THE ROLE OF URBAN FORM IN THE PERCEPTION OF DENSITY

PhD Thesis

by

Madhavi Prashant Patil

Department of Architecture

University of Strathclyde

November 2023

Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

Signed:

Date:

Acknowledgements

I would like to dedicate this work to my late father, Dipak R Thakur, and my late mentor, Prabhakar More. Their unwavering support, counsel, and encouragement have been instrumental in shaping me into the person I am today and without them my thesis would not have been possible.

I would like to express my deepest gratitude to my supervisors Dr Ombretta Romice and Prof Sergio Porta for their invaluable guidance, feedback and support throughout the entire journey of this study. Thank you Ombretta for encouraging me, supporting me and helping me develop my ideas and arguments in meaningful ways and being with me during all my ups and downs. Thank you, Sergio, for challenging me to think critically and add value to the research.

A special thanks to Prof Ashraf Salama for his invaluable guidance and feedback that has been instrumental in shaping my research.

Thanks to Martin Fleishmann, Dalia Aly Gaffar and Preeti Pansare for their never-ending peer support. I also thank Richa Sharma, Sanghamitra Barthakur, Tapan Khopkar to support me in every way throughout this journey. I would also like to thank Salil Sayed and Neha Sayed who encouraged me to embark on this journey.

I would like to express my gratitude to Parimal P More, who has been a source of inspiration and support in both my personal and professional life.

Finally, I would want to express my gratitude to my husband, Prashant, for his consistent support and encouragement during the research and writing process. I would want to thank my daughter Sharvari, whose boundless love and unwavering faith have kept me inspired. I would like to thank my mother for instilling in me a passion for study and a resilient spirit. I would want to thank my cousins Sagar and Apurva, who have helped me throughout my investigation, my aunt and uncle Mr and Mrs Sunita Somwanshi, and my mother-in-law, Jayshree Patil for their support.

Without the contributions and support of all of you, this thesis would not have been possible. Thank you all.

Abstract

Even though urban environments should be consciously designed to foster positive experiences for mental health and well-being, sociability and quality of life, many fail to do so and density, which is much needed, is frequently associated with negative impressions. Individuals experience it differently due to cultural, age and personality variances. The built form, however, is a universal indicator of density that is present everywhere.

Although there are various objective metrics of density that aid in the design and planning of the built environment, there are insufficient methods for recording the subjective sense of density. This study identifies the aspects of the built environment that influence our perception of density while optimising the benefits of density to bridge the gap between the conceptualisation of high-density environments and their subjective interpretation by users.

This study includes both subjective and objective components of density and uses multidisciplinary techniques to conduct field investigations to understand how pedestrians experience built environments. Using psychophysics and the personal construct theory as approaches to map the human perception of density to elicit personal conceptions without introducing researcher bias, two surveys were undertaken. They were intended as short, interactive tasks that are done using a customised web application for the first survey and Qualtrics for the second survey.

This study reaches three conclusions. First, elements of the built environment such as building height, variety of built form, the presence or absence of vegetation, the level of activities and building use influence the perception of density. Second, the contribution of different visual components in the urban environment to the perception of density and determine the percentage representation of each component in high, moderate, and low-density scenarios. Third, visual assessment indexes by developing the quantitative and qualitative database of images representing low, moderate and high levels evaluating environs of different densities.

Contents

Table of Figures

Table of Tables

Abbreviations

HD	**High Density**
MD	Moderate Density
LD	Low Density
CC	City Center (reference location - Glasgow)
EE	East End (reference location - Glasgow)
SE	South End (reference location - Glasgow)
WE	West End (reference location - Glasgow)
GLA	Glasgow
UI	Universal Illustrations
MST	Multiple Sorting Task
SJT	Situation Judgement Task
FAR	Floor Area Ratio
FSI	Floor Space Index

Chapter 1. Introduction

Urban density, often defined as the ratio of total population to a reference area (Rapoport, 1975; Cheng, 2010; Sonne, 2017; Angel, Lamson-Hall and Blanco 2021), is regarded as the most acceptable single measure for describing the density of cities (Angel, Lamson-Hall and Blanco, 2021). We rely on demographic data to derive indicators of sustainability and design urban planning policies. However, the notion of density is multifaceted and has the potential to expose much more complex experiences such as household crowding and over or under-development which can aid in the creation of user-centric, sustainable cities (Rapoport, 1975; Dovey and Pafka, 2016; Angel, Lamson-Hall and Blanco, 2021).

There is a significant amount of theoretical and practical literature on density which illustrates the objective and subjective characteristics of density (Rapoport, 1975; Churchman, 1999). Formulating objective metrics of density continues to be an active field of study since they can aid in the efficient development of a comprehensive strategy (Angel, Lamson-Hall and Blanco, 2021). Research on density, however, demonstrates the negative physiological and psychological impacts on human health and quality of life can be considerable, indicating the importance of its more subjective connotations (Churchman, 1999a). Yet, due to a lack of detailed understanding of user experiences of density, the mitigation measures implemented to address the issue remain largely ineffective or limited (Alexander, Reed and Murphy, 1988; Churchman, 1999b; Cheng, 2010; Lilli, 2013; Emo et al., 2017), necessitating a more rigorous exploration into its subjective components.

1.1 Rationale for the Study

There is a growing interest in the concept of perceived density in the fields of urban design and cognitive psychology, primarily to address a problem with the issues of the perceived comfort of people in high-density developments (Cheng, 2010). Transdisciplinary studies on sustainability indicate that high-density developments are increasingly prevalent and necessary (Neuman, 2005; Jenks et al., 2008; Dempsey, Oliveira, 2021); nevertheless, their positive effects on quality of life are often jeopardised or outweighed by the negative (Jenks, Burton and Williams, 1996;

Sonne, 2017; Berghauser Pont et al., 2021). Despite numerous attempts to reduce these consequences through design considerations, the problem persists. This study investigates how people experience density in urban environments and uses this understanding to retain its benefits whilst minimising its negative perceived connotations. It studies the distinct visual components of urban environments that affect the perception of density in architectural and urban design and planning.

Recent advances in the study of perceived density have highlighted the important role played by several spatial factors in the mitigation of how high density is perceived (Cheng, 2010). The spatial openness index (SOI) for example evaluates the spatial arrangements of urban environments based on their visibility from a reference location (Fisher-Gewirtzman, 2017). Similarly, the sky view factor defines the significance and proportion of visible sky on perspectives of the surrounding built environment (Cheng, 2010). Spaciousness and openness are used to measure the spatial arrangement created by building typologies, setbacks, vegetation and street width (Lilli, 2013). Evaluation of the visual composition of urban landscapes from a pedestrian perspective identifies the features of the urban environment that have a considerable visual impact (Emo et al., 2017). Together they show that the perception of density is strongly affected by the spatial characteristics of built, open and natural environs.

There is a common agreement that a more detailed and actionable understanding is required on perceived density as a concept. This study aims to answer this call. In particular, it investigates urban environments of varying density using a combination of objective and subjective methods to identify the type and extent of the effect that spatial qualities of the environment play on how density is perceived. It bridges the knowledge gap between design experts and users that results from a lack of information on how users interpret built environments and shows how this density can be manipulated to elicit positive responses. It contributes to the body of research that aims to support the creation of efficient, user-centric cities.

Existing research gaps on this matter are generally attributable to limitations in data collection and study design and in particular to the difficulty in linking advanced understanding of objective density with less clarity of and expertise in its subjective experience. By adopting a multidisciplinary perspective, the study will seek to close these gaps through a framework for future research that can help gather responsive, consistent and reliable results which are also contextual and generalisable and ultimately useful for identifying design implications.

1.2 Problem Statement

Researchers in urban studies have had difficulty deciphering the public's perception of density in recent years because people perceive built density differently depending on socio, cultural, personal and environmental circumstances (Taylor, 1981; Evans et al., 2000; Evans, Lepore and Allen, 2000). The same measured density can be expressed in numerous ways resulting in a very diverse urban form. In addition to contextual considerations, individual characteristics make it difficult to generalise study results. This study aims to solve both of these challenges and establish a systematic method for understanding and exploring the process of human perception of density with special reference to urban form. The assumption is that the method can then be applied to specific contexts to capture the role of specific environmental, sociocultural and personal factors.

Understanding the subjective characteristics of density that trigger a favourable perception is vital in determining the methods for designing or altering urban environments, regardless of their density level. The premises supporting this argument are as follows:

1. **Density is neutral**. As a quantitative metric, density is neutral (Churchman, 1999b). It does not inherently imply positive or negative outcomes. Rather, it has both advantages and disadvantages depending on how it is conceived and implemented. Measures on population density and building density, assist planners and design professionals in development, but cannot assure the qualitative value (good density or bad density)(Campoli and MacLean, 2007) as perceived by the public. Thus density, which is the key trait of all settlements, is often an uncontested term. Yet, it often comes with negative connotations (Churchman, 1999; Dempsey, Brown and Bramley, 2012; Sonne, 2017) resulting from the physiological (crowding, congestion, hostility),

pathological (stress) and psychological (task performance, disengagement) repercussions of living in densely populated places.

2. **Density as a subjective and relative construct**. Density is also experienced in subjective and relative terms (Weber, 2003). Residential density perceived, for example, as being at a medium level in Australia or the United States might be considered low in France or Italy (Churchman, 1999a). Although values of 2.5 to 10 dwellings per hectare (dph) and 17 to 29 dph, are generally associated with low and high residential density, respectively, are obtained from the averages of numerous cities (Saegert, 1979; Churchman, 1999a; Cheng, 2010), there is no consensus regarding these numbers because density is subjective, relative and dependent on context (country, city, town, neighbourhood, suburb). There is no standard number to define what is low, medium or high density; rather, there will always be ranges that describe these concepts (Weber, 2003). Its perception also rests on many subjective aspects and individual preferences. This makes it impossible to manipulate density to achieve exact results in acceptance by the public and in overall quality. Yet, what is possible is to understand which characteristics of our environments bear the greatest responsibility for how built density is perceived and how to use this understanding to guide design and planning.
3. **Disparate user opinions**. Urban environments are judged by some people as positive or negative even though they are designed to achieve a favourable experience. Public judgement is based on various factors such as physical conditions of the environment, the social and cultural context, individual preferences, and past experiences. The built form, which includes buildings, streets, pavements, and vegetation, plays a significant role in that judgement. Public judgement cannot be controlled, however, the built form presents several opportunities to be measured and controlled. Although built-form components are similar across all environments – plots, building types, street edges, blocks, and street networks, their specific form and spatial arrangement varies. This results in different spatial and visual compositions of built form which are perceived by people differently based on subjective factors. Hence, the claim that '[d]ensity itself is a perceptual experience'

(Rapoport, 1975;). Since every perceptual experience is unique, it cannot be planned for specific perceptual outcomes. By studying how built-form components are combined in different proportions, it is possible to identify which components can be adjusted or manipulated to create positive perceptions among observers.

4. **Density and aesthetic quality**. Few physical environments are capable of evoking strong positive emotional responses (Wohlwill, 1982; Nasar, 1989a; Churchman, 1999). These environs give character to the space and are simultaneously novel and familiar to the public. Environmental aesthetics (Nasar, 1989) studies the relationship between the form of our environments and the aesthetic responses they trigger. From a design perspective, this is an important source of knowledge for design and planning disciplines as it can help them meet users' aesthetic needs and therefore affect their overall quality of life. The study of the perception of density sits well within this area. Objective measures of density – for example, floor area ratio (FAR)/plot ratios – are flexible and can be expressed as many different built form variations of the built form (Urban Task Force, 2005). However, the aesthetic quality they generate by place-making and imageability has a greater effect. Although every man-made environment accounts for aesthetic quality, not all places and spaces can be novel and impressive. The intensity of it varies based on the context, the culture and the scale of development. Even so, these environments can evoke important feelings and thoughts, although less pronounced. To do this, it is necessary to understand which factors affect how the built environment is perceived.
5. **Temporal exposure to density**. The hypothesis that temporal exposure to density may affect user perception is worth examining (Rapoport, 1975c; Gehl and Koch, 2001; Gehl, Kaefer Johansen and Solvekg, 2016). The urban form of residential areas has a different character from that of mixed-use zones. Therefore, the perspective of residential areas must also differ. The question is whether the perception of a tourist or outsider differs from that of a local. The visitor's perspective of density would be based on their first impression of the city's limited areas, whereas that of the residents would be

based on their shared experience (Julie, 1951); Residents respond to different visual cues embedded in buildings, spaces and streets based on their different needs, whereas a stranger's emotional distance from place allows a more objective interpretation. This study presents an opportunity to verify whether the perception of the built environment is different for a stranger and a resident.

1.3 Research Questions

Past research reveals several urban environment elements that influence the perception of density. However, this exhaustive list of components has gaps and is not sufficient to generate an overall framework to capture the perception of density from respondents which is free of researcher bias, applies to a range of situations and provides useful guidance for the production of new and manipulation of existing environs. Therefore, the following questions are addressed by this study:

1. What factors of the built environment (spatial, use related or personal) influence our perception of density?
2. What is the contribution of the spatial characters of the urban form to the perception of density?
3. In what ways can the urban form elements from questions 1 and 2 be accounted for to provide more favourable perceptions of density?

1.4 Aim and Scope of the Study

This study attempts to understand a comprehensive set of factors that influence the perception of density to develop qualitative and quantitative indices for the visual evaluation of urban environments.

1.5 Objectives of the Study

The objectives of the study are as follows:

1. To develop a comprehensive list of characteristics and variables that influence the perception of density. This will be done as a combination of building on the existing literature and field research and through field research.
2. To quantify the contribution of different visual components in the urban

environment to the perception of density and determine the percentage representation of each component in high, moderate, and low-density scenarios.

3. To build visual assessment indexes by developing the quantitative and qualitative database of images representing low, moderate and high levels for the evaluation of environs of different densities.

1.6 Structure

Chapters 2 and **3** present the literature review. Chapter 2 focuses on objective density. The chapter includes a systematic review of the literature on urban density, examining its definition, measures, and limitations. It discusses various measures of population density and building density, as well as their strengths and weaknesses. The limitations of density measures are discussed, as well as their role in UK urban planning. The chapter also looks at interdisciplinary and transdisciplinary approaches to density, as well as how it relates to sustainability and other goals. It concludes with a discussion of density-based urban planning models.

Chapter 3 of the thesis focuses on the perception of density. It begins with a discussion of the definition of perceived density. The chapter then delves into the concept of perception, investigating its historical evolution as well as the process of perceiving density. Various inquiry and field study methods for mapping perception are investigated, along with perception theories such as bottom-up and top-down theories and Gestalt psychology. The chapter also looks at how people perceive the built environment and how they decode non-verbal cues such as space, time, physical characteristics, paralanguage, and artefacts. It examines empirical studies on perceived density, including aspects such as visibility, liveability index, visual complexity, sky view factor, spaciousness, and openness, and concludes with design implications and limitations of previous empirical studies.

Following this literature review, **Chapter 4** discusses the research methodology. It discusses the research approach (psychophysics and personal construct theory), the research process (including literature review, data collection methods, and analysis), ethical considerations, and frameworks for mapping human perception and studying the perception of density. It introduces data collection methods such as the multiple sorting task (MST) (Canter, 1996) and Situation Judgement Task (SJT) (Patterson, Zibarras and Ashworth, 2016) , and outlines data analysis techniques such as content analysis and image segmentation. The chapter provides a broad overview of the research methodology employed in the study.

Chapter 5 of the thesis focuses on the surveys conducted as part of the research. Survey 1, MST, is discussed in depth, including survey design, structure, mode, pilot study, data collection, and analysis. The content analysis procedure is described in detail, from data preparation to drawing conclusions. Comparative analysis and the identification of constructs associated with high, moderate, and low perceived density are also presented. Survey 2 introduces the SJT, including its design, steps involved, and approaches for analysing results. The chapter provides a thorough overview of the surveys and the results obtained from them.

Chapter 6 of the thesis delves into image analysis methods used in the research. Three approaches to image analysis are discussed: Approach 1 focuses on image visual complexity, Approach 2 investigates image segmentation techniques (Ryan, 1985; Debals and Brabandere, 2020), and Approach 3 involves image analysis using Gestalt psychology principles. Each method is thoroughly explained, including the image segmentation process and results, as well as the development of a qualitative visual index based on Gestalt principles. The chapter also includes specific results from the Glasgow analysis, such as the contribution of visual components for high, moderate, and low density.

Chapter 7 focuses on correlation analysis, examining the relationship between various urban design principles and constructs related to the perception of density. The chapter begins by discussing relevant urban design principles to the study. The Spearman correlation analysis is then used to determine the strength of the correlations. The analysis's results are presented, highlighting the relationships between various constructs and variables such as building height, open spaces, building volume, amount of sky, the density of people in the street, street width, vegetation along the street, and the density of cars in the street. These correlations provide useful information about the factors that influence people's perceptions of density in cities. The chapter concludes with a summary of the key findings.

Finally, **Chapter 8** summarises the key findings and implications of the research. A comprehensive list of factors influencing the perception of density is presented, along with design implications. Threshold values for visual components and the development of a visual assessment index are discussed. A proposed framework for future perception studies is outlined. Limitations of the study are acknowledged, and suggestions for future research are provided. This chapter provides a valuable conclusion, contributing to the understanding of density perception in urban environments.

Chapter 2. Literature Review Part 1 – Urban Density

This chapter presents a review of the literature on density. It identifies the density metrics most widely employed in the field of urban studies and their limitations in representing subjective experience. The transdisciplinary and interdisciplinary approaches to density that have been used to determine its effect on mental health and well-being, quality of life and sustainability are briefly explored to highlight the importance of the study. The role of density as a technical tool in urban studies is also presented using timelines to track the evolution of various density models and determine the current position of this study topic.

2.1 Systematic Literature Review

The purpose of the systematic literature review on density and its perception was to gather and organise the vast amount of information available into themes that could be referred to at various stages of this study. Theoretical and empirical investigations were analysed to discover any existing knowledge gap by compiling crucial information regarding study methodologies, findings and their consistency for wider applicability. The objective was also to determine the current position of this study in urban studies and to avoid duplication.

2.1.1 Search Strategy

Similar objective densities can be conceived differently by professionals (figure 2-4), resulting in several spatial arrangements of the built form to reflect their design philosophy, take advantage of the location and exploit the full potential of the plot. consequently, diverse urban forms conceived as a result of design processes can be interpreted differently by users. This provided the rationale for the literature search.

Identification of Search Terms

The original search terms were the study's title's keywords: d*ensity, perceived density, urban density, density and urban form, perception of density* and *human perception*. Search engines such as Google Scholar and Research Gate were employed to locate terms that were synonymous, similar and metaphorical with density and urban form. Although urban design is the subject of the research, it encompasses objective and subjective characteristics; hence the search was expanded to include databases from other disciplines.

2.1.1.1 Online and Offline Literature

Using the identified search terms, the university repository Suprimo Strath and other online programmes such as internet archives and the Emerald and Elsevier databases generated a massive pool of relevant material. After scanning the abstracts of the collected literature, a citation search was undertaken to identify articles that have been cited in other publications and more current studies on the same topic. For the citation search, Google Scholar, Web of Science and Scopus were used as search engines.

2.1.1.2 Filtering Collected Literature

The gathered literature was filtered to organise the works of the most eminent scholars and authors into sections on density and perception of density. This not only aided in refining the study and reducing the volume of material but also helped to discover the most recent references for the essential themes. Regardless of the exploratory nature of research, the literature recognised several works in various fields. Therefore, the collected literature was sifted by discipline to appreciate the subject's complexity and develop connections. This aided in determining relevant themes under which the topic was investigated. The remaining material was organised by publication date to document the time gap and collect the most recent literature.

Over 1,200 records were identified that included journal articles, research papers, books, websites and blogs. After reading the abstracts, these were narrowed down to 644 records. A further screening based on research methodologies and conclusions identified 221 eligible documents. Objective density, density in urban studies, transdisciplinary and interdisciplinary approaches to density, density and urban form, visual perception, perceived density and quantitative study of urban form were the eight major themes identified. The 221 records were narrowed down to around 104 that are referenced in this thesis.

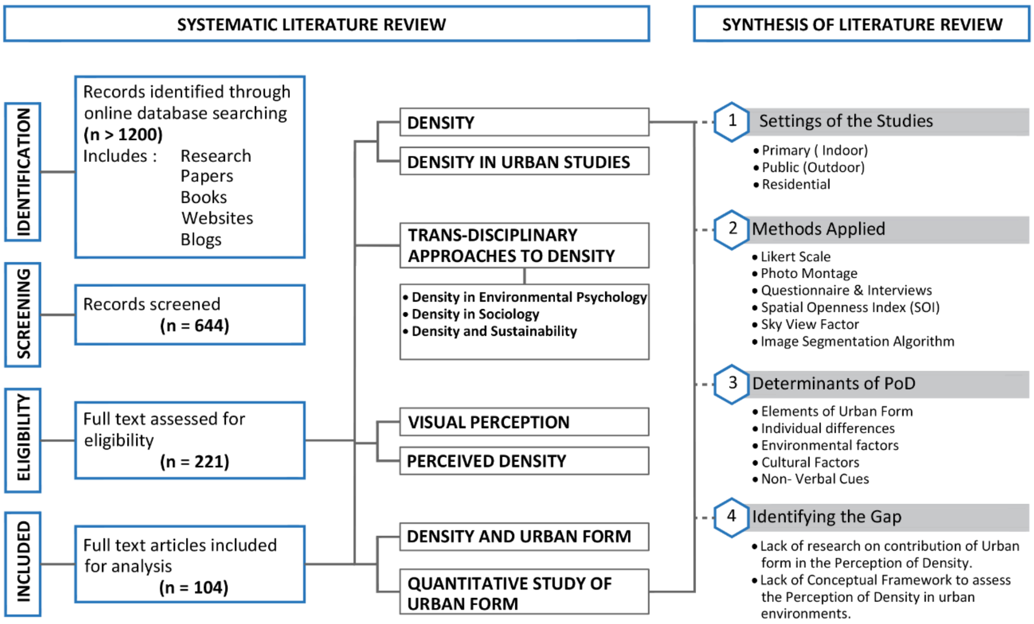


Figure 2-1. Systematic Literature Review

2.2 Density

Density, as a technical term, is not particularly expressive (Campoli and MacLean, 2007; Berghauser Pont, Haupt and D'Vine, 2010). It reveals the size of environments, but not their appearance, feel or impact on people. Density is typically expressed as a ratio describing the number of participants or buildings per unit area and is widely employed in land use regulation (Rapoport, 1975; DETR, 1998b; Churchman, 1999; Cheng, 2010; Sonne, 2017). It has a significant impact on the use, accessibility, efficiency and character of built environs, making it a valuable tool for urban planning.

Density is mostly viewed as a technical tool that yields numerical results, but it is also viewed from the perspective of behavioural studies. Macro-level approaches to density investigate its technical aspects, particularly the relationship between the spatial configuration of the urban environment (size, shape, compact or dispersed city form) and economic factors (consumption and production, access to amenities and services) (Halasz, 2015). Micro-level approaches to density are more concerned with its effects and consider the perceptual and cognitive elements that influence the human experience of the built form. This study attempted to integrate the micro and macro-level approaches and build on the extensive existing literature on objective density to determine the best approach to measure the perception of density.

2.2.1 Definition, Measures and Limitations of Density Interpretations

Density metrics are often criticised for being rigid in that they represent only the objective properties of people and buildings but fail to reveal qualitative aspects of the built form and other phenomena such as crowding and invasion of personal space (Rapoport, 1975; Churchman, 1999; Angel, Lamson-Hall and Blanco, 2021). They are also criticised for being overly flexible in the sense that they can be interpreted in a variety of ways and this, in conjunction with building bylaws, could result in a variety of spatial layouts and unanticipated architectural forms. Recent studies have been motivated by constructive criticism of density measures (see Section 2.3.4) to search for a definition that not only captures its objective meaning but also describes physical density in perceptual terms (Berghauser Pont, Haupt and D'Laine, 2010a).

2.2.2 Defining Density

There is no universally agreed-upon definition of urban density that applies to all contexts, since it varies based on the geographical location, cultural factors and specific objectives of the study or planning process. However, urban density is generally understood as the measure of the concentration of people, activities or structures within an urban area (Rapoport, 1975c; Churchman, 1999; Berghauser Pont, Haupt and D'Laine, 2010; Cheng, 2010; Sonne, 2017; Berghauser Pont et al., 2020). It must be noted that urban density has been explored and discussed by scholars and urban theorists for many decades, and it is challenging to attribute its definition to a single individual and pinpoint a specific year or moment when it was first introduced. The definition and system of measurement of urban density have evolved as urban studies have progressed.

The complexity of the term originates from the varying definitions of density across countries and disciplines (Alexander, Reed and Murphy, 1988; Churchman, 1999; Cheng, 2010). The Collins (2022) dictionary defines density as the extent to which anything is full or covered with people or things, but the Cambridge (2022) dictionary defines it as the number of people or objects relative to the size of a location. These definitions are analogous to the definition of density in physics, which is the relationship between the mass and size of a substance.

This analogy was then refined to define density in terms of spatial characteristics of the built environments and the experience of crowding as a simple physical metric that indicates the ‘space available per person’ (DETR, 1998b) (Density (space per person) = Total area or space /Number of people). Yet, this definition did not account for temporal changes in perception as a result of variation in the number of individuals within a fixed region and of the situation of those experiencing density (i.e., daytime versus night-time density; occasional visit versus permanent residence in the environment). To overcome the limitations of this definition two new concepts: social density and spatial density (Loo, 1972; Stokols, 1972; Freedman, 1975; Novelli, 2010) were derived which could be applied at a street scale. Social density measures how the number of people changes whilst space remains constant, whereas spatial density measures space changes whilst the number of people remains constant (Loo, 1972; Rapoport, 1975; Churchman, 1999; Novelli, 2010). These definitions are currently used to determine indoor congestion or the density of enclosed environments. They are also valuable for examining perceptions at a street scale (a segment of the street), as they allow for an understanding of how population fluctuations (change in intensity of people) or spatial changes (change in intensity/character of built form) impact the immediate surroundings and people experience. However, these definitions cannot be extended to a block scale or neighbourhood scale, since additional factors such as land use patterns, distribution of amenities, access to services come into play. These factors contribute to the quality of public spaces, connectivity and can significantly influence the perception and experience of density. Therefore, a more refined definition that can be applied at all geographical scales was introduced.

This definition refers to urban density as a ratio of the number of people and the geographical area under consideration (Stokols, 1972; Rapoport, 1975c; DETR, 1998b; Churchman, 1999). This ratio provides a quantitative measure of how densely populated an urban area is. A higher density indicates a greater concentration of people within a given area, while a lower density represents a less densely populated urban environment.

Although this more refined definition can be expanded to encompass many geographical regions, it remains ambiguous in two aspects. First, varied interpretations of the concept of density (urban, dwelling, people) influence the collection of data for density calculations and subsequent analysis (Boyko and Cooper, 2011), resulting in the representation of different figures for universal density, which hinders inter and intra-city comparability. Second, its flexibility permits the use of numerous metrics to describe physical density. Distinct metrics reflect different phenomena (Boyko and Cooper, 2011), such as space per person reflecting crowding and person per acre reflecting the gross density of a region and so cannot be employed as universally comparable representatives of physical density. The attempts at resolving this ambiguity have resulted in the development of indoor and outdoor density measures which are described briefly in the following sections.

Stokols (1972) and Alexander et al. (1988) believed that any generic definition of density should also account for the physical nature and properties of the components and that the objective definition of density as a ratio does not warrant the term physical density. To address this, Alexander et al. (1988) defined three distinct forms of density, each of which represents a distinct phenomenon in a unique environment. *Measured density (current urban density)* is the ratio between the number of occupants (people, rooms, households or dwelling units) and the unit area used for statistical purposes and indicating demographic data such as population density in economics. *Physical density* is the manifestation of measured density and physical qualities of the built form of the built environment. This term is used in urban studies and in situations where the urban environment is analysed to determine qualitative density by establishing co-relations between the built form features, other spatial aspects and the measured density such as building height and its relative spacing. *Perceived density* is the interaction of physical density, individual cognitive factors and sociocultural factors (Alexander, Reed and Murphy, 1988). It describes the individual's assessment of the available space and its organisation and of the population in a specific region (Rapoport, 1975; Churchman, 1999). However, measuring perceived density can be challenging due to three reasons, subjectivity (individual differences), multidimensional nature (sociocultural factors) and context sensitivity. These challenges and the critique on the definition of perceived density are explained in the next chapter on the perception of density.

Recent research employing advanced tools to handle massive amounts of demographic and built-form data has sought to contribute more accurate and viable definitions of physical density. Berghauser Pont (2010) presents a multivariable density concept consisting of intensity (defined by floor space index (FSI)), compactness (defined by GSI/ground coverage) and network density (N) that can provide a robust description that is neither overly generic nor overly specific. However, this method does not account for the measurement of perceived density. The authors also find the concept of perceived density highly subjective and reliant on user interpretation of the urban environment (Berghauser Pont, Haupt and D'Laine, 2010a) and acknowledge the need to study this further.

2.2.3 Scrutinising the Definition of Density

The definition of density appears to be objective insofar as it discovers and generalises information about two clusters of density, namely people and buildings. To demonstrate that the concept of density is complex and can reveal more than just numbers, two arguments based on scientific objectivity are presented.

1. Individual perceptions have no bearing on the "true nature" of density. While people's perceptions of density vary due to personal perceptions and cultural influences, the density of buildings remains constant. This highlights the importance of distinguishing between density attributes that vary depending on an individual's perspective and those that remain constant (objective characteristics) regardless of perspective.

   A three-step approach to scientific objectivity is used to understand and bridge the gap between objective characteristics and density perception (Reiss and Sprenger, 2020). To begin, it emphasises the importance of acknowledging that our perceptions of density are influenced by objects in our environment, such as buildings, which have an impact on our minds and bodies. Second, it implies that the same building density characteristics that shape our perceptions can also influence other factors such as quality of life without directly causing perception. As a result, the true nature of density, as defined objectively, may differ from the apparent nature perceived by individuals. Therefore, there is a need for an independent understanding of the true nature of density.

This study argues that understanding the objective characteristics of density, referred to as the "true nature" of density, which is independent of individual perceptions and can be attributed to the visual impact created by the intensity of the built form or the number of buildings, is important. In other words, regardless of how individuals perceive or interpret density, physical characteristics of the built environment, such as the number or intensity of buildings, remain constant. These objective characteristics can be quantified and measured independently of individual perspectives or evaluations. The visual impact of density refers to the visual impression created by the arrangement, orientation, and location of buildings. When they are concentrated in a small area or are closely packed, the result is a visually dense urban environment. The quantity (numbers) and quality (intensity) of buildings in terms of size, volume, height, or spatial arrangement influence their visual impact.

2. The definition of density is descriptive. Its descriptive adequacy can be distinguished into three grades: extensional, intentional and sense. Extensional adequacy refers to whether the definition captures the essential instances of the concept being defined, without any counterexamples. In the case of density, the definition stating it as a ratio of the number of people/buildings to the area of land is extensionally adequate because it accurately represents the relationship between the two. There are no counterexamples where this ratio fails to describe density.
   Intentional adequacy examines whether the definition captures the intended meaning or purpose of the concept being defined. The current definition of density is intentionally adequate because it conveys the intended meaning of

a quantitative measure of the concentration of people/buildings in a given area. Sense adequacy also referred to as analytical adequacy, pertains to whether the definition aligns with how people understand and perceive the concept. In the case of density, the definition based on the ratio may not fully achieve sense adequacy. This is because people do not perceive density solely as a numerical ratio, but rather collectively with other sensory elements of the physical environment. They consider factors such as the arrangement, spacing, visual appearance and overall feeling of crowdedness when perceiving density. Thus, this definition does not capture the complete sense or subjective perception of density.

While the definition of density can be expressed as a formula and is scientifically comprehensive, its interpretation is influenced by the way it manifests in the built environment, as seen from the public perspective or that of a planner/designer. This necessitates a closer examination of the definition of perceived density (please refer to Section 3.1).

To summarise, a review of the definitions of density suggests that it is reasonably simple to collect ordinal data on objective density, hence permitting empirical investigations with varying objectives and methods. This ensures quantification and scientific objectivity. The two arguments assist in defining perceived density by recognising the distinction between the objective characteristics of density (the “true nature”) and subjective perception. They emphasise the need to understand the objective components of density that remain constant regardless of individual perspectives. Additionally, they highlight the importance of considering sensory elements and subjective experiences in perceiving density.

2.3 Measures of Density

Population density and building density are the two most common types of density measurements which are categorised under measured density (Cheng, 2010; Sonne, 2017). Population density is the number of people per unit area, whereas building density is the number of buildings per unit area. All density measures described below are ratio derivations of these two types. The goal of these objective measurements is to provide a reference standard for the quantitative values. Examining various measures such as population density, FAR, social and spatial density, assists in gaining insights into the objective measures of density. The review of these measures can help to identify the specific measures that are most closely related to the perceived density. By comparing different measures with people's subjective perceptions and evaluating their correlation it is possible to determine which aspects of density such as the spatial arrangement, spacing, and visual impact of the building have a significant influence on perceived density.

2.3.1 Measures of People Density

2.3.1.1 Residential Density

Residential density, either net or gross, is the most prevalent measure of population density (Cheng, 2010). It is the ratio of inhabitants, households or housing units to residential land area. Gross residential density considers the denominator as a sum of site/land area allocated for residence (net residential area), half the area of perimeter roads and one-quarter of the junctions (Alexander, Reed and Murphy, 1988.

Table 3-1. Different measures of population density

Type of measure		Numerator		Denominator
Population Density	=	Total Population	/	Geographical Area of Land
Gross Residential Density	=	Number of Residential Units	/	Net residential area + ½ area of perimeter roads + ¼ area of junctions
Gross Residential Density (UK)	=	Number of Residential Units	/	Net residential area + area of internal roads + area of parks+ area of schools+ area of community centres
Net Residential Density (UK)	=	Number of Residential Units	/	Net Residential area + front yards + back yards + ½ width of the adjacent road
Net Residential Density (Hongkong)	=	Number of Residential Units	/	Net Residential area
Occupancy Density	=	Number of Occupants	/	Floor Area (of a building)
Occupancy Rate	=	Total number of occupied dwelling units	/	Total number of dwelling units (in a city)

In the UK, gross residential density considers net residential area along with non-residential spaces such as internal roads, parks, schools and community centres where the percentage of non-residential spaces is undefined (Cheng, 2010). It includes land covered by the residential development (including front and back yards) and half the width of the adjacent road. In Hong Kong, it is calculated based solely on the net residential site area (excluding internal roads and parks) (Churchman, 1999; Cheng, 2010).

Gross density generally reflects macro-level scenarios, whereas net density reflects the characteristics of a particular site. In evaluating the distribution of facilities and

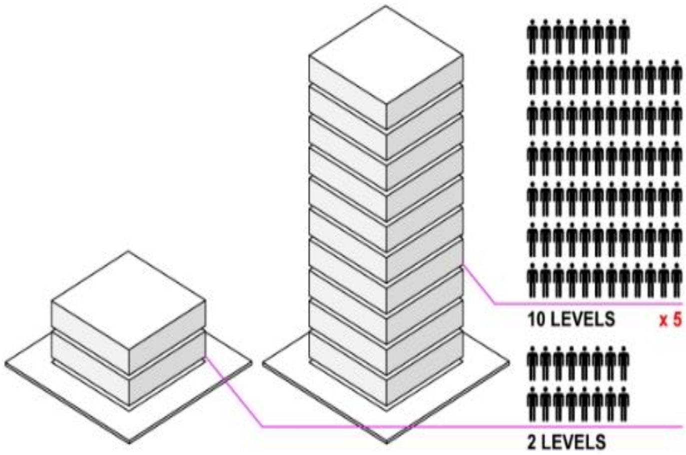


Figure 2-2. Population density measured on the plot; Source: understanding density | density architecture (wordpress.com)

services per unit of land area, these two metrics can result in substantial disparities. Both show a distinct picture of the same urban environment in terms of density perception.

