS. The limited knowledge of the researcher in using statistical software can cause inaccuracies while analysing and interpreting the results.

Chapter 2: Literature Review

This chapter explains the main concepts being explored in the study, the different viewpoints of looking at concepts and the junctions where the concepts overlap to reveal certain relationships. These relationships are then described in the light of the research problem to form a conceptual framework.

2.1 Determinants of preference of people

For the purpose of this research it is first of all important to understand the meaning of preference and what affects it in an urban environment. The seminal research of Kaplan (1987) in the field of aesthetics and visual preference is discussed to understand the factors affecting it.

The preference studies of human beings with their environment come under the field of study called environmental psychology. Environmental psychology was first defined in 1978 by Heimstra and McFarling (in Bell, Greene, et al., 1996)as a field of psychology concerning the relationship between behaviour and physical environment. It was later defined by Bell, Greene et.al (1996, p. 7) as "the study of the interrelationship between behaviour and experience and the built and natural environment". They also highlighted a number of characteristics of the field of environmental psychology, three of which are crucial in order to fully understand the preference of people and are enumerated below:

-it is the study of relationship between environment and behaviour, seen as a unit, meaning this relationship cannot be fully understood by isolated studies of environment and behaviour.

-it is the study of interrelationships of environment and behaviour; which is to say, exists in a cyclic phenomenon in which one affects the other and in turn is also affected by the prior one.

-in this field the research cannot be conducted in a purely applied or a purely theoretical manner.

From environmental psychology we know that humans affect the environment around them and are affected by it. The first step of this interaction is human perception of the environment. Perception is thus ahead of sensation which gives us information about the external stimuli. It is a more complicated process of attaching larger meaning to just the direct meaning derived from sensations. The meaning of perception has been explained in an effective way by Ittelson (1978, in Bell, Greene, et al., 1996, p. 28) , that "environmental perception includes cognitive (i.e., thinking), affective (emotional), interpretive, and evaluative components, all operating at the same time across several sensory modalities." Thus environmental perception is a more holistic process of becoming cognizant of the environment.

After the understanding of the term preference, it is important to understand the characteristics of a view that affects preference of an individual. The view may consist of a natural environment or an urban built environment.

Preference research done by Kaplan (1987) enumerates certain variables that have been empirically proved to have an effect on the preference of individuals. It has also been highlighted by Kaplan that cognition and aesthetic effect together make up environmental preference. The following literature discusses the different predictors of preference of individuals other than the complexity of views which was previously thought to be the most dominant variable in predicting preference.

- Kaplan (1987)found out that nature scenes were more preferred than built environment scenes because of the fact that nature scenes appeared to promise that more information could be gained by moving deeper into the scene. This attribute was labelled by him as ‘mystery’.
- Another predictor or attribute was coherence or the property of the elements in the scene such as repeating elements or symmetries or unifying textures that make the scene “hang together” Kaplan (1987, p.9).
- The concept of legibility was brought as another predictor of preference earlier used by Lynch (1960 in Kaplan, 1987). Legibility meant the ability of a scene to help an individual maintain orientation while possibly going deeper into the scene.
- The effectiveness of individuals in predicting the preference gave rise to the notion that perhaps there is an evolutionary bias in preference and was later given another indicator or predictor of preference of primary prospect (Kaplan,1987) from the prospect and refuge theory of Appleton(1975).

	Understanding	Exploration
Immediately apparent	**Coherence** *(the extent to which the scene seems to "hang together")*	**Complexity** *(information richness of the scene)*
Can be inferred or predicted	**Legibility** *(the predicted navigability of the scene upon further exploration)*	**Mystery** *(the promise of the scene offering additional information upon further exploration)*

Figure 1: Organization of the Kaplan and Kaplan model of environmental preference {{178 Kaplan, Stephen 1987;}}

The predictors of preference was organised in a grid, one dimension of which categorizes them into ‘understanding’ against ‘exploration’ and the other dimension is the degree of time and effort required to process the information. This means that coherence and complexity requires less analysis by our brain than legibility and mystery. Also, coherence and legibility relates to the “making sense of” the environment whereas complexity and mystery relates to explorative aspect of the environment.

Thus in addition to the variable of complexity, other variables such as the level of mystery, coherence and legibility play an important part making a scene look attractive. Additionally Kaplan (1987 in Bell, Greene, et al., 1996) has also emphasized the importance of familiarity, naturalness and spaciousness in judging the attractiveness of a scene. Thus familiar aspects of a scene make it more desirable. Similarly, it was found out that higher level of naturalness in landscape scenes are more preferred. In the case of spaciousness, the more the scene is defined the better it is. Thus spaces with suggestive boundaries are more attractive than endless expanse of an area.

The components that make up perception have been time and again contested. It is sometimes argued that cognition has a larger and a more important role to play in preference than the aesthetic effect of the environment. It is also said that cognition happens very quickly and thus can be disregarded altogether. This matter has been explained by Kaplan (1987) that Zajonc's "preferences need no inferences" does not mean that preference is not dependent upon cognition but that there can be instances when preference occurs without any cognition thereby he suggested that there can be an array of relationships between what he calls input and affect with the component of cognition being present in varying degrees among them.

It has been later clarified by Kaplan that while preference is experienced as direct and immediate, aesthetic reactions could be seen as a set of inclinations that may be intuitive but they influence the direction people choose in the physical environment and other domains.

Physical features of the environment and preference of people:

There exists alternating views regarding the effect of physical features of the environment on the preference of people. A number of authors such as Kaplan and Kaplan, 1982, 1989, Kaplan et al 1972, Hezog, Kaplan (1987, in Cooper and Oskrochi, 2008) have studied the human visual perception through preference and experiential studies and identified the physical elements that affect their notion of preference but according to Hagerhall (2004, p.247) the physical characteristics are not fully determined and are fuzzy and that urban spaces have mixed scenes with both manmade objects and vegetation.

Perception as defined by Ewing and Handy (2009) is the process of being aware or the understanding of information which is actually a product of experiences had earlier, one's culture and one's interpretation of the experience. They also argue that the physical features of the environment affect the walking behaviour both directly and indirectly through this perception of individuals. We could also derive from this argument that the preference of people towards a streetscape can be determined by the physical features and their individual perception.

2.2 Visual variety of streetscape

Visual variety of an environment is a part of visual quality experienced by the viewer. The level of richness of a scene or the complexity of a view appeals to the perception of the viewer. The physical characteristics of street environment make up visual quality. This can be clearly understood by the operationalization of urban design qualities done by Ewing and Handy (2009) to measure the walking behaviour of pedestrians. Since the behaviour is an effect of user perception, the literature from the operationalization of these urban design qualities will be used to understand what makes a scene rich in terms of visual variety and complexity.

A study done by Ewing and Handy (2009)has offered understanding of the physical characteristics of street environment that contribute to more abstract and subjective urban design qualities. Thus the urban design qualities were objectively measured by assessing the physical characteristics of street environments. Out of the 51 urban design qualities found from literature review, Ewing and Handy were able to successfully operationalize and measure 5 subjective qualities in the context of commercial streets.

adaptability	distinctiveness	intricacy	richness
ambiguity	diversity	legibility	sensuousness
centrality	dominance	linkage	singularity
Clarity	enclosure	meaning	spaciousness
coherence	expectancy	mystery	territoriality
compatibility	focality.	naturalness	texture
comfort	formality	novelty	transparency
complementarity	human scale	openness	unity
complexity	identifiability	ornateness	upkeep
continuity	imageability	prospect	variety
contrast	intelligibility	refuge	visibility
deflection	interest	regularity	vividness
Depth	intimacy	rhythm	

Figure 2: Table of Perceptual qualities (Ewing and Handy, 2009, p. 66)

A brief overview of the conceptual framework developed by Ewing and Handy (2009) gives a clear picture as to how the subjective urban design qualities are a resultant of the physical features that make up the street space and these qualities affect the individual reactions or preferences of people. It is important to note that the physical features may directly affect the perceptions as well as indirectly by invoking certain qualities of the environment. In this case the effect of the collective environment is seen as walkability and the walking behaviour of individuals, but the same collective environment will also affect the visual perception of a pedestrian and thereby affect the behaviour of the pedestrian.

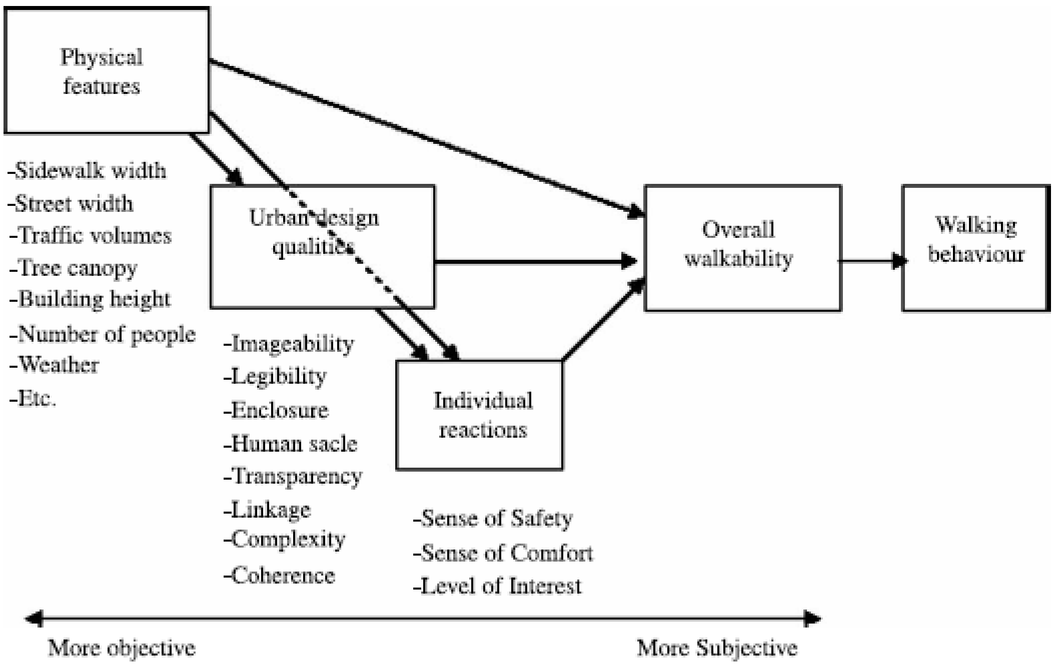


Figure 3: Conceptual framework (Ewing and Handy, 2009, p. 67)

Five urban design qualities operationalized and measured by them were imageability, enclosure, human scale, transparency and complexity. The quality of street environment can be measured using them and association with walking behaviour can be established. The same can be adopted in the case of preference research by adopting the methodology developed by Ewing and Handy (2009).

Qualitative definitions and operational definitions of the five urban quality indicators:

- The qualitative definition of **imageability** given by Ewing and Handy (2009, p.73) is "the the quality of a place that makes it distinct, recognizable and memorable. A place has high imageability when specific physical elements and their arrangement capture attention, evoke feelings and create a lasting impression". Operational definition of imageability takes into account the measurement of variables such as; 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, number of buildings with identifiers (Ewing and Handy, 2009)
- The qualitative definition of **enclosure** given by Ewing and Handy (2009, p.75) is "the degree to which streets and other public spaces are visually defined by buildings, walls, trees and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a room-like quality." The operational definition of enclosure takes into account five variables namely; the proportion of street wall on the same and opposite side of the street, proportion of sky across the street, number of long straight lines and the proportion of sky straight ahead.
- Ewing and Handy (2009, p.77)gave the qualitative definition of **human scale** as "the size, texture and articulation of physical elements that match the size and proportion of humans and, equally important, correspond to the speed at which humans walk. Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale". They also included the variables such as number of long straight lines, number of pieces of street furniture and other miscellaneous items, proportion of first floor with windows on the same side of the street, building height and number of small planters in the operational definition of human scale.
- Ewing and Handy (2009, p.79) explained **transparency** as "the degree to which people can see or perceive what lies beyond the edge of a street and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street. Physical elements that influence transparency include walls, windows, doors, fences, landscaping and openings into mid-block spaces."Variables such as the proportion of first floor with windows, proportion of active uses and proportion of street wall on the same side of the street were used to operationalize the urban quality indicator transparency.
- **Complexity**, the fifth urban design quality was defined by Ewing and handy (2009, p.81) as "the visual richness of a place. The complexity of a place depends upon the variety of the physical environment, specifically the numbers and types of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage and human activity." After being operationalized, the variables included to measure the complexity are namely, the number of people on the same side of the street, number of dominant building colours, number of buildings, presence of outdoor dining, number of accent colours and number of pieces of public art.

On the other hand a different perspective of looking at visual variety in a scene and measuring it is that of Cooper and Oskrichi (2008).Visual variety has been defined by Cooper and Oskrichi (2008) as the level of visual experience provided to the user which depends upon the degree of variation in the subject in terms of recognizable textures, sizes, styles, materials and surface changes. People's perception of visual variety of streetscape was measured by carrying out a survey of purposive sample of experts in the field of urban design. The respondents of this survey were first familiarised with the definition of visual variety and then were asked first to rank the street views and then indicate the relative degree of visual variety by giving a score.

VQM (Visual quality measurement) done by Cooper and Oskrochi (2013) was a multi item measurement of visual quality based on (Gliem and Gliem, 2003 in Cooper, Su, et al., 2013) This kind of measurement brought out the feelings and judgements towards the view. Seven different perception characteristics were selected on the basis of environmental perception and aesthetics approach (Kaplan, 1987) and cognitive judgements and affective judgements ((Wohlwill, 1976 in Cooper, Su, et al., 2013). These were variety, complexity, order, coherence, beauty, interest and preference. The scores of all these attributes by the respondents were then used to formulate one indicator of VQM.
Various studies have successfully shown that visual variety can be measured in terms of fractal dimensions.

2.3 Fractal dimension as a measure of visual variety and complexity

Fractal dimension has been used by many researchers to quantify the visual complexity of fractal patterns found in urban and natural environments. The relationship between fractal dimension and urban structure has been explored by Batty (1995), Batty and Longley (1994) and Frankhauser (1994, in (1994 , in Cooper, Su, et al., 2013). Similarly, streets, their networks, their edges have been studied to have fractal properties in the works of Mizuno and Kakei (1990, in Cooper, Su, et al., 2013) and Cooper (2005). Closely relating to the field of urban design, research has been carried out by Cooper (2000). The relationship of fractal dimension with different levels of visual preference has been investigated by authors such as Aks and Sprott(1996) , Hagerhall (2004), and Richards (2001).

It has been found in the works of Cooper and Oskrochi (2008) a strong correlation exists between perceptions of visual qualities of streetscapes and the fractal dimensions of those streetscapes. Other works have also found out that fractal dimension can reveal people's judgement of attractiveness of streets.

Fractal Geometry- Our modern geometry defines things one, two or three dimensional. For example a line has one dimension which is its length, a plane has two dimensions namely length and breadth while a cube has the three dimensions of length, breadth and height. Mandelbrot (Mandelbrot, 1983)argues that such regular objects that can be defined in either one two or three dimensions do not or exist little in nature. The irregular objects of nature according to Mandelbrot (1983) can be described using the term fractal which he derived from the Latin verb frangere, meaning 'to break'. He used this term to describe objects that showed similar patterns in smaller scales or displayed self similarity. This property of self similarity at different scale is called the fractal nature of an object or an area. Fractal dimension is the measure of the property of self similarity across different scales.

Fractal dimension is way to quantify the degree of irregularity of an object or a fractal pattern's visual complexity in the form of a single number. It is represented by D and the value lies between the Euclidean dimensions of 1, 2, and 3. This can be explained using the popular example of an irregular coastline which , the irregularity of which can be quantified in terms of fractal dimension as having the value between 1 and 2 as it is neither a straight line with one dimension or a fully two dimensional plane but somewhere in between. It has been explained well by Cooper and Oskrochi(2008, p. 351) that "fractal dimension is a measure of how well a particular object fills the space in which it is drawn".

Thus, the low D value for fractals means that the object or shape has less roughness or less amount of fine structure in its construction. Higher D value or values closer to 2 then the fractal has high roughness or large amount of fine and intricate structure (Taylor, Spehar, et al., 2011).