Residential density, whether measured as net or gross, plays a key role in the perception of density. It indicates the visual impact, spatial enclosure, perceived crowding and social interaction of a specific area.

Visual Impact: Higher residential density often means a high number of buildings or housing units in a given area, resulting in a visually dense urban environment (Rapoport, 1975c; Churchman, 1999; Campoli and MacLean, 2002; Cheng, 2010; Angel, Lamson-Hall and Blanco, 2021). This visual impact can contribute to the perception of density, as individuals perceive a greater concentration of dwelling units or buildings in their environs.

Spatial Enclosure: Residential density influences the spatial arrangement of buildings, and their proximity to each other (Burton, 2000, 2002; Urban Task Force, 2005; Harvey, 2009a; Harper, 2013). Higher residential units can lead to closer proximity between housing units, resulting in the sense of spatial enclosure or perceived lack of open space. This spatial configuration can affect the perception of density, as people may feel more boxed in or confined in densely populated residential areas.

Perceived Crowding: Residential density can influence the perception of crowding (Stokols, 1976; Mueller, 1981; Novelli, 2010). Higher residential density is often associated with larger population living in a given area, resulting in increased human activity and sense of crowding. This perceived crowding can impact the perception of density, as individuals may be exposed to a higher level of congestion.

Social Interactions: Higher residential density facilitates more opportunities for social interactions and a sense of community, as people are in closer proximity to their neighbours and community amenities. This increased social interaction adds to the vibrancy of the place, influencing the perception of density.

2.3.1.2 Occupancy Density

Occupancy density refers to the number of individuals occupying a particular space or area regardless of the type of landuse (i.e., residential, commercial, or mixed-use) (Cheng, 2010). It is measured in terms of the number of individuals present per unit of floor area or volume, such as persons per square metre. It is important for crowd management, space planning, and determining capacity limits in various environs (Vicky Cheng, 2010; Angel, Lamson-Hall and Blanco, 2021).

Occupancy density is closely related to the perception of density because it directly influences the level of human presence and activity within a given space. Higher occupancy density can result in a more acute sense of spatial density. Individuals may perceive less privacy in densely populated areas due to the increased likelihood of proximity to others. As a result of the reduced personal space (Sommer, 1969), individuals may perceive higher density and feel more exposed. The level of occupancy density can also influence perceptions of comfort and well-being (Chen et al., 2020).

2.3.1.3 Social and Spatial Density

Social and spatial density (Loo, 1972, 1990; Baum and Koman, 1976; Novelli, 2010) measures are employed in environmental psychology research to examine how the physical environment including the density of people and structures, influences human behaviour, well-being and perception. These measures help investigate the impact of density on social interactions, privacy, territoriality (Altman, 1975; Namazian and Mehdipour, 2013a) and the overall experience of individuals in different settings. In terms of perception of density these measures provide objective indicators that can help researchers and planners understand how individuals perceive and experience density in different contexts. By analysing the relationship between perceived density and social and spatial density measures, it is possible to identify factors that influence density perception such as crowding, visual appearance, arrangement of buildings and so on. This knowledge can guide design interventions to create more comfortable, spacious and enjoyable environs with a positive perception.

2.3.2 People Measures of Density – Constructive Criticism

Constructive criticism of "people" measures of density, such as residential density, occupancy density, social and spatial density can be developed to guide the further refinement of the measures. some constructive criticisms that can be considered are as below:

1. **Lack of Contextual Consideration:** People measures solely focus on the quantitative aspects such as the number of people per unit area. However, they may not adequately consider the contextual factors that influence the perception of density (Rapoport, 1975c; Churchman, 1999; Campoli and MacLean, 2007; Vicky Cheng, 2010). Factors such as the built form, the amenities and infrastructure, and cultural factors can significantly impact the perception of density and its implications on quality of life (Walton, Murray and Thomas, 2008; MacLean and Salama, 2019). Therefore, incorporating contextual considerations into the measurement and analysis of density can

provide a more nuanced understanding.

2. **Neglecting Temporal Dynamics:** "Density is a static measure used to capture a dynamic phenomenon" (Hess, 2014). People measures of density provide a snapshot of a particular moment (when most people are at home) to calculate the average figures and may not capture the temporal dynamics of density (Churchman, 1999). The social density in any given area can vary throughout the day or across the seasons. Incorporating temporal dimensions, such as hourly, daily, weekends or seasonal variations can enhance the understanding of density patterns and their implications.
3. **Overemphasis on Quantitative measures:** People measures of density focus primarily on demographic data or quantitative indicators such as population counts, or people per unit area. These measures overlook qualitative dimensions of density, such as social interactions, perceived crowding and subjective experiences (Rapoport, 1975c; Churchman, 1999; Angel, Lamson-Hall and Blanco, 2021).
4. **Challenges in defining boundaries:** Defining boundaries for measuring density can be challenging and significantly influence the results. The choice of geographical area or administrative boundaries can impact calculated density values (Churchman, 1999). They might not capture the functional or perceived boundaries perceived in daily lives. Considering universal boundary delineations such as neighbourhood boundaries, can offer a more nuanced analysis of density (Haney and Knowles, 1978).

These criticisms informed the consideration of contextual understanding, temporal dynamics, and qualitative insights (subjective experiences, social interactions, crowding), to improve the perception of density studies.

2.3.3 Measures of Building Density

Building density measures such as plot ratios and FAR are tools to designate the degree of building density to plot parcels or areas of land. Building density measures estimate the amount of built-up area but do not dictate the building type. It is up to the architect or planner to conceive the building type or housing scheme and visualise the volume concerning the environment and surroundings. The two measures described briefly below are robust and can be applied in any setting such as residential, commercial or mixed-use, but they do not integrate a user perspective.

2.3.3.1 Plot Ratio

Plot ratio, commonly known as FAR, is an essential measure for regulating the land use of a parcel since it determines its intensity of development (Cheng, 2010; Angel, Lamson-Hall and Blanco, 2021). The plot ratio expresses the relationship between the total gross floor area (built-up area) and the plot area. The gross floor area refers to the superstructure or building envelope (enclosed spaces to the inner face of the external walls), whereas the plot area refers to the total plot (the entire area of land under consideration) land area under consideration.

Plot ratios play a significant role in shaping the perceived density of an area. It helps in determining the intensity of development on a given plot. Higher plot ratio/FAR indicate greater concentrations of built-up area relative to the land, which can contribute to a perceived sense of density (Cheng, 2010a; Cheng, 2010b). Plot ratios/FAR influence the built form, the scale of the buildings and also the visual impact of density. For instance, in the case of a higher plot ratio/FAR, buildings may be closely placed or have little space between them. This can create either a positive or negative perception of density as the visual field if filled with a greater concentration of built structures. Plot ratio/FAR can impact the functional density of an area. A higher plot ratio often leads to increased building density allowing for more residential, commercial, or mixed-use development on the same plot of land. This can result in a higher concentration of activities and people contributing to a perceived sense of vibrancy and activity. Plot ratios/FAR can affect the sense of enclosure in urban environs. A higher plot ratio combined with a narrow street can create a more enclosed or confined feeling and contribute to a perception of density.

Table 3-2. Building density measures

Type of measure		Numerator		Denominator
Plot Ratio /FAR	=	Gross Floor Area	/	Gross Site Area
Site Coverage	=	Total area of building footprints	/	Total area of land

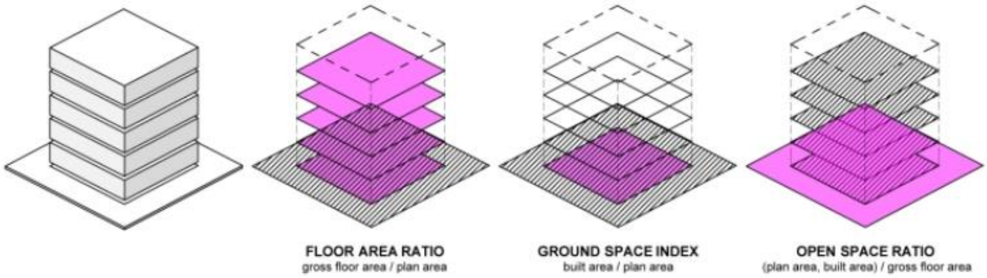


Figure 2-3. Building Density measured on the plot; Source: understanding density | density architecture (wordpress.com)

2.3.3.2 Site Coverage

Site or ground coverage is the area or proportion of land covered by the building on the ground floor and can be expressed as the ratio of the building footprint to the corresponding site area (Alexander, 1993; Cheng, 2010). Regulating site coverage is a way of controlling overbuilding and ensuring greenery and open spaces. This percentage can vary for residential, commercial, mixed or institutional uses.

Site coverage affects the visual impression of density. A higher percentage of the site covered by the building, entails longer façades resulting in continuous street walls. Higher site coverage can result in a spatial compression effect. The more land occupied by buildings, the lesser the available open space. The reduced spatial separation can result in a more confines and compact environment which can influence the perception of density (Zacharias and Stamps, 2004).

Different combinations of plot ratio and site coverage result in a wide range of built form and development types (sprawl vs. compact city) and so the same density might take on a variety of urban forms (Urban Task Force, 2005; Cheng, 2010) and be interpreted differently by individuals. The flexibility of interpretation that these measures offer introduces the aspect of subjectivity in addition to those related to individual differences.

2.3.4 Building Density Measures – Constructive Criticism

The application of different density measures at a plot level results in different building typologies and, at a block level, in diverse built forms, street profiles and spaces. The positive or negative effects of these diverse environments have compelled researchers and authorities to assess density from a technical point of view. A continuous review of this work is ongoing and reported below.

1. **Lack of Contextual Consideration:** Building density measures often focus on the quantitative aspects of the built environment such as the number of buildings or FAR to maximise the potential of land and economic viability, without taking into account the surrounding context. Critics argue that exclusive emphasis on quantitative factors compromises the qualitative aspects that contribute to the perception of density (Berghauser Pont, Haupt and D'Laine, 2010), such as building style and character, height variations and architectural aesthetics.
2. **Neglecting Human Experience:** Building density measures quantify the physical attributes of the built form, however, neglect the human experience and subjective perception of density (Churchman, 1999). Factors such as street layout, green spaces and social interactions are essential in shaping the perception of density but may not be adequately captured by the building density measures.
3. **Limited Consideration of Social and Cultural Factors:** Building density measures overlook the influence of social and cultural factors on the perception of density. The way people perceive, and experience density can vary across different cultural backgrounds (Evans, Lepore and Allen, 2000) and personal preferences (Taylor, 1981a). Neglecting these aspects can result in a limited understanding of the complexities involved in the perception of density.
4. **Current Measures of Density are Ineffective in Defining the Built Form:** Building density measures such as FAR or plot ratios in conjunction with building standards assist in designing buildings on plots. However, most of the time these are developed individually by different design professionals to use the maximum FAR for economic viability. Although design standards help, plot size variations can generate a variety of results, ranging from highly uniform to highly incoherent. To achieve a good balance between uniformity and diversity at the same time it is necessary to establish a co-relation

between the building standards and density measures to be able to define the built form. This co-relation should consider its effects on users.

5. **Specifying Measures of Density Tend to Generate Different Dwelling Mixes:** A variety of density measures have been developed that can be used to determine indoor density, parcel density, residential neighbourhood density and city-wide density (Angel, Lamson-Hall and Blanco, 2021). However, multiple interpretations of density measurements have resulted in a range of architectural styles. For example, dwellings per unit area and habitable rooms per unit area are likely to be interpreted differently (refer to Figure 4).

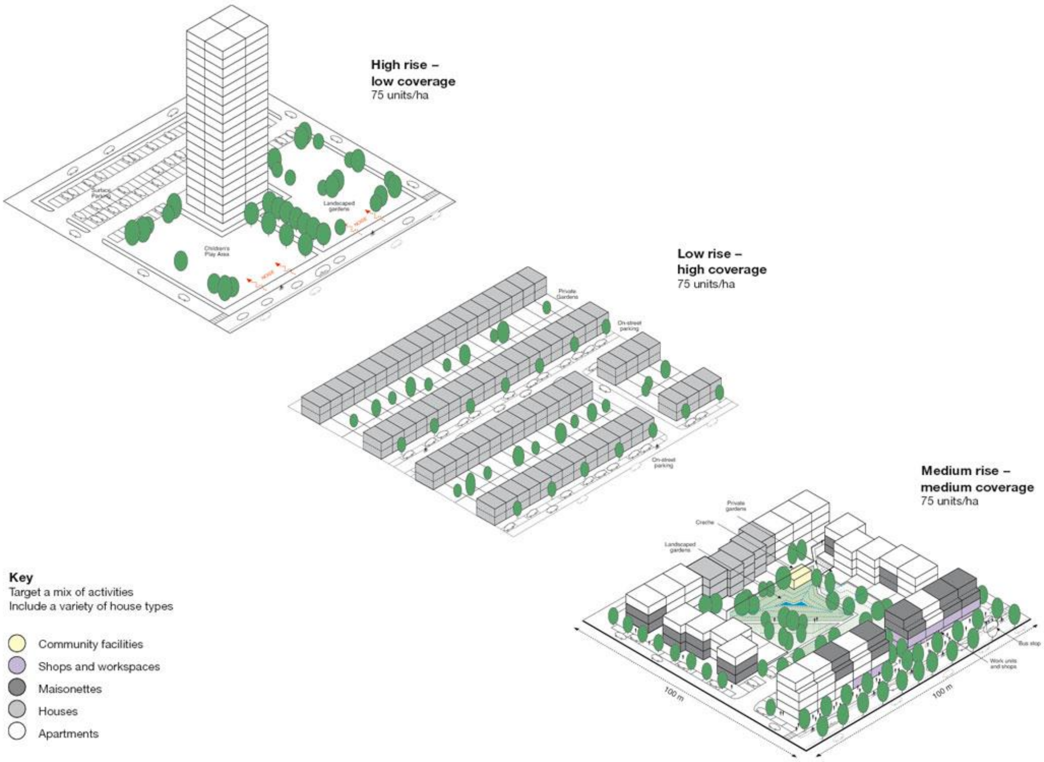


Figure 2-4. Similar Density conceived in different urban forms
((Source: Urban Task Force (2005). *Towards an Urban Renaissance: Final report of the Urban Task Force chaired by Lord Rogers of Riverside*. London: Taylor & Francis e-Library, p. 35.)

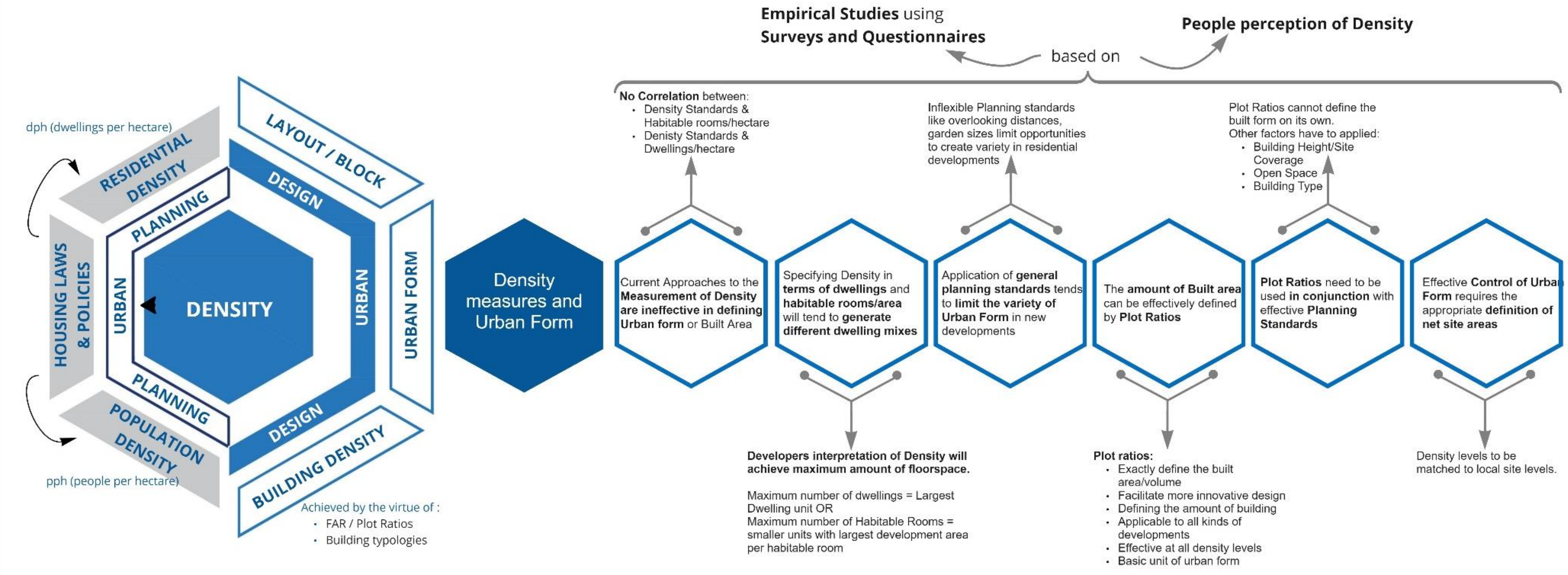


Figure 2-5. Density measures – Constructive Criticisms

Employing plot ratios or FAR as the measure of density that defines the desirable amount of development per plot not only results in a variety of built forms and site layouts, but as different building forms can also depict the same objective density and the built-up area on a plot can be distributed in a variety of ways.

Thus, designers have ultimate control over these circumstances and can successfully apply the architectural standards and guidelines in combination with the plot ratios to generate a coherent urban form. However, the use of current prescriptive and descriptive building regulations to create these surroundings is limited and does not consider the user perspective. There is a need to derive performance guidelines that integrate the user perspective whilst maintaining efficient density (Berghauser Pont, Haupt and D'Laine, 2010b; Haupt et al., 2020). Knowledge of the perception of density can aid in developing a framework to derive visual guidelines that can be used in conjunction with architectural standards to design user-centric comfortable urban environments with favourable perception.

2.3.5 Difference Between People and Building Density Measures

Significant differences exist in the expression of spatial distribution patterns of two types of densities at a large scale with the same reference unit (Bâldea and Dumitrescu, 2012) (see Figure 4). For instance, 3D transposal of population density, expressed through ranges such as 500 -1000 persons per hectare (population density) or 25-50 dwelling units per hectare (dph), is different from that of building density indicated using plot ratios/ FAR distribution. Hence, there are spatial variations and to resolve these, composite measures such as density gradient and density profile have been introduced.

Density gradient refers to the gradual change in population density or the concentration of people over a given geographic area. It represents the spatial variation of density typically observed as a transition from higher density areas to lower density areas or vice versa (V Cheng, 2010). Density profile refers to series of density measurement for a given area but calculated in different spatial scales (V Cheng, 2010). Comparing these patterns through time aids in establishing the density trends concerning urban forms such as concentration, decentralisation and peri-urban development.

The building density measures presented are the most commonly used, but they are not the only ones. Several metrics have been developed to measure a range of phenomena from the city to the household level (Angel, Lamson-Hall and Blanco,

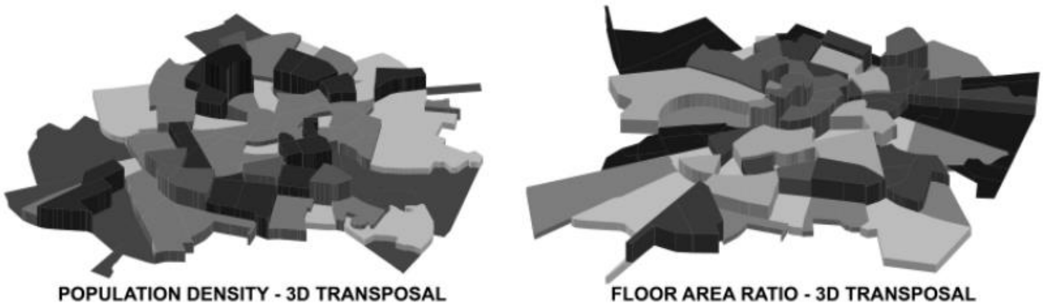


Figure 2-6. Difference in representation of population density and building density (Source- M. Bâldea, C. Dumitrescu, 2013)

2021). However, these measures are not fundamental to the study and hence omitted from the review. These derivations demonstrate that density in the built environment can have multiple meanings and units. In fact, there is no universal density measurement (Bâldea and Dumitrescu, 2012), since the appropriate measure of density depends on the specific purpose, scale and characteristics of the study or analysis being conducted.

2.4 Limitations of Density Measures

Density evaluated by population units (persons, families, households) or units (bedrooms or habitable rooms) accurately represent the demographic data of the population (Alexander, Reed and Murphy, 1988); nevertheless, density is not a measure of living standards (Filipowicz, 2018). Living standards encompass a broader range of socioeconomic, environmental, and infrastructural aspects that influence the quality of life for individuals or communities (Filipowicz, 2018; MacLean and Salama, 2019). While scholars acknowledge the desire for a singular metric that can effectively guide building design standards and serve multiple objectives (Angel, Lamson-Hall and Blanco, 2021), it is unlikely to be feasible. This is due to the contextual nature of density. The perception and implications of density vary depending on the specific geographical, cultural and socioeconomic factors that are at play. Nevertheless, there is a potential for enhancing the current density measures by identifying and addressing their limitations.

2.4.1 A consistent way of measuring density

As a basic standard for describing the density of the region under reference, different countries use different numerators (such as number of people, no of dwellings units per given area; Alexander, Reed and Murphy, 1988; Churchman, 1999; Boyko and Cooper, 2011). The denominators include land units such as acres, hectares, square miles and square kilometres (Churchman, 1999). Although these units can be translated to a standard unit, the problem occurs owing to the definition of geographic boundaries and the scale at which it is measured (Berghauser Pont, Haupt and D'Laine, 2010). These inconsistencies contribute to a systemic mistake that hinders comparisons on a city or national scale and, by extension, generalisation.

Additionally, the densities are typically measured as gross or net densities, but there is no consensus on the definitions, and they vary between local authorities (Churchman, 1999; Cheng, 2010). Inclusions and exclusions of area under roads, pavements and so on in the denominator, also vary (Boyko and Cooper, 2011; Churchman, 1999), but are nevertheless accounted for under physical density.

2.4.2 Inadequate Consideration of Land Use Mix

The generic metric of population density (number of persons per hectare) cannot be applied to a mixed-use building to assess its residential density (Berghauser Pont, Haupt, & D'Laine, 2010). A mixed-use building may have multiple independent uses including retail, office space, hotels residential use. The density can be estimated only using floor-by-floor calculations, which is a laborious and time-consuming technique that, in most situations can be disregarded.

For instance, residential density of the mixed-use area will depict the number of people residing but will not account for the potential temporal variations in the social density on a daily basis owing to the diversity of land uses. Due to these uses, the daytime and night time appearances of the city are also different. By neglecting to account for land use mix, density measure fails to capture the functional density of an area. Functional density refers to the interaction of people with the available spaces, amenities and services within a given area. Therefore, by incorporating the land use mix into density measures, urban planners and designers can gain insights into how different combinations of land uses can contribute to the perceived density and overall quality of life in a given area.

2.4.3 Simplification of Spatial Complexity

While measuring density, it is common to aggregate data at a certain geographic unit. However, by aggregating data, finer spatial variations may be overlooked (Berghauser Pont, Haupt and D'Laine, 2010). Different urban areas exhibit different characteristics such as compact development or sprawl (Alexander, 1993; Berghauser Pont, Haupt and D'Laine, 2010a), variations in building heights, architectural styles, street layouts, which influence the perceived density. Additionally, the distribution of amenities, open spaces may vary across blocks, neighbourhoods or larger areas impacting the overall perception of density.

The simplification of spatial density results in a loss of detailed information about specific areas within high-or low-density environs. To address this limitation, a more granular approach to density measurement can be adopted. This could involve considering smaller units or utilising geospatial technologies to capture and analyse fine-scale variations in density (Berghauser Pont, Haupt and D'Laine, 2010; Bobkova, Marcus and Pont, 2017; Berghauser Pont *et al.*, 2021). By capturing fine-scale variations of density, designers can tailor strategies and interventions to enhance the overall perception and experience of density.

2.4.4 Section Summary

Density metrics are intended to act as standard operating procedures to increase the effectiveness of the urban form in meeting quality of life (QoL) standards. The objective of standardising these measures was to create comparable and generalisable outcomes and to promote compliance with international standards. But the contextual trait of density hampers the feasibility.

The limitations and constructive criticisms indicate that numerous interpretations of the same formula are inevitable. Adapting these measures and building ordinances is a logical approach to urban design. Therefore, it is impractical to propose a further standardisation of the existing objective measures. Due to the relative and subjective nature of density, none of the metrics can identify consistent or universal values for low, moderate or high population density (Churchman, 1999).

Thus, what is needed is not a singular metric, but a consistent way of measuring density through establishing standardised criteria and methods. Some key considerations include:

1. A clear definition of density.
2. Uniform units of measuring density (such as persons per square kilometre or dwellings per hectare).
3. Clear demarcation of geographic boundaries within which density is to be measured.
4. Reliable and consistent sources of data for collecting relevant information (population counts, building density, land area measurements).
5. Consistent calculation methodology (standardised formulas and procedures).
6. Clear documentation of the methodology, data sources, assumptions and limitations associated with density measurements.
7. Periodic updating of data to reflect changes in population, building numbers and intensity, and land use patterns.

2.5 Density in Urban Planning in the UK

This section describes the complex relationship of policymakers and practitioners with density as a planning tool. It chronologically describes the evolution of housing standards and density measures in the UK as a response to the need for better quality and increasing demand for housing during industrialisation.

During the industrial revolution of the 19th century, migration from rural to urban areas generated a significant increase in the need for housing. Housing courts and back-to-backs with a density of 375 dph, became the main form of mass housing, characterised by excessive density, overcrowding and poor sanitation (Berghauser Pont et al., 2010; Churchman, 1999; Dempsey et al., 2012a; Newman and Hogan, 1981). The stories of the plight of the poor presented by Engel (1845, 1987), Booth(1889) and numerous other reformers helped to solidify the connection between high population density that resulted in overcrowding and congestion, bad living conditions and poor health. This relationship continues to affect researchers, practitioners and policymakers. Several planning decisions were taken to alleviate the effects of high population density.

1. Planning of public parks**:** From the mid-19th century, Victorian social reformers advocated for urban green spaces to mitigate the effects of industrialisation such as overcrowding and pollution. In 1847, Joseph Paxton designed the first publicly funded municipal park, Birkenhead Park on Merseyside, following in the footsteps of Haussmann in Paris who designed large tree-lined boulevards and gardens in response to excessive population congestion and unsanitary conditions. It prompted Fedrick Law Olmsted to construct New York's Central Park, and numerous other authorities to create public parks in urban areas.

2. Minimum width of streets**:** Public health and overcrowding concerns not only prompted the development of parks but also gave authorities the right to eliminate substandard housing (Miller, 1992) and mandate minimum street widths (Dempsey et al., 2012a). The result was 'by-law' housing. Terraced homes along straight streets in a grid formation are reproduced in suburban developments (Jenks and Dempsey, 2005). The density of these developments ranged from 33 to 110 dwellings per hectare (dph).

3. Low density suburbs/garden cities: Ebenezer Howard advocated garden cities characterised by low population density and healthy environments as the ideal city form in the late 19th century (Howard, 1898; Churchman, 1999; Dempsey, Brown and Bramley, 2012). Before the First World War, low-density housing plans with densities ranging from 12 to 20 dph in villages and 15 to 30 dph in garden cities were popular but not always implemented. Environmentalists were concerned about the environmental effects of low population density (cited in Van der Ryn, 1986; Churchman, 1999), whereas urbanists were concerned about the decline of cities (Churchman, 1999).

4. State Housing**:** Raymond Unwin, a leading garden city architect, was known for designing *state housing* after the First World War. The Housing and Town Planning Act of 1919 and the Homes Fit for Heroes campaign (Swenarton, 1981; Dempsey et

al., 2012b) allowed large-scale public housing. The Tudor Walter study of 1918 proposed urban densities of 30dph, which became law in 1924 (Local Government Board, 1918).

5. High-Density developments in urban areas**:** This state housing alleviated overcrowding and improved the living conditions, but resulted in long lines of parallel terrace housing with backyards that were heavily condemned for having little aesthetic value and being socially monotonous (Swenarton, 1981). According to the Tudor Walter Report, it was an illustration of a too-rigid interpretation of density zoning, which negatively affected the diversity of building types, the size of open spaces, the design of neighbourhoods and the number of services and facilities. In addition, the separation between private and state housing, lack of amenities and services, and poorly designed neighbourhoods, resulted in the homes being far away from the workplace. Consequently, the decision was made to allow high-density projects (100 dph) in metropolitan areas that eased access to parks, facilities and services, schools and parks. During this time, apartments (flats) as a building type flourished.

6. Utopian city models**:** The suburbs were dominated by low – to medium-density urban forms after World War II, while inner-city slums and low-quality neighbourhoods were replaced by apartments. Flats were popular as a high-density urban form and simplified the management of low-cost housing supply and demand. As city models, utopian city concepts such as Le Corbusier’s Radiant City and Howard’s Garden Cities were used to address the effects of industrialisation such as substandard housing and poor health conditions. The feasibility of the tower blocks predicted by the utopian models was criticised by the researchers, but they were overruled.

7. User perception of high-rise building typology**:** High levels of dissatisfaction were reported by residents of high-rise buildings. However, the argument was dismissed by policymakers, who viewed this as a resident issue and not the outcome of environmental determinism (ibid). Thus, environmental determinism was substituted with environmental possibilism, which holds that people can live in an environment in which they find happiness. Environmental probabilism also assumes

that few urban situations are favoured over others (Carmona, 2003; Dempsey et al., 2012b). The inability of flats to accommodate all household types was considered and the design of flats was improved to accommodate everyone.

In the 1960s, Parker Morris developed space standards in response to concerns about living standards. Since 1967, these regulations have provided minimum square footage requirements for all property sizes and council houses. In 1980, these rules were repealed, resulting in a decrease in house sizes and an increase in density. Suburban living was favoured over urban living. The style and location of new homes in England throughout the 1980s were criticised, leading to the formation of the Labour Government's Urban Task Force in 1999 chaired by architect Richard Rogers. This report advocated for compact, mixed-use, high-density housing (Urban Task Force, 2005), which subsequently influenced housing policy. Assuming that higher density regions encourage social interaction and reduce isolation, it was considered a strategy for urban renewal (Dempsey et al., 2012b). Access to facilities and services, a sense of community, safety and social fairness are also emphasised in compact cities.

The history of housing and density in the United Kingdom demonstrates the significant steps taken to physically alter urban areas to alleviate the effects of high density to get us to where we are today. The establishment of building ordinances to support density has proven effective, but it has not aided in the comprehension of the opposition to high density. However, it also implies that user experience is consistently disregarded and that people's preference for high density is context dependent. This also shows that investigating density from a user's perspective can contribute to debunking myths associated with high density and uncovering arguments against consolidation, strengthening the case for user perception of density.

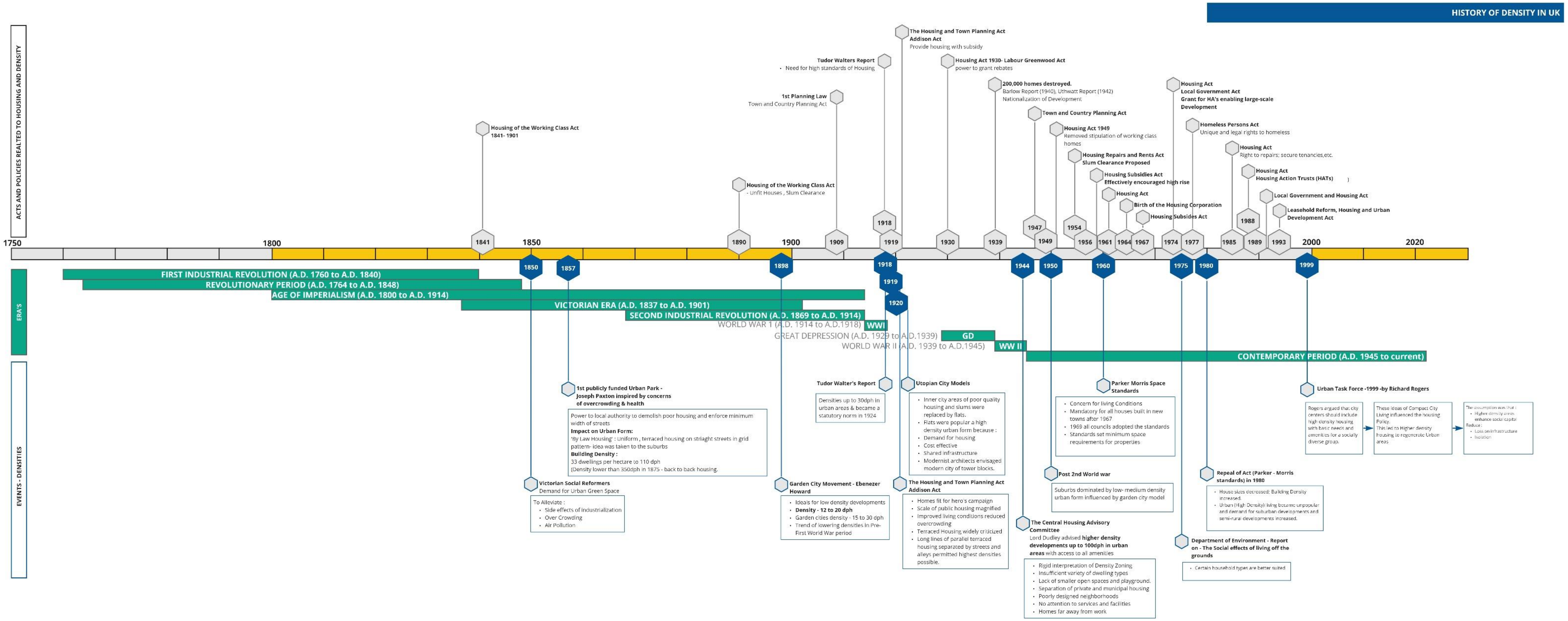


Figure 2-7. History of Density in Housing in UK

2.5.1 Development of Density Measures as an Urban Planning Tool in the UK

This section reviews the historical origins of density standards in the UK (England) and their changing role in the 20th century. The UK's density regulations underwent impromptu revisions in response to a legacy of unfit dwellings, poor living conditions, poverty and ill health. These revisions are sequentially described below independently for residential areas and non-residential areas.

2.5.1.1 Residential Areas

Development Plans and Residential Density (1909 -1946)

In the first half of the 20th century, town planning gained control of the general development of cities and towns and density became an integral part of this control as a result of increased urbanisation and public concern over inadequate housing. During this time, the technical definition of density was revised at least four times to achieve the standard residential density measurement. Between 1918 and 1946, government agencies developed guidelines for residential site selection, density and spatial layout. Low density was encouraged by the granting of funds to develop areas with 30 dph in urban areas and 20 dph in rural areas (DETR, 1998a, 1998b; Stilwell, 2017).

In 1919*, dwellings per acre or hectare* (density measure) became the official unit of measurement, with *net site area* defined as the sum of the plot area and small open spaces. In 1928, the definition of net site area was modified to include half the width of nearby highways. In 1944, the *Housing Manual* (Detr,1998) recommended changing the conventional measurement from *dwellings per hectare to people per hectare* (density measure – 1st amendment). The debate over whether to consider *dwellings per unit area versus people per unit area* or *gross versus net density* as the standard measure ended in 1944 when the Ministry of Town and Country Planning (MTCP) designated *gross residential density* and number of *persons per net acre* (density measure -2nd amendment) as the standard measure for residential density, a designation that remains in effect. The government fostered lower population densities through improved public health and sanitation, access to daylight, sunlight and wide parks which resulted in the adoption of comprehensive building codes.

The residential density zones in town planning schemes (1909-1946) ranged from 10 to 49 dwellings per hectare. However, these density provisions were not economically feasible for developers who proposed to build flats rather than houses. Therefore, to realise the potential of the land when building apartments, the density metric was switched from *dwellings per hectare* to *people per hectare* (density measure-3rd amendment). The maximum density was limited to 100 persons per acre, with 12 homes per acre in a residential zone and a 25 per cent site coverage. These density caps were debated by developers and LGB in 1918(in DETR, 1998a) and an economic break-even density of 40 dwellings per acre was agreed by the town and country planning. However, the evaluation of the living conditions by Dudley Committee (in DETR, 1998a) condemned the apartments and terraced dwellings for not fitting the household type (families with children) and for lacking in privacy, accessibility and design. In accordance with two planning principles: the English countryside was heritage and had to be conserved and; dwellings should be located within walking and cycling distances of the employment, resulted in the flexible application of density standards. The guidance was effective in promoting more open forms of development such as mixed-use areas with a combination of private houses and state housing apartments (DETR,1998).

The Development Plan System 1947 -1967

The Development Plan System was established by MTCP in 1947 as a strategic attempt to meet demographic goals, assess overcrowding, forecast future land needs and secure their economic use. This period witnessed four significant housing trends: an increase in the number of households, an increase in the number of flats (as a building type), a decrease in the average apartment size built by local authorities from 984 square feet in 1952 to 884 square feet in 1959, and difficulties in urban centres resulting from high population density and the scale of built form. To address these issues various density measures were devised to meet the particular requirements of strategic planning (e.g. overall town density) and in 1949, *habitable rooms* replaced dwellings per acre as the net density measurement since it provided an accurate estimate of the residential population (DETR, 1998a). Changing household sizes (including the trend toward fewer persons per habitable room), however, underlined the significance of occupancy density. As a result, in metropolitan areas, the gross densities decreased from 100ppa to 30-40ppa for mixed-use areas not surpassing 60ppa in congested areas. However, authorities found that land savings occurred when densities were increased from low to medium, therefore net densities were eventually increased to 140ppa employing buildings of two to three floors for families with children. The average density prescribed by the development plans for cities was 40ppa. The residential density zones in London, however, ranged from 200ppa in the city to 30ppa in the outskirts (DETR, 1998b).

Structure and Local Plans 1968 -1987

The structure plans represented national and regional planning policies, while the local plans highlighted local planning challenges. The residential and non-residential density proposals were meant to play a major part in the development of these plans. Due to the shifting viewpoints of succeeding administrations and the involvement of the private sector, however, the role of density was marginalised, and local governments took a more flexible approach to residential density regulations (DETR, 1998b).

Planning Policy Guidelines 1988 -1996

The Planning Policy Guidance (PPG) introduced by the government notice encapsulated two new developments. First, a connection was established between residential density and affordable housing and then the relationship between density, mixed-use and sustainable urban form was investigated. The policy emphasised residential density in consideration of environmental policies, local conditions and contextual character and various residential layouts and criteria for internal space. These inclinations fostered denser populations and complemented one another (DETR, 1998b).

Objectives of Density Measures Today

Density metrics in the UK currently serve three purposes: they are a factor that determines the population carrying capacity of a place and they establish the values of what and where housing, commerce and other facilities are necessary (Gordon et al., 2016). The plan emphasises residential density to densify within the city's boundaries to meet the short-term demand for housing. It determines whether increasing density is the most effective means of meeting demand and whether density is directly related to building form. The second purpose is to develop a suitable built form that upholds quality standards while achieving the desired density. The third is to discover underused capacity in terms of population density and to plan for urban renewal and regeneration (Gordon, Mace and Whitehead, 2016).

2.5.1.2 Non-Residential Density

The non-residential density has also been discussed in the policy frameworks however, it has not received as much attention as residential density by the planning authorities.

1909 to 1946

From 1909, the laws for non-residential density focused on building acts that governed both the building envelope and architectural form. Numerous building laws including building height zoning, daylight angles and site covering restrictions were considered for designing the built form.

1947 to 1967

In 1947, the term floor space ratio (FSI) was proposed as a method to limit site coverage and building space and to maintain an even distribution of non-residential uses. within each block, FSI ensured regular shaped plots and street patterns, suitable building conditions and dense expansion. Local planning authorities were directed to control construction densities to preserve the parking-to-building-height-to-mass ratio, encourage redevelopment and protect the characteristics of the urban form. Instead of FSI, plot ratios were investigated for larger communities since they were more adaptable in terms of building form.

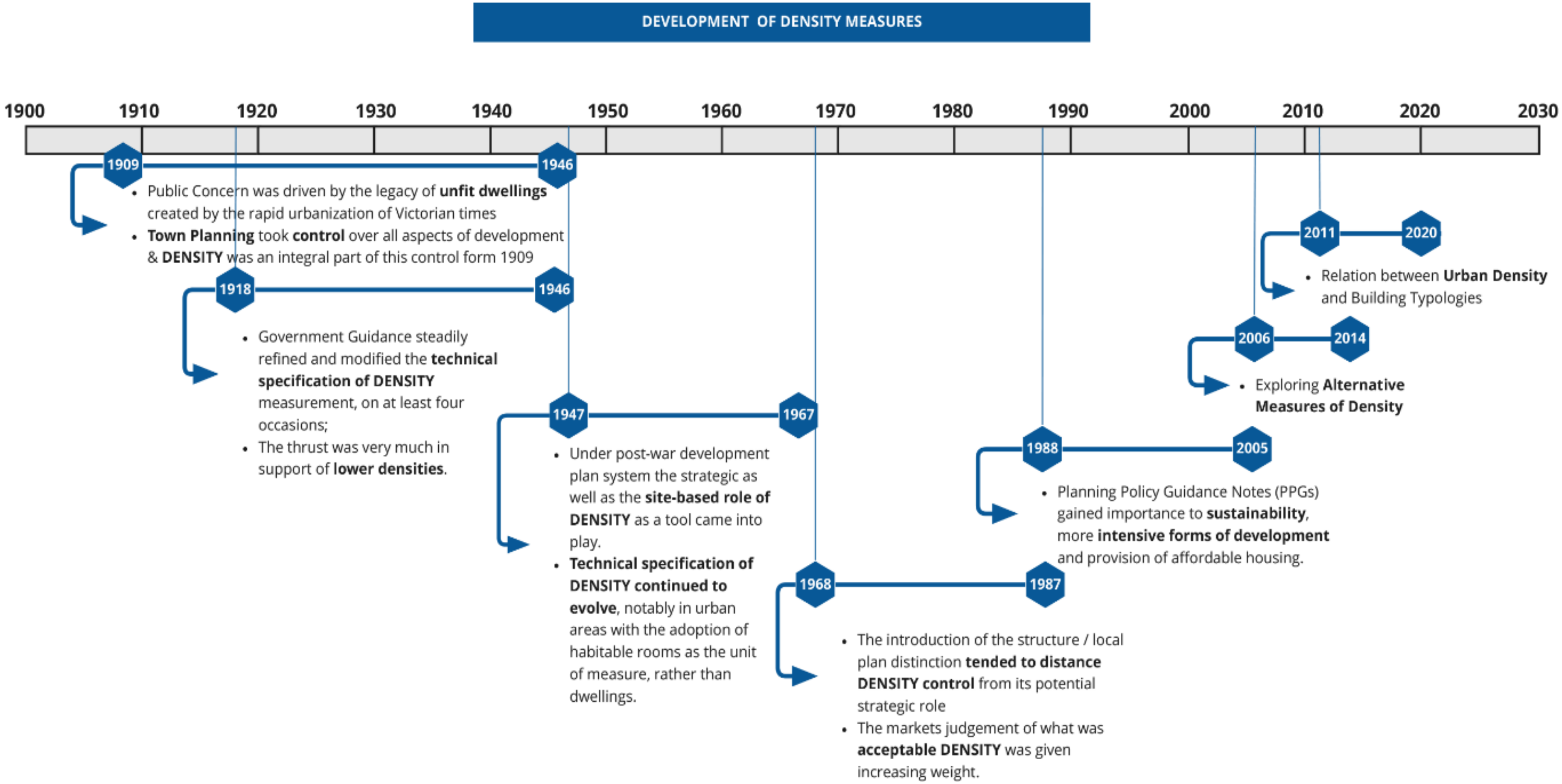


Figure 2-8. Development of density measures in urban planning in the UK.

1968 to 1987

Density was used as an indicator of numerous socioeconomic variables, including employment rates. For non-residential sectors, employment indices (varying from 69 to 325 workers per hectare) were adopted when the effectiveness of density as a measure of employment was called into doubt. Industrial Development Certificates (IDCs) and Office Development Permits (ODPs) monitored the retail-to-office space ratio. Otherwise, there were no density standards for non-residential uses.

Post-1988

The national and regional planning guidance issued since 1988, has overlooked the strategic role of density standards, irrespective of land use patterns (DETR, 1998a). The PPG did not provide specifications and measurements of density. Post 1988, the PPG provided limited guidance for promoting developments that reduce the need for car travel. However, the PPG 1 General policy and principles were revised in 1997 to identify the key role of the planning system to secure the provision of homes and buildings, investments and jobs that align with the principles of sustainable development (Bramley and Power, 2009).

It is essential to acknowledge that the measures discussed in the study are exclusive to England. While Northern Ireland, Scotland, and Wales follow similar plan-led land use management systems, recent changes implemented by the UK Coalition Government between 2010 and 2015 have increased the disparity between the land use management systems in England and the other three countries (Winter, 2016). These modifications may affect the applicability of the measures and findings to other regions in the United Kingdom. Therefore, when considering the results of this study in the context of urban planning and policy development, it is necessary to take into account the specific differences and nuances in land use management approaches among the various countries within the United Kingdom.

2.6 Interdisciplinary Approaches to Density

Density is a multifaceted concept (Alexander et al., 1988; Churchman, 1999; Ottensmann, 2021; Rapoport, 1975) that, over time, has created challenges that frequently require interdisciplinary collaboration to generate new knowledge and drive innovation. There are three primary arguments in support of an interdisciplinary study on density. First, density is mostly addressed in urban studies but is no longer suitable for single-discipline research. Second, discoveries and advancements in density research and development probably occurred at the intersections of disciplines such as urban studies and psychology, sociology, cognitive sciences and economics. Finally, the connections between the outcomes have benefited each discipline and broadened their perspectives.

2.6.1 Density and Sustainability

Regarding density and sustainability, several questions arise. The majority of them are related to density and the ensuing urban form. The Urban Task Force (2005), for instance, suggested that the compact, polycentric urban form characterised by mixed-use is the most sustainable urban form since it promotes walkability and enables the use of public transportation. Additionally, compact urban development is economically, socially and environmentally sustainable (Dempsey, Brown and Bramley, 2012).

Multiple studies demonstrate that dense, compact communities increase the use of public transport, bicycles and walking. The efficient use of infrastructure and land combined with access to facilities conserves land and other resources, hence reducing the city's carbon emissions (Jenks and Jones, 2010; Lehmann, 2016; Angel, Lamson-Hall and Blanco, 2021). A compact city can be characterised as a mixed-use spatial urban form with high density and seamless access to public transit networks that are intended to have a low impact on the natural environment (Dempsey, Brown and Bramley, 2012). However, the concept of the compact city remains controversial, mostly because the link between form, density and energy is complex and hence there is no single optimum solution (Jenks and Jones, 2010; Ahmadian et al., 2019). Even so, to enhance walkability (Lehman, 2016) and maximise density, this concept advocates certain design characters for urban form such as perimeter blocks, shorter block lengths, well-connected thoroughfares, residential lanes and tree-lined streets.

2.6.1.1 Density Sustainability Debate

The debate on high density and sustainability is ongoing (Cheng, 2010; Lehmann, 2019). The expansion of population and economies results in increased urban population, consumption and demand for energy and waste generation (DETR, 1998a; Dempsey, Brown and Bramley, 2012; Lehmann, 2019). Rapid urbanisation, increased population and its effect on economic growth and physical infrastructure suggests a need for more adaptive measures and resilient strategies to achieve sustainable urban futures. It involves pursuing planning policies that encourage higher residential density and new densification measures. For instance, the UK government is authorising local city councils to deny developments on the grounds of insufficient density (Lehmann, 2019).

As the number of people living in urban areas rises, city administration and governance, urban mobility, liveability and population density have become important factors for decision-makers but the tension between urban design, compactness and liveability will be a significant problem for cities (Lehmann, 2019). Diverse urban densities exist in different sections of the city (Urban Task Force, 2005; Berghauser Pont, Haupt and D'Laine, 2010; Oliveira, 2021). Different densities emerge from diversity, resulting in distinct demographic groups. The decision to live in the city or elsewhere at different times of a person's life affects the housing supply and demand and the physical infrastructure. Studies reveal, for example, that smaller and younger households prefer high-density living (cities), whereas families and the elderly prefer low-density (suburbs). Additionally, high-density living can be sustained for a shorter duration than low-density living (Vallance, Perkins and Moore, 2005; Howley, Scott and Redmond, 2009). Therefore, urban density and mixed-use developments are crucial in defining a neighbourhood's sustainability and liveability (Lehmann, 2019).

However, Newman (2005) emphasises the disparity between the concept of sustainability and people's desires and asserts that those desires and needs cannot be met by sticking to sustainability standards only. This shows that individual variances have a significant impact on perceived density, which is a constant and complex characteristic. Therefore, it is vital to determine how high density can be understood and the perception of it can help determine the extent of an area's sustainability.

2.6.1.2 Density and Policy Objectives

Considering the environmental and social effects of density standards derived from a comprehensive literature review, planning authorities formulate policy objectives with a dual motivation to improve infrastructure capacities to support high density and to establish a positive association with travel patterns, energy, social attitudes, biodiversity and design quality for sustainable developments (Alexander, 1993; DETR, 1998b; Lehmann, 2019; Berghauser Pont *et al.*, 2021; Oliveira, 2021). Economic, social and environmental planning policies seek to preserve scarce land and natural resources. The policy objectives outlined below are evaluated by the planning authorities of all nations, although the titles may vary.

2.6.1.3 Economic Objective of Planning Policy

Settlement Pattern and Travel Demand

High population densities build and foster local interactions, hence lowering the demand for vehicle trips. Larger, denser communities can reduce travel time and distance, enhance the number of facilities (shopping malls, hospitals, theme and technology parks), services and jobs in the vicinity and improve public transportation. Thus, policy objectives continue to support mixed-use projects, compact city forms and self-contained units. This not only minimises transport and energy demand but also reduces investment and operation costs (DETR, 1998a; Cullen, 2006; Berghauser Pont et al., 2021; Oliveira, 2021).

Density and Energy Demand

At every spatial scale, the settlement size, urban form, land use distribution, population density and layout itself have a substantial impact on energy generation, distribution and consumption. But density is not the only variable. The socioeconomic status of people provides many explanations for low or high energy consumption (Berghauser Pont et al., 2021). However, higher density developments afford the possibility of incorporating energy-efficient distribution systems and have better access to public and commercial services (Dempsey, Brown and Bramley, 2012). Consequently, there is a greater policy emphasis on compact cities and mixed-use developments (DETR, 1998a; Cullen, 2006). Although density policy is less important in this instance, it is compatible with the strategic goals for energy use and conservation.

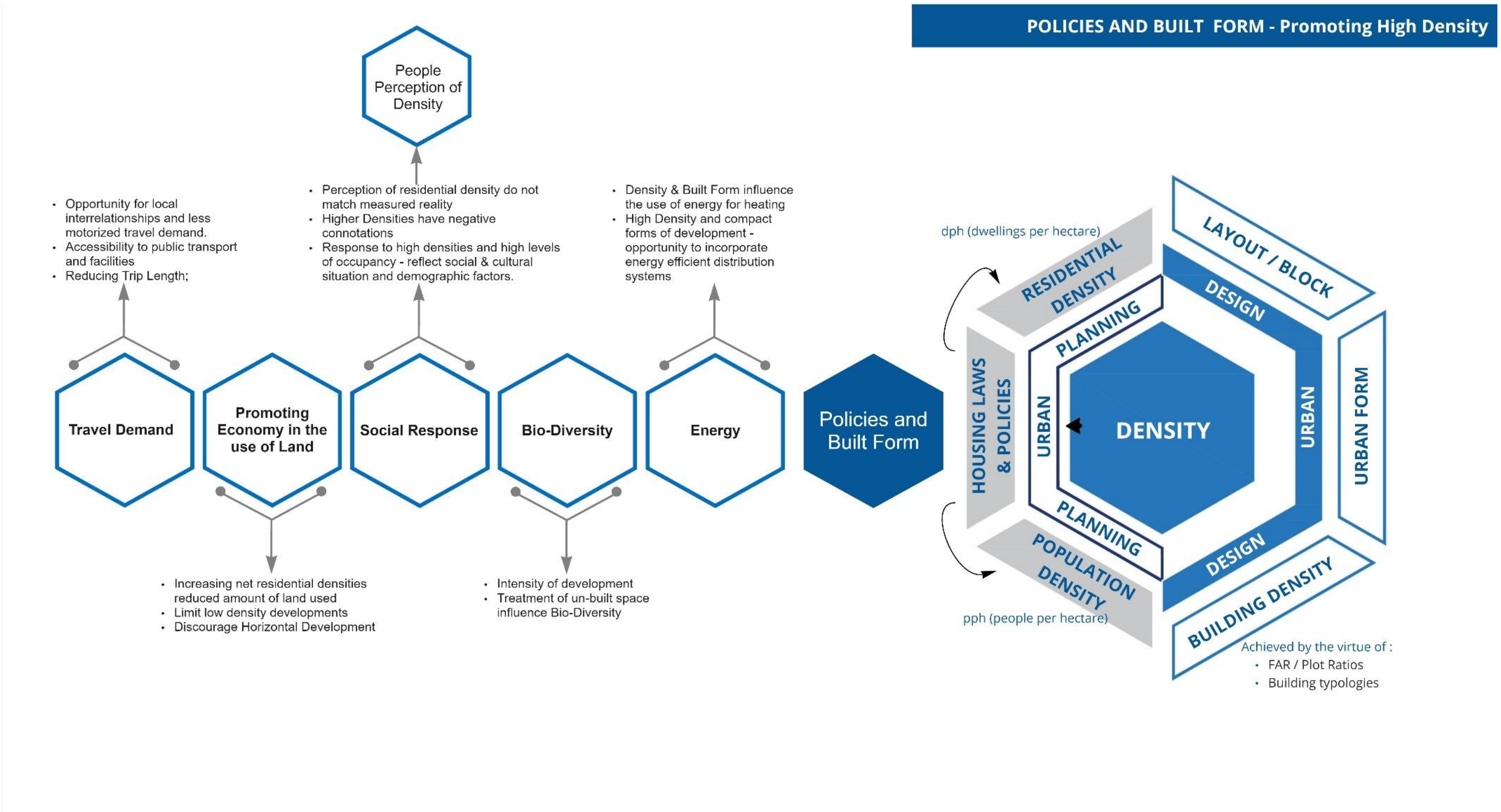


Figure 2-9. Policies promoting high density built form

Density and Economics

Three components of the economy are affected by densification: the rate of productivity and employment, inventions and investments and property values, public budgets and private real estate (Berghauser Pont et al., 2021). Higher population density improves productivity and increases creative knowledge-based services, which are more profitable than conventional manufacturing or agricultural industries. Higher densities reduce infrastructure expenses per capita, so saving public funds (Carruthers & Ulfarsson 2003; Cubukcu 2008; Edwards & Xiao, 2009, cited in Berghauser Pont et al., 2021). To ensure the safety and security of people living in high-density areas, however, more investment in surveillance is required.

2.6.1.4 Social Objective of Planning Policy

Population density does not reflect the complex interactions between urban residents and the built environment. Socioeconomic groupings (SEGs) produced from empirical assessments of density are a valuable indicator of QoL, health and well-being and employment; nevertheless, research has shown that they do not reflect the inhabitants' perception of density (Rapoport, 1975; DETR, 1998a). QoL includes physical, social and cultural indicators (MacLean and Salama, 2019) but concerning density satisfaction levels are central and may have a negative correlation with density. Although high density reduces the proximity between social structures and individuals, its correlation with social interactions is often contested (Berghauser Pont et al., 2021). For instance, high density is often not positively associated with a perception of safety and stability in communities (Dempsey, Brown and Bramley, 2012).

2.6.1.5 Environmental Objective of Planning Policy

Promoting heterogeneous urban environments in terms of land use diversity and open space management is one method for enhancing biodiversity. The function of density in this context is to assure equal distribution of land use to certify distinct built forms for the creation of diverse and complex social systems and to introduce

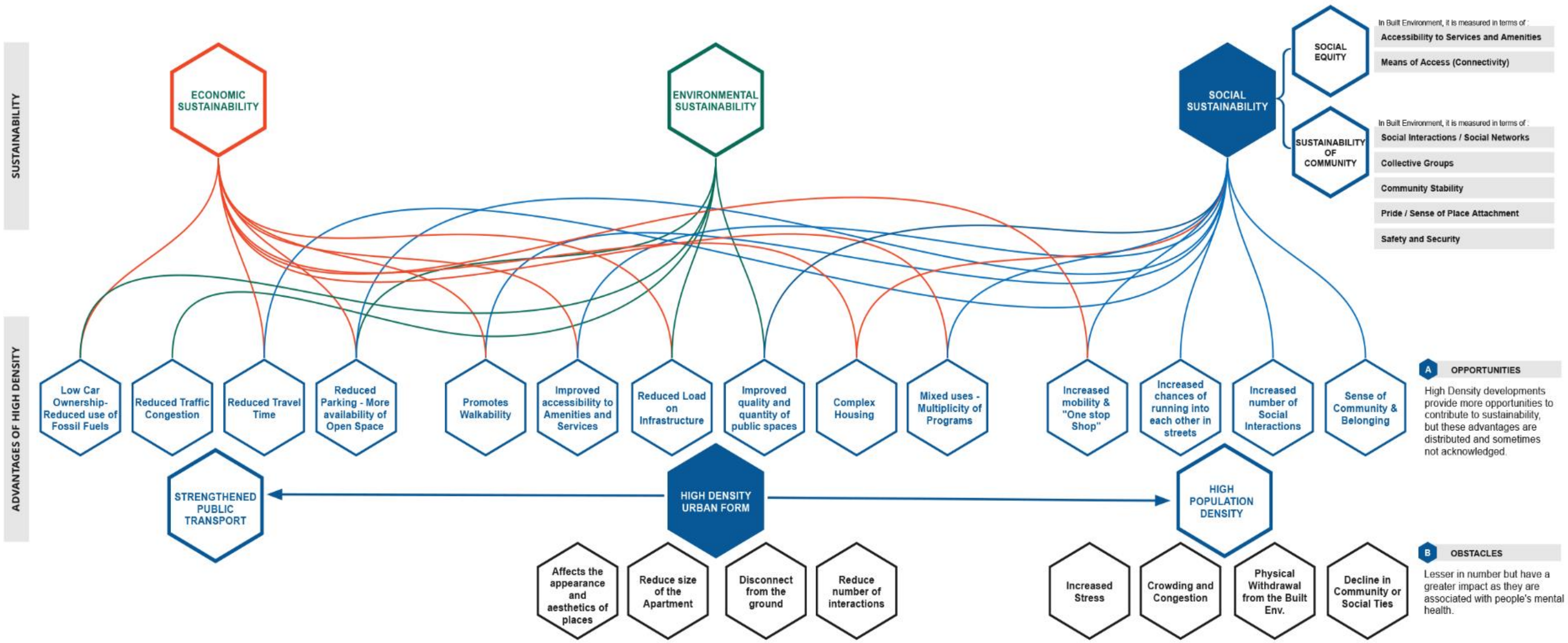


Figure 2-10. Density and three pillars of sustainability

varying scales of open spaces to encourage a wide variety of ecosystems and species (DETR, 1998a). At an urban scale, higher shares of impermeable surfaces and the urban heat island effect resulting in higher temperatures reduce biodiversity. However, the GHG emission originating from high-density living areas is slower than that in low-density areas. The same logic applies to the emissions due to the reduced use of cars in high-density areas (Berghauser Pont et al., 2021).

Several schemes such as infill development or brownfield development which seek to achieve maximum density targets around transit hubs and along transit corridors have been initiated but the link between sustainability and density in planning theories remains contested (Lehmann, 2019). The attempts to tackle the challenges presented by high density suggest that it does not necessarily decrease liveability but is acceptable as long as provisions for green spaces and parks at frequent intervals and walkable distances from the neighbourhoods are provided (Lehmann, 2019). High-quality urban design can also alleviate negative perceptions of density at a metropolitan scale (Lehmann, 2014).

2.6.2 Exploring the Link Between UN Sustainable Development Goals and Urban Density and Form

The UN Sustainable Development Goals (Project Everyone, 2021) do not exclusively address urban density or urban form as standalone indicators. But they indirectly relate to the city planning concepts through various goals (Berggren, 2017; Project Everyone, 2021; RICS, 2021). Four SDGs addressing population density, building density and urban form are discussed below:

Goal 11: Sustainable Cities and Communities: This goal emphasises the need for designing inclusive, safe, resilient and sustainable cities (Project Everyone, 2021). While it does not explicitly mention population density or building density, it recognises the need for affordable housing, efficient land use, accessibility and mobility to amenities and services and sustainable transport systems (Berggren, 2017); Oliveira, 2021).

Goal 9: Industry, Innovation and Infrastructure: This goal focuses on developing sustainable infrastructure and promoting inclusive industries. (Project Everyone, 2021). It does not directly address urban form or density, it aims, it aims to enhance connectivity, upgrade informal settlements, and provide basic access to infrastructure and amenities for all.

Goal 13: Climate Action: This goal aims to combat climate change and its impacts (Project Everyone, 2021). While it does not explicitly mention urban density, it calls for integrating climate change measures into urban planning and policies. This can indirectly influence urban form and density by promoting compact, transit-oriented development and reducing greenhouse gas emissions (Cervero and Bosselmann, 1994; Ewing *et al.*, 2018; RICS, 2021).

Goal 15: Life on Land: This goal emphasises the importance of sustainable land use and the conservation of terrestrial ecosystems (Project Everyone, 2021). While it does not specifically address urban density, it encourages sustainable land management practices and the protection of urban green spaces. These efforts can contribute to sustainable and liveable urban environments.

Sustainable development goals are measured through a combination of indicators. These indicators developed by United Nations in collaboration with member states and international organisations, have developed a framework of indicators that are measurable, relevant and reliable and they measure various aspects of sustainable development, such as poverty, health, education, employment and more (Department for Environment Food and Rural Affairs, 2013; European Commission DG Environment, 2018).

Data for measuring SDGs is gathered from various sources, including national statistical agencies, surveys, census records and other collection methods. Density metrics and land use provide crucial statistics for the SDG indicators. They assist in determining resource consumption, infrastructure needs, housing needs, social dynamic, employment ratios, concentration of jobs, urban form (compact or sprawl) and much more. Yet, the potential of urban density and urban form to contribute to sustainable development is overlooked and are yet to be recognised as indicators in the measurement framework for sustainable goals.

2.7 Transdisciplinary Approaches to Density

Density is a subject of investigation in other fields besides urban studies. There was a high likelihood that this study would benefit from insights from multiple domains, so an investigation was conducted to determine the alignment of significant questions and interests across disciplines and to identify subjective associations with an objective density that would aid in the understanding of perceived density. A systematic literature review identified several studies in environmental psychology and sociology; hence these two disciplines are briefly covered in this section.

2.7.1 Density and Environmental Psychology

Environmental psychology investigations on density concentrate on the micro – and macro-level individual perceptions of the urban environment. At the micro-level, several studies have identified the invasion of personal space as a result of increased social density while at the macro-level, researchers have identified crowding (affective density) and territoriality (Gifford, Steg and Reser, 2011; Newman and Hogan, 1981) as a collective phenomenon. The concepts of personal space (Sommer, 1969) and territoriality were founded on interpersonal connections, whereas the concept of crowding was founded initially on information overload (Simmel, Rapoport, 1975) and, later, social and spatial density. This study found cultural factors to be one of the important predictors of density perception.

According to Freedman's (1975) density-intensity theory, 'crowding is not negative, but it does intensify the reaction to other people'. He claimed that high population density decreases personal space (Brown, 2001), hence increasing social density and making individuals a significant sensory stimulus. In contrast, low-density car-dependent suburbs allow residents to escape urban issues and concentrate on their private lives (Newman and Hogan, 1981; Jenks, Burton and Williams, 1996; Neuman, 2005; Jenks and Jones, 2010; Berghauser Pont et al., 2021).

Some studies have explored the relationship between open space, access, dwelling types and their densities to determine whether certain built forms or typologies, are more effective at maintaining high population densities (Alexander, Reed and Murphy, 1988). From the perspective of social interaction, high-density areas were discovered to be more favourable (Lynch,1977; Gehl, 1977, 1978). The objection to high density is founded on 'half-truths based on ethnocentric perceptions' (Yeung, 1977; Chuang, 2001; Dempsey, Brown and Bramley, 2012; Sivam, Karuppannan and Davis, 2012) and misunderstandings regarding the negative social repercussions of high-rise living. Other research indicates that high-density living has positive consequences (Dempsey, Brown and Bramley, 2012; Burton, 2000).

2.7.2 Density and Sociology

The primary objective of sociological research in this field is to establish a correlation between urban density and social outcomes including public health, economic benefits and social disorder. Another issue that has been evaluated is the relationship between urban density and productivity, which influences task performance (Hummel, 2020). The evaluation of high-density living areas has resulted in identifying crime, employment and suicide rates as social indicators of QoL (Newman and Hogan, 1981; Stokols, Altman and Wiley, 1987; Gray, 2001; Dempsey, Brown and Bramley, 2012). However, these evaluations were based on average statistics which cannot infer a causative relationship and when other variables such as race, poverty and education are introduced, the relationships were less clear.

High density is frequently confused with high-rise buildings and the negative social experiences associated with living in high-rises are the primary reason why low rises are thriving (Newman, 1973). Recent research identifies 'better management' as a collective mitigation strategy that outweighs the negative consequences of high-rise buildings. Yeung (1977) debunks two myths about high-rise buildings: first, high-rises do not inevitably yield high densities and second, they do not limit living space or increase internal densities. Hawley (1972) enumerates the social benefits of density to counteract its negative effects. He asserts that high-density growth gives abundant opportunities for gratification, the selective association of values and motives and aids in task performance. They provide mutual aid in gaining access to scarce services and facilities, and exposure to education, innovative ideas and a multicultural society.

2.7.3 Section Summary

Despite all the benefits, the opposition to high density is well-known and largely due to cultural bias and the failures of dense developments throughout the world (Campoli and MacLean, 2007). Campoli (2007) suggests the terms 'bad density' and 'good density' to describe those environments which have been poorly planned and designed without accounting for human needs and those which achieve a balance between the population and housing respectively. It is not possible to maintain a low-density lifestyle since the costs will be huge in terms of energy and consumption of natural resources. However, high density could be more appealing if overcrowding and monotony are avoided. This can be accomplished by regulating the gross residential density through plot ratios that affect social and spatial density.

The shift to real-life scenarios from the experimental paradigm in environmental psychology explored the behavioural changes that an individual undergoes when exposed to high-density situations. The phenomena identified such as crowding, invasion of space, personal control and territoriality are a result of variations in social and spatial density. However, these phenomena are also seen as cognitions about the physical world which shape an individual's perception, emotional responses, personal values and preferences towards a variety of physical settings. Hence the human associations with density identified in environmental psychology can be considered a first step towards understanding perceived density. The survey analysis conducted for this study can determine whether or not individuals perceive urban areas using these associations.

2.7.4 Density and Urban Form

Testing the layouts or spatial arrangement of the buildings at a block scale in the early 1960s by Sir Leslie Martin and Lionel March, marked the commencement of the first phase of the research on establishing relations between density and urban form (Alexander, Reed and Murphy, 1988). Using figure-ground and juxtapositions, several types of layouts and plot ratios were methodically analysed. Identifying building typologies such as court-type building shapes that can handle greater density with access to amenities than towers, was one of the motives. It was also discovered that block size and street networks have a crucial effect on urban design.

James's (1967) research into high-density layouts questions the thresholds for high density (10-80 ppa) and suggests moderate gross densities between 30 and 50 ppa. He mentions obstacles connected with high population density such as design challenges and individual desire for privacy and space. Keeble (1969) analysed densities as a function of plot size and their association with dwelling types and physical characteristics. By assigning one FAR to one type of dwelling, he pushed for moderate density over high-rises. This proposal assures that occupancy rates, dwelling sizes and density remain consistent. Similarly, the deductive analysis of the independent variables that could influence densities such as dwelling form and size, lot size and block arrangement reveal that dwelling form is the most influential factor in determining density measurements (Alexander, Reed and Murphy, 1988).

The consequences of the prescriptive and descriptive use of density metrics were analysed in the second phase (Berghauser Pont, Haupt and D'Aine, 2010) of relations between density and urban form. Earlier studies made normative use of density measures to create a connection with urban form, leading to predetermined design implications. The investigations revealed numerous issues with density metrics including ambiguity, oversimplification, over-aggregation and a tenuous relationship with perceived density. The designer is expected to follow the prescriptive guidelines and achieve a specified density with one or more building typologies. However, the guidelines do not guarantee the type of development, whether compact or spacious nor the availability of green spaces. Prescribed density is inflexible in that it restricts the composition of urban layouts and building types (Berghauser Pont, Haupt and D'Laine, 2010). In contrast, describing density with a map or a plan begins with evaluating the landscape to uncover patterns based on the correlation between urban form and density to arrive at an abstract representation. However, the majority of urban landscape descriptions are based on averages and there is a risk of overlooking small-scale changes in built form (Cullen, 1971; Berghauser Pont, Haupt and D'Laine, 2010). To bridge this gap between the quality and quantity conveyed by prescriptive guidelines and density measurements, Pont (2010) viewed density as a multivariable phenomenon comprised of three measures: FSI, site coverage (GSI) and network density (N).

Understanding the complexity of the notion and distinguishing between actual density and perceived density is the focus of the third phase of the research on urban form and density (Churchman, 1999; V Cheng, 2010; Fisher-Gewirtzman, 2018). High density is a subjective concept that differs between countries and cultures. To appreciate the methods for reducing the negative consequences of high density, it is necessary to collect information on how users perceive density. A comparison of low versus high-density studies to decide which should be promoted reached an impasse. Both options offer benefits and drawbacks. Even if a high-density city is efficient in terms of transit, infrastructure and amenities from a sustainability standpoint, resource supply and allocation are a concern (Dempsey, Brown and Bramley, 2012; Sonne, 2017). The acquisition of resources is now a global and political priority and rather than developing new high-density cities, it is more important to future-proof the existing ones (Vale and Vale, 2010, Edward NG). Rapid urbanisation and the need for housing have proved that low-density sprawls are incapable of accommodating the requisite population, hence demonstrating the necessity for densification. In contrast to densification, high density is equivalent to optimal density, the threshold for which has not yet been determined. However, the optimal population density of a city is contingent on the availability of local natural resources and its economic capacity. Density must be integrated with land use diversification, spatial layouts and building form to achieve the much-criticised qualitative indicator for high density. It also can be deduced that objective density is crucial, but the construction and design of high-density places that are comfortable and favourable is also an important factor. The evidence for constructing such environments continues to be challenging.