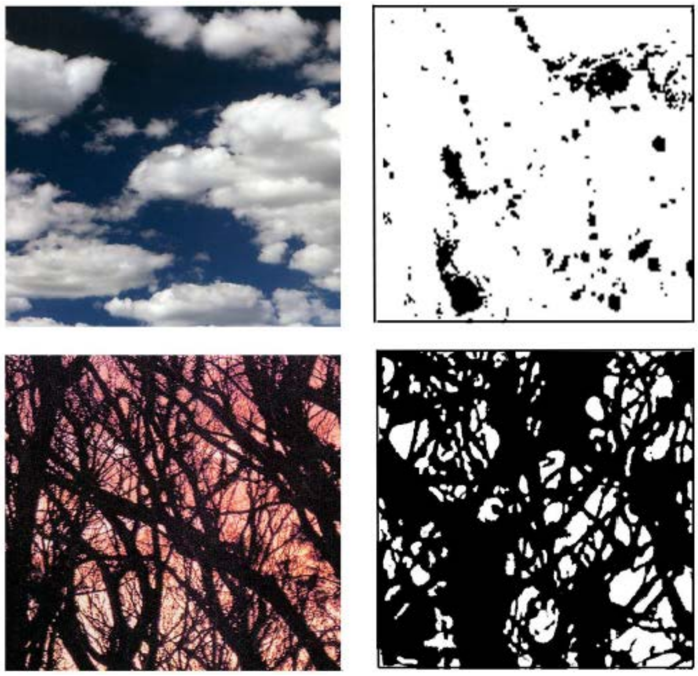


Figure 4: Examples of natural scenery (left column) and poured paintings (right column)(Taylor, Spehar, et al., 2011, p.3)

The same has been explained by means of Figure 4 given above. The top two images of clouds and Jackson Pollock's untitled painting (1945) have the fractal dimension of 1.3 and 1.0 respectively, thereby showing a lower level of visual complexity and roughness. The bottom two pictures of a forest and Pollock's untitled (1950), both have the fractal dimension of 1.89, which is closer to 2 and thus display larger visual complexity and roughness.
In order to measure the fractal dimension of street views for the purpose of measuring the visual variety of streetscape, Cooper and Oskrochi (2008), first processed the images in Photoshop to convert them into black base images with white 'dust' or pixels. Such a picture can be best analysed for its fractal dimension by the 'box counting' method in which the box in grid indicates the measurement scale used. Cooper and Oskrochi (2008, p.351) has explained the basic theory behind the functioning of box counting method as "the key to understanding fractal dimension is in the relationship between measured length and measurement scale" and that all box counting methods "attempt to identify a correlation between measured size (length, surface, or volume) and scale by observing how length, surface and volume increases in relation to measurement using smaller and smaller scales".

Figure 5 Grey scale image (left) and Binary edge detected image (right)(Cooper and Oskrochi, 2008, p.356)

The above images show that street images can be quantified for their fractal dimension by taking standard pictures in greyscale and converting them into binary edge detected images and then processing them in 'box counting' software.

Box counting method- in this method a series of grids are overlaid on the subject, where d stands for the size of the grid square, is recorded and the number of the squares containing some part of the subject (in this case the white pixels) is recorded and represented by N. Since the number of squares containing the white pixels is subject to the grid size, N is usually represented as N(d). The next step is to keep on reducing the grid size d and keep on recording the number of squares containing white pixels for each size of grid. Then the results of measurement at different scales are used to calculate fractal dimension by entering the values of grid size and number of squares in a log-log graph called the Richardson plots (Cooper and Oskrochi, 2008) . For the purpose of this research, the same software will be used to assess the fractal dimension as used in Cooper and Oskrochi (2008), used for the fractal analysis of street vistas as part of the research has been adopted from their methodology. Thus Benoit 1.3 software will be used, where the box-counted fractal dimension is given by exponent D in the formula:

$N(d) = 1/d^D$ (it is important to note here that this fractal dimension relates to the number of squares counted for specific range of grid sizes and thus it relates only to that range of grid sizes) (2008)

With the above literature it is clear that taking out the fractal dimension of a scene or object can translate visual complexity of the object or scene in terms numerical value. This gives us the opportunity to assess and compare varied scenes composed of different physical elements with different levels of urban design qualities. Adopting fractal dimension as a measure of complexity makes correlation analysis with other parameters such as preference of people for particular scenes possible statistically.

2.4 Conceptual framework

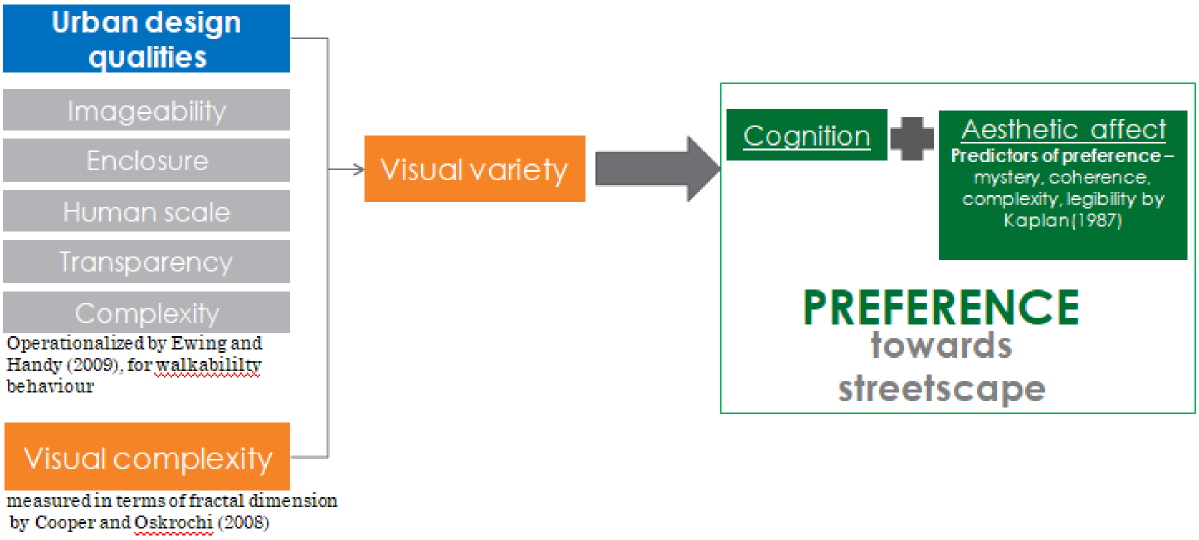


Figure 6: Conceptual framework, Source: Author

From the literature review of the state of the art knowledge was gathered and presented on visual variety and preferences of people, the linkages among these theories have been graphically represented pertaining to the main research question.

The theory on environmental psychology by Bell, Greene et al (1996) highlighted that human perception is the first step of the interaction in the relationship that exists between behaviour and environment. Preference has been defined by Ittelson ((1978, in Bell, Greene, et al., 1996)to include the processes of cognition, affective, interpretive and evaluative components, all operating together through different sensations being recorded simultaneously. Since cognition happens almost automatically other components that make up the perception of an individual take into account more from the surrounding environment and resultant is an effect of the various visual qualities or predictors of preference highlighted by Kaplan (1987). Thus the visual elements of the scene such as mystery, coherence, complexity, legibility highlighted by Kaplan (1987) and others measured by Cooper and Oskrochi (2013) such as order, beauty and interest together can help reveal the preference of individuals. It is important to note here that the predictors of preferences by Kaplan (1987) are subjective and personal coming from environmental psychology background.

On the more objectively measurable side the concepts of urban design qualities adopted from the research of Ewing and Handy (2009) and the measurement of visual complexity by means of fractal dimensions can be combined together and the effect of changes in them can be correlated with the changes in preference for different streetscapes. The objective measurement of subjective qualities of urban design by adopting the methodology and operational definitions of each of the five qualities given by Ewing and Handy (2009), it is now possible to keep these concepts side by side and assess them and draw inferences of the relationships existing between them.

Chapter 3: Research Design and Methods

This chapter deals with the methodology of this research and explains the steps required to be carried out in order to find out the answers to the research questions. First of all the concepts learnt from the literature review and their relationships stated through conceptual framework will be operationalized into variables and measurable indicators. Then an overall strategy for the research work to be carried out will be selected based on the best possible measurement technique required for indicators. The research strategy will guide the data collection methods. At this stage it is also considered as to what can be the possible limitations in collecting data, its analysis and steps will be taken to design the research in a way that maximises the validity and reliability of the research.

3.1 Revised research questions

From the literature review it was discovered that visual variety is an aspect of the visual quality. Visual variety is also a subset of urban design qualities that can be measured of streetscapes by measuring the physical characteristics of the streetscape. Thus the main research question has been altered and is as follows:

"How do urban design qualities of street vistas of Rotterdam and its visual complexity influence the preference of pedestrians for the streetscape?"

Furthermore, the sub-questions supporting the main question are:

1. What are the urban design qualities and how are they measured?
2. What are the physical aspects of streetscape that can influence preference of people?
3. Does the urban design quality of street environment and visual complexity affect the preference of people in the same manner?

3.2 Operationalization

At this step the concepts used in the conceptual framework such as - visual variety, urban design qualities and preference of individuals; are operationalized into variables and indicators in the light of the research question of the study. This done by capturing the definitions adopted for these concepts. The indicators then help in the formulation of guides for questionnaires or interviews for data collection. Thus the basic ground for data collection is laid at this stage.

Since this research focuses on finding out the influence of urban design qualities and visual complexity of street vistas on the preference of pedestrians, we have distinct independent variables of urban design quality and visual complexity and the dependent variable of preference of people.

Urban design qualities: The five urban design qualities operationalized and defined by Ewing and Handy (2009) have been adopted for this research and they are imageability, enclosure, human scale, transparency, and complexity.

Imageability has been defined by Ewing and Handy (2009, p.73) as "the quality of a place that makes it distinct, recognizable and memorable. A place has high imageability when specific physical elements and their arrangement capture attention, evoke feelings and create a lasting impression".

Enclosure has been defined by Ewing and Handy (2009, p.75) as "the degree to which streets and other public spaces are visually defined by buildings, walls, trees and other vertical elements. Spaces where the height of vertical elements is proportionally related to the width of the space between them have a room-like quality."

The definition of human scale as per Ewing and Handy (2009, p.77) is "the size, texture and articulation of physical elements that match the size and proportion of humans and, equally important, correspond to the speed at which humans walk. Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale".

Ewing and Handy (2009, p.79) explained transparency as "the degree to which people can see or perceive what lies beyond the edge of a street and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street. Physical elements that influence transparency include walls, windows, doors, fences, landscaping and openings into mid-block spaces."

Complexity, the fifth urban design quality was defined by Ewing and handy (2009, p.81) as "the visual richness of a place. The complexity of a place depends upon the variety of the physical environment, specifically the numbers and types of buildings, architectural diversity and ornamentation, landscape elements, street furniture, signage and human activity."

These urban design qualities have been successfully operationalized by Ewing and Handy (2009) and thus the indicators adopted from their research are known to have influence on the behaviour of people. The last urban design quality which is the complexity has been operationalized using the fractal theory. Through the literature review it has been found out that visual complexity can be measured by fractal dimensions (Cooper and Oskrochi, 2008, Hagerhall, Purcell, et al., 2004, Cooper, 2003)

The urban design qualities however will be quantified but not statistically correlated with preference as the methods to measure both the variables are based on different methodologies. Urban design qualities will be measured using video sequences of the streetscape whereas the perception towards the streets will be measured by black and white photographs. Qualitative relationships will be drawn between the measured urban design quality and fractal dimension and the preference towards a particular street.

Thus the independent variable of visual complexity will be measured by the indicator of fractal dimension of street view.

Preference of a street view comes from the perception of the environment which has been explained in an effective way by Ittelson (1978, in Bell, Greene, et al., 1996, p. 28) , that "environmental perception includes cognitive (i.e., thinking), affective (emotional), interpretive, and evaluative components, all operating at the same time across several sensory modalities." Thus environmental perception is a more holistic process of becoming cognizant of the environment.

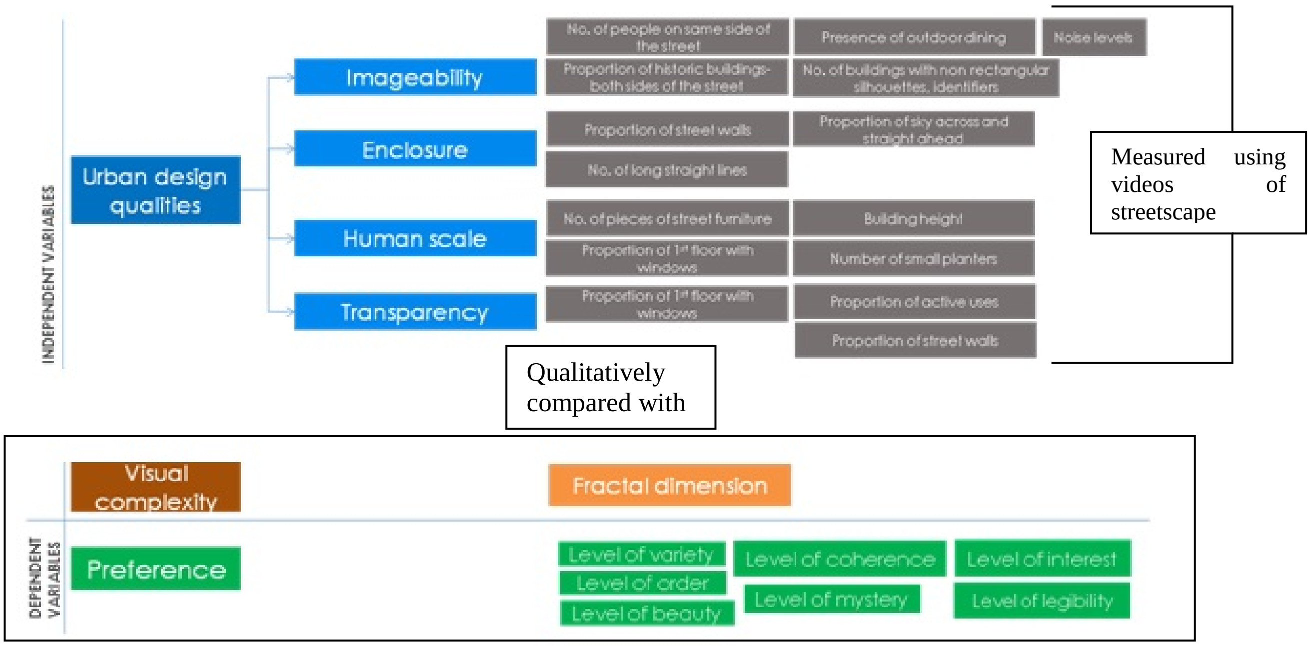


Figure 7: Operationalization of concepts into variables and indicators, Source: Author

The predictors of environmental preference given by Kaplan(1987) and VQM (Visual quality measurement) done by Cooper and Oskrochi (2013) have been amalgamated to arrive at the indicators for measuring the preference of pedestrians. When the level of mystery, variety, order, coherence, interest, legibility and preference are measured on a scale, it becomes necessary to combine these different sub-indicators into and overall preference indicators. This term has been called visual quality measurement unit or VQM.

Table 1: Operationalization of Independent variables into indicators, Source: Author

Concept	Variable	Sub - variable	Indicators	Scale
Visual variety	Urban design qualities	Measured on a scale of 1-5, and qualitatively compared with visual complexity indicator of fractal dimension and the overall preference of visual variety of streets		
	Visual complexity		Fractal dimension	Ordinal

Table 2: Operationalization of Dependent variable into indicators, Source: Author

Preference	Cognition and Aesthetic response	level of variety		Ordinal
		level of mystery		Ordinal
		level of order		Ordinal
		level of coherence		Ordinal
		level of beauty		Ordinal
		level of interest		Ordinal
		level of legibility		Ordinal

*ordinal- this is a type of scale of measurement where data is in ordered form but cannot be compared in numeric size, for eg. Health scores, educational level.

Research strategy and method

According to Van Thiel (2014), survey as a strategy is applied to research when a large amount of new data is to be collected in a standardized format. This approach is adopted when the units of study are large, spread over a large geographical area (that is more breath rather than depth of research) and the variables to be measured are also significant.

Survey as a strategy is the best for this research as a large amount of new information is to be collected for perception of pedestrians the different levels of commercial streets of Rotterdam. The large number of variables to be measured for independent variables will be done by physical survey of the streets.

The data thus collected can then be easily generalized thereby giving a high external validity to the research. This strategy helps in bringing out the relationship between variables through quantitative data analysis.

The initial hypothesis is that higher the urban design quality of streetscape, the higher is the preference of pedestrians for it. This hypothesis will be tested by the quantitative data analysis.

3.3 Sample size and selection

For the purpose of this research, the preferences of pedestrians will be recorded from different levels of commercial streets in the city of Rotterdam. Since the methodology of preference research is adopted from Cooper and Oskrochi (2008, Cooper, Su, et al., 2013) and Cooper,Watkinson, et al., (2010), a similar sample size will be taken to carry out statistical analysis.