2.8 Models of Urban Planning Based on Density

Cities are complex and dynamic systems that have piqued the interest of researchers from various disciplines (Jacobs, 1961; Kostof and Tobias, 1999; Kostof, Castillo, and Tobias, 1999; Sergio Porta, Paolo Crucitti, 2008; Ewing et al., 2018). Urban density, regardless of city form, has been found to have both direct and indirect effects on social, economic and environmental factors. Human or individual-oriented models and physical or system-oriented models are the two main types of urban density models (Newman and Hogan, 1981). Human-oriented models derived from behavioural science focus on the psychological and sociological consequences of increasing density. Ethological models emphasise physiological stress and territorial violation as consequences of increasing urban density, whereas sociological models emphasise crime, health issues caused by space congestion, and the loss of rural or suburban lifestyles. In relation to urban density, psychological stress has also been observed as a result of space violation and overcrowding. These human-centred models shed light on the personal experiences and social dynamics associated with density. Physical or system-oriented models, on the other hand, see density as a component of the larger urban system. They investigate resource consumption, infrastructure costs, transportation patterns, and environmental consequences. These models look at the physical design and layout of cities, as well as how density affects energy and material consumption, waste generation, and environmental sustainability. Researchers gain a more comprehensive understanding of the multifaceted nature of urban density and its implications for cities by considering these various perspectives and relationships with density.

The term ethological models refer to the application of theoretical constructs embodied in animal research. The two important concepts used by ethologists to examine urban density are physiological pathology and territoriality.

Animals in crowded environments have been shown to experience physiological overstimulation, decreased reproductive activity, and other effects (Calhoun, 1962; Leyhausen, 1965; Southwick, 1967; Christian et al., 1960). While these outcomes have been attributed to a lack of space, it is important to note that the relationship between population density and these outcomes is complex and may be influenced by other variables (Morris, 1968; Lorenz, 1966). In addition, animal study results may not directly apply to human behaviour, and other factors may play a more significant role in human behaviour (Freedman, 1974, 1975).

Territoriality, which is commonly associated with animal behaviour, has been used to imply that humans have an innate need for private space and that high-density situations can increase aggression (Altman, 1975; Taylor and Stough, 1978). However, the concept of territoriality as an instinctive trait of animal behaviour is not universally accepted, and there is scant evidence that humans possess a territorial instinct. As culture and social factors play a significant role in human behaviour, it is dubious to directly apply animal behaviour theories to human society and spatial requirements (Altman, 1975; Namazian and Mehdipour, 2013b). There is some validity to territorial theories, but their applicability to high-density urban settings is uncertain. As demonstrated by architectural designs that cater to individual territorial needs, the concept of human territoriality can be maintained without being negatively associated with high-density living (Newman and Hogan, 1981) .

Public health officials have traditionally linked high urban density to poor health because they believe infection spreads faster in densely populated areas. The Black Death and industrial revolution studies of inner-city slum children support this belief. However, recent empirical studies have not consistently linked urban density to ill health (Newman and Hogan, 1981). Population density is complex, and diet, sanitary engineering, and disease control have improved public health. Health has improved dramatically in developing world high-density cities with clean water, waste collection, and healthy diets. The idea of providing a "wholesome supply of good air" in homes is unfounded because energy conservation concerns have replaced air, light, and sunshine. Low-density suburbia's spatial needs are more influenced by culture (Newman and Hogan, 1981).

Personal space and proxemics research shows that violating it can be uncomfortable (Brown, 2001; Sommer, 2007). Personal space and urban density are culturally complex. Studies show that people prefer an optimal interpersonal distance and are uncomfortable with extremes. Age, status, gender, similarity, and setting affect the comfortable distance zone and responses to its violation. Invasion of privacy can also foster relationships(Altman, 1975). Thus, personal space and urban density are not necessarily negative and subject to cultural norms and expectations. Personal space studies can help determine a family's room needs, but not urban density (Newman and Hogan, 1981). Human culture and adaptability must be considered.

Crowding is a perceptual phenomenon, not a uniform density level at which abnormal behaviour occurs, according to psychological research on crowding and density (Freedman, 1975; Rapoport, 1975c; Edney, 1977a; Mueller, 1981). Crowding varies according to cultural factors, the number of individuals interacting, their tasks and roles, their relationships, and their psychological states (Saegert, 1973; Freedman, 1975; Loo, 1990). Environmental psychologists contend that cultural and microenvironmental differences are more influential than physical density levels in determining the effects of density. In situations where there is an excessive amount of information to be processed, crowding is also viewed as information overload. Recent psychological studies have highlighted the positive aspects of density, namely increased interaction, community integration, and human satisfaction (Freedman, 1975; Edney, 1977b). The criticism of high-rise living and its socially isolating effects is attributed more to low density on the ground floor than to the building's height. Studies indicate that low-density environments may limit children's exposure to diverse people, activities, and places, thereby inhibiting their creativity. The rejection of high density based on individual-oriented studies is increasingly being criticised (Newman and Hogan, 1981), and it is becoming increasingly apparent that the relationship between density and behaviour is complex and culturally dependent.

Incorporating ecosystem variables and ecological theories, ecological systems models provide a holistic approach to comprehending urban systems. These models emphasise the connection between urban and natural ecosystems and the significance of urban ecosystem density (Newman and Hogan, 1981). Compared to low-density, sprawling cities, high-density cities have advantages in terms of energy and material use, waste production, pollution levels, and land use efficiency. While high-density cities may have higher levels of pollution, their resource consumption and waste production per capita are significantly lower than those of low-density cities (Dempsey, Brown and Bramley, 2012). According to the ecological systems model, increasing urban density is essential for addressing resource conservation and environmental impact. However, additional information and analysis are required to fully comprehend and apply this model. The significance of transportation, particularly automobiles, is also acknowledged in these models of ecological systems (Dempsey, Brown and Bramley, 2012).

Throughout history, descriptive historical models such as transit oriented developments and transit adjacent developments, examine the relationship between urban form and transportation technology. These models emphasise the impact of increased mobility on urban expansion and dispersion. Studies on particular cities delve into the specifics of transportation technology and its social ramifications, focusing on how individuals interact as transportation evolves. Many future prescriptions are based on historical trends, with some advocating for low-density trends based on the development of electronic communication and automobiles and others emphasising the social benefits of higher-density cities with public transport(Cervero and Bosselmann, 1994). The inequities and limitations of low-density automobile cities, including restricted access for certain segments of the population, are highlighted. It is believed that higher-density cities with walking and public transportation foster greater interaction and community cohesion (Jenks, Burton and Williams, 1996; Dempsey, Brown and Bramley, 2012). These models raise questions regarding the reliance on technology, especially automobiles, in contemporary cities and suggest the need for urban systems that prioritise personal contact, accessibility, and community integration. Other models investigate the economic, energy, and environmental aspects of this dependence in greater depth (Newman and Hogan, 1981; Ewing *et al.*, 2018).

Historically descriptive models examine the relationship between urban form and transportation technology over time (Cervero and Bosselmann, 1994). These models highlight the influence of increased mobility on urban growth and dispersion. Studies on specific cities delve into the specifics of transportation technology and its social implications, with a focus on how people interact as transportation evolves. Historical trends are frequently used to predict the future, with some proponents of low-density trends based on the development of electronic communication and automobiles and others emphasising the social benefits of higher-density public transport cities (Newman and Hogan, 1981; Ewing *et al.*, 2018). The disadvantages and restrictions of low-density automobile cities, such as restricted access for certain population segments, are highlighted. Denser cities with walking and public transportation are viewed as fostering greater interaction and community cohesion. These models raise questions regarding the reliance on technology, specifically automobiles, in contemporary cities and suggest the need for urban systems that prioritise personal contact, accessibility, and community integration. Other models further investigate the economic, energy, and environmental ramifications of this dependence.

The models of urban density resulting from these approaches are summarised in Table 3-3. These models describe the potential physiological, psychological and pathological consequences of human density. They predict human spatial behaviour in situations of high and low population density. They determine the environmental and ecological effects of urban density. In proportion to how often these models are cited, they are also contested because models rely mostly on demographic information generated from objective assessments of population density and exclude user experience. The controlled studies used to validate these models get their social equivalents from ethology. Individual differences and cultural relativism are also limitations that prevent the generalisation of the findings and continue to be a concern for researchers. This constraint necessitates a larger number of inquiries into the subjective aspects of density to account for the disparities in opinion that result from cultural differences. Environmental psychology investigated human spatial behaviour to determine the theories of personal control and personal space (Katz, 1937; Sommer, 1959; Hall, 1966, cited in Stokols et al., 1987); territoriality (Altman, 1975; Taylor and Stough, 1978; Duarte, 2017); and crowding (Freedman, 1975; Stokols et al., 1987). As negative effects of high population density, sociology and environmental psychology has focused on establishing correlations with stress, arousal, aggression, behavioural modifications and withdrawal. This empirical research shed light on the phenomenon of crowding, but because the distinction bet3ween crowding and density was not made, crowding was viewed as a function of space alone and the interaction of social and personal factors with spatial determinants was disregarded (Stokols, 1972).

Table 3-3. Planning models of cities with density at their core (adapted from Newman and Hogan, 1981)

HUMAN OR INDIVIDUAL-ORIENTED MODELS		
DISCIPLINE	**Models**	**Effects of high density**
ETHOLOGY	Physiological Pathology Models	Greater physiological stress.
	Territoriality Models	Aggression through increased violation of territories.
SOCIOLOGY	Social Disorder Models	Social disorders such as crime, suicide and drug taking.
	Public Health Model	Ill health due to a greater opportunity of infection, less air and less light.
	Loss of Rural Innocence Models	Removes the beneficial value of rural lifestyles available in garden suburbs.
PSYCHOLOGY	Personal Space Models	Psychological stress through more frequent violation of personal space.
	Crowding Models	Crowding causes behavioural effects, although the feeling of crowdedness varies with culture.
	Arousal Theory	Source of arousal and affects the task performance and social behaviour.
	Density-Intensity Model	Intensify the individual's typical reactions to the situations.
	Behavioural Constraint Model	Imposes limitations on freedom to choose among a number of behavioural options.
	Personal Control Model	Affects the actual or perceived control of an individual over the urban environment.
PHYSICAL OR SYSTEMS-ORIENTED MODELS		
ECOLOGY	Ecological Systems Model	Increasing urban density will lower resource and environmental impacts.
HISTORY	Descriptive Historical Models	Favours the public transport city and walking city rather than vehicle city.
ECONOMICS / GEOGRAPHY	Density Gradient Model	Provide cheaper access as transport costs, particularly of energy rise.
	Central Place Theory	The theory explains the number, size, location and spatial distribution of cities.
	Concentric Zone Model	This model is based on the idea that land values are highest in the centre of a town or city and so is the density.
TRANSPORTATION ENGINEERING	Prescriptive empirical and simulation model; Transit-Oriented Models (TODs) and Transit-Adjacent Models (TADs)	Promote public transport, shorten car trips, encourage bicycling and walking, save energy, lower infrastructure costs and improve environmental quality.

Urban studies examined objective measures of density such as gross residential density, and FAR and FSI to implement planning models for cities in central place theory (Getis and Getis, 1966), concentric zone theory (Burgess), the sector model (Hoyt, 1970), the multiple nuclei model (Harris and Ullman, 2014) and many others (Newman and Hogan, 1981). These models constitute the city's urban armature which refers to the placement, arrangement and relationship between social and physical elements. The concentric zone model is based on the processes of invasion and succession, where invasion refers to the natural extension of inner-city zones to the outer zone. Succession occurs when a region is swamped and overburdened by invading activities. This hypothesis led to competition for limited space in the city due to its central location, conflict between city dwellers and suburban residents and the concentration of dispersion of densities and the social structure of the city (Urban Sociology, 1980). Along similar lines, the sectors concept was created to permit access to all the sectors intended as wedges emanating from the city centre and including mixed-use, from the outskirts to the core. In contrast, the numerous nuclei theory (Harris and Ullman, 2014) hypothesises that cities are not monocentric and feature multiple small centres. It is a natural process rather than a deliberate one that these centres may have varied primary uses.

2.9 Towards Perception of Density

From the early 1900s to the present, density has been a subject of study for a considerable amount of time. As a result, there is a large body of literature from a variety of disciplines that is briefly described in this section in order to comprehend the progression of density to perceived density. This section focuses on the past research on density from two viewpoints: that of the behavioural sciences (reflecting users' and laypersons' views) and that of the urban studies (design professionals) on how environments were examined and are divided into three key periods.

2.9.1 1950 to 1974

A first group of behavioural science studies undertaken between the 1950s and the 1970s was primarily driven by the need to examine the psychological and pathological impacts of living in high-density urban districts on people (Stokols et al., 1987), sometimes known as overcrowding. Four methods were used to investigate crowding: ethology (animal studies; Calhoun.1962,1966 as cited in Stokols, 1972); experiments on human use of space; experimental studies to determine the effects of crowding on humans (Stokols, 1972); and using census data to conduct field studies in urban environments.

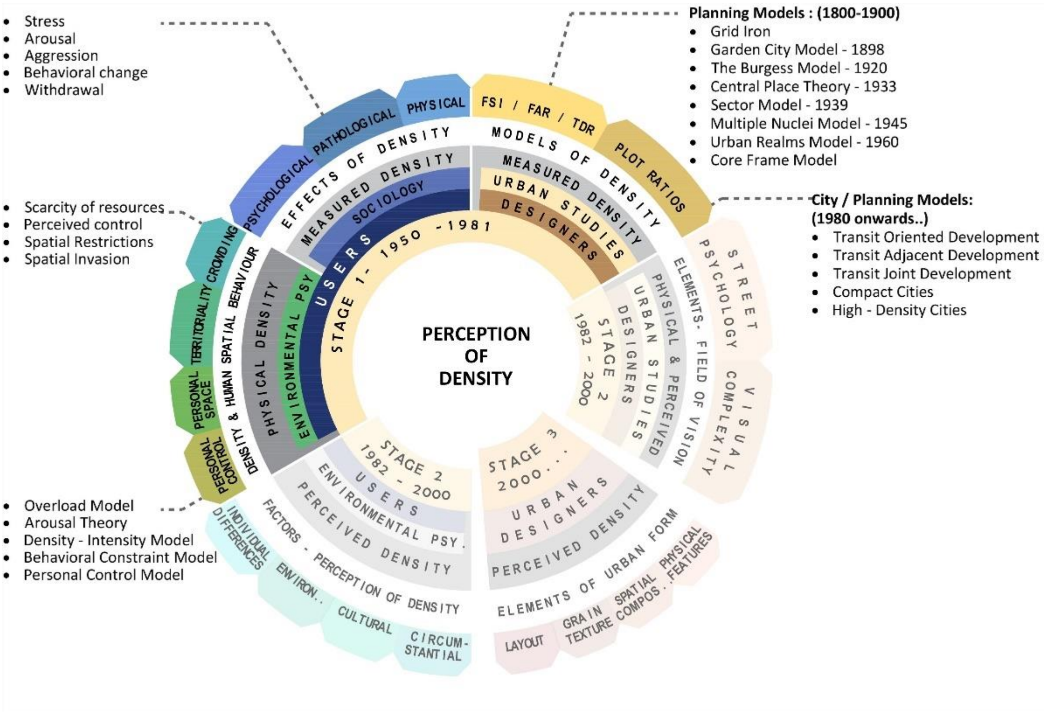


Figure 2-11. Stage 1 – 1950-1974

Environmental psychology investigated human spatial behaviour to determine the theories of personal control and personal space (Katz, 1937; Sommer, 1959; Hall, 1966, cited in Stokols et al., 1987); territoriality(Altman, 1975; Namazian and Mehdipour, 2013; Thwaites, Simpson and Simkins, 2020), and crowding (Freedman, 1975; Stokols et al., 1987). As negative effects of high population density, sociology has focused on establishing correlations with stress, arousal, aggression, behavioural modifications and withdrawal. This empirical research shed light on the phenomenon of crowding, but because the distinction between crowding and density was not made, crowding was viewed as a function of space alone and the interaction of social and personal factors with spatial determinants was disregarded (Stokols, 1972).

Urban studies examined objective measures of density such as gross residential density, and FAR and FSI to implement planning models for cities in central place theory (Getis and Getis, 1966), concentric zone theory (Burgess), the sector model (Hoyt, 1970), the multiple nuclei model (Harris and Ullman, 2014) and many others (Newman and Hogan, 1981). These models constitute the city's urban armature which refers to the placement, arrangement and relationship between social and physical elements. The concentric zone model is based on the processes of invasion and succession, where invasion refers to the natural extension of inner-city zones to the outer zone. Succession occurs when a region is swamped and overburdened by invading activities. This hypothesis led to competition for limited space in the city due to its central location, conflict between city dwellers and suburban residents and the concentration of dispersion of densities and the social structure of the city (Urban Sociology, 1980). Along similar lines, the sectors concept was created to permit access to all the sectors intended as wedges emanating from the city centre and including mixed-use, from the outskirts to the core. In contrast, the numerous nuclei theory (Harris and Ullman, 2014) hypothesises that cities are not monocentric and feature multiple small centres. It is a natural process rather than a deliberate one that these centres may have varied primary uses.

2.9.2 1975 to 2000

The second group, encompassing the years 1975 to 2000, investigated perceived density and its contributing elements using a different methodology. This series of investigations was based on Rapoport's (1975) theoretical framework for environmental cues for perception studies. This key work prompted the study of the built environment to distinguish between measured, physical and subjective density. The three densities were interdependent, with measured density accounting for statistical calculations using objective measures, physical density being an association between measured density and the physical attributes of the built form and perceived density accounting for the cultural and social factors of the users in interpreting physical density (Alexander et al., 1988).

Rapoport's hypothesis also questioned the effect of culture on social interaction. Environmental psychology conducted additional research on behavioural responses to density to identify individual and cultural characteristics that influence human perception (Evans et al., 2000; Taylor, 1981). This study examined if individual differences vary with density and their nature and magnitude. Using concepts such as visual complexity (Bergdoll and Williams, 1990; Cheng, 2010b) and contextual compatibility (Groat, 1985), urban studies examined the relationship between street scale urban form and perceived density. Visual complexity examined the role of the physical attributes of the built form in terms of variety and distinctness of form, colour, material and pattern, and contextual compatibility examined the urban environments at the street level to identify the congruity between built form elements of façades that people use to evaluate.

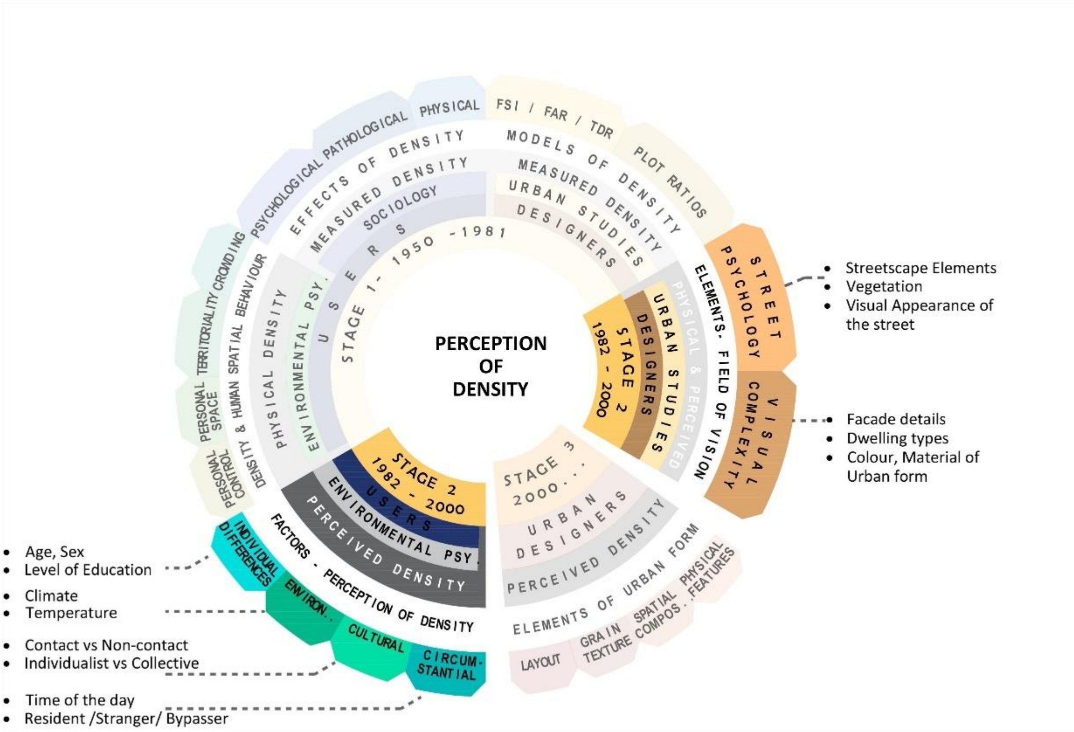


Figure 2-12. Stage 2 – 1975-2000

2.9.3 2000 Onwards

In response to the high-density problem, this most recent wave of research has focused on establishing measures for perceived density, such as the SOI (Fisher-Gewirtz and Wagner, 2003) and the sky view factor (Cheng, 2010b). The importance of ground level pedestrian density perception research is increasing (Araldi and Fusco, 2016; Ewing et al., 2016; Ewing and Handy, 2009). The SOI examines the volume of free space from reference sites to establish its association with perceived density (Fisher-Gewirtzman and Wagner, 2003). Using virtual reality tests, this metric was then used in indoor settings to analyse perceived density and visual privacy in minimal apartments (Fisher-Gewirtzman, 2017). Similarly, the sky view factor was developed alongside other built and non-built form elements to determine the perceived density and satisfaction of high-density areas. The necessity and significance of including pedestrian perspective when measuring perception is informed by an attempt to ascertain the user perspective.

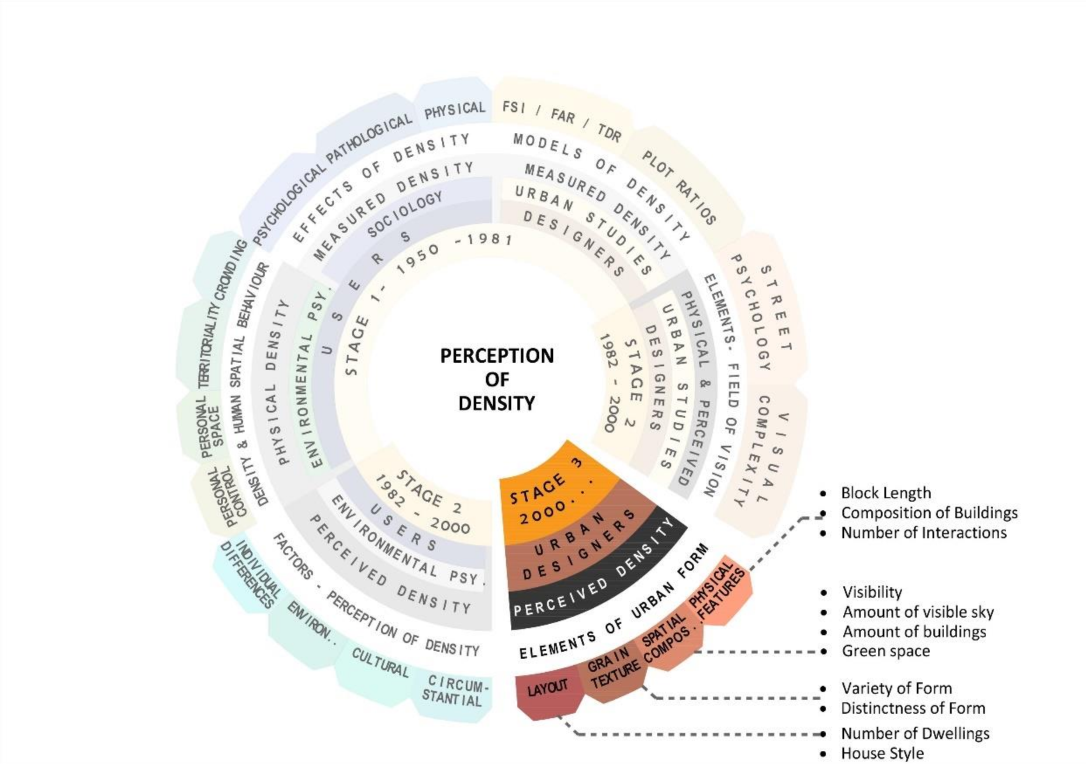


Figure 2-13. Stage 3 – 2000 onwards

2.10 Summary

Over time, research on the perception of density has evolved, exploring psychological and pathological impacts, objective measures, and perceived density. Studies have examined crowding, personal space, territoriality, and the relationship between urban form and perceived density. Recent research focuses on developing metrics like the Sky View Factor and Sense of Openness Index to evaluate perceived density. It is evident from these studies that the interplay between physical attributes, cultural influences, and individual differences shapes how people perceive and experience density in urban environments.

Besides, it is not only important to extend the use of density measures to reveal the spatial characteristics and properties of the urban form, but also to acknowledge the duality of the concept as both subjective and objective. Two people's perceptions of the same numerical density can vary based on their tolerance and attitude toward a specific condition. This exemplifies the disparity between how cities are conceptualised and how their inhabitants see them. There are thus four reasons to pursue research on perceived density: first, to assist in visually evaluating the quality of urban form; second, to eliminate the negative connotations and misconceptions associated with high density; third, to successfully integrate user perspective into the design of high-density cities; and fourth, to assist in the design of sustainable urban form with positive user perception.

Chapter 3. Literature Review Part 2 – Perception of Density

This chapter covers the literature on perceived density and visual perception theories and concepts. It begins by examining the definition of perceived density and the factors that led to its change. Then follows the history of visual perception, which aids in deciphering the process and establishing the essential principles for understanding visual perception. The final section examines the theoretical premise and empirical research on density.

3.1 Definitions

The term perceived density was coined by Rapoport (1975) to derive more meaningful insights based on current definitions of measured density. It is an individual's perception of the space available and its organisation and the estimate of the number of people in the given area (Rapoport, 1975; Churchman, 1999). Rapoport argued that density is a perceived experience and recognised the role of other factors such as spatial attributes of the built form, social interaction and personal traits in influencing such experience. Building on Rapoport's work, perceived density is also defined as the interaction between three factors: physical density (inclusive of measured density), individual cognitive factors and sociocultural factors (Alexander, Reed and Murphy, 1988). Although the concept of perceived density is rigid and means the same (i.e., density perceived by people) across the world, the descriptions of the three factors involved are not rigid and have different interpretations.

Physical density is a combination of objective and physical characteristics of the built environment and its users that contribute to the density that is perceived by people in real-life situations (Alexander, Reed and Murphy, 1988). It includes measured density (population density, building density), while the physical characteristics are the attributes of the built environment such as building height, space between the buildings, enclosure ratios which are not included in density measures. Individual cognitive factors include feelings of control or lack of it, privacy (Taylor, 1981a; Alexander, Reed and Murphy, 1988), personal preferences, psychological states, etc. Social and cultural factors include users with different cultural backgrounds, sociocultural norms of interaction, and levels of social interaction (Rapoport, 1975c;

Alexander, Reed and Murphy, 1988; Evans, Lepore and Allen, 2000). However, measuring individual cognitive factors and sociocultural factors can present challenges. Both, encompass a wide range of variables, including beliefs, values, social norms and cultural practices. Moreover, individual cognitive factors and sociocultural factors are influenced by the context in which they occur (Evans, Lepore and Allen, 2000). Additionally, the methods used to measure these factors include surveys, interviews and observations, which often rely on self-reporting or subjective interpretations and can introduce biases or limitations in data collection. This explains why there are significantly more empirical and theoretical investigations on objective density than perceived density.

3.2 Redefining Perceived Density

Rapoport's theoretical approach to perceived density provides ample material for future inquiries, but it is old, and a new approach can aid in decoding the phenomenon more accurately. The definition of perceived density by Rapoport (1975) was last refined by Alexander et.al in 1988, as explained in the previous section.

Current definitions of perceived density are a mix of social density and spatial organisation (Rapoport, 1975; Churchman, 1999) or a combination of objective density and its relationship to architectural form and sociocultural elements (Alexander, Reed and Murphy, 1988). They depend on notions such as the perception of space, which is an independent field of study, and sociocultural aspects, which cannot be speculated in a random situation. Although these definitions are used as a starting point for investigating the concept of perceived density, they are broad and subject to interpretation. Rapoport's concept is still used today, but research on perceived density as a topic has improved since the 2000s and given the volume of study on density as a concept in the field of behavioural science, it is possible to combine the data and reinterpret the term 38 years after its introduction.

The logical treatment of the phenomenon of perception of the urban environment and theories on visual perception suggest that one considers two aspects while perceiving the urban environment: the physical attributes of the object and the stored knowledge (past experiences) or sociocultural variables (personality traits, culture) that describe the self. The former is dependent on the analytical abilities of the individual, while the latter depends on an individual's background. However, because the current definitions and the notion of perception incorporate sociocultural variables which are highly subjective, it is impossible to generalise the findings of these empirical studies.

The recent studies on the perception of density and the built environment rely heavily on visual perception (Bergdoll and Williams, 1990; Fisher-Gewirtzman, 2003; V. B. Cheng, 2010; Ewing et al., 2016; Emo et al., 2017; Fisher-Gewirtzman, 2018). This is because vision is one of the primary senses through which one perceives and makes sense of their environment. Visual perception provides crucial information about the spatial arrangement, scale and characteristics of the objects and elements within a given space. Consequently, building on Rapoport's rational definition of perceived density (1975), the revised definition could incorporate the visual cues and architectural characteristics that contribute to the subjective assessment of density.

3.3 Perception

The Latin root of the word perception implies 'understanding or taking note'. It comes from the Latin verb *percipere*, to perceive or to 'become aware of or gain knowledge about', particularly through direct experience (Etymology Dictionary, no date). Figuratively, it implies 'to study and understand with the mind'. This chapter uses this meaning to describe the process of perception of the urban environment and that of density.

Perception is a sensory process that employs all five senses. Knowledge of the sensing and perceiving process aids in the interpretation of an experience (Gifford and Ng, 1982; Démuth, 2012). However, history recognises sight as the primary sense, making visual perception a crucial aspect of understanding the human perceptual process. The brief history below also acknowledges the contributions of other disciplines to the study of perception and explains the theories and approaches used to decode the process.

3.3.1 Perception as the Function of the Eye (460 BCE to 1704)

Human cognition was frequently the focus of philosophical inquiry and perception was a component of that domain (Figure -3-1). Philosophers undertook the first investigation on perception. The possibility of seeing due to *eidolons* (small copies of real objects) consisting of small, indivisible particles called *atomos*, which fly into eyes was one of the earlier concepts. On similar lines, Democritus's (c.460-371 BC), Plato's (c428-348 BC) and Aristotle's (c-384 -322 BC) ideas discussed the effect of object reflections on vision. Alhazen (1011-1021) in his *Book of Optics* and Kepler (1604) in his book *Astronomiae Pars Optica* developed numerous speculative theories based on the anatomical structure of the eye and the process of seeing to explain the human perceptual process. Epistemologists produced more theories on human perception, and the gap between perceived and real entities compelled thinkers to combine knowledge of geometry, optics and physics to support their beliefs. Numerous medieval thinkers also relied on geometry and physics to investigate perception. As a result, modern science produced a distinct branch of scientific research centred on the construction of equipment to enhance human vision (Galileo's telescope), a universal language (*Characteristica universalis*), a basis for computer system (Newton's binary system) and interdisciplinary efforts on optics and perception. Descartes (1629-1633) and Kant, modern philosophers, focused on the relationship between sensory perception and intellectual knowledge (Démuth, 2012; Fon, 2021).

Alexander Gottlieb Baumgarten's *Aesthetica (1750-58)*, a theory of beauty, established the link between human senses and aesthetics as the ultimate basis for judgement. Kant (1790) in his *Critique of Judgement* argued that aesthetic evaluation is subjective. The start of the industrial revolution stimulated the investigation of moving images. It was also recognised that images can produce deception as presented by Michael Faraday (1831) in his essay *Class of Optical Deceptions*, followed by the invention of the phenakistoscope by Joseph Plateau (1832) and the stroboscopic disc by Simon Stampfer (1833), which used a sequence of images to generate illusions. This was regarded as the most crucial aspect of visual perception.

with the aid of experimental psychology and physical equipment and methods for researching perception receptive mechanisms, the 19th century saw the beginning of research on receptors and sensory physiology (fig 3-2). During this period, numerous psychological and philosophical theories on perception emerged. Wundt (1879), whose school of psychology was known as voluntarism (the process of organising the mind), investigated three areas of mental functioning – thoughts, images and feelings – which provided insights into the perceptual process and made a significant contribution to cognitive psychology (McLeod, 2023). Von Helmholtz stated that perception is not solely the result of stimuli, but also incorporates previous experiences. The psychological aspect of perception was studied by different schools of Gestalt psychology. In the 1930s, the emphasis moved from examining the fundamental components of perception to understanding the phenomenon as a whole. Mentalists and gestaltists analysed the organisational patterns and structure of the sensory field to determine the essence of perception. Christian von Ehrenfels in his essay *Über Gestaltsqualitäten* (1890) viewed perception as a combination of physiological and mechanical data acquisition processes and subjective comprehension and interpretation. In contrast, Berlin School of Experimental Psychology with Max Wertheimer, Wolfgang Köhler, Kurt Koffka stated a figure (Gestalt) as a primary object. In the 20th century, behaviourism and neuropsychological techniques influenced the research of neuroanatomical correlations of perception (Démuth, 2012). These advancements offer the most effective method for analysing human perception, although they have limitations.

In the latter half of the 20th century, a cognitive revolution began. New research technologies and transdisciplinary investigations facilitated the investigation of human cognition and perception. It has become the most investigated topic in communication and contemporary design to be integrated into smart technologies (Démuth, 2012). Perception is, now, an interdisciplinary and multi-aspect field of study that is explored using different study methods.

This progression of the concept of perception is organised chronologically in Figures 4 -1 to 4-3.

History emphasises visual perception as a crucial technique for understanding how humans perceive the real environment and these advances are covered in this chapter. It also recognises experimental psychology as the most common research approach and Gestalt psychology as the method used to enable the investigation of real-world phenomena. It established a pattern of using photographs or images to test theories, which led to current advancements in environmental simulation techniques to depict the real world in three dimensions. History claims that knowledge of perception in many fields will only aid in understanding the human viewpoint.

3.3.2 Decoding the Process of Perception of Density

Perception of density is a typical example of psychophysics; a sub-domain of psychology where the purpose of this study is to understand how objective density translates into subjective perception. It is a case of 'intentional intervention' (Rock, 1985), knowledge of the possibility of perceiving something differently. In this case, the intentional intervention will involve deliberate efforts to influence how people perceive and experience density within the built environment using the surveys. Therefore, it is necessary to understand the process of perception, in general, to apply this understanding to the perception of density, more specifically, the density of the architectural form. To accomplish this, it is necessary to grasp the properties of perception and the terminology that will be used in the subsequent parts.

Decoding the process of perception involves understanding the cognitive process, psychological factors, and environmental cues that shape how individuals perceive and interpret the world around them. Some important steps in decoding the process of perception are described below:

1. Stimulus analysis: This step involves the analysis of the built environment to identify the environmental stimuli, such as physical attributes of the built form, visual cues, sounds and other sensory inputs, that people are exposed to. Stimulus analysis in this case will include the identification of specific features of physical surroundings such as building height, architectural style, spatial configuration or presence of open spaces (Rapoport, 1975c; Wohlwill, 1982; Nasar, 1989a) that may influence the perception of density.
2. Psychophysical Experiments: This includes conducting psychophysical

experiments to understand how individuals perceive and interpret different levels of density. This can involve presenting participants with stimuli that can vary in density and measuring their responses, such as rating scales or perceptual judgements (Flachsbart, 1979; Beck *et al.*, 1987; Aiden, Boland and Evron, 1988; Bergdoll and Williams, 1990; Emo *et al.*, 2017).