Probability sampling will be the method adopted and representative random sample is required for preference to be judged. It has been seen from previous studies that gender, age and other demographical data does not have any impact on the preference of people towards visual variety of streetscape(Cooper, Su, et al., 2013). Thus a random sampling for the purpose of quantitative data analysis will require 100 respondents.

3.4 Data collection methods

The following steps will be undertaken to collect data:

- Five streets of commercial areas of Rotterdam will be selected based on their location from the city centre and size. This will ensure variability in terms of urban design quality.
- Five images of each street at regular intervals (to experience streets as serial vision) will be taken for the purpose of preference survey by at least a 100 respondents.
- The same five streets will be physically surveyed for the urban quality indicators.

Figure 8: Street views will be taken from the middle of pedestrian path, Source: (Cooper, Su, et al., 2013)

- The sample questionnaire for perception adopted from Cooper and Oskrochi (2013) and expanded to incorporate the predictors of preference indicted by Kaplan(1987).

Question	Scale
1. Please indicate the level of 'variety' that you feel each street has in comparison with the others...	unvaried/monotone (1) → varied/diverse (6)
2. Please indicate the level of 'complexity' that you feel each street has in comparison with the others...	simple (1) → complex (6)
3. Please indicate the level of 'order' that you feel each street has in comparison with the others...	ordered/regular (1) → chaotic/irregular (6)
4. Please indicate the level of 'coherence' that you feel each street has in comparison with the others...	coherent/harmonious (1) → incoherent (6)
5. Please indicate the level of 'beauty' that you feel each street has in comparison with the others...	not beautiful (1) → beautiful (6)
6. Please indicate the level of 'interest' that you feel each street has in comparison with the others...	boring (1) → interesting/attractive (6)
7. Please indicate your level of 'preference' for each street in comparison with the others...	unlikeable (1) → likeable (6)

Figure 9: Sample questionnaire for perception, Source:(Cooper, Su, et al., 2013, p. 50)

- All the 25 images of streets will be processed and transformed to be fed into Fractalyze software to obtain their fractal dimensions.

Figure 10: Process of taking greyscale images and converting them into binary images to calculate fractal dimension, Source:(Cooper and Oskrochi, 2008, p. 356)

3.5 Data analysis methods

To find out the correlation between independent and dependent variables, the statistical methods will be employed using MS Excel and STATA which can establish correlations between variables by feeding quantitative data into it.

Table 3: Data analysis methods, Source: Author

Research question	Data used	Method	Tool/ Software	Outcome(s)
What is the degree of relationship between quality of street environment and the preference of people?	Urban quality index, Fractal dimension and preference survey data	Qualitative comparison	-	Establishing a preliminary relationship between UQI, Fractal dimension and preference of people
What are the physical aspects of streetscape that can influence preference of people?		Inferential analysis (OLS regression analysis, ANOVA)	MS Excel/ STATA	Key physical aspects that influence preferences
What accounts more for the perception , the visual complexity or the urban design qualities?		Inferential analysis (OLS regression analysis) and qualitative comparison	MS Excel/ STATA	If there is correlation between visual complexity and perception and if this relationship can be qualitatively compared with urban design index.

3.6 Validity and reliability

Validity and reliability will be achieved firstly by using reliable data gathering technique – for preference study and deriving fractal dimension of street views using the methodology formed by Cooper and Oskrochi (Cooper, Su, et al., 2013).

Precise documentation at all the steps of data collection and analysis will ensure transparency of the process. Further data inspection process will be carefully followed so that the results don't get skewed and internal validity is achieved. In the Operationalization table as already shown multiple indicators used to measure the indicators will ensure some level of internal validity.

Triangulation by validating findings with other literature sources will be carried out at the end of the research.

Chapter 4: Presentation of data and analysis

This chapter elaborates on the process of data collection from the chosen study area; the description of processing the images of streets for software analysis of fractal dimension; method, testing, revision and administering of perception survey; carrying out the physical survey for urban quality measurement and lastly the analysis and presentation of the results. It also takes into account the various shortcomings faced in the duration of data collection and analysis of results.

4.1 Study area

Rotterdam is a port city of The Netherlands and is nestled in the Rhine-Meuse-Sheldt river delta at the North Sea. It is the second largest municipality after Amsterdam and houses a population of approximately 623,652 people within the city. It is a part of the Randstad conurbation with the population more than 7 million. As the largest port of Europe and being extensively connected with a network of railroads, waterways and roads Rotterdam is nicknamed the ‘Gateway to Europe’. The city center of Rotterdam has 70% population consisting of singles between the ages of 20 and 40 which explains the renting of 80% of homes rather than being owned. Out of the residents of the Rotterdam, about 45% are foreign born. Most of the foreign born residents come from Suriname, Turkish, Moroccan and Dutch Caribbean descent (Central Bureau of Statistics,2015). This composition of the population and being the largest port in Europe and housing the headquarters of corporations including Unilever, Eneco and Roboco, makes Rotterdam living environment a vibrant one.

The municipality of Rotterdam is divided into 14 districts that include Charlois, Delfshaven, Feijenoord, Hillegersberg- Schiebroek, Hoek van Holland, Hoogvliet, Ijsselmonde, Kralingen-Crooswijk, Noord, Overschie, Pernis, Prins Alexander, Rotterdam Centrum and Rozenburg. Out of these, this research focuses on the different scales of commercial areas of Rotterdam of different scales. Thus the streets studied in this research are from the city center of Rotterdam which is the urban commercial hub. The second level of commercial node being studied is the streets around the shopping center area of Prins Alexander, a north eastern borough of Rotterdam. It is expected that the urban design quality of the commercial streets of Prins Alexander is lower than that of the city center. The third level of commercial

Figure 11:Satellite image of Rotterdam with study areas highlighted, Source: Author

street is that of the neighbourhood commercial street of Lusthofstraat in Kralingen.

4.2 Data collection process and analysis

As explained in the previous chapter the method employed for data collection is survey. The urban design quality was measured through the measurement of operationalized variables by physical survey of the streets by the researcher. The visual variety was measured by taking out the fractal dimensions of street views. The perception of pedestrians for their preference towards the same streets was measured by primary survey though online questionnaire and face to face survey. Thus it was required to select a series of photographic images from the different scales of commercial streets.

In order to capture the street as a whole a series of photographic images were taken in the study area as was done by Cooper and Oskrochi (2008). Following the same methodology, five images from five selected commercial streets of Rotterdam were taken at approximately 100m distance in a sequence to capture the walk of a pedestrian. This gave an overall impression of the street as a whole. To mimic the pedestrian view of the street, the vistas were captured standing in the middle of the pedestrian path on one side of the street, using a normal 50mm lens, at a height of 1.6m. This produced images of 480x320 pixels. Thus 25 images in total were taken and then the images were processed in Photoshop software in order to be fed into Fractalyse software to take out the fractal dimensions of every image by box-counting method.

Figure 12: Sequence of images captured from 1 street at a distance of approximately 100m, Source: Author

4.2.1 Calculation of fractal dimension of the streets

According to literature review, the fractal assessment of images has been recognized by various authors such as Pentland (1984), Peleg et al (1984) and Vuduc (1997), Sato et al (1996); used for realizing the texture of the image. The technique to assess the fractal character of the street image converted into its black and white granular binary image is adopted from Sato et al (1996). There are various other methods to carry out the fractal assessment of images namely through full colour images, greyscale image but in this research the binary edge detected images were used as the processing of fractal dimension is faster in this case. Compared to the other techniques to calculate fractal dimensions of the images it was concluded "using the binary data is enough to calculate the fractal dimension ... and that the 256 grey level of data is not required" (Sato et al, 1996, page 464).

The 25 images taken of the 5 commercial streets were processed in the following manner taken from (Sato et al, 1996, page 464):

1) All the full colour images were separated into red, green and blue components using Photoshop software.
2) The green component of the image contains more information regarding the brightness and has better contrast than the other components and thus it was used to convert into greyscale (Sato et al, 1996, page 464).
3) Then all the greyscale images were processed for better edge enhancement by being subjected to the same gradient transformation in Photoshop.
4) These images are then converted into binary edge defined black and white image.
5) The binary images are imported into Fractalyze software, where the black granular pixel on white background are box counted. This is illustrated by Figure 12(a) and (b).

Figure 13 Full colour image (a) is converted to grayscale and then to edge detected binary image (b) to be fed into Fractalyze software , Source: Author

As already discussed, the fractal dimension is the relationship between the measured length and measurement scale. This can be done by various methods. For the purpose of this research and also following the method used in Cooper and Oskrochi (2008), box counting method has been adopted. In this method, a series of grids are superimposed on the image where the size of grid measured as'd' and the number of squares of the grid that contain any amount of black pixels are measured as 'N'. The number of squares of the grid containing black pixels depends upon the grid size. The finer the grid size, more the number of squares containing black pixels. The grid size that is overlaid on the image is progressively decreased; both the grid size and the pertaining number of squares containing black pixels are recorded.

In this research the software carries out the process of overlaying the grids of different sizes on the binary image and then plots the recordings in log-log diagrams. The box counted fractal dimension given by Fractalyze software is represented by exponent D:

N (d) = 1/ d^D where N(d) is the number of grid squares of size d that contain black pixels. When the results are plotted in the log-log graph and the plot forms a straight line then this reflects that the data set is fractal. The slope of the plot is negative, that is –D.

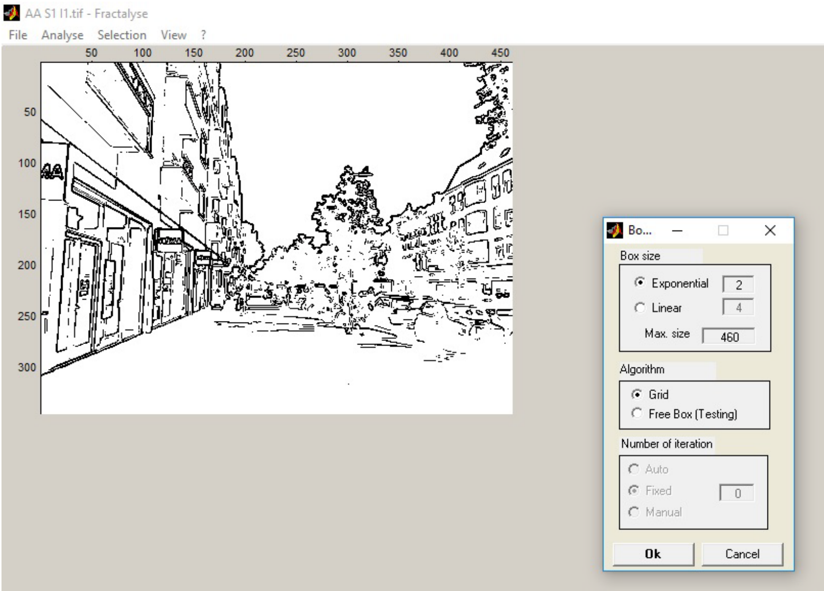


Figure 14: The edge detected binary image processed in Fractalyze software, Source: Author

While calculating the fractal dimension by box counting method it should be kept in mind that the fractal dimension is related to only the specific range of scales in which the measurements have been taken. Thus selection of measurement scale is very important. It was suggested by Koch(1993) that fractal dimension should be measured between the parameters of 0.25l to 0.03l where l is the height of the image.

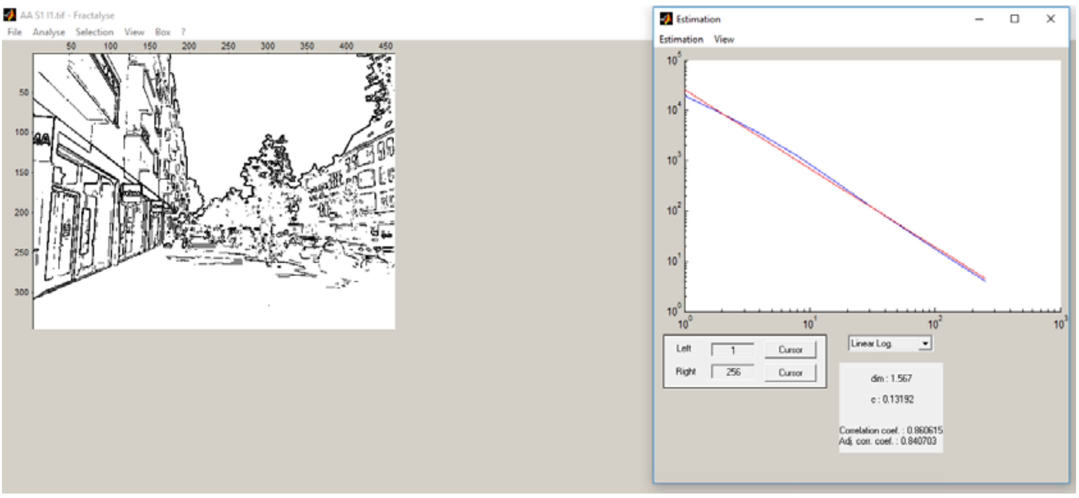


Figure 15: Fractal dimension taken out by log-log graph plotted with an inverted straight line plot , FD = 1.567

Thus for the purpose of this study the 480X320 pixel images were processed in the range of 90-10.72 pixels.

4.2.1.1 Assessing the homogeneity of fractal dimensions

After processing all the 25 images for fractal dimensions and studying the differences in the images and ranking them in the order of increasing fractal dimension, some preliminary inferences can be drawn. The fractal dimensions of the images closely relate to the amount of trees or shrubs (vegetation), proportion of sky, buildings, open areas, prominent shadows and level of detail in the foreground of the image. The foreground detail consists of the detail of the built form along the street, the amount of street furniture present, amount of vehicles present in the street, details of the design of street elements such as bollards, fences, railings, signage, and street art.

Figure 16: Street with least FD = 1.45 **Figure 17: Street with highest FD = 1.7**

Going through the images it was realized that the fractal dimensions were being affected by the proportion of vegetation, vehicles present in the image. As shown by Figures 16 and 17, the fractal dimensions are very different but the quality of built structure and the street urban design shows very less difference.

Then it was decided to capture the street views again keeping all the elements of the street almost comparable. This would imply capturing images with the same amount of vegetation, at same distance from the researcher so that the textural quality of the vegetation remains the same. Consideration was also taken to have the same proportion of vehicles, bicycles, pedestrians in the images.

Also, it was decided that for the purpose of perception of visual variety survey, one image per street to be included. The image of the street vista was chosen in a way that it represented the overall character of the street on the whole.

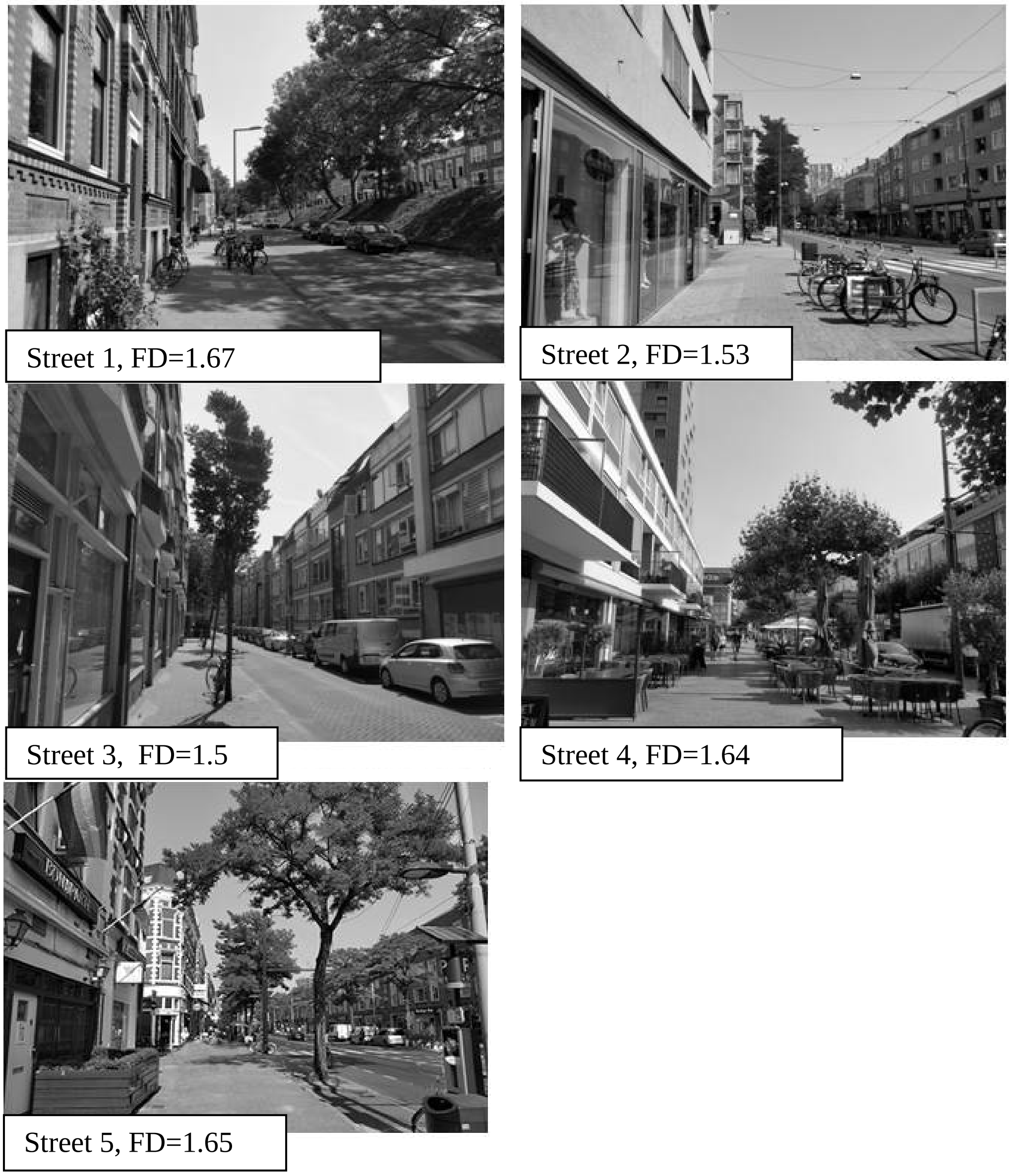


Figure 18: Final selected street images used for the preference survey with fractal dimensions 1.67, 1.53, 1.5, 1.64 and 1.65, Source: Author

4.2.2 Physical survey of urban qualities of the streets

This section deals with the collection of data for urban design qualities in terms of physical characteristics of the streets. As the aim of this research is to assess the influence of urban design qualities together with visual complexity (measured in terms of fractal dimensions), on the preference of pedestrians, the urban design quality assessment can be done by people with the prior knowledge of urban design terminology. Thus for this purpose a self administered physical survey of the streets was done in a first hand manner.

The physical survey of the streets required the researcher to approach the streets when there is same amount of sunlight, traffic on the streets and on the same day of the week. These conditions needed to be constant for all the streets to conduct a comparative measurement of the levels of activity in terms of the presence of pedestrians. For this reason a pedestrian walk on the 5 streets was video recorded through a camera. It also helped the researcher to go back and consult the videos while rating the different parameters. It was possible to run the videos side by side and do comparative rating.

All the different indicators of the operationalized parameters of urban design qualities were studied. These parameters were then rated on a scale of 1 to 5. The proportion of a particular parameter being present in the street video was rated.

The shortcoming of this survey was that the ratings were from one expert rather than a large pool of respondents required for such a study. Nevertheless the ratings can be compared with the visual variety survey (in which ratings of 100 respondents were recorded) and fractal dimensions.

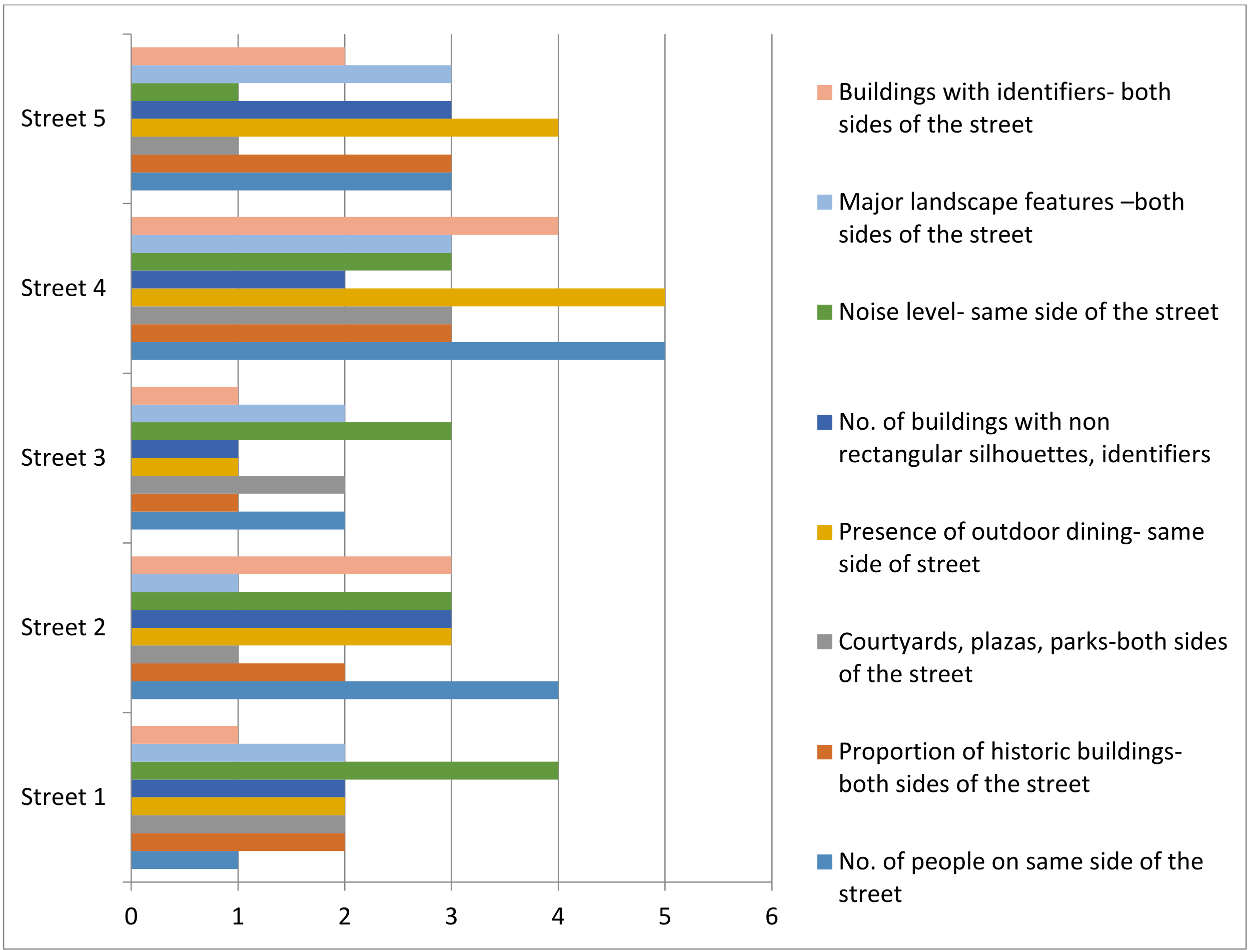


Figure 19: Level of Imageability of the 5 streets shown as bar graph, Source: Author

The imageability of streets was rated by assessing eight factors operationalized by Ewing and Handy (2009). It was found that the street 4 scored higher than the others in seven out of eight parameters. It had more number of people on the pedestrians, proportion of historic buildings in the street, identifiable courtyards, plazas and open areas along the street, low noise levels, landscape features such as street planters and trees. This street also had more number of identifiable buildings. This street had buildings with more rectangular silhouettes, implying more modern buildings with straight roof lines. Thus it scored less as it had less identifiable buildings.

Street 3 was the least imageable street according to the study. It scored low on all the parameters except for noise level which was low compared to the other streets. This street had least amount of street furniture, straight building facades. The other streets such as street 1 and 5 had more imageable built structures, more landscape features and outdoor dining areas on the sides of the streets.

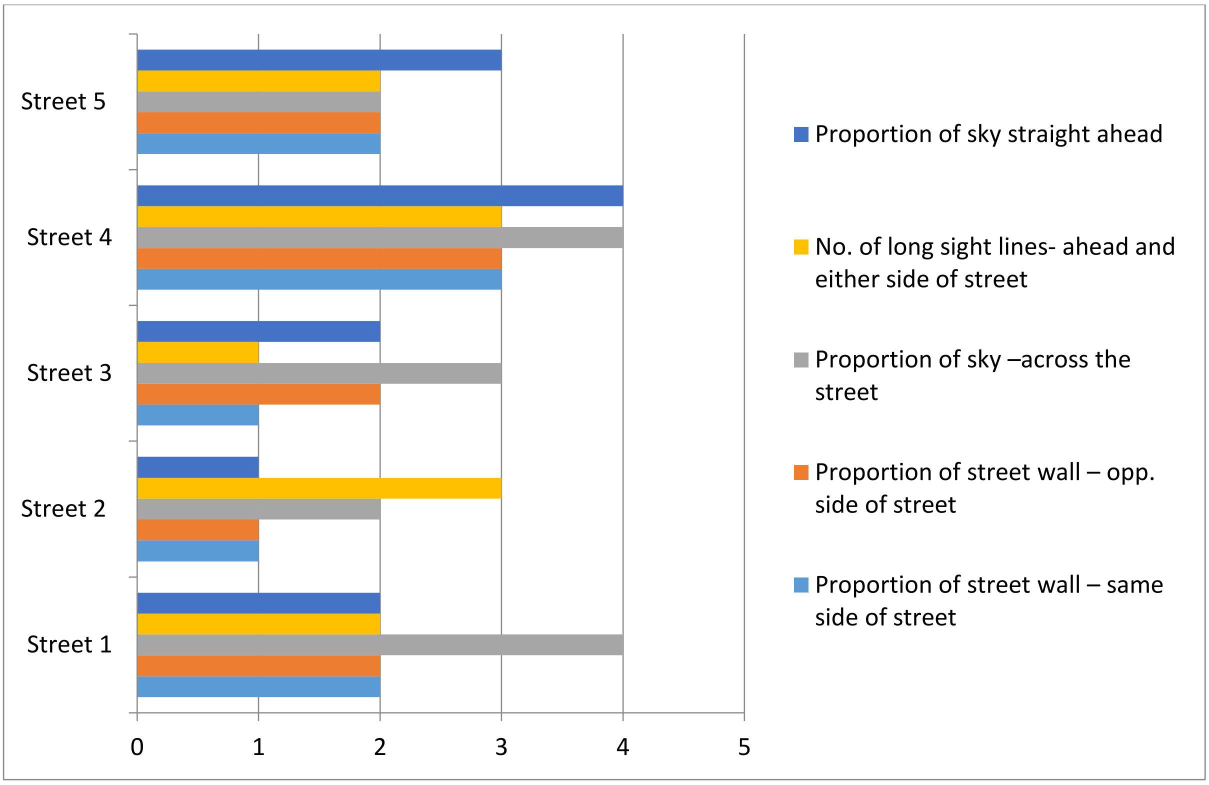


Figure 20: Level of Enclosure of the 5 streets shown as bar graph, Source: Author

Enclosure level of streets denotes the outdoor room like quality of streets where the intimate relationship between the pedestrians and street environment is felt. Thus the proportions of street wall composed of built structures along the street and on both sides of it are comparable to the width of the street. Out of the five properties measured to assess the level of enclosure, only the proportion of street wall on both the sides of the street positively affect the level of enclosure felt. The other three parameters of the proportion of sky visible across and ahead in the street and number of sight lines on either side of the street are negatively related to enclosure felt by the pedestrians. Streets 1 and 5 had the same building height on both the sides of the street with comparable building facades. Thus these two streets scored same on the proportion of street walls and the number of long sight lines formed by built structure details. The streets 2 and 3 scored low as the proportion of sky across and straight ahead were very less compared to the street walls giving them a tunnel like feeling. Street 3 also had very strong and straight sight lines which work negatively for the enclosure quality.

Street 4 scored well on the enclosure level because of proportion of sky visible was less due to presence of trees. The street trees played a role in reducing the scale of buildings along the street. Also, the upper floors of taller buildings were recessed breaking the sight lines.

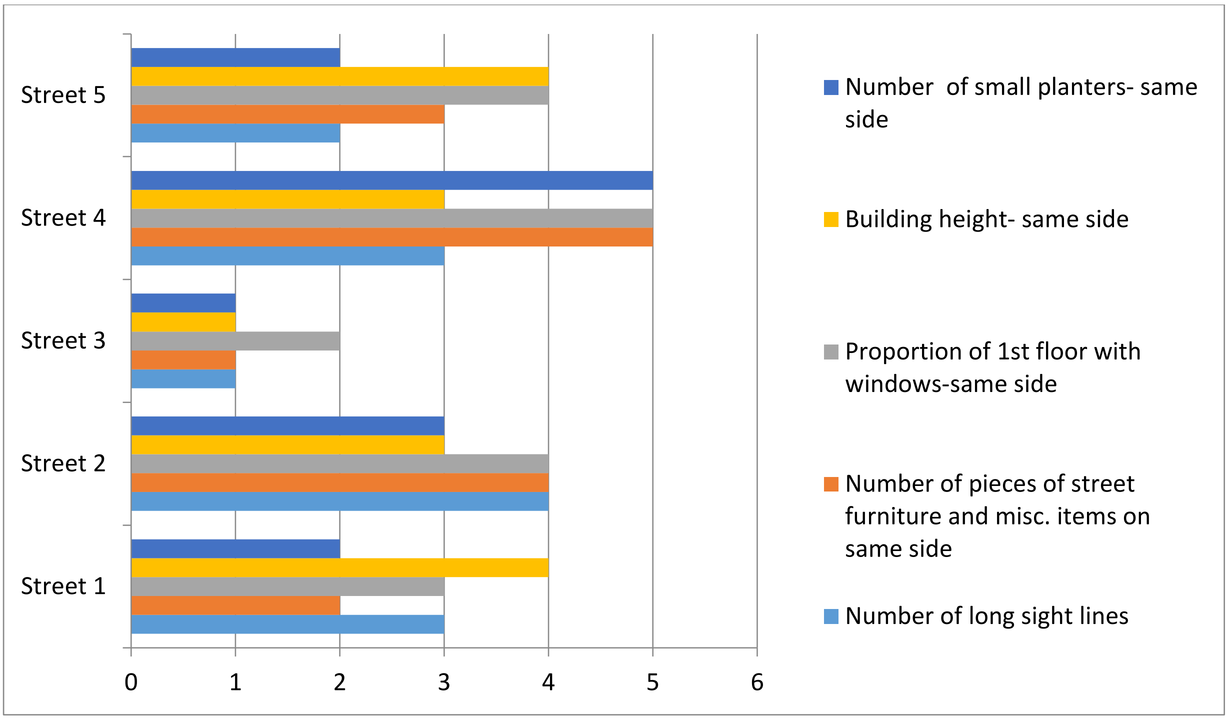


Figure 21: Level of Human scale of the 5 streets shown as bar graph, Source: Author

"Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale" Ewing and Handy (2009, p.77). Street 4 scored the highest as it contained large number of street furniture. Trees and small planters that break down the scale of the street, upper floor of the buildings with setback also breaks the scale of the buildings making the lower floors more intimate with pedestrians. The other streets such as 2 and 5 scored little less as they had less street furniture. Also, the building height in these streets was a little less than street 3 which did not relate to the human scale. Street 3 lacked relationship with the human scale due to massive plain facades making long sight lines with no element to break the scale of the street. Also, the windows on the 1st floor were less than the other streets making it less interactive with pedestrians.