3. Cognitive Psychology Analysis: The next step is the application of cognitive psychology principles to understand mental processes involved in the perception of density. This includes investigating factors such as attention, memory, pattern recognition (image segmentation)(Emo *et al.*, 2017) and cognitive biases (confirmation bias, availability heuristic), recognising the perception of density as a relative and subjective construct (see Section 3.3.2.1).
4. Perceptual Mapping: Use techniques like perceptual mapping to understand mental representations and spatial organisation of density perception (Whyte, 1985). Participants taking the survey can be asked to express their mental or conceptual representation of perceived density, allowing the researchers to identify patterns and relationships in how density is mentally organised and conceptualised (see Sections 3.4 and 3.5).
5. Contextual influences: Consider the influence of contextual factors on perception, such as cultural, social, and individual differences (Feibleman, 1970; Taylor, 1981a; Nasar, 1989a; Evans, Lepore and Allen, 2000; Feibleman, 1970; Taylor, 1981a; Nasar, 1989a; Evans, Lepore and Allen, 2000) (see Section 3.3.2.2). Examine how cultural norms, past experiences, personal preferences (James J Gibson, 1966; Gregory, 1974; Démuth, 2012) and social dynamics affect perceived density (see Section 3.3.2.2).
6. Statistical Analysis and Modelling: Analyse collected data using statistical techniques to identify relationships, correlations and predictive models. This involves analysing survey responses, experimental data and other collected measures to understand the factors associated with perception of density.
7. Iterative Process: Decoding the process of perception is an iterative process. It requires feedback from participants, experts and other stakeholders to enhance the validity and applicability of the findings.

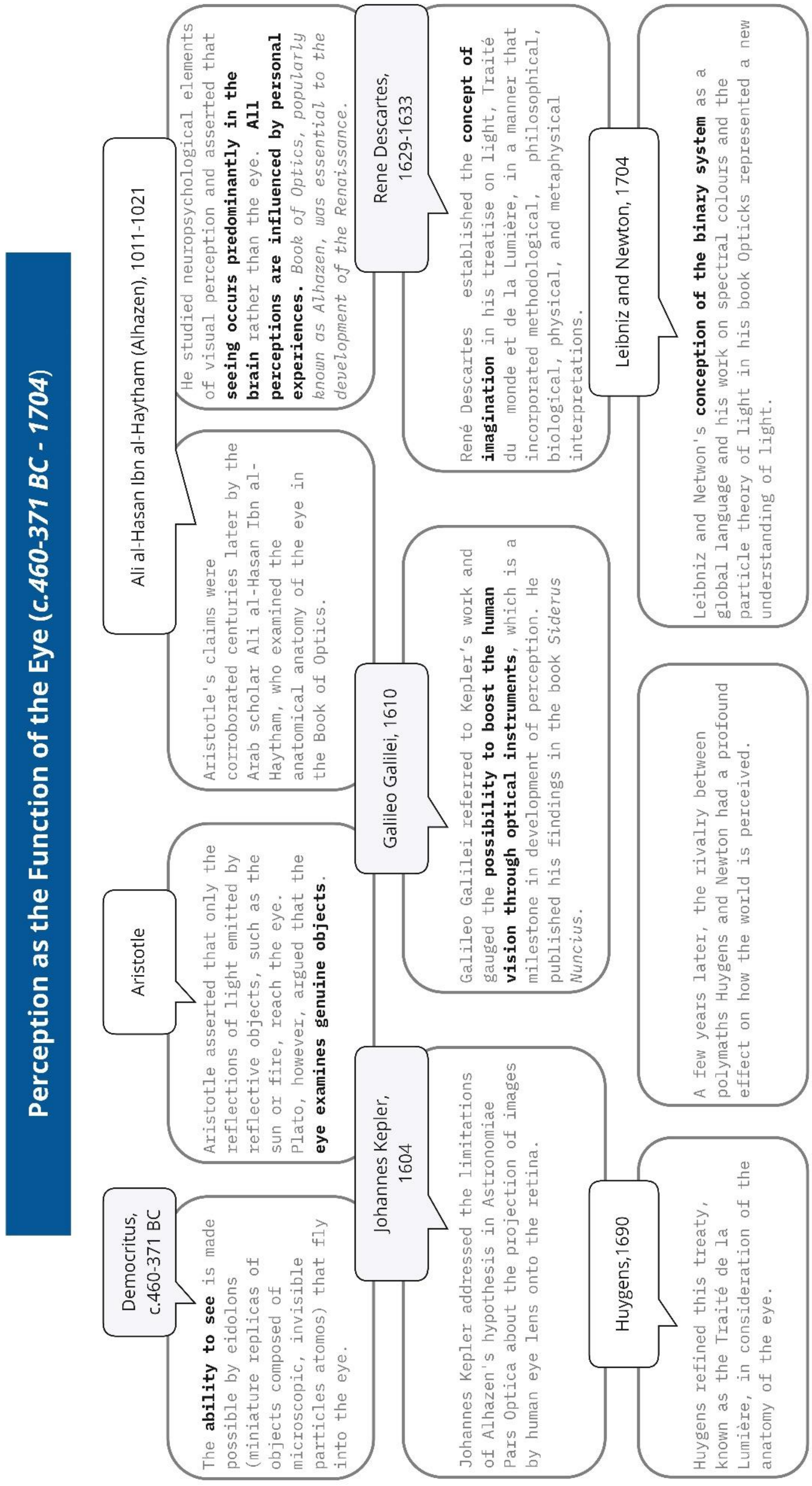


Figure 3-1. Perception as the function of the eye.

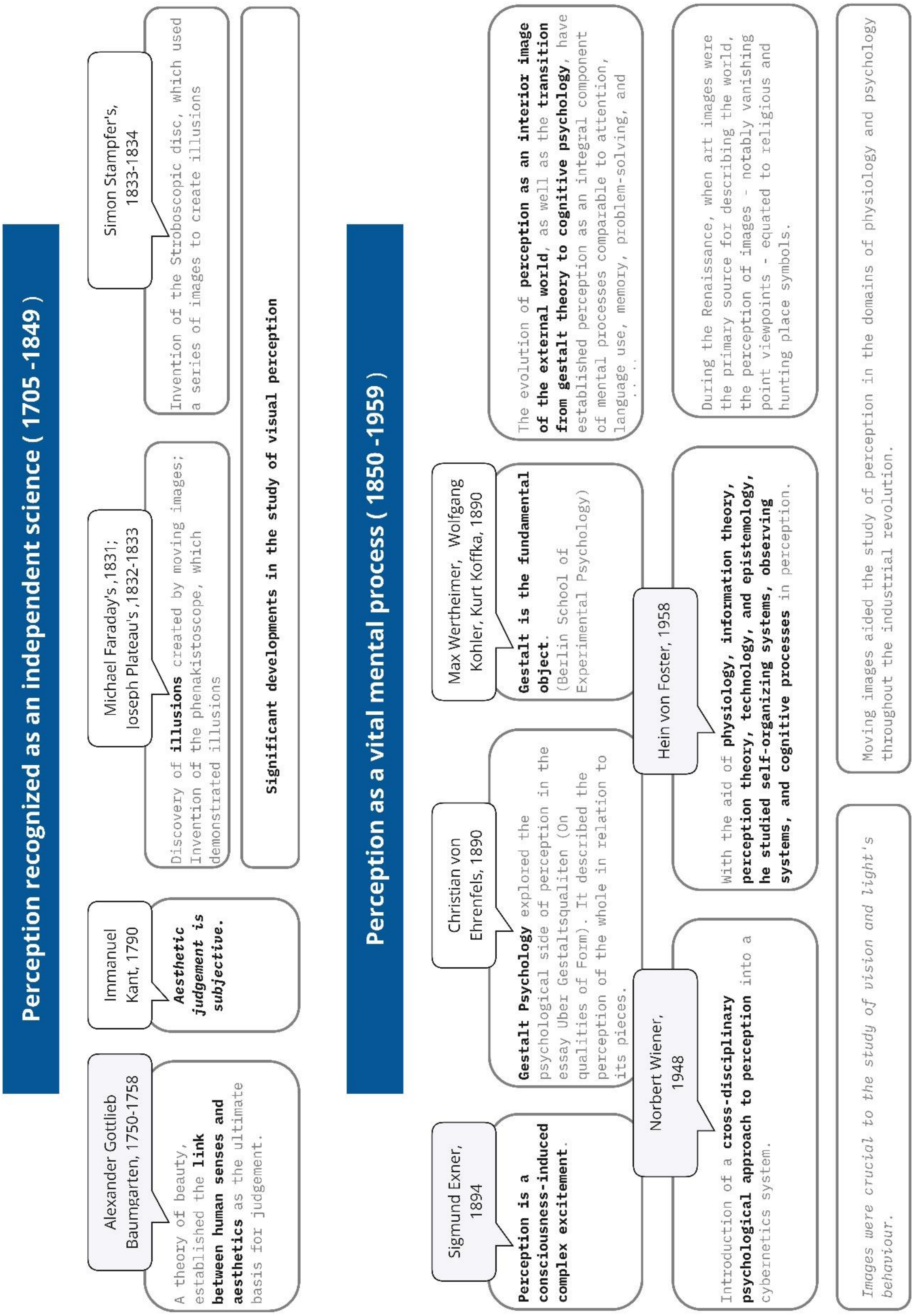


Figure 3-2. Perception as an independent science.

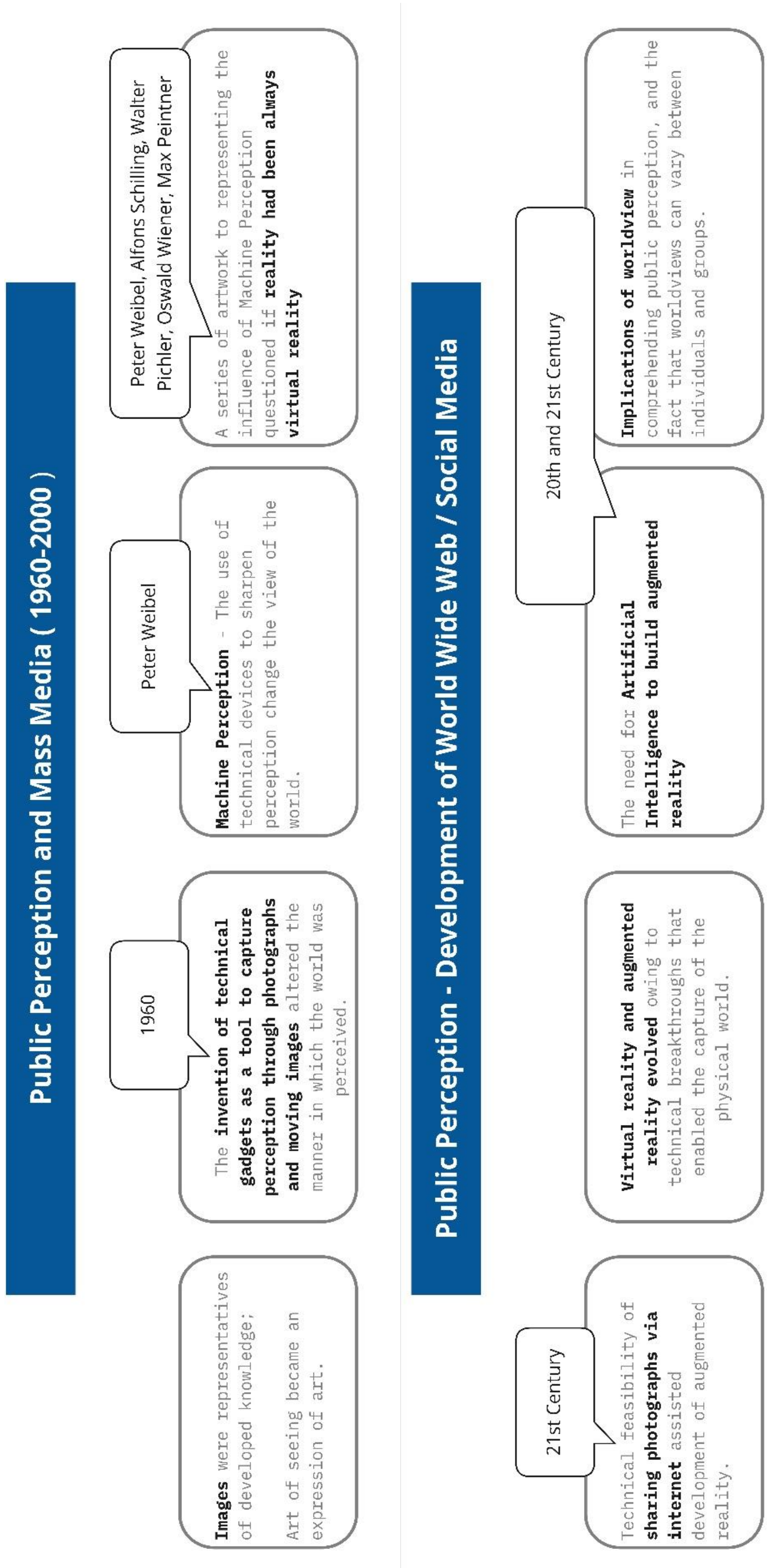


Figure 3-3. Public perception and mass media.

3.3.2.1 Cognitive Psychology Analysis

Cognitive psychology analysis in the perception of density involves studying how individuals process and interpret information related to density in the built environment. It examines the cognitive processes, biases, and mental representations that influence how people perceive, understand, and make judgements about density. It considers how subjective and relative processes contribute to the interpretation and evaluation of density, recognising that perception is not solely based on objective stimuli but also influenced by individual and cultural factors.

Confirmation Bias: Confirmation bias is a tendency(Hren, 2022) in which people tend to seek, interpret and remember information in a way that confirms their pre-existing beliefs, hypotheses while disregarding contradictory evidence (Simkus, 2023). It is a common human tendency that can significantly impact perception and decision-making processes.

3.3.2.2 Perception is Constructive and Subjective

An individual's subjective interpretation of a situation can be extrapolated by the small differences in decision-making when one has been presented with choice-relevant information (Weber, 2003). Helmholtz (1866) demonstrated that the perception of a simple object or that of a complex environment requires major acts of construction by the nervous system (Weber, 2003). For instance, if two similar objects are placed at a certain distance from each other to create the same image on the retina, viewers will view one object to be larger but farther away than the other. The brain constructs the correct representation by the process of unconscious inference (Weber, 2003). Thus, the objective realities we perceive are not mere representations of the real world, but the function of constructive activities of the brain.

Every perceptual experience has two dimensions: objective and subjective (Gilchrist, 2012). For instance, railroad tracks are parallel but appear to converge seen from a vantage point as retinal projections (Gilchrist, 2012). The parallel tracks are objective facts whereas they are converging at a distance in visual experience. The objective information is the attributes (size, shape and colour) of the object whereas its appearance constitutes the subjective experience. The potential of an object to appear differently when viewed from different vantage points to elicit varied responses postulates the subjective and constructive nature of human perception.

3.3.2.3 Perception is Relative

The variations in explanations or responses to even modest alterations in the object indicate that perception is relative. Relativity is the capacity to be influenced by other beings, conditions or references. It is frequently used to describe things that are difficult to quantify. Relativity is associated with the distinct perspectives of individuals that vary with situation and time. In this case, the objective density of cities is low, moderate or high in an urban environment and varies at different times of the day. All interpretations of relativity imply that the user's perception, regardless of its value cannot be ignored. Concerning time, the opinion of people evaluating the density of cities as a tourist versus that of a resident can vary dramatically. Also obvious from the studies is that individuals find it easier to form relative rather than absolute judgements (Weber, 2003). It is easy to generalise over relative judgements which are consistent (Weber, 2003), but absolute judgements exhibit inconsistency over time.

3.3.2.4 Perceptual Constancy

Perceptual constancy is the human tendency to perceive a known item as having a constant shape, size and intensity despite changes in stimulus (Cohen, 2015; Dember, Jolyon West and Epstein, 2023; Green, 2023). Due to perceptual constancy, an object at a distance initially appears to occupy a smaller portion of your field of vision, but as it approaches it appears to occupy a larger portion. However, you do not perceive the object to have grown as its shape, size and properties remain the same. Perceptual constancy enables us to recognise objects under varying settings by mentally reconstructing their representations. For instance, a building appears to be the same size in both summer and winter. A person's perceptual constancy can be diminished by unfamiliarity with the object or a reduction in contextual clues pertinent to the object's identification. Size constancy is a type of perceptual constancy in which, within a particular range, objects are perceived to have the same size independent of changes in retinal image size or distance. Regardless of changes in an object's position or orientation, its perceived shape will remain consistent. This means that the buildings seen in perspective appear to be a particular size and shape or that from the pavement on one side, the structures appear to be skewed but yet perceived to have a definite shape. Objects are believed to have a constant amount of brightness regardless of the amount of light striking them. This posits that the environmental quality of an urban area could have a minor effect on human perception.

3.3.2.5 Contextual Influences

Cognitive psychology analysis explores the role of individual differences such as personality traits, and cultural backgrounds, in shaping the perception of density.

Individual differences: The ability of people to view things differently is determined by individual differences in age, gender, education level, cultural background, belief system and personal ethics (James J Gibson, 1966; Taylor, 1981a; Dember, Jolyon West and Epstein, 2023). Individual cognitive factors such as attentional capacity and visual processing abilities can influence how individuals perceive density (Gibson, 1966). For instance, some individuals may observe fine-grained details and notice small changes in density, while others may focus on broader patterns or overall impressions.

Although individual differences in perception are based on preferences and choices, they are highly influenced by the context and the environment. Similarly, people have varying preferences for density in their surroundings. Some individuals may prefer high-density urban environments with a bustling atmosphere and a sense of vitality, while others may prefer a lower density setting with more open space.

One's psychological state also has some influence on the way we perceive. Factors such as personality traits, mood states, and cognitive biases also affect the perception of density. For instance, an extroverted individual may find high-density environments energising, stimulating, while an introverted person may feel overwhelmed or anxious in the same setting. Additionally, an individual's perception of a situation is also a function of his plans and the physical and social characteristics of the situation (Taylor, 1981a).

Cultural differences: Culture is a multifaceted term and is continuously evolving. Previous research on perceived density has revealed that cultural differences play a significant role in human perception (Evans, Lepore and Allen, 2000; Démuth, 2012; Dember, Jolyon West and Epstein, 2023). Cultural influences on perception can be seen in a variety of ways, including:

1. Social norms and values. In a given environment, cultural norms and beliefs can affect what is deemed significant or relevant. This in turn can affect how individuals perceive and interpret stimuli and their emotional responses.
2. Cognitive processes. Culture can alter cognitive functions such as attention, memory and reasoning, which in turn can influence perception. For instance, cultures that promote holistic thinking may pay more attention to the context and interrelationships between stimuli, whereas cultures that emphasise analytic thinking may pay more attention to the stimuli's components.
3. Environmental cues. The form and arrangement of the physical environment can also be influenced by cultural influences, which can alter how individuals perceive and navigate that environment (Evans, Lepore and Allen, 2000). Different cultures may have varying preferences for the level of stimulation or sensory input in the environment, for example.

Thus, analysing cultural and social effects on an individual's perception is a complex task. Démuth (2012) believes that one way of doing it would be by eliminating individual differences and identifying the characteristics of the collective culture. Cross-cultural studies would assist in eliminating or reducing these influences (Evans, Lepore and Allen, 2000). Perceptions are not culturally universal, and neither are the physical attributes of the urban environments (objects), hence it is practically difficult to eliminate the variation in judgements arising due to culture.

Pre-existing knowledge: Prior ideas or pre-existing knowledge about a concept, can influence perception (Gregory, 1974; Démuth, 2012). If individuals have preconceived notions or expectations about what density should look like, it can shape their perception and judgement. This prior knowledge can be attributed to formal education, personal experiences, or cultural influences.

Information from past experiences: Past experiences stored in memory play a crucial role in perception (Gregory, 1974; Rock, 1985). Individuals recall past experiences to make sense of and interpret the environment. In the case of density perception, past experiences of living in different urban environments, exposure to various types of built environments, and social interactions in different contexts can influence how individuals perceive density.

3.3.2.6 Summary

The terminology discussed here informs the design of the investigation. It facilitates several stages of research, including data gathering, survey design and analysis. It also identifies the limitations that may occur due to the nature of perception and demonstrates how to transcend them to a certain extent.

Although the distinction between factual and stored knowledge based on experience is evident, the effect of both on human perception is harder to discern. This is mostly because perception is a function of both knowledge, with cultural and individual differences being part of the knowledge stored. The state of the observer, whether naive or informed, may also influence perception. Validating it, however, requires distinguishing between two responses: one that is recognised spontaneously and one that is a function of the information presented.

Perception is a subjective and relative construct; hence, it is bound to the properties of its environment. As a result of the subjective and relative character of the responses, it is difficult to calculate an average, but there are a few ways to mitigate the effect.

1. **Use multiple methods**. To acquire a more comprehensive understanding of an event, researchers may employ multiple methodologies to examine perception. Combining psychophysics and personal construct theory, for example, can assist in triangulating and validating findings across multiple levels of study.

2. **Use standardised measures**. Standardised measures can eliminate subjective biases and enhance the validity and reliability of perception assessments. Using standardised surveys or rating scales might help ensure that individuals consistently understand and respond to stimuli.
3. **Consider the context**. Perception is influenced by context, meaning that the same stimulus may be perceived differently depending on the situation. Researchers can consider the contextual factors that may influence perception such as the physical environment, social norms or cultural values.
4. **Use mixed methods**. In addition to providing objective and quantitative data, a mixed methods approach that blends quantitative and qualitative methods can help to capture the subjective and relative aspects of perception. Combining psychophysics and in-depth interviews, for instance, might provide a more nuanced picture of how individuals perceive density in a particular setting.

3.4 Methods of Inquiry of Mapping Perception

Human perception of density is studied mainly in the domains of urban design and planning, visual perception and environmental psychology. Studies on the perception of density in urban design and planning focus on understanding how people perceive and experience the density of the built environment, particularly in urban areas. Studies on the perception of density typically focus on how people perceive, and process visual information related to density. This includes understanding how they perceive the density of visual stimuli such as dots, lines, volumes and textures and how this perception is influenced by factors such as spatial arrangement, contrast and colour. In environmental psychology, studies on the perception of density focus on how people perceive and experience the density of their physical and social environments. This includes investigating how people's perceptions of density affect their behaviour, attitudes and well-being.

This study combines the intent of understanding human perception of the three disciplines through the lens of visual perception to record their experience and association with the built form using one methodology. This will help in creating a complete picture that comprises all the factors that influence the perception of density including population density, spatial layout, individual and cultural differences and emotional responses.

No single method or discipline can assist in decoding the nature of perception as a whole, since every method has limitations (Stufflebeam, 2003). This section intends to identify different ways of conducting perception studies and identify the appropriate one to conduct this study.

3.4.1 Introspection

In experiential studies, introspection refers to the exploration of one’s thoughts and emotions or self-observation (Xue and Desmet, 2019). Introspection permits the researcher to observe the scenario and record their own emotions. During introspection, an individual watches the stimuli, questions their thinking, builds a logical argument and then responds. A researcher can engage in many sorts of introspection including retrospective, concurrent and imagined (Xue and Desmet, 2019). In retrospective introspection, the researcher relies on the recall function of their memory, which stores pertinent events from their prior life. Concurrent introspection refers to the recording of simultaneous or immediate experience of the present moment and is typically conducted through field observation. This decreased temporal lag ensures an accurate depiction of the experience. In contrast, imaginative introspection is related to design fiction and aids in imagining the design possibilities of the future. In this instance, the researcher engages in a series of hypothetical tasks.

It must be noted that introspection has its limitations. The accuracy and reliability of introspective reports can be influenced by various factors, including memory biases, social desirability, and the ability to accurately introspect (Whyte, 1985; Xue and Desmet, 2019). Therefore, this method is often complemented by behavioural mapping and physiological data.

3.4.2 Experimental Psychology

In experimental psychology, many variables are used to demonstrate cause-and-effect relationships to test the researcher’s proposed hypothesis (Whyte, 1985). The researcher observes the respondent and analyses their responses to evaluate the hypothesis and determine whether a positive or negative correlation exists (Bergdoll and Williams, 1990; Goldstein, 2009). These techniques involve exposing the respondent to stimuli such as those found in the urban environment. The developed experiments assess perceptual phenomena such as visual illusions, matching ability and discriminating skills. A participant is required to execute a perceptual task infrequently. The technique encourages three distinct types of experiments. Experiments in the laboratory are conducted under controlled conditions to control variables and facilitate reproducibility (Whyte, 1985). However, the results may not reflect real-world events, making generalisation difficult. Field experiments are frequent and represent real-world variables, yet they have less control over extraneous variables that may introduce bias (Whyte, 1985). Additionally, it is difficult to duplicate the study exactly. Natural experiments are likewise conducted in real-world settings, but they lack control over any variables and are similarly constrained.

3.4.3 Neuroscientific Methods

Cognitive neuroscience, computational neuroscience, neurology and neurobiology are areas of neuroscience that contribute to the study of perception. Human perception is a combination of sensory, cognitive and motor systems. Since a single research approach cannot answer questions about every system, neuroscientists use a variety of methodologies and strategies to study perception. Perception studies currently employ neuroimaging techniques such as magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI). Although this method yields nearly precise results, cognitive processes cannot be monitored and must rely on inferences (Brooks, Stolier and Freeman, 2021). Neuroscientific procedures may be invasive requiring surgery, or non-invasive, superficial and more prevalent. The cost of the technology itself is also high and not all researchers have access to this technology and it is difficult to recruit participants for the experiments.

3.4.4 Computational Models for Deep Learning

The recent advancements in the computer vision technique for recognising image content by deep learning have attracted much attention and achieved great success in multiple fields (Hinton et al., 2012; He, Gkioxari, Dollár, & Girshick, 2017; LeCun, Bengio, & Hinton, 2015 cited in Zhang *et al.*, 2018). Several computational models including visual attention-based, memory-based, inference perception-based, feedback based and many more cover the visual perception reach using deep learning (Wei *et al.*, 2021). They assist in the investigation of the underlying mechanism and principles in a controlled and systematic manner by simulating different perceptual scenarios, creating virtual environments and simulations that resemble real-world perceptual experiences. The computational models provide a means to test hypotheses and theories about perception by constructing models based on theoretical assumptions and evaluating their predictions. Visual perception computational models oriented artificial intelligence are beneficial for this research in two ways. First, biological visual perception provides a rich source of information (collected in a traditional format) for new types of algorithms programmes. Second, visual perception can provide validation of deep neural network techniques such as image segmentation, pattern recognition that already exist (Wei *et al.*, 2021).

3.5 Field Study Methods for Environmental Perception

The urban environment is a combination of physical and social elements. This section focuses on methods of measuring the physical components. Numerous strategies have been created for environmental perception field research, they all rely on three approaches: observation, listening and questioning (Whyte, 1985). These strategies complement other field research methodologies employed in the research. There is no ideal method for mapping human perception as it relies on the aims of the research and the scenario. Observation, questioning, projective approaches, listening, recording and coding and the selection of research variables are addressed below.

3.5.1 Observation

Observing human behaviour in an environment is the most straightforward environmental perception technique (Stewart *et al.*, 1984; Whyte, 1985; Dudovskiy, 2018; Kumar, 2022). Direct observation approaches are straightforward and versatile in time, cost and methodology. However, it requires skilled observers, extended periods of observation and objective interpretation. In landscape evaluation, direct observation is used to identify the visual landscape elements that influence people's response, determine which is the most relevant and build a correlation between the features and their perceived value. Behavioural mapping in which human behaviours and their location are mapped as symbols, also benefits from direct observation (Whyte, 1985; Sanoff, 2016). It entails documenting the pattern of behaviour for a certain area to create categories based on comparable evaluations. Indirect observation uses the effects of human action as a metric of behaviour. It may rely on historical material, directories or census data, among other indirect information sources. However, it is difficult to isolate the necessary data or variables for the process analysis investigation. People observation involves direct observation, attentiveness and questioning. The researcher performs both the observer and the participant roles. But, in some cases participants' direct interaction with other respondents may risk influencing the perception and experience data (Whyte, 1985).

3.5.2 Questioning and Interviewing

Interviews and questionnaires are the most common survey methods used for field research in social sciences (Whyte, 1985). They entail asking difficult-to-observe questions such as those about personal preferences, the past and future, traditions and beliefs (Whyte, 1985; Rubin and Rubin, 2005). The standard approach to method selection depends on precoding relevant information to formulate questions on different categories, a large number of responses to facilitate quantitative analysis, time and enough people, knowledge of this method of inquiry and clarity of the research questions and objectives. If the criteria are met, a questionnaire or standard view can be used. Questionnaires are the most structured type of questioning with respondents answering the questions without the presence of an interviewer(Whyte, 1985; Dudovskiy, 2018). Although standard interviews are excellent at measuring perceptions, there is a trade-off between validity, reliability and efficiency. The difference between a standard and nonstandard interview is the respondent's subject knowledge. Some respondents are more knowledgeable than others, which influences their interpretation.

There are a variety of question formats that can be used to evaluate verbal responses (Whyte, 1985; Sanoff,2016). Open inquiries, despite being the most frequent and time-consuming, maximise respondents' perspectives on an issue. The responses to open-ended questions are recorded verbatim to collect facts and subtleties of meaning. Closed questions or choice-based questions are typically limited to pre-questionnaire items (age, gender, etc.) and are rarely used in environmental perception. However, the number of options available to achieve this simplification is extensive. Forced-choice questions are dichotomous and include two or more options. These are difficult questions to answer, and a respondent may be forced to choose between the alternatives even if they disagree. Scaled questions, often known as Likert questions, provide ordinal data and are hence useful. Frequently, these are statements against which the respondent's agreement or disagreement is assessed. It reduces the power of labels on intermediate points and allows respondents to make their own decisions. The smallest scale consists of three points, while complex scales contain between five and thirteen. However, the three – to seven-point scale is the most popular. Card questions, in which the sentences, elements or images are portrayed on a card, are typically employed when data must be ranked in a particular order. They can be organised into sets that highlight the distinguishing feature. Possessing the capacity to manipulate cards and rearrange them if a response has second thoughts is advantageous(Canter D, J and Groat L, 1985; Whyte, 1985).

3.5.3 Projective Techniques

Projective approaches enable the respondent to record both their conscious and unconscious emotions in their responses (Whyte, 1985; Doherty and Nelson, 2010; Miguel and Pessotto, 2016). The tasks designed using projective approaches range from word association to the creation of illustrated storyboards. These strategies may use verbal or pictorial stimuli. A basic way is to present a list of adjectives to describe the circumstance. Similarly, semantic differential provides a more detailed adjective checklist and is more common in environmental perception(Whyte, 1985; Takahashi, Ban and Asada, 2016). The sentence completion test presents a sentence's beginning or stems for respondents to finish. They lack any emotive language to avoid influencing the responses. Typically, sentence completion is employed in the completion of a paragraph, argument or story to record the respondent's subjective feelings.

3.5.4 Graphic Tests

Environmental Apperception Tests (EATs) are graphic tests that use images to elicit environmental perception (Whyte, 1985). This is a technique for field research that allows for replies to specific settings; nevertheless, the images presented should be sufficiently ambiguous to allow the respondent to use his imagination(Downs and Stea, 2017). Moreover, photos should illustrate a variety of transitional conditions to facilitate comparison. This test allows for free responses, which are essential for environmental perception. Mental maps are a frequent technique used by researchers to construct a spatial relationship between environmental features and mental imagery (Lynch, 1964; Downs and Stea, 2017). They could depict maps of locations perceived either through direct sensory experience or through cognitive processing of sensory perception concerning distance, orientation and readability.

3.5.5 Summary

The methods discussed in this section are reviewed to establish a need for a mixed method that combines graphic tests and interviews for a study on the perception of density. The graphic tests provide a visual representation and a structured framework for participants to compare density, while the open-ended questions provide the opportunity to express their subjective experiences, thoughts and insights in their own words. In this method, the participants can be presented with visual stimuli, such as images or diagrams representing different urban environments with varying levels of density. They can be asked to perform specific tasks or make judgements related to density perception, such as:

- Comparative ratings: Participants can be asked to rank or rate the perceived density of different urban scenes presented by the images by comparing various elements such as buildings, streets or green spaces.
- Density Mapping: Participants can be presented with images and asked to classify images they perceive as high, moderate or low.
- Open-ended Questions: Following the graphic test, participants can be asked short, descriptive open-ended questions to elicit more detailed and qualitative insights into the perception of density. They can describe and/or elaborate on specific features, visual cues or aspects that contribute to the

perception of density.

The data collected from the combination of graphic tests and open-ended questions can be analysed using both quantitative and qualitative methods. Quantitative analysis can involve summarising ratings, and rankings while qualitative analysis can involve thematic coding and identification of recurring patterns or themes in participants' responses.

3.6 Theories of Perception

The theories defining the human vision process (see Section 3.3) can be split into two groups. The first cluster employs a bottom-up methodology. It indicates that the process of perception begins in the visual cortex of the brain and progresses to the higher cortical structures responsible for conceptual ways of thinking, which deal with more complex processes. The second cluster is a top-down methodology. It claims that sensory information is initially obtained by receptors that sense stimuli and then organised and determined by higher cognitive processes. This approach supports the premise that sensory data processing and organisation require prior experience or other effects.

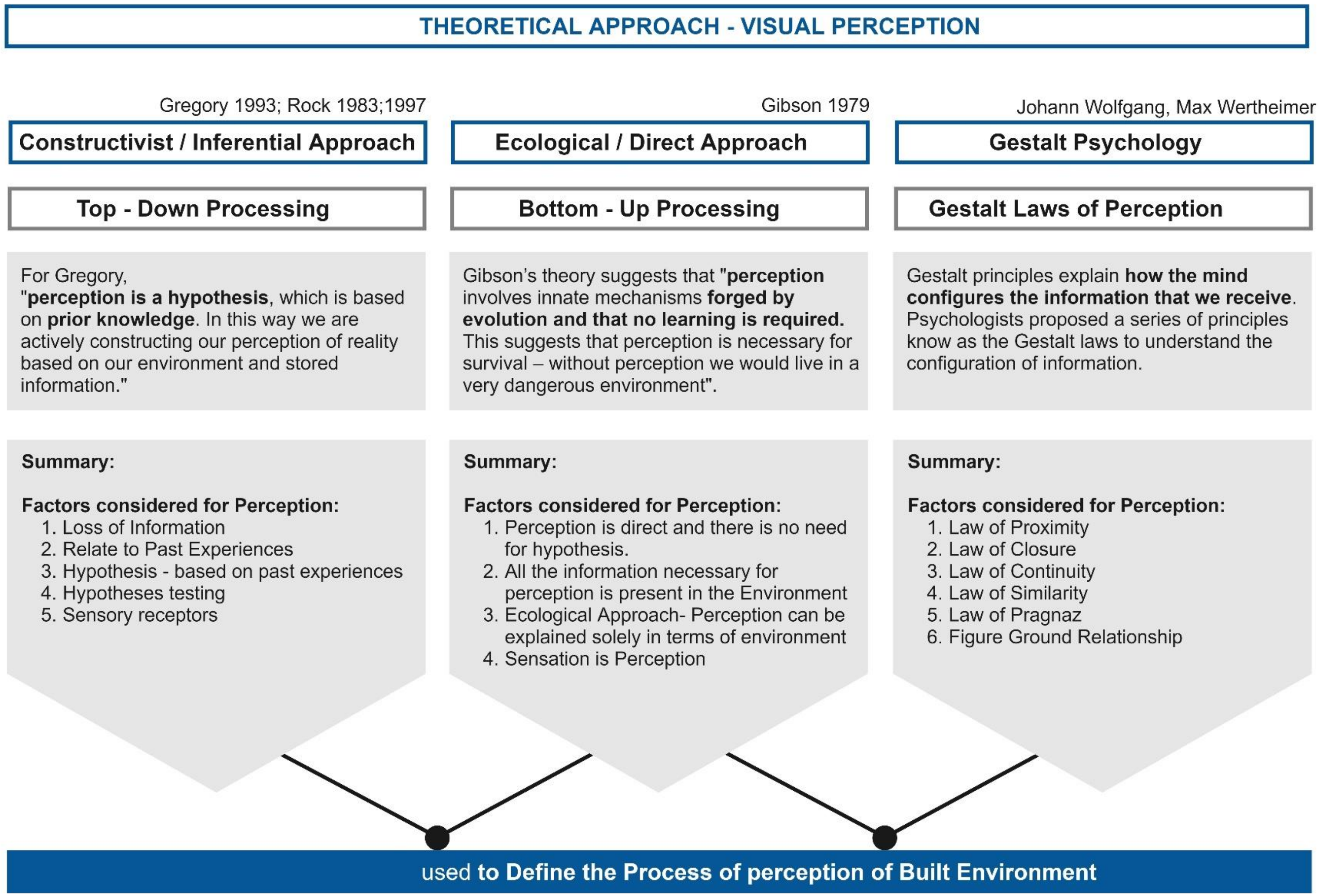


Figure 3-4. Theories on Visual Perception

3.6.1 Bottom-up Theories – Direct Perception

Bottom-up theories of perception (Gibson, 1966; Démuth, 2012; Intaitė et al., 2013; Gibson, 2015; McLeod, 2023), propose that perception is primarily driven by sensory input or "bottom" level of information processing. These theories focus on stimulus-driven processing. For instance, our brain processes incoming visual information, such as light, colours, shapes and textures to create a representation of the external world (Gibson, 1966; Gibson, 1977; McLeod, 2023). These theories suggest that visual processing occurs sequentially and hierarchically, in the sense that basic features such as lines, edges, colours are detected and combined to form more complex representations of objects, scenes, or patterns. Bottom-up theories emphasise that perception is driven by incoming sensory data and less influenced by higher cognitive processes (see Section 3.3.2), such as expectations or prior knowledge (see Section 3.3.2). The focus is on the objective properties of the stimulus and the extraction of information directly from the environment (Gibson, 1966; Gibson, 1977, 2015; Adolph and Kretch, 2015).

Ecological Theory of Perception

Gibson's (1966; 2015) theory of perception is an example of a data-driven direct approach. He argued that humans experience objects as information packets entering their sensors and that human vision is determined by the optical flows or light patterns in the surroundings (Gibson, 1986; Démuth, 2012). These beams of light reflected off the surface of the objects reveal their physical qualities such as shape, size and texture, depth and distance and are then grouped to form the perception.

According to Gibson's Ecological Theory of Perception (2015), perception is an active process that involves direct perception of the environment without the need for internal mental representations or cognitive processes. He argued that perception is based on the detection of invariant properties in the environment, known as affordances. Affordances are the opportunities for interaction that the environment provides to an organism. An example of an affordance on the street is a crosswalk or pedestrian crossing. A crosswalk affords pedestrians the opportunity to safely cross the road. It is marked by designated lines and signage and also often accompanied by traffic lights. The visual cues and infrastructure signal to pedestrians that it is a safe and appropriate place to cross the street. Pedestrians perceive the affordance of the crosswalk and can confidently use it to navigate the street while expecting vehicles to yield to them.

Gibson (Gibson, 1966; Adolph and Kretch, 2015; Gibson, 2015) understood that position, distance and motion affect perception. For instance, the number of items viewed in a seated versus a standing position will differ. One may also view the same objects from a different perspective defining their characteristics differently, yet the reality remains the same. Changing the position of the body or receptor (reference point) is vital for mapping human perception. A texture gradient is created when the distance between the viewer and the object gradually increases. When the distance increases, the pebbles on the beach become less distinct and what we perceive is the background texture. with increasing distance, the texture's density increases. When an observer is in motion, nearby things appear closer and to be travelling quicker than those at a greater distance. Therefore, motion significantly affects depth perception.

The process's speed and automation make Gibson's (2015) model more useful than others that rely on intricate mathematical calculations. It also explains the precision and swiftness of perception as a cognitive process. However, to be able to deduce abstract mental representations, it is necessary to engage the memory's recall and recognise functions, which is contrary to the theory. Gibson's (2015) approach does not recognise the role of familiar situations that may produce varied perceptual outcomes, but this theory's most significant flaw is its concept of affordance which suggests that the visual field has sufficient information to make sense of objects and does not require prior experience to create a meaningful experience (Démuth, 2012). This calls into question the intelligence, ingenuity and uniqueness of the individual's opinions. This approach also makes no distinction between seeing and understanding inputs and completely disregards the relationship between visual composition and Gestalt figures.

3.6.2 Top-Down Theories – Indirect Perception

Top-down theories (Gregory, 1974; Démuth, 2012; McLeod, 2023) also known as constructivist theories emphasises the role of higher-level cognitive processes reasons and logical thinking, problem-solving, critical thinking, decision-making, metacognition) in the perception process and is the distinguishing characteristic between top-down and bottom-up theories. Top-down theories propose that our perception is influenced by our expectations, knowledge and past experiences. These cognitive processes actively guide and interpret the sensory input to form meaningful representations of the world. These ideas value Gestalt psychology expertise that identifies unconscious perceptual patterns and influences conscious experience.

Constructivist Theory

Gregory's (1970) theory is the most popular constructivist theory of perception. He argued that without prior experiences, sensory input for perception is useless. The data has a history and a future; they affect each other (Gregory, 1974). Gregory argues that the process of perception is comprised of complex and involved raw material that, to be understood, requires higher cortical centre activities and learning (Démuth, 2012; McLeod, 2023). The term constructivist refers to the construction of the sensory object to organise it according to the hypothesis, using the sensory data accessible by receptors. In an attempt to make meaning of the object, information that does not conform to the hypothesis is ignored. This also shows that the modest amount of information and its connection with the whole is sufficient to read the passage. Gregory believes that substance and ideas are more important than sensory input for interpretation. He also highlights the role of hypotheses and inferences in perception. When faced with ambiguous or incomplete sensory information, we generate hypotheses or mental representations of what we think might be present in the environment (Démuth, 2012). These hypotheses are continuously tested and refined based on incoming sensory data until a coherent and meaningful perception is formed.

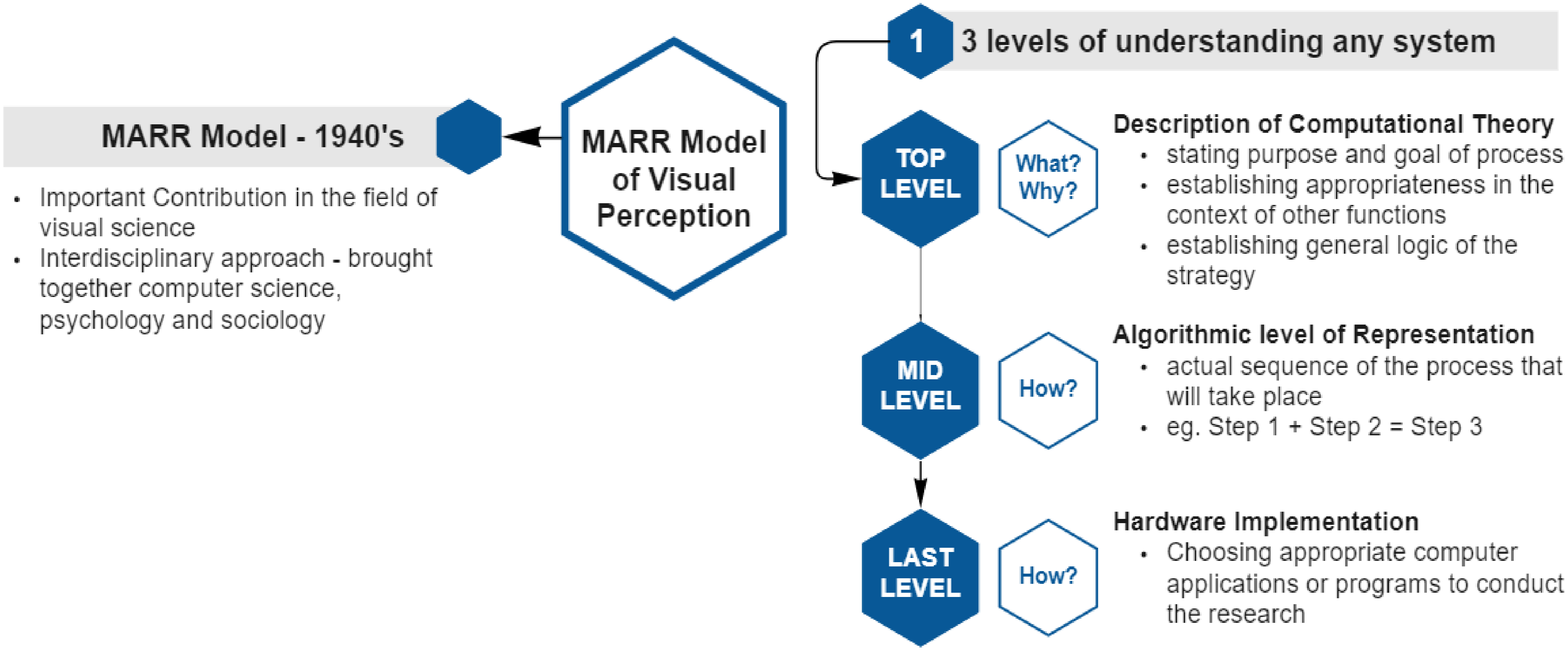


Figure 3-5. Marr Model of Visual Perception

3.6.3 Computational Theories

The proponents of computational theories attempt to solve the problem of perception by ignoring the issue of conscious experience (Démuth, 2012). This is a common practice in the fields of informatics and artificial intelligence. By analysing the systems that humans employ to analyse sensory input or stimuli, the algorithms in these programmes can determine the fundamental patterns that comprise human perception.

Marr's Model of Perception

Marr's model is an example of computation theory that views perception as problem-solving. This paradigm has three stages of understanding analysis. The first level is referred to as the computational level because it assumes that each function involved in perception may be regarded as a computer problem with a desired conclusion. The second level is specific and defines the representation system that transforms algorithm-identified inputs into representations. This level analyses the actions that facilitate the transformation of stimuli into mental representations. The third level is the hardware or implementation level which aids in the operation's execution.

By applying Marr's model, this study on the perception of density can systematically examine these three levels. It can define the computational goals of density perception (identifying factors that help in distinguishing between low and high perceived density), identify the algorithms or processes involved in transforming stimuli into mental representations of density (includes analysing the visual cues), and investigate the neural mechanisms and physiological processes that support density perception (includes psychophysical experiments such as analysing participants performance). This framework provides a structured approach to understanding the perceptual processes and mechanisms underlying the perception of density.

3.6.4 Gestalt Psychology

Gestalt is a physical, biological or symbolic arrangement of an element pattern that is united as a whole in the sense that its qualities cannot be recognised by combining the properties of its pieces. Max Wertheimer's Gestalt theory is predicated on the perception of movement and action as a whole, rather than as the sum of its parts. Gestalt psychology is a school of thinking that proposes the same Wertheimer-inspired concepts for a holistic view of the human and behaviour. It assumes that humans tend to perceive objects as wholes or as complex systems, rather than focusing on their components (Guberman, 2017). The premise of the Gestalt approach is that life only occurs in the moment, not in the past or future.

Perceptual organisation is largely based on the grouping principle, which determines that observers perceive qualitative elements of the visual field as grouped and interpret these elements in terms of shape, location, textures and surfaces in the real-world 3D environment (Wagemans et al., 2012). Wertheimer presented further grouping principles such as resemblance, in which all pieces with the same or similar colour, size and orientation are grouped. Another essential principle is that of common destiny, which groups all elements going in the same direction. Physical characteristics such as lines, curves, symmetry, parallelism and continuity are additional elements that influence grouping.

Since the earliest studies on Gestalt, significant progress has been achieved leading to the discovery of additional principles and fresh insights into the process of perceptual grouping. Sekular and Bennett (2001, cited in Wagemans et al., 2012) offered an extension of the idea of a common fate that implies elements might be grouped based on the changing brightness of the 3D physical space. Synchronicity is the tendency for elements undergoing simultaneous change to cluster together. This refers to the occurrence of observable changes due to temporal consistency. The notion of common region states that elements inside the same defined area or region are likely to be grouped. This principle is based on the topological attribute of being 'inside' or 'contained by' something. Element connectedness is the tendency for distinct elements to share a border, whereas uniform connectedness is the analysis of the visual system that divides an image into mutually exclusive connected regions. The uniformity of connectivity is determined by the qualities of colour, texture, motion, depth and brightness.

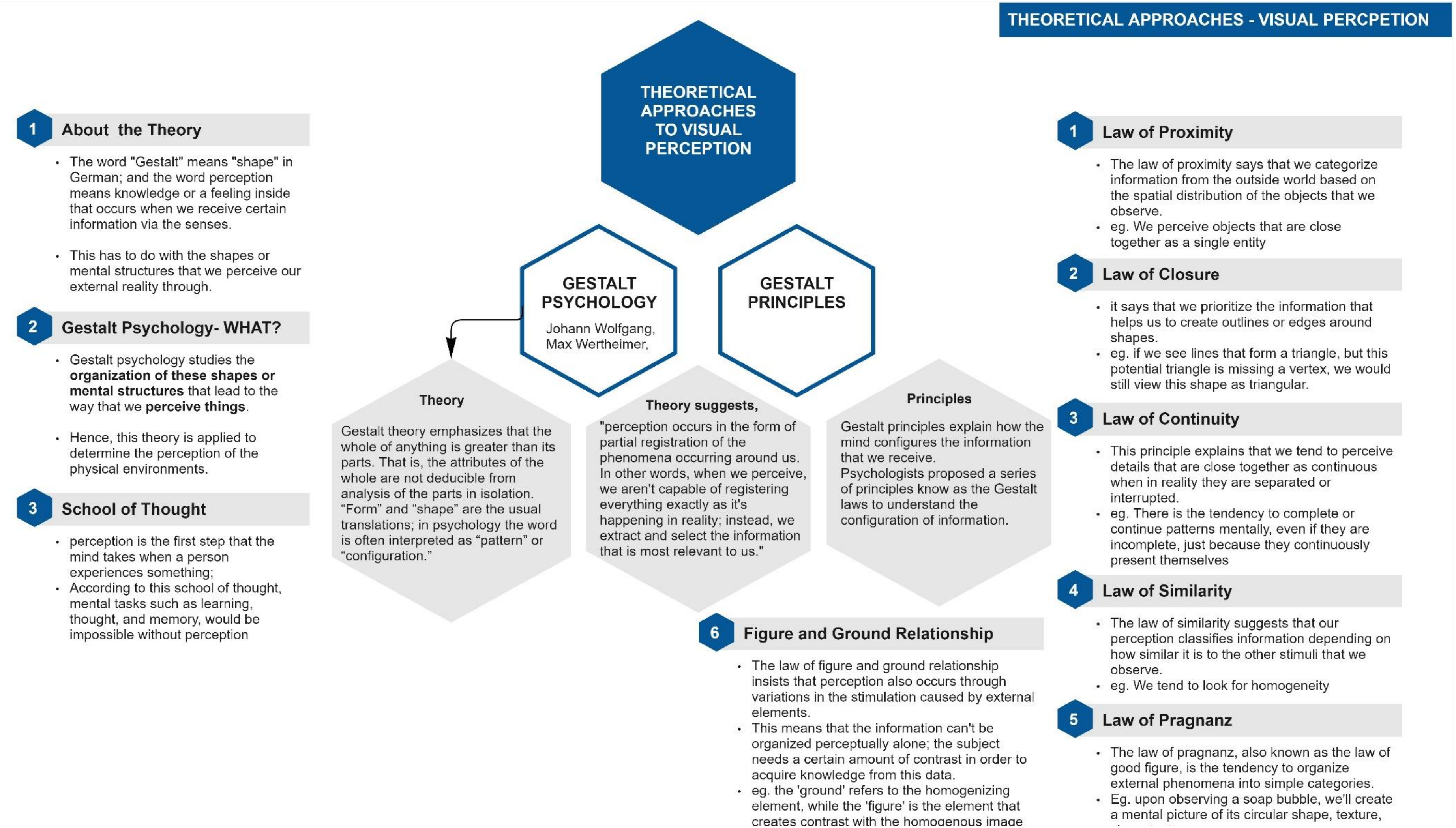


Figure 3-6. Gestalt Psychology

3.6.5 Summary

In this study on density perception, the theories of Gibsonian visual perception, Constructive Theory by Gregory, Marr's computational model, and Gestalt psychology can be applied in different ways. Gibson's theory of visual perception (Gibson, 2015), which emphasises the active perception of meaningful information from the environment, can be used to examine how individuals extract density-related cues from their visual surroundings. The Constructive Theory (Gregory, 1974) emphasises the active construction of mental representations based on sensory input, directing researchers to investigate how individuals construct mental representations of density. The computational model developed by Marr (Démuth, 2012)provides a framework for comprehending the computational goals, algorithms, and neural mechanisms involved in density perception. Gestalt psychology (Wertheimer, 1938; Wertheimer and Riezler, 1944) provides principles for organising perceptual experiences, aiding in the analysis of how individuals perceive and group patterns in relation to density. These theories and frameworks facilitate comprehension of the active, interpretive, and computational aspects of density perception (see Section 4.1.3).

3.7 Perception of Density – 'Process Matters'

Perception is a subjective, active, and creative process through which individuals assign meanings to sensory information to understand themselves and others. No two people perceive the same object in the same way all the time. This process occurs repeatedly throughout the day without our knowledge. One person's view of the other person determines their interaction during a conversation. A person's emotional response to the feelings of another cannot justify their own feelings. One can only attempt to understand by seeing a person's cue selection, organisation and interpretation. People also tend to make instantaneous judgements that provoke unconscious positive or negative responses and consider them unbiased.

To decode the process of human perception of density, this study employs the psychophysical principle 'process matters' that suggests two things. First, cognitive processes (see Section 3.3.2) involved in judgement or decision-making frequently have correlates; for example, the higher the number of cars, the higher the perceived density. These correlations can be determined from the patterns uncovered by analysing the responses. Second, the process is significant in the sense that people have limited access to the information on which judgements are to be rendered; hence, they rely on similar past experiences (Weber, 2003).

3.7.1 Process of Perception of Built Environment

The process of perception involves three main stages: selection, organisation and interpretation (Gerber and Murphy, no date; Goldstein, 2009; Qiong, 2017; Dember, Jolyon West and Epstein, 2023). These stages contribute to our understanding of the built environment and are influenced by the subjective and relative nature of perception. Different principles from visual theories are utilised at each stage to shape our perception.

Selection: The selection stage involves the initial filtering and focusing of sensory information from the built environment. This stage is influenced by both bottom-up and top-down processes of visual perception. Bottom-up processes involve the automatic and involuntary capture of attention by salient visual cues in the environment, such as colour, contrast, and motion (Nasar, 1989a). This corresponds to principles from Gestalt psychology such as the principle of figure-ground segregation or the principle of similarity (Wertheimer, 1938; Wagemans, Elder, Kubovy, Palmer, Peterson, Singh, von der Heydt, *et al.*, 2012; Guberman, 2017).

Top-down processes in the selection stage are influenced by our goals, expectations and personal interests. We selectively attend to certain aspects of the built environment based on our individual preferences and needs. This involves the use of prior knowledge and cognitive biases to guide our attention (Démuth, 2012; Green *et al.*, 2018; Dember, Jolyon West and Epstein, 2023). For example, if we are interested in studying the density of buildings, we may selectively attend to areas with a higher concentration of structures.

Organisation: The organisation stage involves the grouping and structuring of selected visual information. It is influenced by Gestalt principles, which describe how we naturally organise elements into meaningful patterns and wholes. Principles such as proximity (grouping objects that are close together), similarity (grouping objects that share common attributes), and continuity (perceiving smooth and continuous lines) play a role in organising visual elements related to the built environment (Koffka, 1935; Wertheimer, 1938; Wagemans, Elder, Kubovy, Palmer, Peterson, Singh, von der Heydt, *et al.*, 2012).

During the organisation stage, we also integrate and combine different visual cues to form a coherent perception (Lozano, 1974; Rapoport, 1975c, 1990; Nasar, 1989a; Dember, Jolyon West and Epstein, 2023). This process involves extracting relevant features, such as building size, shape, and arrangement, to create a structured representation of the built environment. These organising mechanisms are innate and instinctive. We have a natural tendency to classify or categorise objects to identify patterns, but the evaluation of these patterns varies according to culture and context.

Interpretation: The interpretation stage involves assigning meaning and making sense of the organised visual information. It is influenced by our subjective experiences, knowledge, cultural background, and individual perspectives (Taylor, 1981a; Evans, Lepore and Allen, 2000; Dember, Jolyon West and Epstein, 2023). The interpretation stage is highly subjective and relative because it depends on our personal understanding, values, and expectations.

During interpretation, we rely on stored knowledge, memory, and cognitive schemas to interpret the built environment. This includes drawing upon our understanding of urban planning principles, cultural norms, and personal experiences. For example, our interpretation of density may be influenced by our familiarity with different urban contexts, where a high density in one city may be perceived as normal while the same density in another city may be seen as overcrowded.

Thus, the human perception of the urban environment is dependent on the decoding of the constant cues transmitted by that environment which is made up of social, cultural, symbolic and temporal cues that convey numerous non-verbal messages that humans use to evaluate the environment (Rapoport, 1975; Nasar, 1989; Carp, 1997). Non-verbal communication is usually seen on an individual level and decoded from a person’s behaviour by establishing their association with space, time, physical traits, kinesics (body movements of the people present), haptics, paralanguage, artefacts and surroundings. Environmental cues can be detected by employing a similar analogy to interpret the non-verbal messages transmitted by the urban environment.

3.8 Decoding the Non-verbal Cues of the Urban Environment

Decoding the non-verbal cues of the urban environment involves the interpretation and understanding of the visual, auditory, and sensory signals present in the built environment. Non-verbal cues refer to the physical characteristics, elements, and interactions within the urban environment that communicate information and evoke certain responses from individuals. These cues can include architectural features, street layout, public spaces, signage, lighting, sounds, and other sensory stimuli. This section examines the literature on non-verbal cues, verifying and expanding on the environmental cues framework hypothesised by Rapoport (1982).

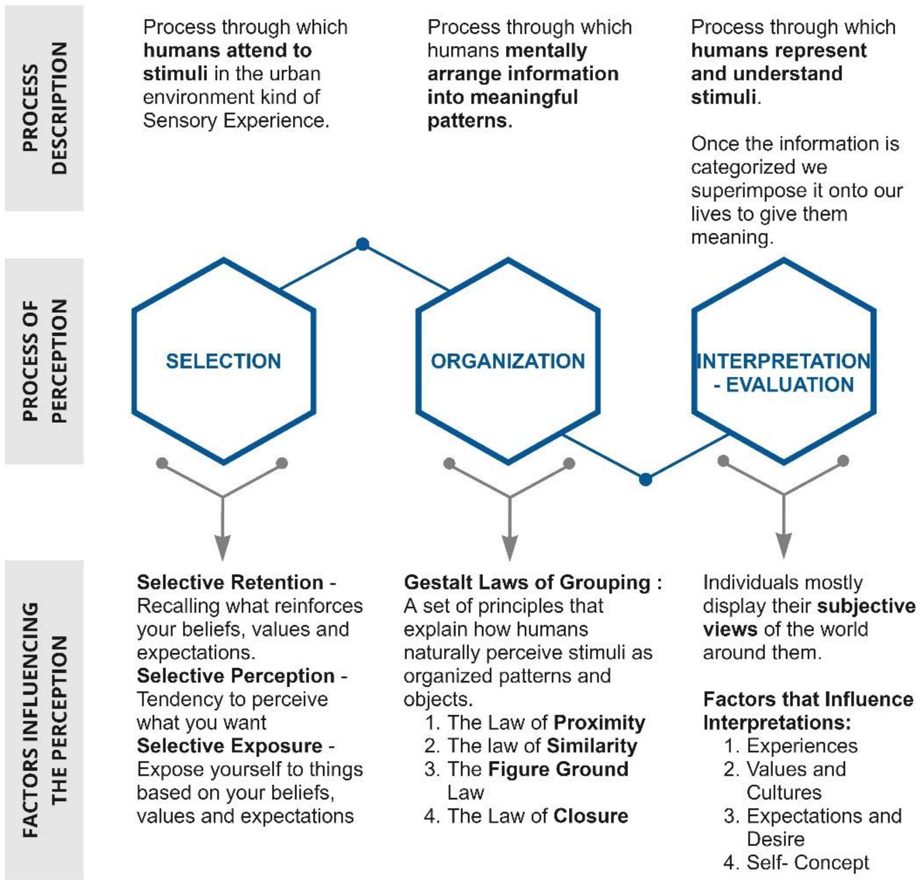


Figure 3-7. Three stages of perception process

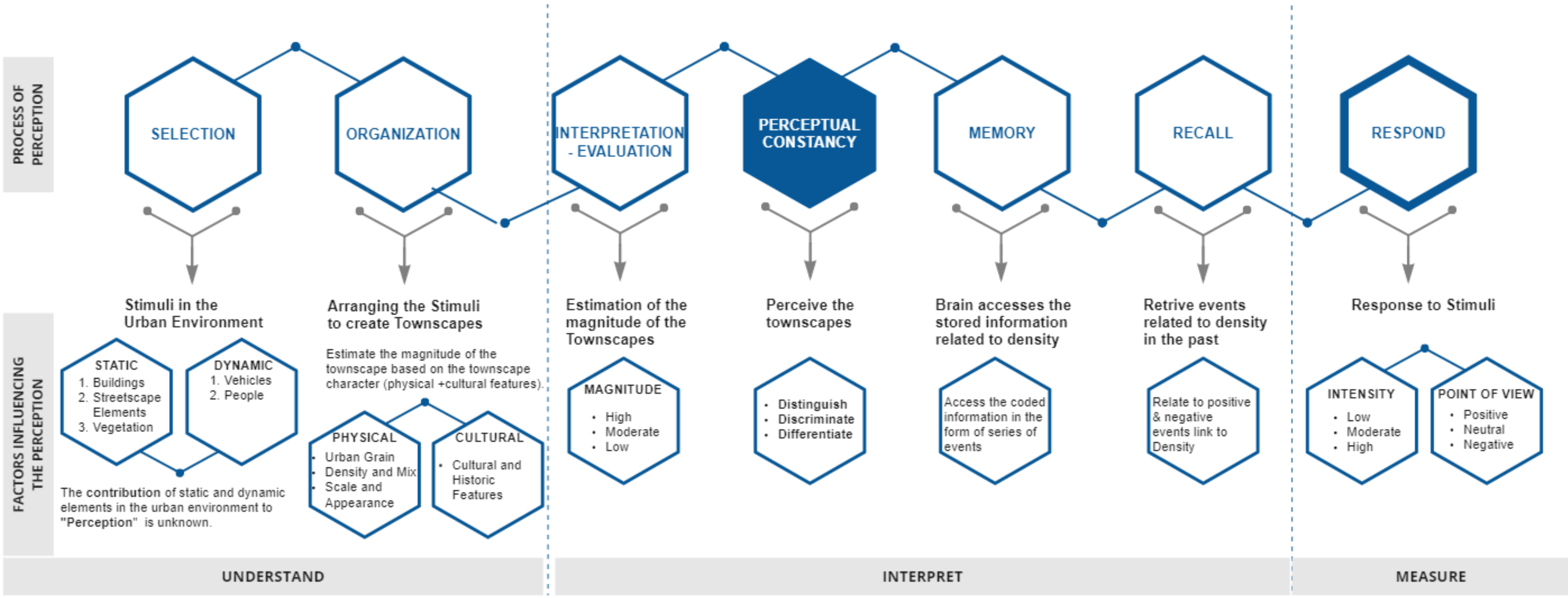


Figure 3-8. Process of people perception of built form

3.8.1 Space

Space refers to the distance between buildings (Rapoport, 1975c) and interpersonal space (Sommer, 1969, 2007). There are two ways to characterise the space between buildings (Newman, 1972; Gehl, 2011): as the distance between neighbouring buildings and as the distance between opposed structures (with the street as the divider). In both cases, the distance between buildings is governed by the planning and design regulations and is mostly determined by the plot ratios and the width of the street. For example, a wider street with a higher plot ratio of 3.5 (case of Manhattan), may result in a high-rise or a bulkier building that maximises the potential of the plot.

Jan Gehl (2011), in his book "Life Between Buildings" emphasises the importance of human-scale spaces and the need for buildings to create a sense of enclosure and define the urban realm. He argues that the spacing and arrangement of buildings can shape the quality of public spaces, influence social interactions, and contribute to the overall liveability of cities. According to Gehl, well-designed spaces between buildings can create a sense of intimacy and enclosure, fostering a sense of belonging and encouraging people to engage in social activities. These spaces provide opportunities for pedestrians to interact, rest, and enjoy the environment.

In "Defensible Space: Crime Prevention Through Urban Design," Oscar Newman (1972) argues that the design of spaces between buildings can have implications for safety and security. Newman's research suggests that well-maintained, clearly defined, and open spaces between buildings enhance natural surveillance and create a sense of territoriality, deterring potential criminal activities.

In terms of perception, the spacing of buildings can create visual cues that affect the perceived density. When buildings are closely spaced and form a continuous street frontage, it can give a sense of high density (Gehl, Kaefer Johansen and Solvekg, 2016; Harvey and Aultman-Hall, 2016). On the other hand, when buildings are widely spaced, it can create a more open and spacious feel, suggesting lower density. Moreover, the space between buildings can also impact the functional aspects of density (Gehl, 2011; Gehl, Kaefer Johansen and Solvekg, 2016). Adequate spacing allows for movement, circulation, and accessibility within the urban environment. It can provide room for amenities such as sidewalks, public squares, parks, and other gathering spaces, which contribute to the overall liveability of a place (Newman, 1972; Gehl, 2011; Gehl, Kaefer Johansen and Solvekg, 2016; Harvey and Aultman-Hall, 2016). Therefore, careful consideration of the spacing and arrangement of buildings is crucial in shaping the perception of density.

3.8.2 Time

Time, in the context of the urban environment, can also serve as a non-verbal cue that influences the perception of density. While the concept of time is not directly related to physical spatial arrangements, it plays a role in how people experience and perceive density in an urban setting. Temporal variations, such as the rhythm, pace, and activity patterns within a space, can create a sense of density (Rapoport, 1975c). For example, areas with a high volume of pedestrian traffic, bustling street life, and continuous activity may be perceived as denser compared to quieter, less active areas.

The perception of time in relation to density can be understood through the concept of "perceived time" as described by Gehl (2011). Perceived time refers to how individuals experience the duration of their activities in different urban settings. It is influenced by factors such as the presence of interesting sights, social interactions, and the overall quality of the environment. When people are engaged and stimulated by their surroundings, time may appear to pass more quickly, and the density of the environment may be perceived as higher.

3.8.3 Physical Characteristics

Physical characteristics of the built form, such as the size, shape, and arrangement of buildings, also serve as non-verbal cues (Lynch, 1964; Cullen, 1971a; Appleyard and Lintell, 1972; Rapoport, 1975c; Clemente *et al.*, 2005; Gehl, 2011; Ewing *et al.*, 2016; Gehl, Kaefer Johansen and Solvekg, 2016; Kent and Madden, 2016) that influence the perception of density in the urban environment. These physical attributes can affect how individuals perceive and interpret the density of a particular space.

Perceptual constancy (see Section 3.3.2) plays a role in the perception of physical characteristics. Perceptual constancy (Cohen, 2015; Green, 2023; McLeod, 2023) refers to the propensity to perceive objects as maintaining their size, shape, and colour despite changes in viewing conditions. In the context of the built environment, perceptual constancy allows individuals to perceive the size and scale of buildings consistently, even when viewed from different distances or angles. Gehl (2011) emphasises the importance of designing human-scaled, pedestrian-friendly environments that promote social interaction and create a sense of intimacy, ultimately contributing to a positive perception of density. Additionally, well-defined entrances, clear sightlines, and active ground floors can create a sense of security and make spaces feel more densely populated and vibrant (Newman, 1972).

3.8.4 Urban Punctuation

Urban punctuation (Lynch, 1964) refers to the strategic placement of distinctive architectural or landscape features within urban environments. These features act as visual markers or points of interest that break up the monotony of the built form and provide a sense of rhythm, hierarchy, and character to the urban landscape (Cullen, 1971a; Carmona *et al.*, 2010; Gehl, 2010). Urban punctuation can include various elements such as landmarks, plazas, squares, parks, fountains, sculptures, or any other design elements that create focal points or attract attention.

The effect of urban punctuation on the perception of density can be twofold. On one hand, urban punctuation can create visual breaks and points of interest within the urban environment. These distinctive elements, such as landmarks or open spaces, can help alleviate the perception of density by providing visual relief and creating a sense of spaciousness (Lynch, 1964). They serve as focal points that draw attention and create a sense of scale, making the surrounding built form feel less overwhelming.

On the other hand, urban punctuation can also enhance the perceived density in certain areas. By strategically placing dense clusters of buildings or architectural features, urban designers can create areas that appear more compact and densely populated. This deliberate manipulation of the built environment can influence the perception of density by shaping the visual composition and spatial organisation of the urban fabric.

3.8.5 Artefacts

Artefacts, particularly landmarks (Lynch, 1964; Gehl, 2010; Gehl, Kaefer Johansen and Solvekg, 2016), play a significant role as non-verbal cues in the perception of density and the understanding of the urban environment. Landmarks are distinctive physical features or objects that stand out in the built environment, serving as reference points for navigation and wayfinding.

Landmarks provide visual anchors in the urban environment. They stand out and draw attention, helping people orient themselves and understand the spatial layout (Lynch, 1964; Cullen, 1971a). Landmarks create reference points that allow individuals to gauge their position in relation to the surrounding built environment. This visual anchoring can affect the perception of density by providing a sense of scale and spatial context. Landmarks contribute to the legibility and identity of a place. They can act as distinctive features that help people recognise and remember specific areas within a city or neighbourhood. The presence of well-known landmarks can give a sense of character and distinctiveness to an area, shaping the perception of density by providing recognisable points of reference. Landmarks that are visible from multiple vantage points or are unique in their appearance can assist in orienting oneself and estimating distances, thereby influencing the perception of density.

In summary, the knowledge of the visual impact of non-verbal cues provides a valuable framework and context for analysing survey results related to the perception of density. It can help to interpret data, generate hypotheses, identify variables, and communicate findings effectively. By incorporating this knowledge into the analysis process, researchers can gain deeper insights into the factors that shape people's perceptions of density in urban environments.

Table 3-1. Framework of non-verbal environmental cues

Environmental Cues
Perceptual
Distance between adjacent buildings
Distance between opposite buildings
Associational / Symbolic

Arrangement and Orientation of buildings	
Physical attributes of the Built form	
Street attributes	
Pavement attributes	
Ground Floor Activity	
Temporal Aspects	
Tempo of pedestrians	
Speed of the cars	
Level of Activities	
Physical / Sociocultural	
Presence of a Boundary or Territory	

3.9 Theoretical Premise

Rapoport's idea of density as a subjective phenomenon sparked fresh research on density as a concept and its differentiation from crowding. He described crowding as the evaluation of perceived density concerning standards, norms and desired levels of interaction and information, while density was defined as the perception and estimate of the number of people per unit area, available space and its arrangement (Rapoport, 1975; Churchman, 1999). He recognised the concept's inability to generate a connection between the built environment and human emotional response.

Rapoport asserted that the objective measures of density could not explain the behavioural or subjective effects associated with it. Rapoport coined the term 'perceived density' to distinguish between the concepts of physical density and affective density (crowding) and to analyse the concept's contradiction. He hypothesised that people 'read' the urban environment by unconsciously classifying its features according to perceptual, symbolic and temporal cues. Some of these cues are connected with dense environments, whilst others are associated with less dense situations and are less dependent on population density.