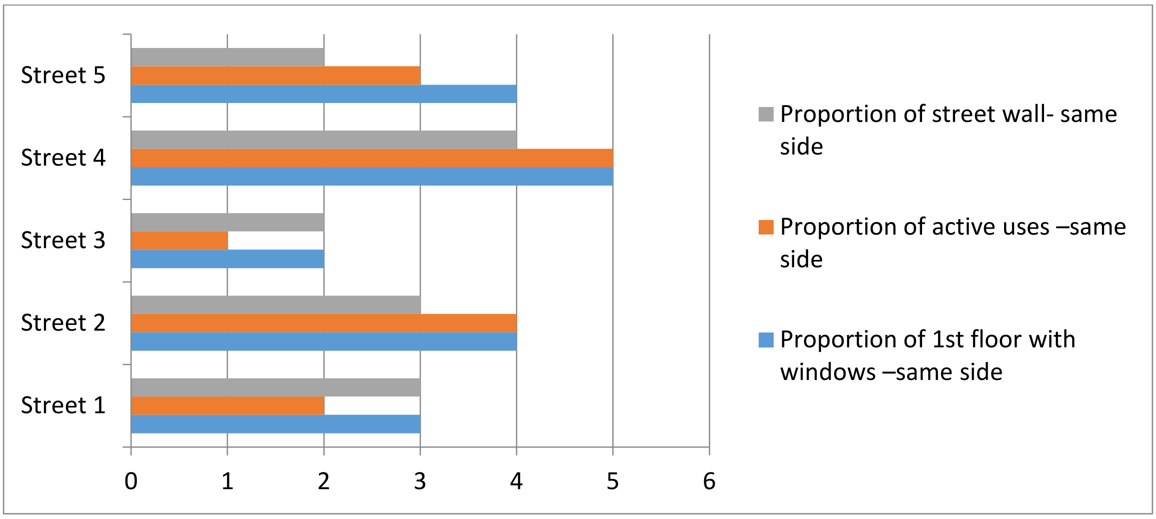


Figure 22: Level of Transparency of the 5 streets shown as bar graph, Source: Author

There are a number of physical elements that affect transparency of street. Walls hinder transparency while windows and doors along with midblock openings, landscape, fences along the buildings allow the pedestrians to see and maybe perceive what happens beyond the building edge. Street 3 had lesser proportion of windows and larger proportion of blank walls. Also, there was very less activity in the street thereby making it less transparent as a street. Street 1 scored higher than street 3 but less than street 2 and 5. Street 4 again scored the highest among all the streets owing to large windows of shops visible all along the street. Furthermore, all the activity was visible from the street making it more transparent than the other streets.

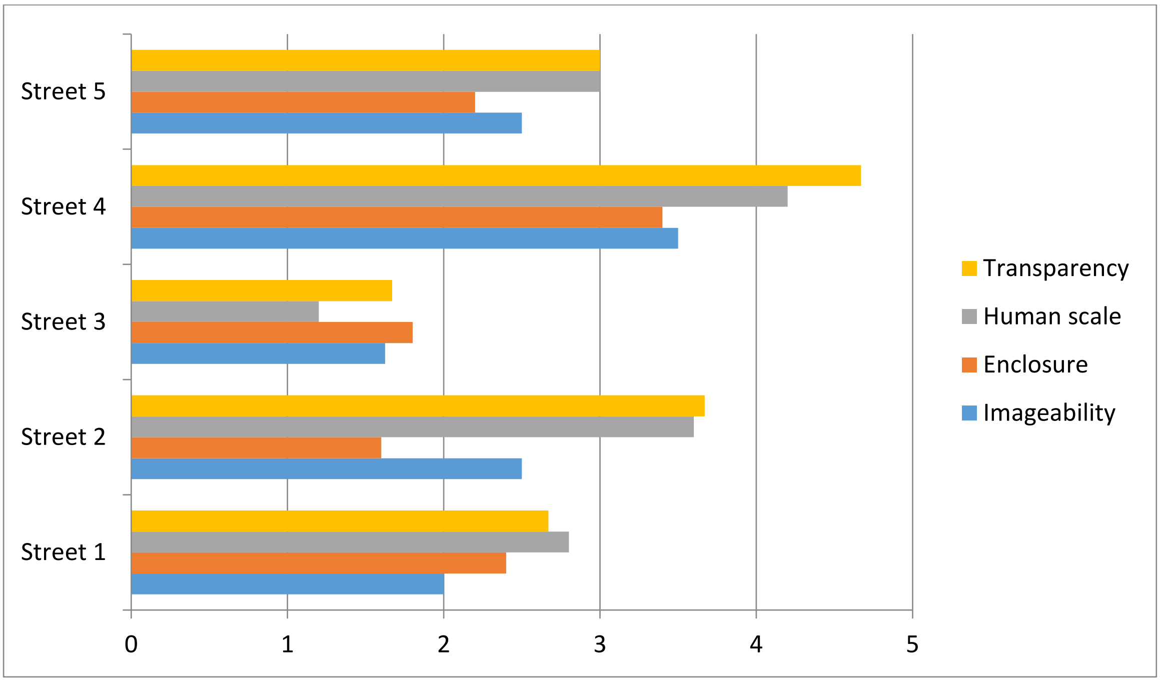


Figure 23: Urban quality of 5 streets shown through bar graph, Source: Author

The above bar graph shows the average scores of all the streets in qualities of imageability, enclosure, transparency and human scale after the summation of all the parameters of each quality. Street 4 ranked highest among all the streets in all the parameters while streets 2 and 5 scored almost similar in transparency and human scale. Street 3 scored the lowest in urban design quality, scoring the lowest in all the sub-qualities except enclosure.

It is important here to highlight that the street 4 ranked highest in urban design quality as well as fractal dimension.

Table 4:Urban design quality and fractal dimension scores of the 5 streets, Source: Author

Independent variables	Street 1	Street 2	Street 3	Street 4	Street 5
Fractal dimension	1.67	1.53	1.5	1.64	1.65
Imageability	2	2.5	1.625	3.5	2.5
Enclosure	2.4	1.6	1.8	3.4	2.2
Human scale	2.8	3.6	1.2	4.2	3

Transparency	2.67	3.67	1.67	4.67	3

Amalgamation of the different sub-variables of urban design quality in to one variable for easy comparison was done in STATA by taking the mean values of imageability, enclosure, human scale and transparency for each street.

Table 5: Urban quality measurement index computed using all the sub-variables

Independent variables	Street 1	Street 2	Street 3	Street 4	Street 5
Urban quality measurement index	2.62	2.84	1.84	3.29	2.63

4.2.3 Preference survey of visual variety of streets

A subjective survey was done taking the greyscale images of 5 streets and pedestrian perception for the degree of visual variety of each street was recorded. Since the objective of the research is to explore the potential link between independent variables of urban design quality, complexity of streetscape measured by its fractal dimension and the perception of preference towards streetscapes, it was decided to use a multi item measure of visual quality of each street image.

This survey is based on the methodology adopted by Cooper et al (2010) that had the assessment of visual quality by measurement of 7 items. These 7 items were refined and modified to suit the present research question and conceptual framework. It was decided to remove the item ‘complexity’ from the survey as the survey results from Cooper et al (2010) were opposing the results of Taiwanese participants of Cooper and Oskrochi (2013). In the 2010 survey complexity was perceived as a positive contributor to visual variety of a street image, whereas in 2013 survey by Cooper and Oskrochi (2013) the response from Taiwanese participants suggested that they perceived ‘complexity’ as a negative contributor to visual variety. To avoid this ambiguity, it was decided to remove the perception of complexity from the multi-item measurement.

Another new indicator ‘mystery’ considered as a predictor of preference indicated by Kaplan (1987) was added to the survey questions. From the literature review it was found that scenes with more vegetation was preferred more than the scenes with more built environment because of the fact that they revealed more information by moving deeper into the scene. This predictor of preference was named ‘mystery’ by Kaplan (1987). Other predictors suggested by him were coherence; legibility and complexity have been incorporated already by Cooper and Oskrochi (2013) in their multi-item measure of visual quality for preference survey.

The only differences from the Cooper and Oskrochi (2010) survey were that larger sample of participants were included and the seven perception attributes were refined. This survey was partially self-administered and partially filled in over the internet, which included 100 respondents from Rotterdam ages 21-65 years, 35.4% respondents were male and 63.6% female out of which 58.6% respondents came from architecture or urban planning background. The questionnaire comprised of an introduction about the survey and a display of the 5 images of 5 streets of Rotterdam. The respondents were asked to take time and look at the 5 images together and in comparison with each other. Then they were asked to rate each image based on 7 questions related to 7 attributes with bipolar paired adjectives to set the scoring boundaries. They were asked to answer each question on a 5 point Likert scale, and after answering the perception questions, they were asked to answer a set of general question related to age, period of stay in Rotterdam, their familiarity with the city and their background in architecture or urban planning. A pilot survey was undertaken to assess the validity and practicality of the method and then the final questionnaire was circulated.

The descriptive analysis of all the responses for each street was analysed using statistical software SPSS. The results of each street are discussed in the next section.

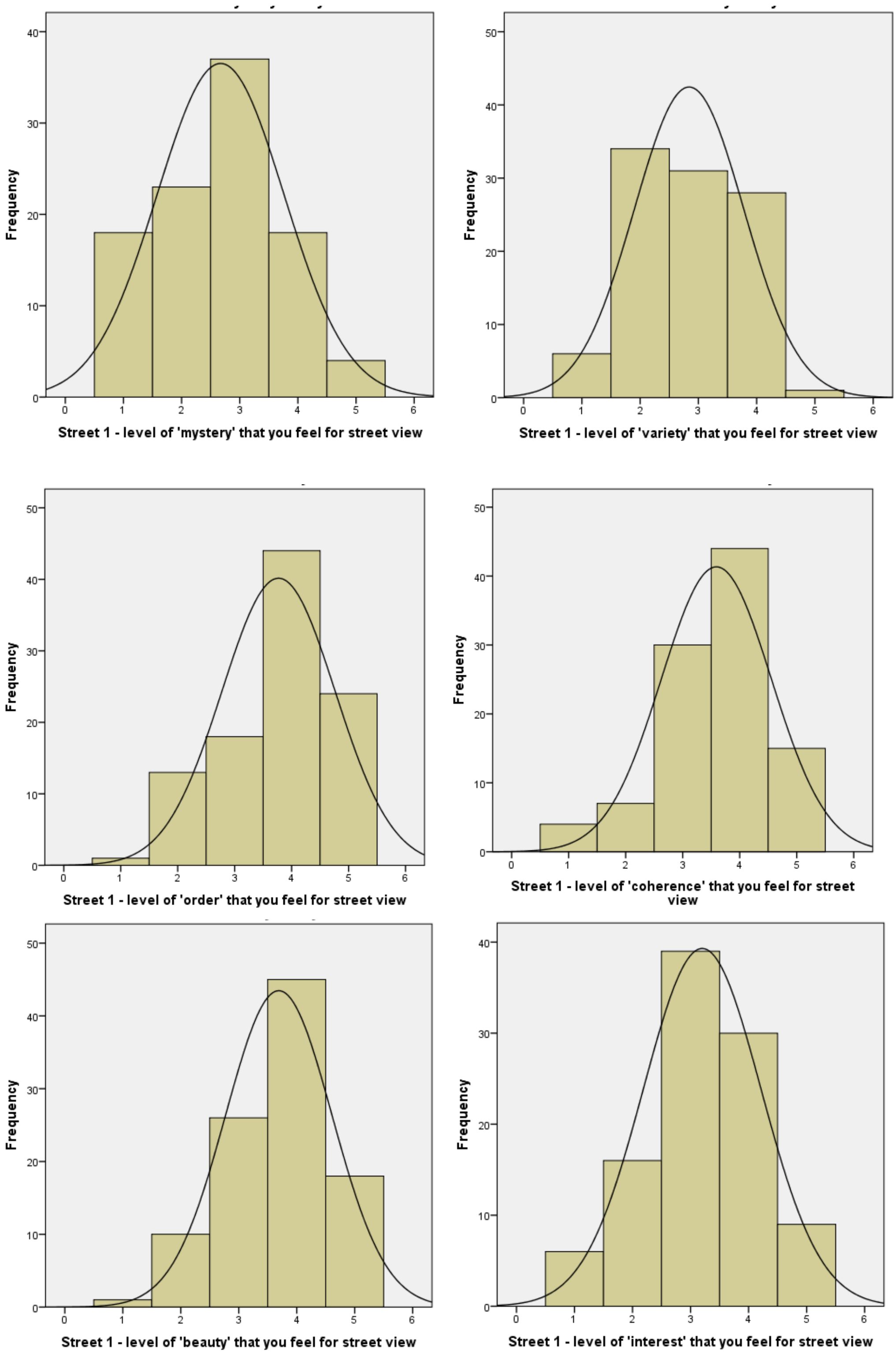
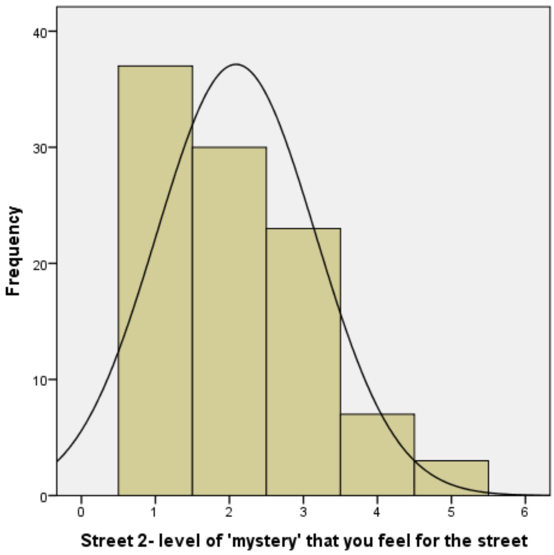


Figure 24: Street 1 -frequency distribution of the 7 predictors of preference, Source: Author

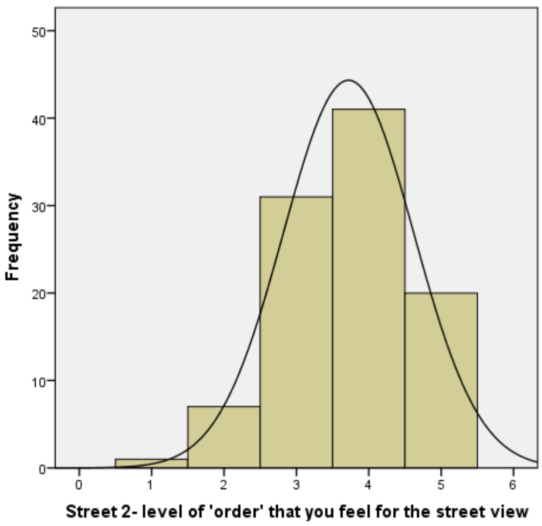
Table 6: Descriptive Statistics of street 1, Source: Author

		Street 1 - level of 'mystery'	Street 1 - level of 'variety'	Street 1 - level of 'order'	Street 1 - level of 'coherence'	Street 1 - level of 'beauty'	Street 1 - level of 'interest'	Street 1 - level of 'preference'
N	Valid	100	100	100	100	100	100	100
	Missing	0	0	0	0	0	0	0
Mean		2.67	2.84	3.77	3.59	3.69	3.20	3.29
Median		3.00	3.00	4.00	4.00	4.00	3.00	3.00
Mode		3	2	4	4	4	3	3
Std. Deviation		1.092	.940	.993	.965	.918	1.015	1.038

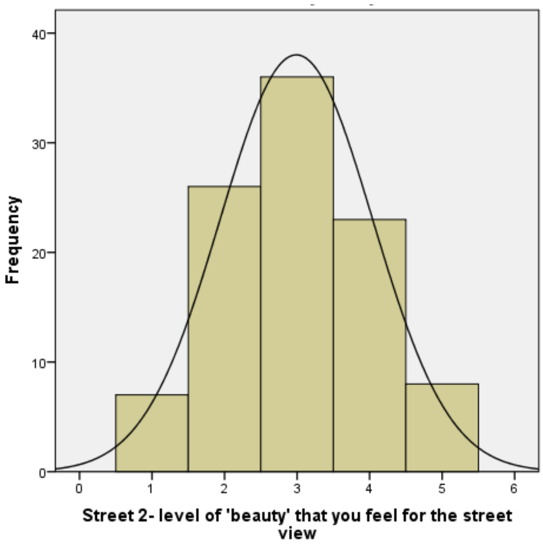
The results of Street 1 showed that maximum respondents rated the mystery as 3 out of 5and mean score was 2.67. The level of variety was given the rating 2, 3 and 4 by maximum number of respondents with mean of 2.84 while level of order and coherence was rated 4 (mean 3.77 and 3.59). Large number of respondents rated the beauty, interest and preference as 3 and 4 with mean scores of 3.69,3.59 and 3.20 respectively. Thus the ratings were on the higher side by most of the respondents for visual variety of street 1.


Frequency
Street 2- level of 'mystery' that you feel for the street


Frequency
Street 2- level of 'variety' that you feel for the street view


Frequency
Street 2- level of 'order' that you feel for the street view


Frequency
Street 2- level of 'coherence' that you feel for the street view


Frequency
Street 2- level of 'beauty' that you feel for the street view

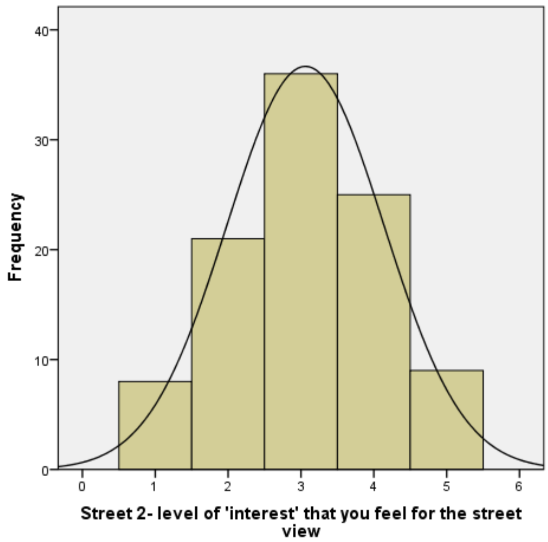

Frequency
Street 2- level of 'interest' that you feel for the street view

Figure 25: Street 2 -frequency distribution of the 7 predictors of preference, Source: Author

Table 7: Descriptive Statistics of street 2, Source: Author

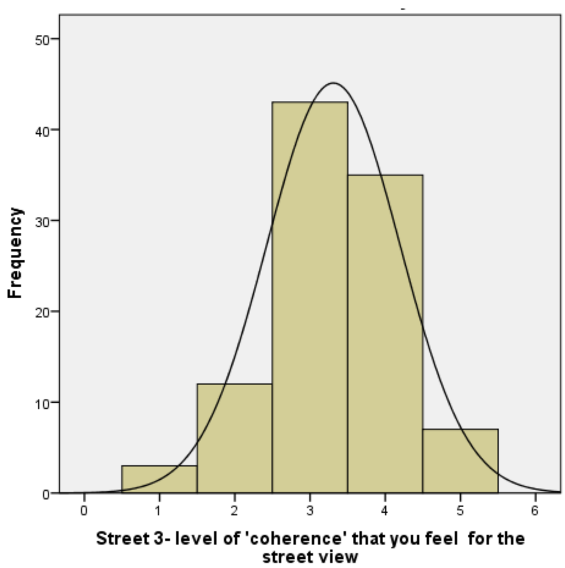
		Street 2- level of 'mystery'	Street 2- level of 'variety'	Street 2- level of 'order'	Street 2- level of 'coherence'	Street 2- level of 'beauty'	Street 2- level of 'interest'	Street 2- level of 'preference'
N	Valid	100	100	100	100	100	99	100
	Missing	0	0	0	0	0	1	0
Mean		2.09	2.94	3.72	3.47	2.99	3.06	3.14
Median		2.00	3.00	4.00	3.00	3.00	3.00	3.00
Mode		1	4	4	3	3	3	3
Std. deviation		1.074	1.062	.900	.858	1.049	1.077	1.054

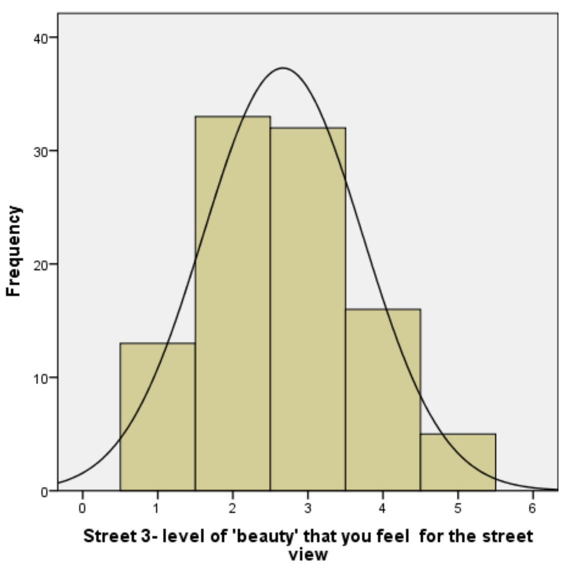
Street 2 was scored less than street 1 on most of the parameters. The mean scores on the level of order were above the other scores. It fared low on coherence, beauty, interest and preference.


Frequency
Street 3- level of 'mystery' that you feel for the street view


Frequency
Street 3- level of 'variety' that you feel for the street view


Frequency
Street 3- level of 'order' that you feel for the street view


Frequency
Street 3- level of 'coherence' that you feel for the street view


Frequency
Street 3- level of 'beauty' that you feel for the street view


Frequency
Street 3- level of 'interest' that you feel for the street view

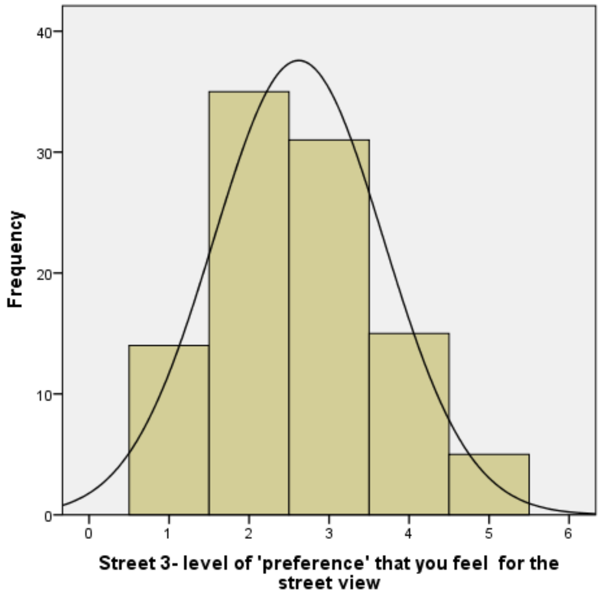


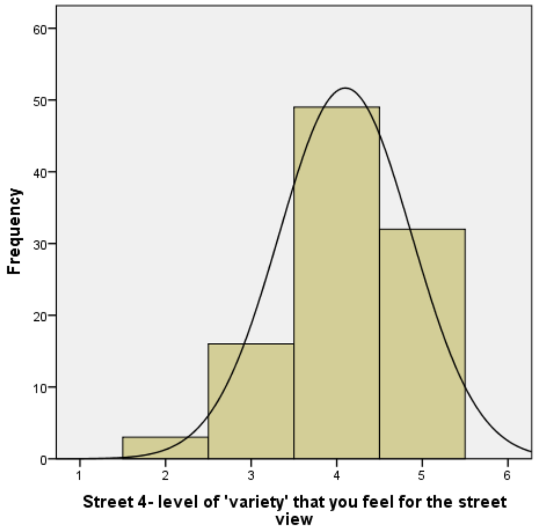
Figure 26: Street 3 -frequency distribution of the 7 predictors of preference, Source: Author

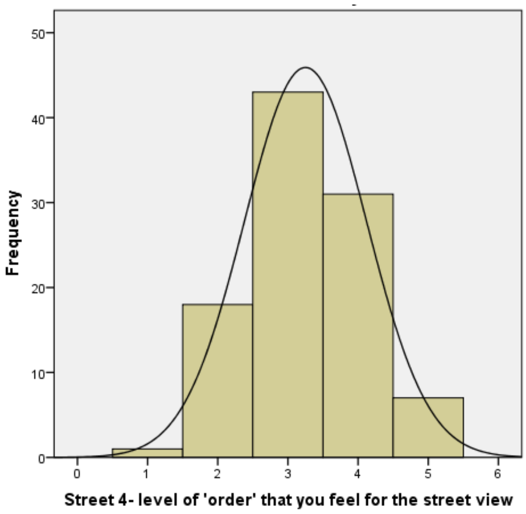
Table 8: Descriptive statistics of street 3, Source: Author

		Street 3- level of 'mystery'	Street 3- level of 'variety'	Street 3- level of 'order'	Street 3- level of 'coherence'	Street 3- level of 'beauty'	Street 3- level of 'interest'	Street 3- level of 'preference'
N	Valid	100	100	100	100	99	100	100
	Missing	0	0	0	0	1	0	0
Mean		2.76	2.38	3.55	3.31	2.67	2.53	2.62
Median		3.00	2.00	4.00	3.00	3.00	2.00	3.00
Mode		3	2	4	3	2	2	2
Std. deviation		1.147	0.940	.936	.884	1.059	1.058	1.062

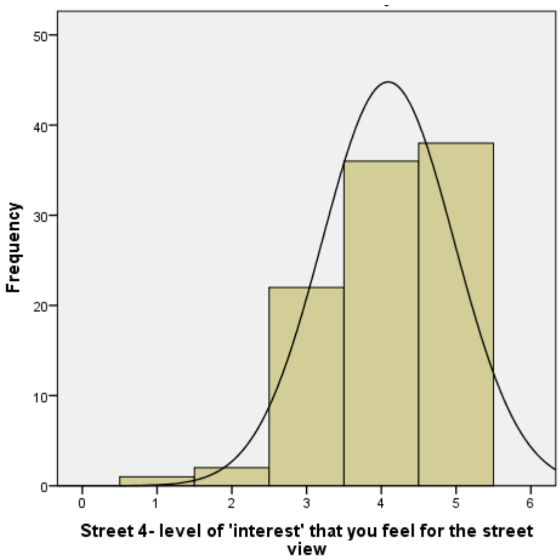
The street 3 scored low on all the parameters than street 2 except for mystery in which it scored slightly higher. It is important to reiterate here that this street scored the lowest in urban design qualities and fractal dimension as well.


Frequency
Street 4- level of 'mystery' that you feel for the following street


Frequency
Street 4- level of 'variety' that you feel for the street view


Frequency
Street 4- level of 'order' that you feel for the street view


Frequency
Street 4- level of 'coherence' that you feel for the street view


Frequency
Street 4- level of 'interest' that you feel for the street view


Frequency
Street 4- level of 'beauty' that you feel for the street view

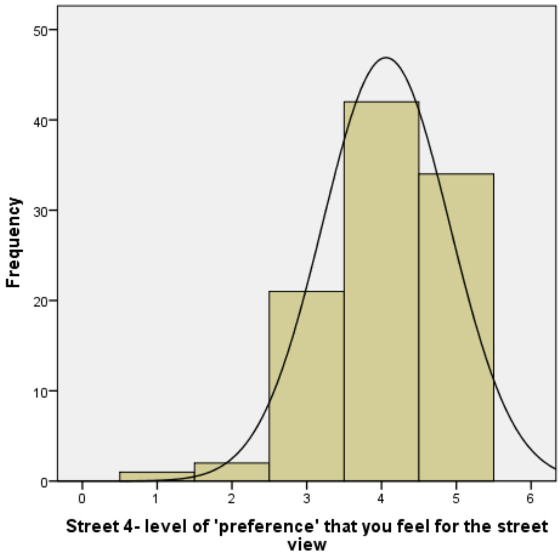
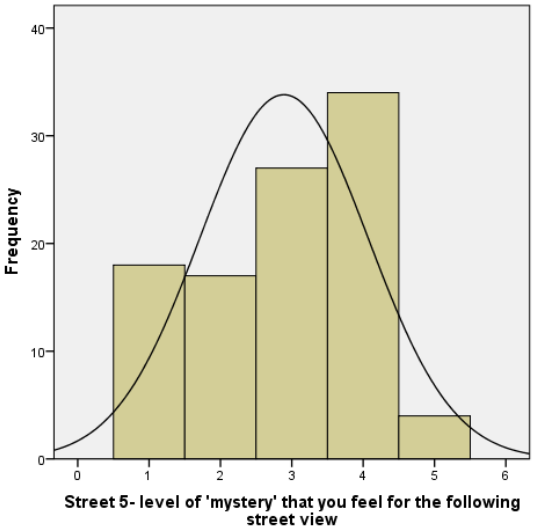


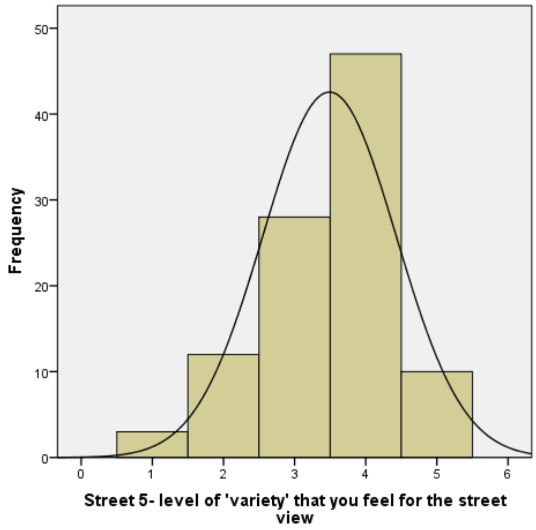
Figure 27: Street 4 -frequency distribution of the 7 predictors of preference, Source: Author

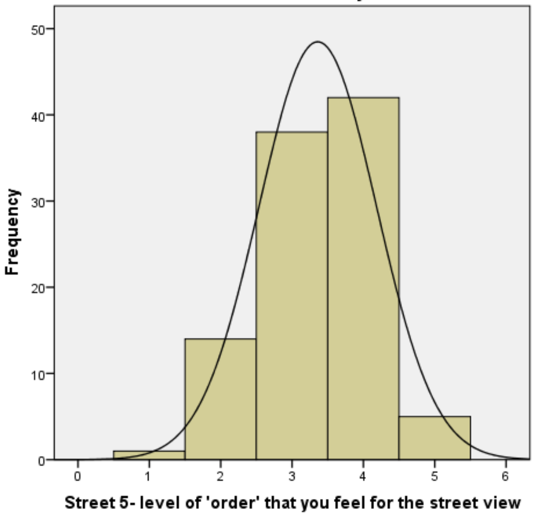
Table 9: Descriptive statistics of street 4, Source: Author

		Street 4- level of 'mystery'	Street 4- level of 'variety'	Street 4- level of 'order'	Street 4- level of 'coherence'	Street 4- level of 'beauty'	Street 4- level of 'interest'	Street 4- level of 'preference'
N	Valid	100	100	100	100	100	99	100
	Missing	0	0	0	0	0	1	0
Mean		2.95	4.10	3.25	3.51	4.00	4.09	4.06
Median		3.00	4.00	3.00	4.00	4.00	4.00	4.00
Mode		4	4	3	4	4	5	4

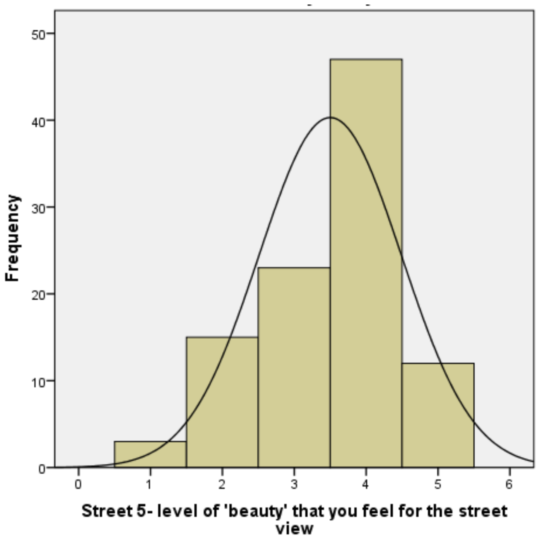
The mean scores of street 4 shows that it was rated higher than all other streets on almost every parameter. This result is consistent with the higher rating in urban design qualities and highest fractal dimension value among the 5 streets


Frequency
Street 5- level of 'mystery' that you feel for the following street view


Frequency
Street 5- level of 'variety' that you feel for the street view


Frequency
Street 5- level of 'order' that you feel for the street view


Frequency
Street 5- level of 'coherence' that you feel for the street view


Frequency
Street 5- level of 'beauty' that you feel for the street view


Frequency
Street 5- level of 'interest' that you feel for the street view

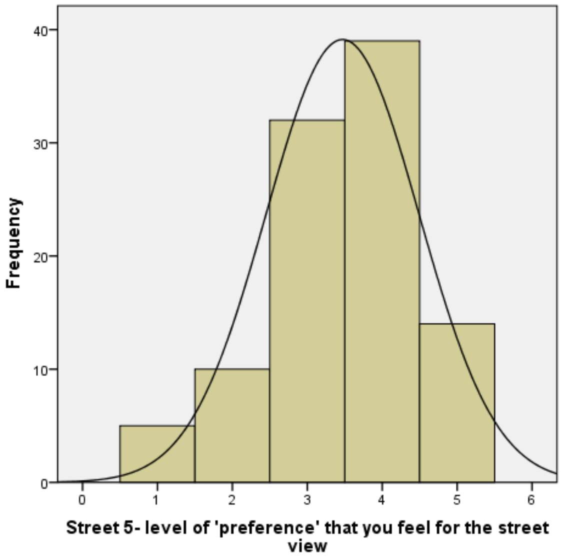


Figure 28: Street 5 -frequency distribution of the 7 predictors of preference, Source: Author

Table 10: Descriptive statistics of street 5, Source: Author

		Street 5- level of 'mystery'	Street 5- level of 'variety'	Street 5- level of 'order'	Street 5- level of 'coherence'	Street 5- level of 'beauty'	Street 5- level of 'interest'	Street 5- level of 'preference'
N	Valid	100	100	100	100	100	100	100
	Missing	0	0	0	0	0	0	0
Mean		2.89	3.49	3.36	3.37	3.50	3.46	3.47
Median		3.00	4.00	3.00	3.00	4.00	4.00	4.00
Mode		4	4	4	3	4	4	4
Std. Deviation		1.180	.937	.823	.812	.990	.979	1.020

Street 5 scored a little lower than street 4 in all the parameters. It is important to note here that the respondents preferred it more than it was expected from the urban design quality scores and the fractal dimension.