Table 3-2. Framework of environmental cues – adapted from Rapoport,1975

Dense	Not-Dense
Perceptual	
Tight spaces	Open Spaces
Intricate spaces	Simple spaces
Large building height-to-space (high amount of subtended building in the field of vision)	Low height-to-space ratio (little subtended building in the field of vision)
too many signages	Fewer signages
Many lights	Few lights

High intensity of artificial lights	Lower light intensity
Many people	Few people
Man-made, less of nature, less greenery	More of nature, much greenery
High noise levels	Low noise levels
Sense of man-made smells	Fewer man-made smells
Many cars	Few cars
much parking	Less parking
Distance between adjacent buildings	
Distance between opposite buildings	
Associational/Symbolic	
Tall buildings	Low buildings
Absence of private gardens in residential areas	Presence of private gardens in residential areas
Arrangement and Orientation of buildings	
Physical attributes of the Built form	
Street attributes	
Pavement attributes	
Ground floor activity	
Temporal Aspects	
Fast tempos	Slow tempos
Activities throughout the day	Activities only at peak times
Physical/sociocultural	
Absence of defences	Presence of defences
High levels of attractive stimuli	Low levels of attractive stimuli
Absence of other adjacent places for use (streets, meeting places, so on)	Presence of other adjacent places for use (streets, meeting places, and so on)
Presence of mixed land use	Absence of mixed land use
Sociocultural	
High levels of social interaction-social overload	Low levels of social interaction – absence of social overload
Lack of control or freedom as a result of less space available	Presence of control and freedom with more space available
Social heterogeneity	Social homogeneity
Absence of culturally shared and accepted non-physical defences	Presence of culturally shared and accepted non-physical defences
Previous experience, socialisation at low densities	Previous experience, socialisation at high densities
Presence of a boundary or territory	

According to Rapoport (1975c) perceptual cues pertain to the concept of compactness or spaciousness and the intensity of things such as enclosures, cityscape elements, people or cars. In contrast, symbolic signals refer to the actual elements and their characteristics such as building height, building type, or the presence of trees or green spaces. Temporal features are recurring phenomena such as rhythms and activity levels that continuously affect the landscape. Over the years, this system of cues has been examined to demonstrate its ability to distinguish between dense and sparse settings. Table 4-2 lists the cues identified under each category. Rapoport anticipated that a comprehensive set of factors would prove valuable and provide a more efficient method for evaluating perceived density in various circumstances.

This theoretical premise assists in generating testable hypotheses about the relationship between visual cues and perceived density. These hypotheses provide a basis for designing research questions and guiding data collection and analysis. This framework assists in organising and interpreting the collected data, allowing for meaningful comparisons and analysis of the relationships between visual cues and perceived density. It enhances the generalizability and comparability of the study findings.

3.10 Empirical Studies on Perceived Density

This study considered seven studies that examine the concept of perceived density either by evaluating the spatial layouts of residential settings (Beck et al., 1987; Flachsbart, 1979) or by assessing the visibility (Emo et al., 2017; Norcross, 1974) and visual complexity (Bergdoll and Williams, 1990) of the built form along the streets or by evaluating both (Cheng, 2010; Lilli, 2013). Through empirical methods such as graphical surveys, observations and spatial analysis, these studies collected data on participants perception of density in relation to the urban form elements(Dempsey *et al.*, 2010) (density, housing/building type/form, layout, land use and transport infrastructure). The investigations are described chronologically by date in this section.

3.10.1 Visibility

The first study, undertaken by Carl Norcross (1973), surveyed 49 residential developments in Washington, DC area and California (19 in Maryland, 15 in northern Virginia, and 15 in Washington DC). The building density of these projects ranged from minimum of 1 unit to multiples of 12, up to 1200 units or more. These dwellings (walk-up houses) included duplexes, triplexes, fourplexes and rows of up to 10 units with a maximum height of three storeys. This project focuses on understanding the likes and dislikes of 1800 people and families in 49 projects about their townhouses and condominiums. It involved the inquiry on density and its relation to owner satisfaction.

The results revealed a strong inverse link between population density and satisfaction; i.e., the lower the population density, the greater the satisfaction. Norcross observed that lower priced-townhouses have higher densities than expensive houses and that slightly higher densities could deliver the same owner satisfaction as lower densities (Norcross, 1973). Thus, he proposed design considerations that would make higher densities more desirable.

Norcross described spatial design recommendations for house layouts from the perspective of indoor and outdoor visibility. He discovered that the sense of density was directly proportional to the location of the dwelling unit within the housing cluster and also within the plot. Space around the building counts the most, as it is what the owner sees and uses. A pleasant view of green space, a park or any natural element such as a pond was also associated with a perception of lower density. Smaller neighbourhoods separated by open areas, staggered fronts, unequal setbacks, diverse rooflines and shorter rows of townhouses built around a courtyard will also help achieve a lower perception. The presence and positioning of trees around parking lots and the screening of on-street parking with landscaping also mitigate this perception (Norcross, 1973; Flachsbart, 1979).

3.10.2 Liveability Index

A second similar study by Zehner and Marans evaluated the liveability of eight neighbourhoods in Columbia, Maryland and Reston, Virginia, based on two factors:

degree of planning and population density. Degree of planning refers to highly planned (variety of housing types and clusters, recreational facilities in proximity to residences and separation of pedestrian and vehicular traffic) or moderately planned (residences with some recreational facilities and amenities) residential neighbourhoods. Liveability is measured using 3 indicators: informal socialising (percentage of acquaintance and interaction with neighbours); neighbourhood characteristics (privacy, amount of outdoor space, place ratings, neighbourhood rating); neighbourhood satisfaction. The building density ranged from 7.2 dwellings per acre to 10 dwellings per acre. They found that the proximity to neighbourhood amenities has a detrimental effect on liveability (Zehner and Marans, 1973). The rise in the number of amenities increases social contact and associated factors including noise and traffic and diminished play areas (Zehner and Marans, 1973; Flachsbart, 1979). The presence of common open spaces, walkways and nearby recreation facilities contributed to higher levels of satisfaction.

This study suggests that a balance between access to amenities and the preservation of open spaces and recreational facilities is important for creating a positive perception of density and enhancing the overall quality of the urban environment.

3.10.3 Perceived Density and Satisfaction

Flachsbart (1979) selected 17 residential neighbourhoods in Los Angeles, based on comparable socioeconomic and land use parameters. Density, which he defined by the number of dwelling units, distinguished the neighbourhoods. The respondents were shown seven levels of density ranging from fewer than 10 dwellings per block (dpb) to over 200 on photo cards. This study was based on three questions: perceived density, perceived satisfaction and desired improvement level. The purpose of the study was to distinguish between perceived and objective densities based on their physical properties, examining street and block characteristics such as street width, block length, number of intersections, slope and block size and shape to gauge perception and contentment. This study discovered that shorter block lengths and a greater number of intersections induce visual breaks to support the perception of lower density.

Table 3-3. Seven empirical studies on perceived density

Author (Year)	No of cases/ projects	Number of Peoples	Settings; Country	Concept	Method
Carl Norcross (1973)	49 projects	1800	Residential, USA	Visibility	Hypothesis
Zehner and Marans	8 areas	-	Residential, USA	Liveability	Survey research
Peter G Flachsbart (1979)	17 areas	319	Residential, LA, USA	Perception & Satisfaction	Hypothesis
Bergdoll & Williams (1990)	3 Streets	37	Residential, CA, USA	Visual Complexity	Hypothesis
Cheng (2010)	8 high density areas	51	Residential, Hongkong	Sky View Factor	Hypothesis
Lilli (2013)	11 areas	52	Residential Oregon, USA	Spaciousness and Openness	Hypothesis
Emo (2017)	2 streets	190	Zurich, Switzerland	Visibility	Survey Research

Gross density, as measured by residences per acre, was found to be related to both satisfaction and the percentage of improvement. Satisfaction levels decreased as the population density increased, whereas the improvement with density, percentage increased. Perceived density measured with the help of visual cues included street width, block length, number of intersections, slope, and indexes of block diversity index (size and shape of the block; Lynch, 1964) and street shape. This study argued that environmental perceptions are influenced by nearby stimuli (a thing or event that evokes a specific functional reaction) (Flachsbart, 1979; Snow *et al.*, 2014) and deficiency of even one data set would result in inaccurate results. Although this study derived guidance to comprehend the relationship between urban form and perceived density from Sprerigen (1981), Rapoport (1975c), Jacobs (1961), Hall (1966), Zehner and Marans (1973) it could not establish a correlation due to deficiency of data sets on physical form attributes, street length, street width.

3.10.4 Visual Complexity

Bergdoll Williams (1990) investigated the effect of physical qualities on the sense of density. For the survey, three streets with moderate density (35-47 dwelling units per acre) with identical street widths and building heights that retained similar enclosure ratios but differing visual complexity were chosen. The study aimed to determine what factors people consider when evaluating density. Visual complexity included attributes of the built form such as building articulation, architectural details (variety of door and window patterns), building types, building material and colour, complementary elements such as streetscape elements, parked cars and landscaping, and temporal aspects such as activity levels along the street and traffic volume. The type and size of dwellings (single-family homes), open space between buildings, a greater quantity of trees and smaller buildings contributed to reduced perceived congestion. The lack of space between buildings, a greater number of apartment buildings and more windows contributed to the impression of higher density.

This was the first-time density had been identified as both a positive and negative feature and this study demonstrates that density is relative and can be seen differently even when there are just small contextual variations. The study identified three streetscape features: façade area, building articulation and building type. It found that an increase in façade area correlates with an increase in perceived density, increased building articulation was connected with decreased density perception, and there was a correlation between detached building types and lower perceived density.

3.10.5 Sky View Factor

Cheng (2010) conducted an investigation in Hong Kong with 18 high-density examples with plot ratios varying from 2.3 to 7.8. The study examined the role of 4 types of hypothetical urban design variables: physical density parameters, built-form features, non-built-form features and spatial complexity factors. The two physical density criteria – plot ratio and site coverage determine the density of buildings in a region. Built form and non-built form characteristics were obtained from earlier research on perceived density, except for the sky view factor. The number of buildings, building heights, street width, enclosure ratio, ground openness, space between buildings and sky view were among the built-form features while, footfall, traffic, street signs, stores, vegetation, illumination and street art were amongst non-built-form features. Additionally, the study evaluated the building skyline and urban layout as spatial complexity characteristics using both field observation and simulations.

Cheng found that perceived density has a positive and significant correlation with the number of buildings, whereas building height does not have a significant influence on perceived density. However, building height has a greater visual impact and has a greater capacity to influence the perception of density, but the study showed otherwise, hence the researcher identified the need for further investigation. that user pleasure is inversely proportional to perceived density. A negative significant correlation was observed between street width and perceived density, which indicates that as the street width increases, perceived density decreases. A positive significant correlation was observed between building height to street width (enclosure ratio) and perceived density, which suggests that perceived density increases with an increase in enclosure ratios. Space between the buildings and visual open space significantly influence the perception of density. This study identifies that there is a weak association between the expression of physical features and building density. The effects of plot ratio and site coverage on perceived density were minimal. It also identified sky view and ground openness as key perception-enhancing elements. Non-built factors, particularly those in constant flux such as vehicular activity, have a greater influence on perceived density.

3.10.6 Spaciousness and Openness

A study conducted by Lilli (2013) in the US examined four independent factors from a spaciousness and openness perspective: house type, street width, setback depth and tree coverage. It was discovered that the presence of trees in the front yard had a greater impact than the dwelling type itself. This indicated that trees and setbacks are two characteristics that can help mitigate the negative effects of high-density dwelling types. Additionally, single-family homes with a higher density and some trees may be preferable. The study found a correlation between building type and the width of the front setback and the number of trees. Fewer trees improved visibility, which is correlated with expansiveness. Wider streets were connected with a sense of space and, thus, a diminished perception of density. In contrast, wider setbacks limited social interaction with street level activities; hence, shallower setbacks were favoured.

3.10.7 Visibility

Emo et al. (2017) selected six parameters to evaluate an individual's density perception: visibility, number of buildings, street width, amount of visible sky, amount of visible green space and number of vehicles. Five of these parameters, excluding visibility, were evaluated using two colour images and a questionnaire by around 190 individuals from around the world. Participants identified four characteristics that influence the perception of urban density: the number of visible buildings, building height, visibility and availability of green spaces.

Table 3-4. Summary of findings of empirical studies on perceived density

Categories	Factors Influencing Perceived Density	Author (Year)
Morphology / Layout	Block sizes (length/ width/shape)	Flachsbart (1979)
	Street width/profile (shape slope)	Flachsbart (1979) Cheng (2010)
	Space between the houses	Beck, Bressi & Early (1987) Bergdoll & Williams (1987)
	Setbacks	Beck, Bressi & Early (1987) Lilli (2013)
	Number of buildings	Emo (2017)
Visibility	Views and vistas	Beck, Bressi & Early (1987)
	Visible open space	Cheng (2010)
	Sky view	Cheng (2010)
Vegetation	Vegetation along the street	Beck, Bressi & Early (1987)
	Tree coverage	Lilli (2013)
	Visible green	Emo (2017)
Built form Characteristics / Façade Articulation	Architectural style	Beck, Bressi & Early (1987)
	Taller buildings	Bergdoll & Williams (1987)
	Building heights	Cheng (2010); Emo (2017)
	Less façade area / smaller buildings	Bergdoll & Williams (1987)
	Large number of windows	Bergdoll & Williams (1987)

The number of buildings has been identified as the lone factor suggesting that the built-to-open ratio is of great importance in urban planning and design. The two images were evaluated using an image segmentation method to obtain a detailed classification of urban environment elements to validate the questionnaire's answers.

3.11 Design Implications

Positively perceiving urban environments may benefit greatly from the knowledge provided by the empirical investigations described. Design implications for a creative spatial layout with prominent building features, conscious placement of vegetation along the streets and interspersing amenity buildings with dwellings can help create a positive perception (Norcross, 1973), but they are subject to the interpretation of the design professional who determines the urban form as a result of the objective density. For mixed-use environments, factors such as building separation, façade articulation and archetypal home forms may aid in obtaining higher densities while inducing lower perceived densities (Bergdoll and Williams, 1990). These implications presented in Table 3-5, are used to create a diversified urban environment. The attempt to maximise efficiency trumps consideration of aesthetic quality and perception of density.

Table 3-5. Summary of design implications for lower perceived density

Rapoport's Framework of Cues	Design Implications for Lower Perceived Density	Author (Year)
Perceptual Cues	Views and Vistas seen from windows	Norcross (1973)
	Neighbourhoods separated by open spaces and greenery	Norcross (1973)
	Use of natural building materials for garages	Norcross (1973)
	Greater space between the buildings	Copper, Marcus & Sarkissian (1986)
	Visual access to open spaces	Copper, Marcus & Sarkissian (1986)
	Enclosures	Bergdoll & Williams (1990)
	Use of trees along the street	Lilli (2013)
Symbolic Cues	Varying roof lines	Norcross (1973)
	Staggering fronts/ uneven front setbacks	Norcross (1973)
	Small parking lots	Norcross (1973)
	Trees and shrubbery around parking	Norcross (1973)
	Small neighbourhood size	Copper, Marcus & Sarkissian (1986)
	Variations in building façades	Copper, Marcus & Sarkissian (1986)
	Façade articulation / archetypal house forms	Bergdoll & Williams (1990)
	Far/plot ratios	Bergdoll & Williams (1990)
	Narrow streets, shallow setbacks	Lilli (2013)
	High density, wider street, deeper setback	Lilli (2013)

The reviewed empirical studies on perceived density have investigated various factors such as visibility, visual complexity, spaciousness, openness, and spatial layout. These studies have examined the relationship between these factors and the perception of density in the built environment, using methods such as surveys, image analysis, and field observations.

The lessons learned from these studies can inform the current study on the perception of density. Firstly, visual cues play a significant role in shaping the perception of density. Factors such as building height, building density, and spatial arrangement can influence how people perceive the density of urban environments. Therefore, it is important to consider these visual cues when studying and analysing the perception of density.

Secondly, the studies emphasise the importance of considering the holistic environment and the interaction of multiple factors. It is not solely the physical attributes that determine the perception of density, but also the overall spatial configuration, aesthetics, and cultural context. These factors should be taken into account when designing the study and analysing the data.

However, it must be noted that these studies are limited to residential layouts and many of them cannot be applied to commercial or mixed-use environments. Although ambiguity in the findings can be attributed to context under study, it is necessary to consider case studies that illustrate varying densities and urban forms. This diversity enables the determination of the relative degree of perceived density (high, moderate and low) and values (positive or negative) associated with it.

3.12 Limitations of the Previous Empirical Studies

The outcomes of the research could be influenced by the limitations of the empirical studies. Hence, identification of study constraints facilitated the development of opportunities for future research and guided the investigation's course. The overview of the studies reveals that study design and data collection are two constraints.

In each of the investigations, hypothesis testing offered a dependable framework for conducting data research, established the relevance of the data, measured the validity and reliability of the results through systematic examination and helped to identify prospects for future research. However, each considered all or a small number of variables (built-form features and non-built-form features) to expand or limit the scope of the studies (Ross and Bibler Zaidi, 2019). Depending on the research objectives, these studies also focused either on specific places or attempted to validate alternative notions such as visual complexity (Bergdoll and Williams, 1990), spaciousness and openness (Lilli,2013). These delimitations reflected a systematic bias that was knowingly incorporated into the study design by the researcher to improve the practicality of the research. However, this resulted in context-specific conclusions that could not be generalised to similar situations.

Photographs were the qualitative data assessed in these studies to determine correlations between the independent and dependent variables. Photographs are substitutes for actual events (Stewart et al., 1984; Nasar, 1989). Between two and 18 images were used in the studies. Although this number is contingent on the research purpose, it is essential to establish comparisons. Given that every urban setting is distinct in terms of its visual composition, the fewer cases there are, the less likely it is that they will reflect optimal scenarios. A greater number of images can reflect distinct urban surroundings and evoke a variety of responses. Even in consistent environments, a minor alteration can result in diverse perceptions. While a smaller number of case studies guarantees the completion of the survey, they may not be sufficient to generate generalised results.

Furthermore, data acquired across different years and months may result in a systematic error due to the possibility of physical change in urban settings. Similarly, using existing research data to undertake a study can cause a systemic error. The use of census data without on-site verification at the time of the survey will also result in errors. The sample size and type selection based on a socioeconomic level, culture, age or ethnicity could give a basis for comparison but would result in context – and culturally-specific findings. Similarly, considering only design experts and not the general public to comprehend the process of perception can establish a systemic bias. The restrictions may also stem from the methods of measuring perceived density. Responses could be collected by viewing photographs or conducting on-site interviews but measuring perceived density using indoor measurements (within the window aperture) presents a problem since the frame of vision is limited. The design implications based on this measurement would need verification before wider application.

3.13 Summary

This chapter explored the topic of the perception of density in urban environments. The importance of understanding the perceptual process and the role it plays in shaping our experiences of density was discussed. The chapter highlighted the subjective and constructive nature of perception, influenced by individual and cultural differences, as well as prior knowledge and past experiences.

Different theoretical perspectives, including bottom-up and top-down theories of visual perception, and their relevance to understanding density perception were examined. Gestalt psychology and Marr's computational model were discussed as examples of top-down approaches, while the constructivist theory by Gregory represented a bottom-up perspective.

The chapter also delved into various non-verbal cues that contribute to our perception of density, such as the space between buildings, temporal variations, physical characteristics, urban punctuation, and artefacts. These cues interact with our perceptual processes and influence our interpretation of density in the built environment.

The reviewed empirical studies focused on factors such as visibility, visual complexity, spaciousness, openness, and spatial layout, establishing relationships between urban form and these perceptual factors. The limitations of these studies were acknowledged, including sample size, sample characteristics, methodological approaches, contextual specificity, and the need for longitudinal analysis.

Overall, this chapter provided a comprehensive overview of the theoretical foundations and empirical research related to the perception of density. The insights gained from this chapter will inform the subsequent analysis in the study, helping to understand how people perceive density in urban environments and its implications for design and planning decisions.

Chapter 4. Research Methodology

This chapter explains the approach and procedures used to conduct the study. It provides a detailed explanation of the research design, data collection methods, data analysis techniques and ethical considerations.

4.1 Research Approach

This study used two approaches to study density perception: psychophysics and personal construct theory. By combining psychophysics, which provides objective measures of density, with personal construct theory, which explores the subjective evaluation of density, the study acknowledges that density can be perceived and evaluated differently by individuals. The approach in this study also incorporates insights from visual perception theories.

Psychophysics is a branch of psychology that stresses the objective assessment of physical stimuli and their relationship to perceptual experience (Encyclopaedia, 2017) and reflect positivist research philosophy. Positivism assumes that reality is objective and that knowledge is attainable through empirical observation and measurement (Dudovskiy, 2018). Personal construct theory is anchored in the constructivist research philosophy which emphasises the subjective aspect of human experience and the significance of individual differences in perception and making meaningful associations. Constructivism suggests that reality is the result of subjective perceptions and experiences, and that knowledge may be acquired via subjective inquiry and discovery (Dudovskiy, 2018).

By combining psychophysics and personal construct theory, it is possible to gain a deeper understanding of the intricate relationship between objective sensory stimuli and subjective perceptual experiences. A study that combines psychophysics and personal construct theory could, for instance, investigate how individual differences in personal constructs influence the perception of physical stimuli and vice versa. This section discusses the approaches and their methodologies.

4.1.1 Psychophysics

Psychophysics is a subfield of psychology that investigates the relationship between environmental physical stimuli and subjective experience and perception to understand how the physical features of stimuli such as colour, intensity and frequency translate into psychological experiences such as brightness, loudness and magnitude (Encyclopaedia, 2017).

This study seeks to understand the human perception of density by decoding the urban user experience, both of which fall under the purview of psychophysics. Experience is necessarily subjective, but objectivity is required to generate results that are repeatable by others (Isaac, 2013). However, the emotional response to a conscious experience is inseparable from the person who has it, except that one can verbally express it to describe 'what it is like' (Isaac, 2013). Consequently, what is received as a response is a verbal or written description. Interpreting these responses using descriptive statistics is one way to decode the experience.

In contrast, perception contains both physical and mental components. Gustav Fechner (1801-1887) believed that perception is an active process involving the interpretation of sensory data by the mind (Gepshtein, 2010). He introduced the concept of 'just noticeable difference', which refers to the smallest change between any type of stimulus (visual, aural, olfactory or tactile) that an observer can identify. Franz Brentano (1838-1917) argued that perception was directed toward an object, or a mental representation of an object and that this intentionality was the defining characteristic of conscious experience (Gepshtein, 2010). Brentano viewed perception as an active mental representation and interpretation process.

Applying this analogy, Fechner's interpretation of the perception of density would be understood in terms of the relationship between the physical properties of an object (physical attributes, height, mass, volume – things that can be measured) and the subjective experience of that object's density (its visual impact). Brentano's interpretation of density includes sensing the physical properties of the objects but also recognising a particular quality or value (good/bad; positive/negative) or property of an object.

4.1.1.1 Methods Used to Measure Perception in Psychophysics

Psychophysicists' research of perception uses a range of techniques including threshold testing, discriminating testing, scaling, signal detection theory, adaptation and magnitude estimation to measure two distinct stimuli such as visual and aural. There are two techniques applicable to this study on the perception of density.

Discrimination testing. This evaluates a participant's capacity to distinguish between two stimuli that differ in some aspect (Moye, 2021). For instance, participants could be given pictures of cityscapes and asked to differentiate them based on specific characteristics such as building height, architectural style, street width and so on. Typically, this method is used to determine the just noticeable difference (JND) between two stimuli. It permits the assessment of the smallest discernible variations between stimuli, which can be used to characterise the perceptual system's sensitivity.

Magnitude estimation. This is a method for estimating the subjective perceived magnitude of a stimulus, such as the brightness or loudness of a sensory signal. This method allows individuals to rate sensory or emotional stimuli (Moskowitz, 1977). For instance, participants could rate the perceived spaciousness of a plaza on a scale of 1 to 10, with higher numbers indicating a greater sense of openness. It permits the measurement of a vast array of sensory modalities such as vision, hearing, touch and taste, and is a useful technique for measuring subjective perception (Moskowitz, 1977).

4.1.2 Personal Construct Theory

Personal construct theory is a mid-20th-century psychology theory proposed by George Kelly (2017). It posits that individuals generate and employ personal constructs or mental frameworks to understand and interpret the external environment. This theory has diverse applications in the field of psychology. It is used in: therapeutic settings to help individuals identify and understand their constructs; personality assessment; education and learning in recognising that learners have their constructs; organisational development and so on (Kelly and Kelly, 2017). The purpose of these personal constructs is to classify and categorise information based on their unique perspectives and beliefs. with regards to the perception of density, it suggests that people will construct their own mental categories and criteria for what constitutes the density of the urban environment.

These mental criteria will be based on the individual's past experiences and contexts.

According to Kelly, personal constructs are typically binary in nature, meaning that they are founded on dichotomies such as good/bad, honest/dishonest or friendly/unfriendly (Goffin, 2014; Kelly and Kelly, 2017). Personal constructs are unique to each individual and are shaped by past experiences, cultural background and social interactions. Kelly believed that several procedures including interviews, questionnaires and projection techniques might be used to study personal constructs. He also devised a methodology known as the 'repertory grid'(Goffin, 2014; Kelly and Kelly, 2017), which is a strategy for eliciting personal conceptions by having individuals compare and contrast items in their surroundings based on numerous dimensions.

4.1.2.1 Methods Used to Measure Perception Using Personal Construct Theory

Several methods such as the repertory grid technique, semantic differential technique, cognitive mapping, free-listing technique and Multiple Sorting Task are used to measure perception using personal construct theory. The two most relevant for this study are explained below.

Multiple Sorting Task (MST). In this activity, participants are presented with a set of stimuli (images, words, objects) and asked to sort them into piles or categories according to some relevant criterion or characteristic (Canter and Groat, 1985; Barnett, 1996). A participant may be asked to sort images of people based on whether they appear kind or unfriendly, for instance. After the sorting has been completed, the researcher can examine the participant's constructions by analysing the sorting patterns and assess the degree of overlap or similarity between the participant's categories and the salience or significance of each category. In addition, the researcher might compare the participant's sorting to that of other participants to find shared or common constructs.

It is a versatile and open-ended strategy that permits the use of a wide variety of stimuli and dimensions. It is simple to administer and can be used on both children and adults. However, the interpretation of the data can be subjective and may necessitate some personal construct theory expertise and may also be time-consuming and unwieldy for large studies (Chollet, Valentin and Abdi, 2014).

Repertory Grid Technique. The repertory grid technique includes asking participants to name a collection of significant people or objects and then comparing these individuals or items on a set of binary constructs (e.g., good/bad, friendly/unfriendly). Researchers might thus gain insight into an individual's perceptual structure by analysing patterns of similarities and differences among constructs (Bjorklund, 2008; Kelly and Kelly, 2017). The technique entails a structured interview in which the participant is asked to compare and contrast aspects of their surroundings along multiple dimensions. As the interview progresses, the interviewer makes notes on the participant's comments and begins to uncover the personal constructions underlying the comparisons. The participant's cognitive map or mental model of the world is then organised into a grid which serves as a visual representation of these constructs and can be analysed using a variety of statistical and qualitative techniques to show patterns in the participant's thought processes and an insight into their worldview and the way they make sense of their experiences (Bjorklund, 2008).

For this study, the two methods chosen for data collection were a MST and situation judgement. An MST assisted in deriving the personal constructs and also in deriving objective data regarding the physical attributes of the urban environment, reflecting Fechner's philosophy of perception. The ideology of the psychophysical methods such as distinction, matching and discrimination crucial for identifying the minor variations in stimuli are inherent parts of MSTs. A part of the repertory grid – judging the urban environments with the help of binary constructs – was incorporated into the situation judgement task. This assisted in recording the value or quality of the urban environment as perceived by the participants, reflecting Brentano's philosophy of perception.

Both research methods are typically conducted as workshops where verbal description becomes a source of rich data. However, this study was conducted during the COVID-19 pandemic, so these workshops were designed as online interactive tasks to be taken by an individual on their own without the presence of the researcher. The interview part in both methods was replaced by written descriptions and multiple-choice questions in the MST and situation judgement task, respectively.

4.1.3 Integrating Visual Perception theories into the Research Process

The Gibson's theory of visual perception, Gregory's Constructive theory, Marr's computational model, and Gestalt psychology offer valuable insights and frameworks for the study of density perception (see Section 3.9).

The Gibsonian theory (Gibson, 1966; 2015) of visual perception emphasises the environment's influence on perceptual process. It suggests that perception is an active process in which individuals perceive meaningful information directly from their environs. This theory can be applied to the study of density perception by investigating how individuals extract and interpret density-related cues from their visual environment. It highlights the importance of visual cues like texture gradients, occlusion, and perspective in perceiving density.

Gregory's Constructive Theory (Gregory, 1974) focuses on the active construction of mental representations in response to sensory input. It suggests that perception is not a passive process of information recording, but rather an active interpretation and organisation of sensory information. This theory can be applied to the perception of density by analysing how individuals construct mental representations of density in response to various sensory cues and contextual information. This emphasises the significance of top-down processes and cognitive interpretation in density perception.

The computational model developed by Marr (Démuth, 2012) provides a framework for comprehending the various levels of analysis involved in perception, such as the computational, algorithmic, and implementation levels. This model can be used to study density perception by guiding this research to identify the computational goals (desired conclusions), algorithms (specific methods and processes), and implementation (neural mechanisms) involved in density perception. It helps to comprehend how sensory information is translated into meaningful density representations.

Gestalt psychology (Wertheimer, 1938; Wertheimer and Riezler, 1944) focuses on integrating perceptual experiences into meaningful wholes. It proposes principles such as proximity, similarity, closure, and figure-ground segregation that govern how individuals perceive and group visual elements. Gestalt principles (Koffka, 1935; Wertheimer and Riezler, 1944) can be applied to the study of density perception in order to comprehend how individuals organise and perceive patterns and structures in relation to density. It facilitates the examination of how individuals classify and categorise objects and people based on their perceived density.

In conclusion, these theories and frameworks are be applied to the study of density perception by shedding light on the active and constructive nature of perception, the role of visual cues and organisation principles, and the computational processes underlying density perception. They aid researchers in analysing the perceptual processes involved and comprehending how individuals perceive and represent environmental density.

4.2 Research Process

This overview of the research process describes the steps involved in planning and conducting the research to achieve the objectives and to seek a solution to a problem. In particular, it reviews the research design, data collection techniques and methods for analysis and involves a series of steps.

4.2.1 Selecting the Research Area

The subject of the research is interdisciplinary. It analyses and synthesises links between objective density and perceived density into a unified and coherent whole to express the concept from the user's point of view. Environment psychology investigates the consequences of population density on human behaviour. In sociology, population density statistics are used to determine the markers of social disorder, indoor crowding, crime rates, and so on. Many sustainability indicators are also derived from the demographic data on population density. Density in urban studies facilitates spatial investigation of the built form, yet it has been criticised for not revealing its performance, efficiency, planning and design. Despite, these various applications, there has been a general failure and paucity of studies to interpret the user experience of density. This study aims to overcome this gap and crosses over the domains of urban design, environmental psychology and psychophysics.

Not all urban environments designed to provide a positive user experience manage to do so. By understanding the phenomenon of user perception of the urban environment, it might be possible to identify the elements of urban form accountable for this failure. This is the task of this study.

4.2.2 Formulating the Research Aim, Hypothesis, Objectives and Research Questions

Knowledge of the perception of density to create, alter and design urban environments is crucial to create positive, efficient and sustainable urban environments. The research questions (see Section 1.3) and objectives (see Section 1.4) can be addressed by reference to three hypotheses:

H1. The perception of density is relative and is interpreted differently in place-based studies as compared to general unfamiliar settings. Using both scenarios might help understand variations between the opinion of residents versus that of strangers.

H2. The perception of density is in part associated with the visual composition of the urban environment.

H3. The change in viewing angle as an outcome of self-captured images to that of the Google Street imagery does not affect the identification of factors that influence the human perception of density. But it might affect the visual composition and consequently the percentage of the visual components derived using image segmentation and magnitude estimation.

4.2.3 The Literature Review

The literature review is structured into two parts and presented in Chapters 3 and 4. Chapter 3 examines the importance of objective (measured) density in urban planning but also identifies a knowledge gap in regard to user interpretation of density. Chapter 4 focuses on the concept of perceived density and previous empirical investigations to identify principles and methods which could be used close this gap; it also informs the current study, helping with the selection of research settings and investigative methods.

4.2.4 Methods for Data Collection

Most studies presented in Chapter 3 (see Section 3.10) have been conducted in residential settings and at a street scale, focusing on specified, pre-set variables to test a set of hypotheses in regard to the factors affecting the experience of density. They have employed qualitative research methods such as visual surveys, interviews and questionnaires and direct observation techniques, often in combination. Overall, these studies reveal issues of consistency, significance and replicability of the results and warn of important limitations to be aware of.

Therefore, a review of research methods in psychology and psychophysics was conducted to find ways to overcome the limitations. This review identified the theories on personal constructs (Kelly and Kelly, 2017b) and visual perception (Gibson, 1977; Norman, 2002) and a set of useful visual research methods to use in combination: the Multiple Sorting Task (MST) (Groat, 1985) based on card sorting and the situation judgement task, relying on questions. These two were then used in case studies to capture sets of information to describe respectively: 1) respondents' own constructs (ways to make sense of) used when they observe and experience urban environments and 2) the qualitative values associated with them and the experience of density.

In this study, which recognises the lion's share of the visual aspects of urban space in its perception, it was felt that a suitable means would be a visual iteration of the MST (see Section 4.6.1), an exercise based on a card sorting activity able to extract criteria solely through the activity of respondents, without researcher influence. The collation of all criteria of assessment affecting the perception of density was then coupled with a Situation Judgement Task (SJT) (see Section 4.6.2) which allowed to verify the role of each factor on the perception of density. The combination of these theories and applications resulted in a process that, whilst initially top-heavy, gave a replicable and agile survey easily applicable to any situation, overcoming earlier studies' narrow focus and limited applicability.

As the study was conducted during the COVID-19 pandemic, it was designed to be online. The MST used a tailored web application while SJT was designed using

Qualtrics.

4.2.5 Collecting the Primary Data

Previous studies have investigated photographs, panoramas, sketches, line drawings and photographic elevations for visual surveys. Of these, images and photographs were chosen because they represent the human perspective from a particular reference point and accurately portray the real situation. For the first survey, two sets of images were collected. The first consisted of street perspectives captured at eye level from the streets of Glasgow, and the second of Google Street Views imagers depicting universal examples of density. The photographs were used to create two surveys based on an MST, one for Glasgow and the other for universal illustrations. For the second survey, which was an SJT, 16 images were selected based on density perceived by the users from both sets and presented for qualitative evaluation.

The first survey intended to identify the factors that influence the perception of density (objective 1). A greater number of responses would assist in developing a comprehensive list and so the survey was circulated online to around 300 people and 250 responses were recorded.

The target population was laypeople, architecture students and professionals between 18 and 65. Since the case examples considered were greater in number (27 cases represented by images), it was not possible to ask for additional information on the quality of the urban environment, so the second survey was conducted to identify the qualitative values (positive or negative) associated with the environment. This second survey was circulated to around 150 people and around 82 responses were received.

4.2.6 Data Analysis

The MST survey generated qualitative raw data in the form of written descriptions. This data was analysed using descriptive statistical analysis techniques, including content and frequency analysis. Content analysis entails methodically analysing various forms of communication – in this case, text – to identify patterns and classification of descriptions according to distinct concepts or themes. Subsequently, frequency analysis was performed to analyse the themes by determining the frequency of occurrence of particular values. with the aid of these two techniques, approximately 7,000 descriptions were analysed to determine 65 constructs spanning 17 categories. The frequency analysis assisted in determining the constructs linked with high, moderate and low density. The constructs and categories included a range of descriptions: the physical characteristics of the built form, the spatial characteristics of the urban environment, the number of people and vehicles, and the emotional response.

The SJT asked the respondents to evaluate the urban environments represented in the images and assign a positive, negative or neutral value, followed by a justification for the evaluation in the form of a multiple-choice question where the choices represent the key constructs of the first survey. This helped validate that well-designed high-density urban surroundings can also be seen as positive, so eliminating misconceptions regarding the design of high-density urban environments.