For each street if the combined values of the preference were to be computed using the mean mystery, variety, order, coherence, beauty, interest and preference; street 1 would score 3.396 ; street 2 would score 3.22; street 3, 2.906 ; street 4, 3.835; street 5, 3.441.

Table 11: Fractal dimension, urban quality measurement index and visual quality combined value computed , Source: Author

Independent variables	Street 1	Street 2	Street 3	Street 4	Street 5
Fractal dimension	1.67	1.53	1.5	1.64	1.65
Urban quality measurement index	2.62	2.84	1.84	3.29	2.63
Visual quality measurement	3.396	3.22	2.906	3.835	3.441

Following the methodology of Cooper and Oskrochi (2010), a combined unit as an assimilation of all the parameters of perception of visual quality was formed and named VQM. The Chronbach's α was calculated to assess the degree to which a combined value of VQM be used to indicate the perceived visual quality of each street by the respondents.

4.2.3.1. Assessing the validity of VQM

By calculating the Chronbach's α , it is ascertained whether and how much a combined value reflecting a concept relates to set of measured items such as mystery, variety, order, coherence, beauty, interest and preference. In this case the Chronbach's α coefficient of 0.845 between 7 measured items and shows a very high consistency between them. Thus they can be merged into one single unit of VQM, visual quality measurement.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Street 5- level of 'mystery' that you feel for the following street view	20.65	19.462	.291	.314	.880
Street 5- level of 'variety' that you feel for the street view	20.05	17.987	.632	.526	.819
Street 5- level of 'order' that you feel for the street view	20.18	19.987	.438	.511	.845
Street 5- level of 'coherence' that you feel for the street view	20.17	19.294	.551	.525	.831
Street 5- level of 'beauty' that you feel for the street view	20.04	16.463	.802	.769	.791
Street 5- level of 'interest' that you feel for the street view	20.08	16.579	.797	.761	.793

Street 5- level of 'preference' that you feel for the street view	20.07	16.248	.803	.769	.790

Figure 29: Table showing the Chronbach's alpha when an item is deleted, Source: Author

The above table shows that all the coefficients are higher than 0.7 and none of the items need to be deleted.

4.2.3.2. Assessing the demographic effect of the respondents on perception survey

The demographic effect of respondents on the perception survey was checked by conducting a T-test. A T-test is used to assess if the mean scores of a scale variable, here, visual variety perception mean score are equal for the two groups (that is for group of women and men, group of people having a background in architecture or urban planning). A T-test is done by dividing the group mean by the variability of groups. The results show that gender and background of people (those received architectural training or not) are not significant with p-values of 0.393, t=0.857 and p=0.134, t= -1.510; respectively. This means that the perception of visual variety measurement, VQM does not depend on the gender and background of the respondent.

4.3. Association between FD and VQM scores

The main question of the study is how strongly do fractal dimension and urban quality associate with the perception of visual variety of streetscapes in Rotterdam. This can be found out by establishing relationships between fractal dimension and visual variety perception. This has been done by carrying out the correlation tests between these variables and then carrying out linear regression which shows how much change happens in dependent variable when the independent variable changes by one unit.

Table 12: Correlation between fractal dimension and preference towards visual variety of streetscapes, Source:Author

		FD	Level of mystery	Level of variety	Level of order	Level of coherence	Level of beauty	Level of interest	Level of preference
FD	Pearson correlation	1	.119**	.312**	-.067	.053	.398**	.317**	.300**
	Sig. (2-tailed)		.008	.000	.135	.239	.000	.000	.000
	N	501	493	494	493	493	490	491	493

The above table shows the correlation between fractal dimensions and the seven visual variety indicators. The fractal dimension shows moderate positive correlation with visual variety indicators of ‘variety’, ‘beauty’, ‘interest’ and ‘preference’ with Pearson’s **r** of 0.312**, 0.398**, 0.317**, and 0.300** respectively.

		VQM (visual quality measurement)	FD of all 5 streets
VQM (visual quality measurement)	Pearson Correlation	1	.322**
	Sig. (2-tailed)		.000
	N	501	501
FD of all 5 streets	Pearson Correlation	.322**	1
	Sig. (2-tailed)	.000	
	N	501	501
**. Correlation is significant at the 0.01 level (2-tailed).			

When the visual variety indicators are combined together in a single unit of VQM and correlated with fractal dimension and urban quality index, it shows moderate positive correlations with Pearson's **r** of 0.322** with fractal dimension of streets.

Table 13: Linear regression coefficient computed between fractal dimension and visual variety index, Source: Author

Coeff. [a]	Unstandardized Coefficients		Standardized coefficients	t	Sig.	95.0% confidence interval for B		Correlations		
	B	Std. Error	Beta			Lower bound	Upper bound	Zero-order	Partial	Part
(Constant)	-2.149	.712		-3.02	.00	-3.547	-.751			
FD	3.378	.445	.322	7.59	.00	2.504	4.252	.322	.322	.322
a. Dependent variable: overall visual variety preference- VQM										

The above table shows the linear regression unstandardized coefficient ***b*** of 3.378** between fractal dimension and visual variety measurement. The correlation and linear regression models are run without urban design quality index as independent variable with fractal dimension. <u>This done to show the independent of the relationship between fractal dimension and visual variety as the method followed to capture the urban design quality is different from that of preference survey for visual variety</u>. <u>Thus may involve extra items captured in the urban design quality assessed through video study of the streets rather than just looking at the static images of the streets reflected in the fractal dimension and visual quality perception survey.</u>

Dependent variables	**Independent variable - Fractal dimension**
Overall Visual variety preference	B =3.378,b=0.322 Sig= 0.000
Mystery	B = 2.097,b= 0.119, Sig= 0.008
Variety	B = 5.025,b= 0.312, Sig= 0.000
Order	B = -0.911,b= -0.067, Sig= 0.135
Coherence	B = 0.693,b= 0.053, Sig= 0.239
Beauty	B =6.267,b=0.398, Sig= 0.000
Interest	B =5.181,b=0.317, Sig= 0.000
Preference	B =4.839,b=0.300, Sig= 0.000

** B= un-standardized coefficient, b= standardized coefficient, Sig= significance level

The linear regression with fractal dimension and urban design quality was run to see which indicators of visual variety showed positive relationship with them. From the above table it is evident that 'order' and 'coherence' do not show significant relationship with fractal dimension. 'Variety', 'interest', 'preference', 'beauty' and mystery' indicators on the other hand show significant relationship with fractal dimension.

4.4. Association of UQM with FD and VQM score

Table 14: Fractal dimension, urban quality measurement index and visual quality combined value computed, Source: Author

Independent variables	Street 1	Street 2	Street 3	Street 4	Street 5
Fractal dimension	1.67	1.53	1.5	1.64	1.65
Urban quality measurement index	2.62	2.84	1.84	3.29	2.63
Visual quality measurement	3.29	3.058	2.83	3.70	3.36

The above table shows fractal dimension for all the five streets, measured by converting the street images to edge detected binary images and feeding into fractalyse software. The urban quality measurement index was computed for every street by taking out mean values of imageability, enclosure, human scale and transparency for each of them elaborated in section 4.2.2. Visual quality measurement unit is the new combined variable that was computed in SPSS by taking the average of best six out of the scores of mystery, variety, order, coherence, beauty, interest and preference scores given for each street. Then the mean values of VQM for each street were taken out by carrying out descriptive statistics in SPSS.

The independent variable of fractal dimension has already been correlated with visual quality measurement index and found to have a significant positive relationship with it. Urban quality index can be now be qualitatively analyzed with fractal dimension and visual quality of each street. It is important here to reiterate the fact that it was not possible to carry out statistical analysis with urban design quality measurements as they were assessed on the basis of videos of streets whereas the visual variety preferences and fractal dimensions were based on static images. Thus they cannot be compared using correlation and regression tests, however qualitative comparisons can be drawn as the values of urban design quality for each street has been computed.

When the urban quality measurement for all the 5 streets are put adjacent to the corresponding fractal dimensions and the visual quality scores, it is seen that the lowest fractal dimension corresponds with a low score on urban quality and similarly a low score on visual quality measurement. The street 4 with high fractal dimension also scored high among the 5 streets in urban quality and visual quality preference. The increase of urban quality has resulted in an increase in fractal dimension and thereby an increase in perception of visual variety. This can be explained by elaborating on the components of the street image that are reflective of the physical characteristics of the street. As also explained earlier through the literature of Ewing and Handy (2009), that it is the physical characteristics of the street environment that contribute to the abstract and subjective urban design qualities. The streets with higher scores on fractal dimension and urban design quality showed buildings that could be identified easily which means having striking features, large presence of outdoor dining, greater proportion of historic buildings, greater number of people in pedestrian area. These streets also displayed less uniformity in building facades making the buildings adjacent to pedestrian walking area more amorphous and heterogeneous in nature. Such streets did not display long straight lines in facades, rather broke them. Streets with higher enclosure rating meant more number of trees coving the sky which also increases the fractal dimension of the streets. The streets with more number of closely spaced large trees resulted in higher fractal dimension of streets and are more preferred by people. The more the amount of street furniture and planters which are components of effectively designed streets for pedestrians relating to the scale of the pedestrians; the more is its fractal dimension and the better it is preferred by pedestrians. A street with large number of windows in the ground floor which is often a characteristic of commercial activity in the streets is more preferred by the pedestrians due to its human scale and transparency. Lastly the larger the amount of active uses perceived by pedestrians from the street, the more enjoyable and attractive it becomes and thus is preferred more. The urban design quality scores reflect positive association with fractal dimension among the 5 streets studied and can further be developed in subsequent research in this field to enable statistical correlations to be computed.

4.5 Inferences from statistical analysis

Pearson's correlation test and linear regression was carried out between fractal dimension and the perceived visual quality preference for streetscapes in Rotterdam. Only commercial streets were assessed in this study. These were five streets from the city centre and peripheral neighbourhood commercial areas thereby showing varying levels of urban design quality. The widths of these streets were also varying. This resulted in images of 5 streets taken up for the study which showed different proportional compositions of buildings, trees, sky, activities, street furniture. The range of fractal dimension that the 5 images of the selected streets displayed was less, 1.5 to 1.67, owing to the same nature of the streets. Also, it is evident from the street images that street 1 had proportionally large amount of trees and green areas covering the image, with strong shadows falling on the road. This resulted in abnormally high fractal dimension of street 1. Street 5 also displayed a similar outcome in terms of fractal dimension owing to larger trees that were nearer to the photographer when the image was taken. However, the street with the higher fractal dimensions were street 1 ,4 and 5 with very little difference, while street 2 and 3 displayed lower fractal dimension. Similarly, the preference scores of visual variety of streetscapes perceived by the pedestrians were higher for street 4, 5 and 1 and quite low for street 3 and 2. Pearson's correlation showed significant moderate positive correlation of fractal dimension with the perception of visual variety with a coefficient **r** of 0.322**.

The linear regression is a method to test if there is a significant linear relationship between two variables measured in an interval scale given by the formula y=c+b*x, where y is the dependent variable, c is the constant of graph line on an xy plot (the point at which the line crosses the vertical axis of the graph), b is the gradient or the regression coefficient. With the help of linear regression a line is plotted on the graph that best describes the data collected and estimates the gradient. In this case the B or unstandardized regression coefficient is found to be significant and the value of 3.378. This implies that a 1unit change in fractal dimension can result in a 3.378 times change in visual variety preference for a streetscape.

The above inference can be tested again through the values of fractal dimension of each street and its corresponding VQM value. There is a difference of 0.11 unit between the fractal dimension of street 2 (FD=1.53) and street 4 (FD=1.64). Thus the visual variety preference should increase by 0.3378, putting the values of constant, x (FD) = 1.53 we get the y (VQM) of 3.05 which is same as the value got from the preference survey. Similarly putting the value of x (FD) of 1.64, we get y (VQM) of 3.5 which is almost equal to 3.7.

Chapter 5: Conclusion and recommendations

This chapter entails the summary of the findings in terms of answers to the research questions, the interpretation of the results, and relevance of this research to the academic field and includes the recommendation on future research it may give rise to.

The main aim of this research was to delve into the relationship between visual variety and perception of visual quality. It was uncovered that in the field of urban design and environmental psychology, this topic has been researched from the angle of level of complexity, linking fractal character of the streets to the pedestrian perception, what makes for more complex looking streets. Through literature review it was known that both content and complexity of the urban street is an effect of the urban design qualities made up by the physical features of space. Thus this research has tried to take a step further and find out the influence of the effect of urban design qualities together with visual complexity measured in terms of fractal dimension on the visual preference of pedestrians.

The main hypothesis here is that there is a positive linear relationship between urban design qualities of a street and the visual preference towards the street. This means that streets with better urban design qualities are preferred more for their visual variety than the streets that score less on urban design qualities. Also, visual complexity of a street measured in terms of fractal dimension is a resultant of the physical components that make up street which is also explains the urban design quality of the street. Thus there is a positive relationship between visual complexity and urban design quality as well.

The main research questions of the study are what are the urban design qualities and how can they be measured, which physical aspects of the streets influence the preference of people towards that street and what is the proportion of effect both urban design quality and visual complexity have on the preference of people.

Urban design qualities and their measurement- As discussed in the literature review of this study, there are five urban design qualities that have been successfully operationalized by Ewing and Handy (2009) and have been adopted for this research. These are imageability, enclosure, human scale, transparency and complexity. The operationalization of these qualities involved measuring of the physical characteristics of the street that make up the subjective urban design qualities. Imageability for instance was measured in terms of number of people occupying the pedestrian space on the street, proportion of historic and thereby identifiable buildings on both sides of the street, presence of courtyards or plazas or parks, outdoor dining, iconic buildings and presence of landscape features. All these physical characteristics can be easily measured on a likert scale in comparison to other streets. For the purpose of this study all the parameters to measure all the urban design qualities were studied by the researcher by capturing videos of the streets and placing them side by side to rate them. Ideally this should have been done by an expert group, where each expert in the field of urban design could have given ratings to the five streets on these urban design qualities. Due to the length of the research this was not possible. Thus a physical survey was carried out by the researcher to rate the streets on the urban design qualities. Other urban design qualities such as enclosure was measured by proportion of street walls on both the side of the streets, proportion of sky, presence of long sight lines. All these components form a street view. Different proportions of which give the impression of narrow, long, street or wide, interesting street thereby influencing the preference of people walking in it. On the other hand, human scale is a quality measured by the absence of long straight lines, amount of street furniture and miscellaneous items on the street, proportion of ground floor with windows, number of low height buildings that correspond more to the human scale and the number of planters as a part of the street design. These elements make the street more humane and pleasant to walk in. They also help in creating interest for the pedestrians, giving them more items to appreciate and record in their subconscious mind while walking or carrying out other activities on a particular street. Lastly, transparency is a quality measured in terms of proportion of ground floor with windows, amount of active uses on the street perceivable by the pedestrians and proportion of street wall. All these characteristics help in revealing the activities happening within the built spaces on both the sides of the street. The better informed the pedestrians are of the activities, the more interesting and preferable the street becomes.

The qualitative comparison done between urban design qualities measured and the visual preference of people revealed certain physical aspects of streetscape that influence the preference. Statistical correlation, of course, is the only method to confirm this relationship but as stated earlier this could not be done because of difference in the basis of measurement of urban design qualities and fractal dimension and preference of people. The urban design qualities were rated based on the videos of streets and fractal dimension as well as the preference survey was done using black and white images of the same 5 streets. However, the qualitative comparison done revealed that those streets that had more number of street furniture, entire ground floor with transparent windows, more landscaped street sides, lesser proportion of sky visible through buildings and street trees, those streets had higher fractal dimension and were preferred more than the others. This can be further confirmed with literature. In the research by Cooper, Su, et al. (2013), on the relationship between fractal dimension, vegetation and perception of streetscape quality in Taipei, vegetation was found to be critical element of the composition of the street with positive and significant correlation with perceived variety, preference, interest and beauty of the street. This means that streets with more vegetation judged the views as varied, likeable, interesting and beautiful. On the other hand, the presence large proportion of sky in the composition of the street image was found to have negative correlation with the perception of visual variety, order, coherence and complexity. One way in which this study differs from the study by Cooper, Su, et al. (2013), is that street furniture along with railings, vehicles, signage was found to have negative correlation with order, coherence and beauty. In this study, street furniture has been found to have positive effect on the fractal dimension and the preference of the pedestrians. This will again have to be confirmed using statistical analysis in further research.

Urban design quality and visual complexity affect on the preference of people- The main finding of the research has been the positive correlation found between fractal dimension of the streets and visual preference towards them. Fractal dimensions of the streets were taken out by first taking photographs of the five streets to be studied. These images were then processed in Photoshop software to convert them into edge detected binary images that could be recognized by Fractalyse software to compute their fractal dimension. The images were taken from different commercial streets within the city of Rotterdam ranging from city center commercial area to peripheral neighbourhood commercial areas. The fractal dimensions corresponding to the five streets displayed a limited range from 1.5 to 1.67. The Pearson's correlation test and linear regression with visual preference data for the streets showed moderate positive correlation. A wide range of fractal dimensions of the streets with corresponding preference data would have resulted in a strong positive correlation between the two variables as was seen in the study by Cooper and Oskrochi (2010), where strong positive correlation was found between mean VQM of each street and fractal dimension of all the images of that street. It is important to note here that the number of streets studied were ten in number with ten images captured for each of them. Thus the range (between 1.262 to

1.737) of fractal dimensions computed was large and strong positive correlation was found between both the variables. Fractal dimension has been found to be greatly affected by the presence of vegetation and there are many studies that concur with the presence of this relationship. From the study by Cooper, Su, et al. (2013), it was concluded that in the context of Taiwan vegetation strongly affected the perception of people; meaning that streets with higher level of vegetation was preferred more than the streets that were dominated by built mass. It was also found through this study that street 1 inspite of scoring low in other parameters of urban design quality displayed a higher fractal dimension than others due to the presence of large trees covering the sky and presence of strong shadows cast on the street. This street was preferred less than the street 4 that got high ratings in both urban design quality and fractal dimension. Unusually high fractal dimension of street 1 was the resultant of large trees covering the sky which was much larger in proportion to other streets and the presence of very strong shadows on the street. Thus such images that display anomalies should not be used for comparative statistical study.

Recommendations- An attempt was made with this study to relate the subjective urban design qualities to the visual complexity and visual preference of pedestrians for streetscapes. This was done by using the five qualities operationalized in terms of physical characteristics of the street. At this point the methodology of the research needs to be tweaked so that the basis of collecting data from the urban streets remains constant and thus comparable. This can be carried forward in two ways. One way is to interview the pedestrians walking on the streets, those that have the knowledge of the full length of the street, to give their preference for the street. This can then be statistically correlated with the urban design quality measurements made using videos. The other way is to carry out all the collection of data using just the street images. This would imply not only taking out the fractal dimension and carrying out the preference survey based on street images but also quantifying only those predictors of urban design quality that can be easily quantified by looking at the street images. Statistical analysis would yield valid results regarding the relationship between urban design qualities and preferences of pedestrians.

Moreover the link between fractal dimension and the preference of pedestrians and the effect of changes in one reflecting a change in other also means that the change actually takes place in the urban design realm of streets that affects the proportion of built mass and vegetation. Thus studies like this can help urban designers make the urban streetscape more attractive for pedestrians and all other type of users. It makes promotion of visual variety as key element in urban design to induce more public participation, attraction of more commercial activity and more lively social spaces for the urban area. It remains to be seen, however, how this valid relationship is used and employed by urban designers to make the cities more vibrant, pedestrian friendly by altering the urban design qualities and thereby the fractal dimension values to create vibrant streetscape.

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Annex 1: Questionnaire

Rotterdam Streetscape Perception Survey

Hello! This is a quick survey about the streets of Rotterdam. It will approximately take you 5 minutes to complete the survey. It contains 7 questions about 5 different streets in the city illustrated by photographs. Thanks in advance!

This survey is being done to assess the pedestrian perception of preference for streetscapes based on certain urban design qualities and visual variety of streetscape. This survey will help to inform my masters thesis- " The influence of visual variety of streetscape on the preference of pedestrians in Rotterdam". I am pursuing M.Sc. in Urban Management and Development from Institute of Housing and Urban Development Studies, Erasmus University, Rotterdam.

<u>Please take some time to view the street images of Rotterdam:</u>





Street-1 Preference Questions: (on a scale of 1-5)

1. Please indicate the level of 'mystery' that you feel for the following street view
2. Please indicate the level of 'variety' that you feel for street view shown above
3. Please indicate the level of 'order' that you feel for street view shown above
4. Please indicate the level of 'coherence' that you feel for street view shown above
5. Please indicate the level of 'beauty' that you feel for street view shown above
6. Please indicate the level of 'interest' that you feel for street view shown above
7. Please indicate the level of 'preference' that you feel for street view shown above

Street-2 Preference Questions: (on a scale of 1-5)

1. Please indicate the level of 'mystery' that you feel for the following street view
2. Please indicate the level of 'variety' that you feel for street view shown above
3. Please indicate the level of 'order' that you feel for street view shown above
4. Please indicate the level of 'coherence' that you feel for street view shown above
5. Please indicate the level of 'beauty' that you feel for street view shown above
6. Please indicate the level of 'interest' that you feel for street view shown above
7. Please indicate the level of 'preference' that you feel for street view shown above

Street-3 Preference Questions: (on a scale of 1-5)

1. Please indicate the level of 'mystery' that you feel for the following street view

2. Please indicate the level of 'variety' that you feel for street view shown above
3. Please indicate the level of 'order' that you feel for street view shown above
4. Please indicate the level of 'coherence' that you feel for street view shown above
5. Please indicate the level of 'beauty' that you feel for street view shown above
6. Please indicate the level of 'interest' that you feel for street view shown above
7. Please indicate the level of 'preference' that you feel for street view shown above

Street-4 Preference Questions: (on a scale of 1-5)

1. Please indicate the level of 'mystery' that you feel for the following street view
2. Please indicate the level of 'variety' that you feel for street view shown above
3. Please indicate the level of 'order' that you feel for street view shown above
4. Please indicate the level of 'coherence' that you feel for street view shown above
5. Please indicate the level of 'beauty' that you feel for street view shown above
6. Please indicate the level of 'interest' that you feel for street view shown above
7. Please indicate the level of 'preference' that you feel for street view shown above

Street-5 Preference Questions: (on a scale of 1-5)

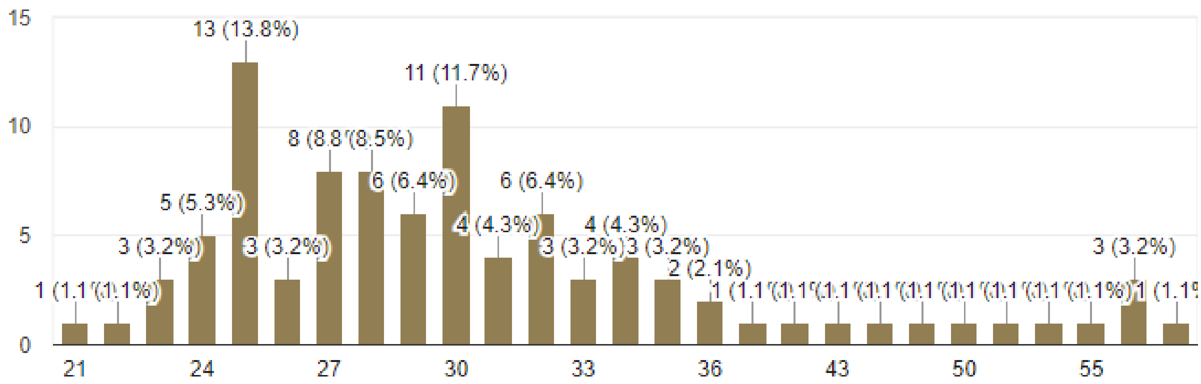
1. Please indicate the level of 'mystery' that you feel for the following street view
2. Please indicate the level of 'variety' that you feel for street view shown above
3. Please indicate the level of 'order' that you feel for street view shown above
4. Please indicate the level of 'coherence' that you feel for street view shown above
5. Please indicate the level of 'beauty' that you feel for street view shown above
6. Please indicate the level of 'interest' that you feel for street view shown above
7. Please indicate the level of 'preference' that you feel for street view shown above

General Questions:

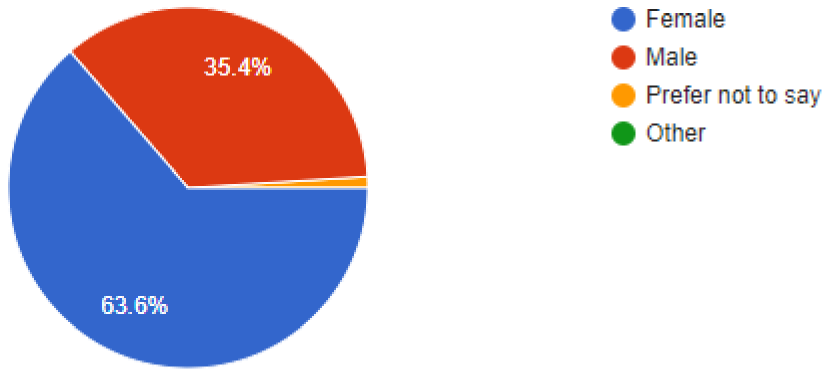
1. Age of respondent
2. Which gender do you identify with? –Male/Female/Prefer not to say/ other
3. What is your current education level?- Secondary Education/ Undergraduate/ Postgraduate/ PhD/other
4. Do you have an architecture/urban planning background?-yes/no
5. How familiar are you with the city of Rotterdam?- (1-5)
6. How long have you been living in Rotterdam?- less than 6 mths, 6mths-1yr, 1-3, 3-5, more than 5 yrs.
7. How would you rate your knowledge on the urban design of Rotterdam?- (1-5)

Responses of general questions:

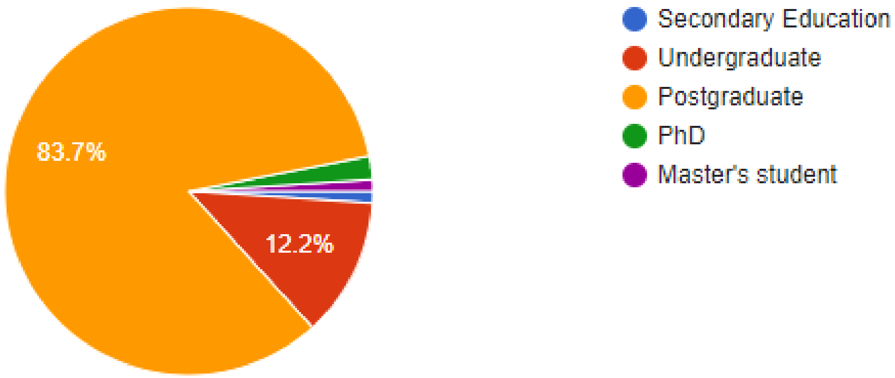
Age



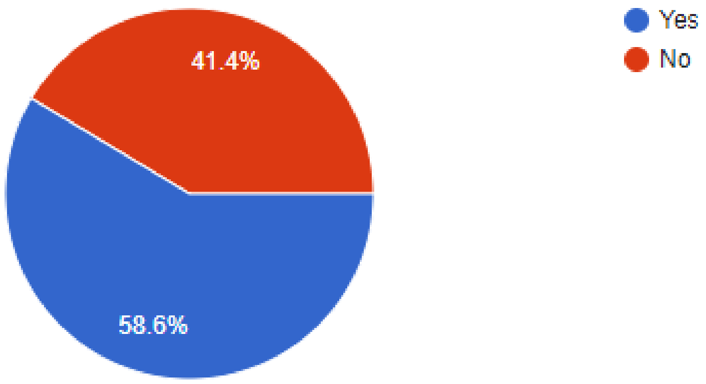
Gender



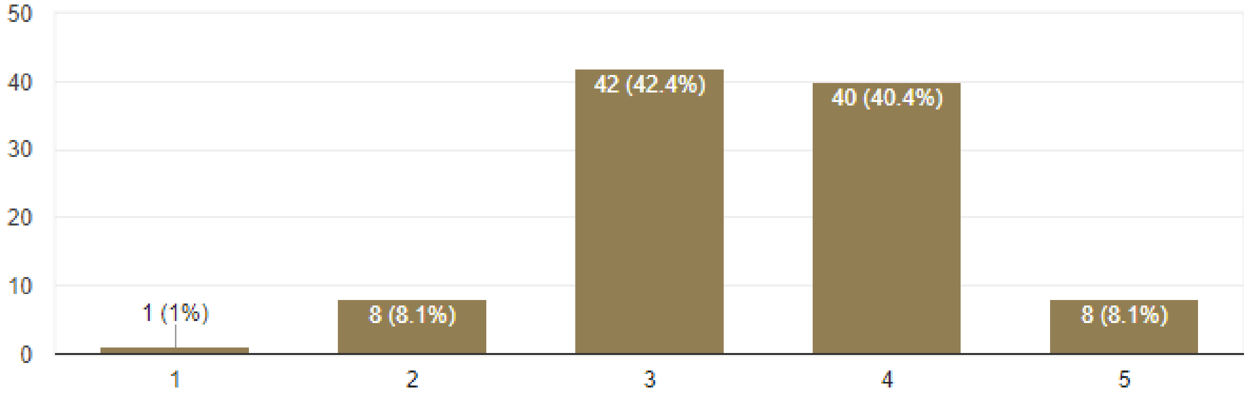
Educational qualification



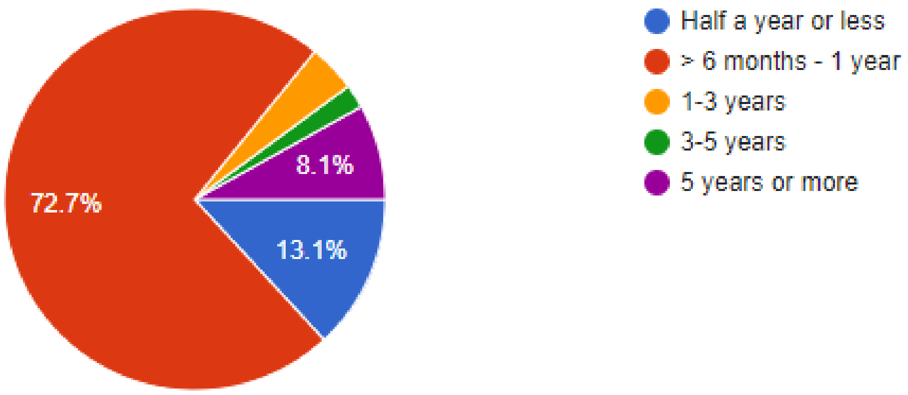
Architecture or urban planning background:



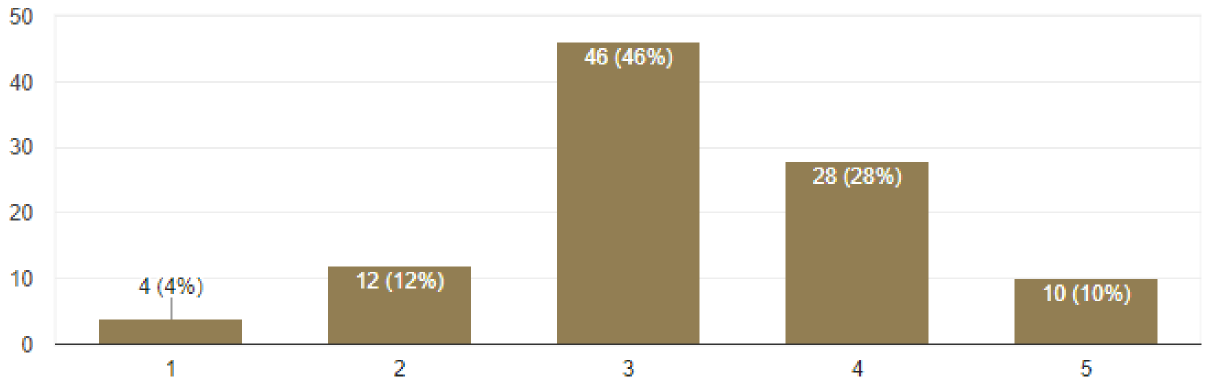
Familiarity with Rotterdam:



Length of stay in Rotterdam:



Knowledge of Rotterdam:



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