Seventy per cent of the overall cited constructs were the spatial elements of urban form with the greatest visual impact represented by the images. To understand the breakdown of these key spatial elements and their role in the perception of density, a process of image analysis was undertaken using the online image segmentation software. This study assisted in assessing the relative magnitude and contribution of eight visual elements within the field of vision, measured in percentages. Cross-referencing this calculation against the results of the 2^{nd} part of the 1^{st} MST survey allowed the proportions of each spatial field most frequently associated with perceived high, moderate and low density to be established. This aided in the determination of visual thresholds for perceived high, moderate and low density using the threshold analysis.

Judging any urban environment is a perceptual, cognitive and evaluative process that primarily employs Gestalt psychology principles such as similarity, symmetry, continuity and contrast to infer value. Consequently, the images were also analysed using Gestalt principles (see Chapter 6), which aided in the development of an index for visual assessment of density perception. This index can help design experts assess the visual composition of the urban environment and derive design interventions to instil a positive perception.

4.2.7 Conclusions

This study concludes by identifying several outcomes. The outcomes corresponding to the surveys are listed below:

MST:

1. A comprehensive list of 65 constructs (factors and variables) in 17 categories that influence the perception of density and may be tested in any context is generated.
2. A list of 20 critical constructs derived from the frequency analysis of the 65 constructs that influence the perception of high, moderate and low density in Glasgow and the universal illustrations are derived.
3. Using Spearman correlation analysis, these 20 critical constructs are further screened to find urban form elements that influence each other and can be managed, altered or manipulated to yield favourable perceptions of low, moderate and high density.

SJT:

1. A set of constructs associated with the positive or negative evaluation of the urban environments represented by the images.

Image segmentation analysis:

1. Using image segmentation analysis and magnitude estimation, the lower and upper limits for eight visual components in high, moderate and low urban density areas are determined. These constructs can facilitate the categorisation of any image representing an urban environment that has been segmented into high, moderate or low perceived density.
2. Based on the segmentation results, visual thresholds are independently generated for each of the eight visual components for high, moderate and low density.
3. A visual index is produced to assist design professionals in evaluating urban

surroundings and predicting how users would perceive them using Gestalt psychology principles.

4. Suggestions are made for design considerations that can be considered during the planning phase to ensure a favourable perception with optimal density.

Whilst the process of image segmentation in this study was done manually, recent advances through AI could automatise this step, thus allowing quick measurement of the effect of individual visual fields on the perception of the density of selected contexts for targeted and efficient intervention.

4.3 Ethical Considerations

The university's ethical approval process was followed and obtained before conducting the surveys. It contained the survey design sample, the consent form and the participant information sheet.

The instructions given to the participant before commencing the survey included:

- **Informed consent**: Before agreeing to participate, participants were fully informed about the purpose of the survey and how their responses will be gathered and analysed. They were permitted to withdraw their approval at any moment.
- **Anonymity and confidentiality**: Participants were informed that their responses and identities would be kept confidential. This was accomplished using anonymous questionnaires.
- **Respect for participants**: The survey designs used neutral language and respected the preferences of respondents. No physical or emotional harm was inflicted on participants as a result of their participation in the survey.
- **Data Security**: The unprocessed and processed data were stored securely, with no unauthorised access provided.
- **Privacy**: The anonymity of the analysed data was ensured and the participants' privacy was preserved. There was no sharing of the information.

Ethical consideration for data analysis:

- **Bias**: The study's findings are presented accurately, and the study's limitations were noted to prevent researcher bias from influencing the survey results.
- **Fairness and Equity**: The survey was done fairly and equitably before it was distributed online.
- **Reporting of results**: The summary of the survey's results is documented in a manner that is accessible to the general audience.

4.4 Framework for Mapping Human Perception

It is extremely difficult to methodically map the contents of one's perception as, due to the subjective characteristics of experience, there is no single or optimal strategy for deciphering its nature (Démuth, 2012; Stufflebeam, 2003; Whyte, 1985). But, given that every approach has limitations, it is possible to construct a trustworthy system or framework for mapping human perception by using the knowledge gained from the limitations of a range of approaches.

This framework includes decisions regarding the choice of visual survey method, and field settings in mixed-use, commercial and residential areas, site selection, type of environmental and whether the study is location-specific or consists of random case examples. All of these clarifications aid in establishing a framework for doing field research on the perception of density.

4.4.1 Survey Method – Non-Participatory Visual Method

The use of non-participatory visual methods generally involves the use of photography, video or photo surveys to portray scenarios around which to elicit responses. This study uses photography to capture, characterise and represent urban settings with varying densities for comparison.

The use of visual research methods in the majority of perception studies suggests that they can overcome some of the most frequent hurdles with verbal engagement (Whyte, 1985; Pollak, 2017) and in establishing a rapport between the researcher and participant not based on discussion but still facilitating the extraction of more qualitative descriptions (Meo, 2010, cited in Pollak, 2017). The use of images also produces more thorough and extensive responses than traditional interviews

(Whyte, 1985). These techniques help the researcher to establish the physical characteristics (scale, size and layout) of the settings and characterise the artefacts within. The adaptable and reactive nature of these methodologies makes it possible to describe social phenomena that are difficult to determine using quantitative methods (Pollak, 2017). Visual methods can also pique people's curiosity and arouse their interest more than verbal or written methods (Wang et al.,1996, cited in Pollak, 2017).

4.4.2 Identifying the Setting for Research

The physical environment at all scales (city, town, neighbourhood, street) is capable of eliciting significant emotional responses, such as the aesthetic experience (Nasar, 1989), sense of identity and attachment and influence human behaviour (Gifford, Steg and Reser, 2011). Since streets are the most frequently used public spaces (Nasar, 1989; Gehl, Kaefer Johansen and Solvekg, 2016), they are ideal settings in which to study the public perception of the character and quality of surrounding environments (Nasar,1979, cited in Nasar, 1989).

Investigations at the street scale can yield three types of information important for determining the perception of density. One is the public opinion or global perception of the quality (positive or negative) of the urban environment and the other is the knowledge of the spatial attributes that contribute to community acceptance of the location which is best defined by the pedestrian experience (Nasar, 1989). Third is the variation in responses based on physical surroundings, particularly the architectural form, which varies with every 100 metres or block length.

Streets are the primary pedestrian circulation routes but they also determine legibility and give non-verbal clues for orientation and navigation (Lynch, 1960, cited in Nasar, 1989). Aesthetic quality, which has been established as the primary predictor of people's perceptions, may also be analysed at the street level (Carp, Zawadski and Shokrkon, 1976). It also aids in triggering emotional responses associated with the attractiveness of urban surroundings, which influences human perception (Nasar, 1989).

Streets are where users have contact with buildings by necessity and most frequently (Gehl, Kaefer Johansen and Solvekg, 2016); hence, they are ideal settings for documenting density perception. Investigations at the street scale can also yield information useful to the study of how density is perceived. Streets provide an ideal setting to assess the visual composition of the urban environment, presented as a perceptual armature or street perspective delineating the reference frame for the photographic simulation.

4.4.3 Method for Selection of Streets

This study tests the hypothesis that the perception of density is influenced by the land use that informs the building typology, the objective density and the resultant urban form. To test this hypothesis, it is necessary to select streets that represent variable density and so four criteria for street selection were used. The street choice had to present: 1. varying building densities; 2. varying building typology; 3. varying street use and activity levels; and 4. varying street widths.

The selection of streets that match the established criteria could have been performed manually or using Geographical Information systems (GIS) applications for fabric assessment. The manual process is relatively straightforward and might entail: 1. Examining the urban fabric using Google Earth imagery; 2. Superimposing the land use map over the Google Earth imagery to identify the mixed-used precincts; 3. Overlaying the two maps with population density to identify precincts with varying densities; 4. Narrowing down to the streets with mixed-use urban forms and varying residential density.

GIS applications for fabric assessment could improve manual selection by providing areas based on quantitative data from which to extract comparable locations. Three applications analysing density and urban form were therefore reviewed to determine the most effective site selection strategies.

A multiple fabric assessment (MFA) (Araldi et al., 2018) integrates the pedestrian perspective into urban fabric studies using geoprocessing techniques. It emphasises the idea that urban areas are perceivable by pedestrians and can aid in the design of aesthetically pleasing urban forms. This method recognises a proximity band or street segment (Araldi et al., 2018) as a spatial unit to measure the human visual

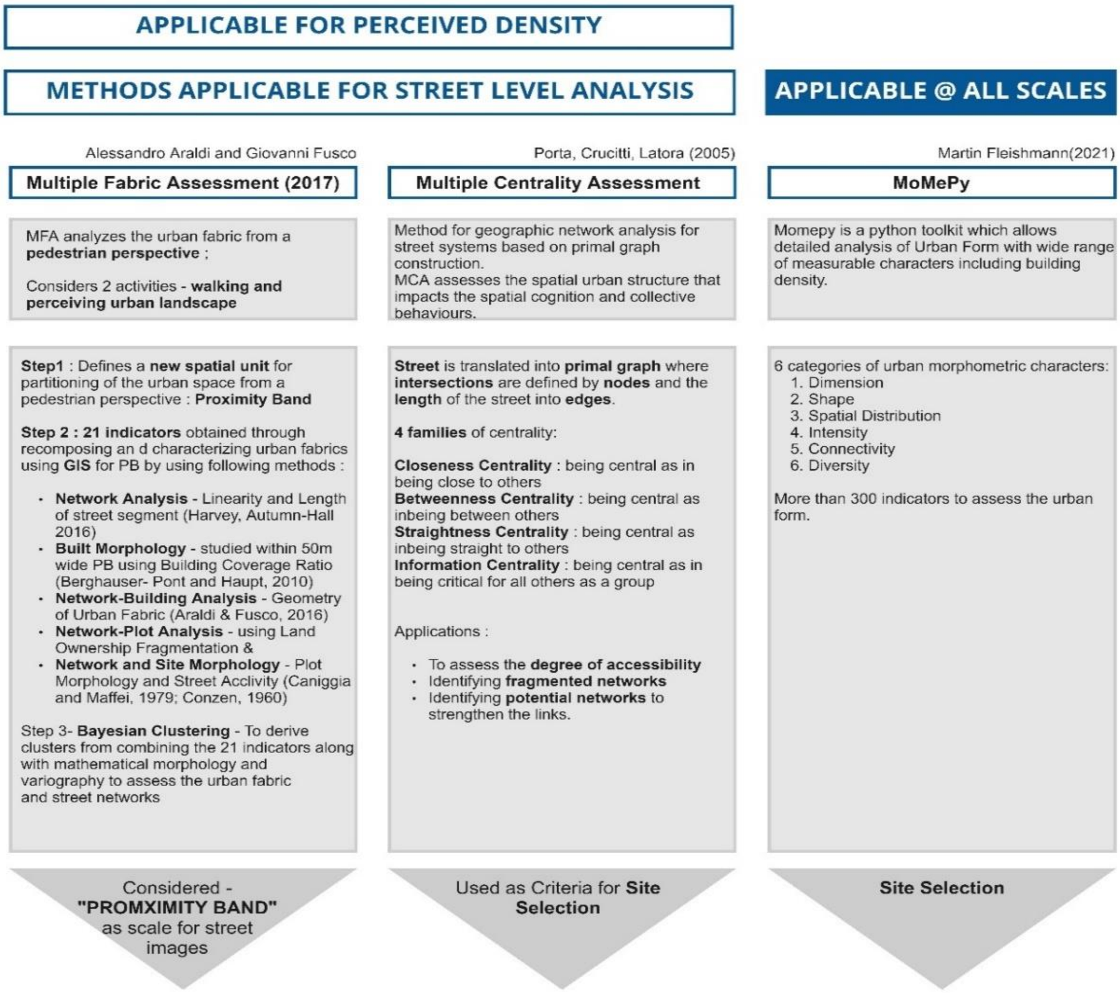


Figure 4-1. Review of methods for Street Selection

field. This approach guides the definition of the perceptual armature and has been established as a spatial unit that specifies the human frame of view in elevation in this study. Multiple centrality assessment (MCA) (Porta et al., 2013) helps detect street patterns based on the co-relationship between street centrality and intensity of economic activity, which is crucial to this study on the perception of density. Urban morphometrics is an emerging, unsupervised and systematic approach to the study and classification of urban form with an unprecedented precision of detail and extent of coverage measures (Fleischmann, 2019).

This study selected two approaches to street selection to eliminate researcher bias, MCA (Porta et al., 2013) and Urban Morphometrics (UMM+MoMePy) (Fleischmann, 2021). MCA assisted in identifying mixed-use transactional streets (Lovene, Smith and Seresinhe, 2019) where diverse activities were concentrated. By measuring around 250 spatial characters of urban form, it allows for the selection of street fronts of identical or very similar built density and within areas of similar activity but with a range of urban forms composing the street edges. UMM uses measures of centrality for its computations. The study of UMM is operationalised through MoMePy, the Urban Morphology Toolkit.

Whilst the combination of MCA and UMM+MoMePY allowed the selection of an objectively good range of comparable streets, a final visual inspection was conducted to ensure a significant range in diversity. This was conducted in Glasgow since the GIS data was available.

Overall, the process of site selection for Glasgow using quantitative approaches involved (Figure 4-5): 1. identification of diverse streets with similar levels of centrality using MCA (Figure 4-2); 2. identification of streets with similar building densities using the toolkit of MoMePy and GIS (Figure 4-3); 3. superimposing the data on land use to identify areas with heterogenous use and different building typologies; and 4. A field survey to confirm the streets met the criteria (Figure 4-4).

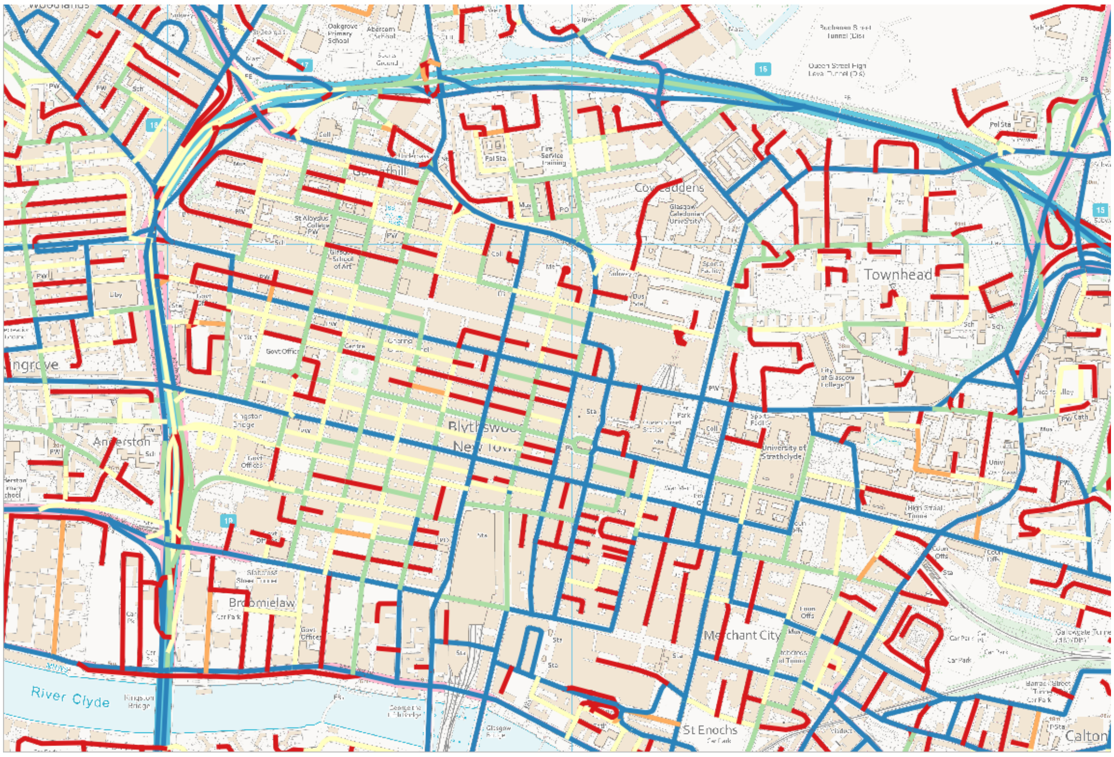


Figure 4-2. Straightness Centrality- Glasgow
Underlying map data "© Crown copyright and database rights 2023 Ordnance Survey (AC0000851941)

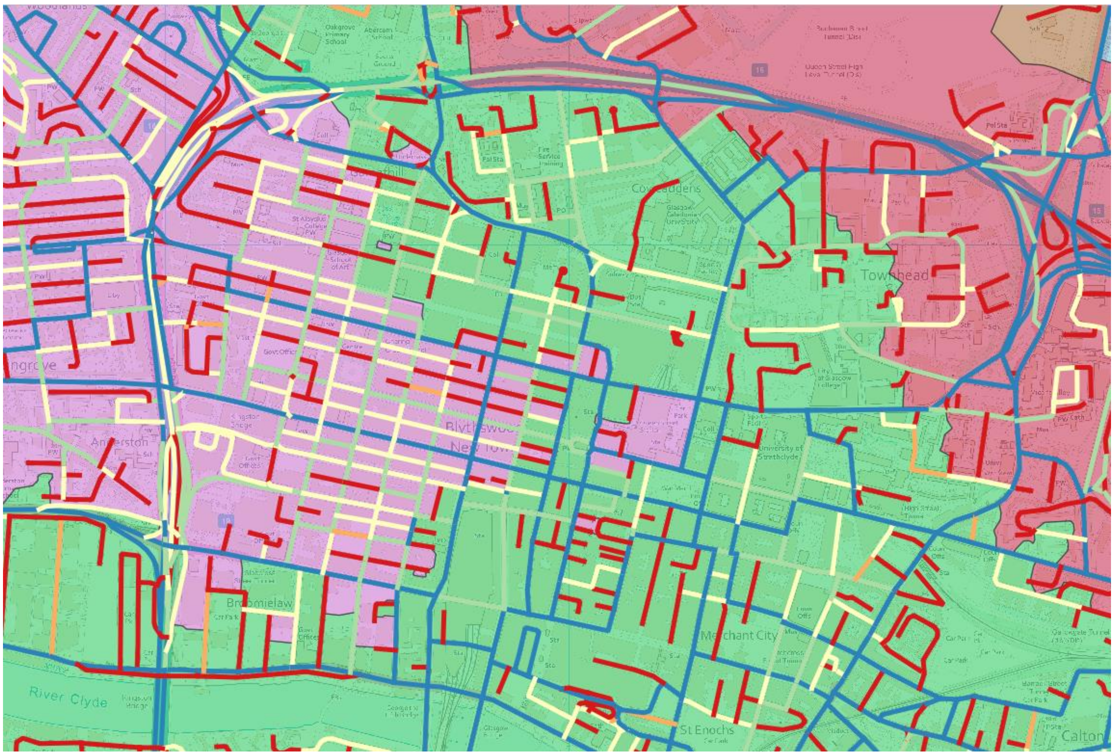


Figure 4-3. Urban Form Types
Underlying map data "© Crown copyright and database rights 2023 Ordnance Survey (AC0000851941)

It was not possible to repeat the exercise for selecting cases of varying density around the world (the universal illustrations) due to the limited availability of GIS data. Hence the case for universal illustrations was selected with the help of objective data gathered on density by the Atlas of Urban Expansion (Angel et al., 2016).

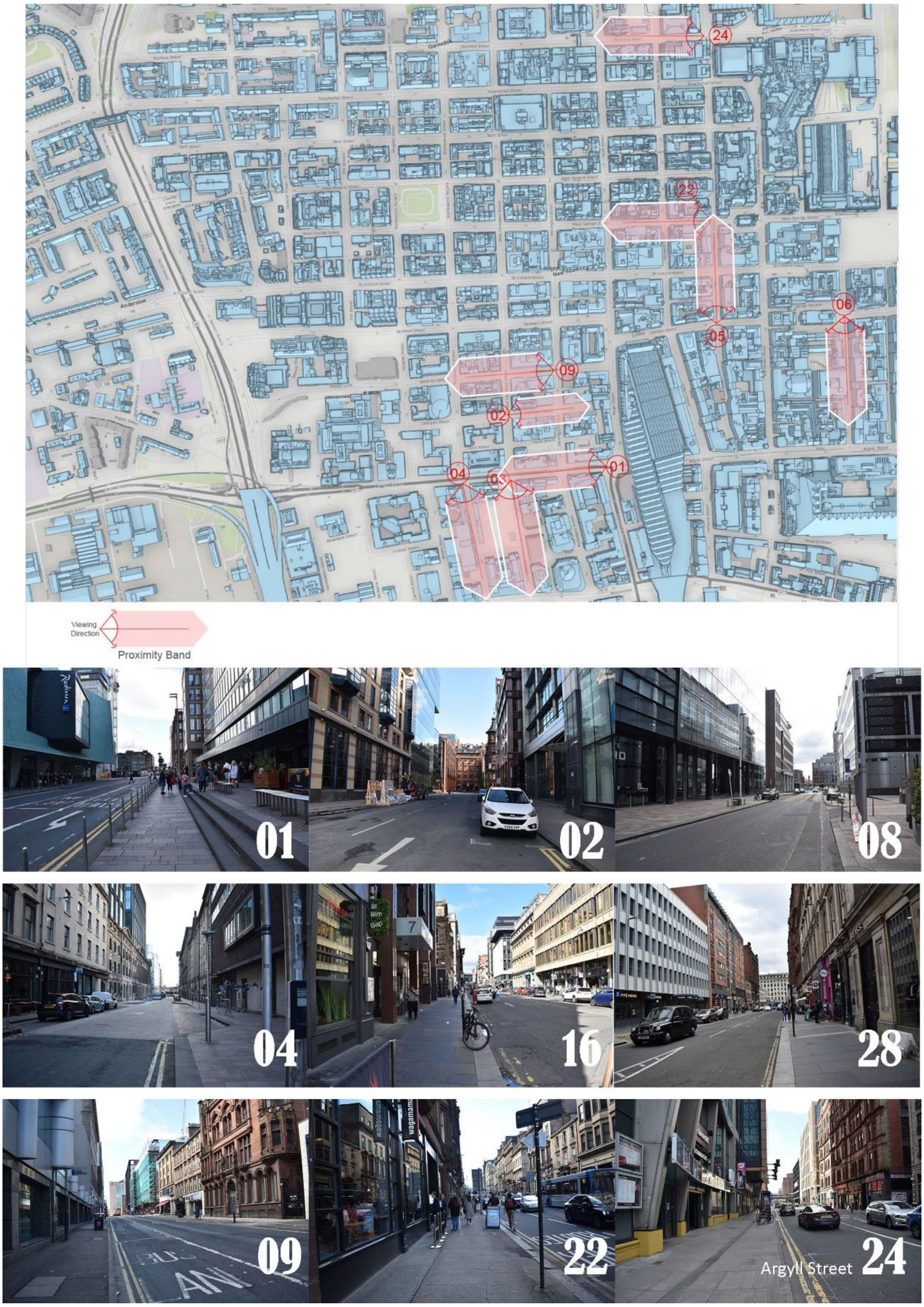


Figure 4-4. Street selection
(Map data from *Glasgow Open Data: Glasgow Urban Model*, reused under the Open Government Licence)

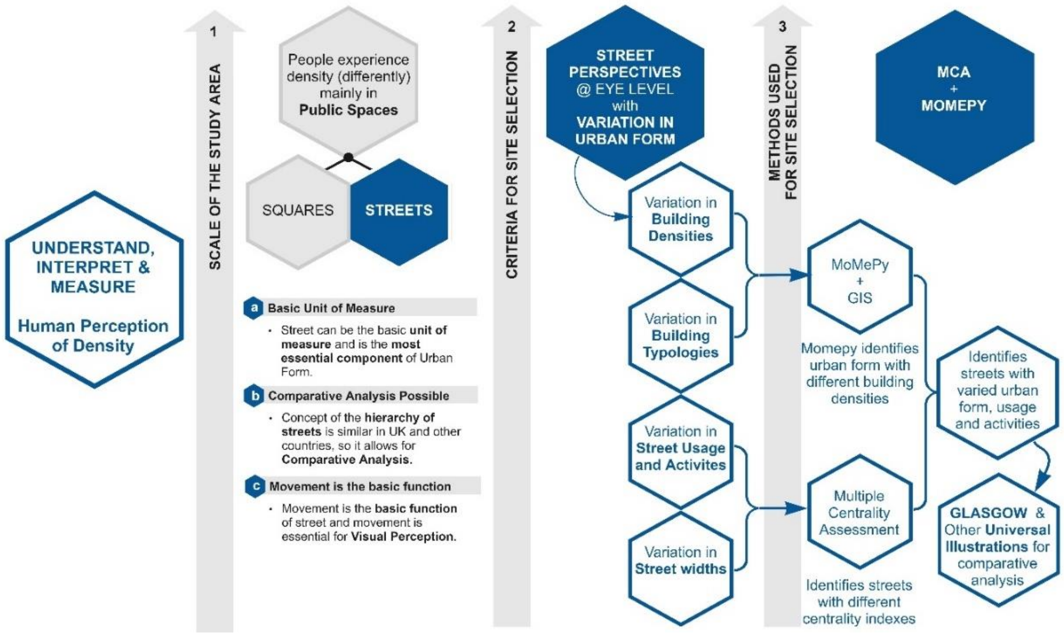


Figure 4-5. Objective method of site selection

4.4.4 Choice of Environmental Simulation

The functional importance of visual imagery is expanding in cognitive science (Roldan, 2017), particularly in gaining a deeper knowledge of object features connected to perception. The urban environment can be portrayed as sketches or three-dimensional models, all of which have been used in previous density studies. In comparison to real-time photographs, however, they have distinct limitations. The sketches and three-dimensional models lack visual indicators of the object and lack the stimuli that impart reality to the objects. In a study of environmental perception, photographs are generally considered superior to abstract or even realistic man-made representations (Ward and Russell, 1981). The visual signals and stimuli that trigger the recall and recognition function of the human memory allowing one to link to prior experiences are more effectively elicited by colour images (Snow et al., 2014). Therefore, this study uses colour images as photographic simulations to engage respondents which have proven to be a viable alternative (Ward and Russell, 1981). Secondly, there is little evidence that real environments affect cognition differently than colour images (Snow et al., 2014). Therefore, this study depends on the visual analysis of images to forecast the density of the built environment. The activity will centre on recognising the content of the coloured photographs to record the user's description and judgement of the surrounding environment and will not entail sensory stimulation.

4.4.5 Place-Based Study Versus Generic Case Examples

The human perception of density varies from place to place (Rapoport, 1975; Nasar, 1989). This suggests that the relative character of density can be best understood by comparing similar situations and to measure the level of perceived satisfaction or density, location-based investigations are favoured over general case examples. Public opinion is also influenced by the length of time spent in a built environment, so the view of a resident may differ from that of a visitor. A resident also develops a sense of belonging to the location, which can also elicit emotional responses and alter the human perception of density distinct from those of visitors.

For this reason, part of the first survey used streets in Glasgow, the city where 50 % of respondents lived. The aim was to elicit the factors that respondents use to 'read' density and the values they associate with them. It was expected that familiarity with the environment would play a part. It was also expected that the same characters could be used to 'read' density in less familiar or unfamiliar environments, but the values might change because of this lack of familiarity. Hence the second part of the survey used streets from a range of environments around the world.

Google Street View was used to select generic examples. Unlike real photographs, however, Google Street View has certain limits. Figure 2-3 shows the height and position differences between real pictures and Google Street View images. Google collects street views at a distance of 2.5 metres from the centre of the street, but the average height of a person is 1.5 metres. Thus, the viewing angles are different; hence, perceptions may vary. This is a systematic error and we can use it to explore the variation in human perception based on viewing angles and to determine any distinctions between the components of perceived density.

Figure 4-2. Images captured from the sidewalks: from left a- Left Sidewalk; b – Google Street View (©2023 Google); c- Right sidewalk

The city can be observed from a variety of street level vantage points and while walking at about 5 kilometres per hour, one can examine the buildings and appreciate the nuances and proximity of the ground level activity (Gehl, Kaefer Johansen and Solvekg, 2016). Earlier studies assumed the middle of the street to be a photographic reference point but for this study, photographs were collected from the pavements for location-specific examples, and Google Street View for universal examples.

4.5 Comprehensive Framework for Studying the Perception of Density

To use a combination of the investigation methods described whilst overcoming their limitations and producing reliable and applicable results, certain criteria were adopted:

1. Selection of environmental simulation (Photos, sketches) that represents the pedestrian point of view.
2. Sites and streets with diverse settings in terms of use, typology, density and activities (streets can represent residential, commercial or mixed land use).
3. Comparable cases with similar objective density but different uses and built forms.
4. Research methods and techniques extract the complexity of factors that encapsulate the perception of density and eliminate preconceived bias. (MST and Situation Judgement tasks are used in this case. There could be other methods).
5. A large number of case studies (27-Glasgow -GLA) +27-Universal Illustrations-UL) were used for this study) and greater responses (around 250 received for this study) to allow for the generalisation of results in different contexts.

The proposed framework involved the following eight conditions drawn from the critical analysis of previous studies.

1. **Scale**. The city is best experienced on foot at a speed of 5 kilometres per hour, which not only allows users to admire the architecture but also elicits sensory experiences (Nasar, 1989; Gehl, Kaefer Johansen and Solvekg, 2016). Therefore, factors affecting the perception of density and the resulting

emotional response must be documented at a pedestrian scale.

2. **Settings**. The chosen streets must depict a variety of uses, whether homogeneous (residential or commercial) or heterogeneous (mixed-use), with perceptual, symbolic and temporal clues (see Chapter 4). The context for this study was Glasgow and the settings are mixed-use streets; and a range of international contexts each represented by mixed-use streets.
3. **Method for street selection**. The streets must be selected for maximum comparability using a method to identify built forms with similar objective density along the street, urban centrality position within the street network of the city and similar uses but distinct urban forms. GIS, Google Earth and field observations can meet the requirements. For this study, multiple centrality assessments (Porta et al., 2013) and urban morphometrics (Fleischmann, 2021) were used as GIS applications to select the streets.
4. **Photographic simulation selection**. A photographic simulation that represents the real-life scenario must be considered for the studies. Coloured photographs of the streets could be one of the alternatives to represent a real-life scenario, which also eliminates the factor of mobility (moving people and vehicles). These images, however, must be street perspectives captured from either of the pavements, which are the actual corridors of pedestrian movement and not from the centre unless it is a pedestrian street. Around 45 streets in Glasgow were selected for the study.
5. **Count of case examples**. For optimal findings, perception experiments employing photographic simulation must generally include at least 15 to 25 images (Canter and Groat, 1985a; Chollet, Valentin and Abdi, 2014). This study employed two sets (Glasgow and universal illustrations) of 27 coloured street perspectives and triads (multiples of 3 images) can be formed to sort the images based on their content similarity.
6. **Sample size**. Perception is unique; hence, reactions will differ. The inconsistency can be addressed, however, if the sample size is sufficient, at least 25 and up to 50 or more (Groat,1982), to permit the standardisation of the data. Depending on the objective of the study, random or stratified sampling with various target groups may be employed.

7. **Survey type**. The visual survey must be complemented by open-ended questions so that respondents can freely express their experiences. It could be a single survey or a collection of surveys to accomplish multiple objectives. Two small, interactive surveys based on the multiple sorting process and the SJT were constructed for this study.
8. **Participant type**. As the surveys can also be used to identify not just individual conceptual systems but also the difference in opinion between laypeople and experts, participants in this study were selected to be from 18 to over 65 and include laypeople, architectural students and design and planning professionals.

4.6 Data Collection Methods

Two methods, MST and SJT, were chosen to conduct two surveys based on a review of methods used in psychophysics, personal construct theory and environmental perception, theories on visual perception and the advantages of visual research methods. The principles and procedures of the approaches are detailed in this section. Chapter 5 discusses the detailed processes with step-by-step directions and the results.

4.6.1 Multiple Sorting Task (MST)

MST (Canter and Groat, 1985b), as adapted for density research, provides a robust tool for examining individual preferences toward particular built environments. This strategy results in the establishment of 'distinct categories of sets of components based on the evaluation of their relative similarities' (Groat, 1982, pg.8) and the ability to provide sorting criteria and create several categories (Barnett, 1996) makes this method more flexible. Previous research in environmental psychology has demonstrated that MST can be used to investigate conceptual frameworks and compare the perceptions of laypeople and professionals (Barnett, 1996).

It is a type of card sorting in which participants are required to sort items (text or images) into distinct groups based on the content similarity of the cards. There are various strategies for sorting. The first is known as the free sort or the open card sort in which users create their own categories and sort cards based on content similarity

(Barnett, 1996). The researcher then records the sorted categories and performs the task again. The process goes on until there are no new ways to sort the items. The second type is the structured sort in which the researcher predefines the categories. This can be used to validate the researcher's predefined categories by the participants. Typically, this task is executed as a live workshop in which all participants sort the items simultaneously.

4.6.1.1 Using MST for the Study on Perception of Density

The research was conducted during COVID-19 circumstances and so developed as an online application that individuals may complete at their convenience. This online application also enables the collection of a greater number of responses than would be possible in a workshop.

The purpose of this task was to investigate the set of features of the built environment that individuals use to organise and establish categories by sorting photos of diverse urban environments with variable densities and to discover the factors that influence the human perception of density. It was intended to produce the following results:

1. Identify the distinctive themes or concepts of the built environment that respondents use to group and by extrapolation describe the images representing streets of variable density.
2. Classify images of streets characterised by low, moderate and high density and their justification for this classification.

The task's objective was to record the complex correlation between perception and density and so the design must adhere to the multiple sorting concept, but the technique was tailored to create a hybrid sorting type. This provided participants with a structure for creating groups and categories and validated their agreement with the categories produced by the researcher. This hybrid sorting allowed users to sort, create and label categories, name the photos and classify the images.

4.6.2 SJTs

Whilst MST allowed the examination of density and perception of density separately, it did not provide the participants' qualitative evaluations of the streets. SJT was used to investigate participants' thoughts and opinions regarding the urban environment and to determine if the urban environment meets their expectations. It uses an individual's answers presented as a set of statements to hypothetical or actual scenarios presented as a statement or question (Patterson, Zibarras and Ashworth, 2016). SJTs are built on the premise of presenting various scenarios with a variety of responses and asking the respondent to score the effectiveness of each response. SJTs are a robust tool that can be used to investigate cognitive bias in individuals due to their capacity to incorporate a variety of items in a variety of formats, along with varied answer and scoring possibilities.

A typical SJT requires the creation and presentation of a plausible, task-relevant scenario. The scenario contains a description of the event and several potential responses. Participants are required to rank or make an order based on the most appropriate and effective reaction based on the scenario presented. SJTs are usually administered using a computer-based platform. Following completion of the SJT, the responses are assessed using a predetermined scoring key. This key finds the best suitable response and assigns points to each choice depending on its level of appropriateness. The third phase is analysing the results. This entails analysing each participant's scores to establish their level of decision-making skill.

4.6.2.1 Using SJT for the Study of the Perception of Density

The SJT for this study differs from that often employed in mainstream fields. The aim is to record the qualitative value that the participant associates with each image and so images of diverse urban landscapes with differing population densities replace descriptive situations or hypothetical scenarios. This task seeks to record 3 outcomes: 1. the emotional response associated with the urban environment; 2. the justification for this response; and 3. the duration they would like to spend in the presented urban environments.

To achieve these outcomes the participants were presented with the images in conjunction with the emotional responses representing binary constructs such as comfortable/overwhelming, cheerful/depressing and vibrant/dull. Later they were presented with multiple choice options which represented the reasons or justification for their emotional response. These justifications were deduced from the top 20 critical constructs associated with high, moderate and low density derived in the MST. Finally, they were asked to state the duration they would like to spend there. This was repeated 16 times for 16 images. This task was built with the survey platform Qualtrics and was mobile-friendly.

4.7 Advantages of the Selected Research Methods

MST and SJT both use the personal construct theory framework that emphasises the importance of individual differences and how participants construe or perceive their experiences (Kelly and Kelly, 2017). Eliciting personal constructs involves identifying how the individual organises and interprets the real world.

MST was preferred over interview or participant observation techniques due to some characteristics that assist in understanding unbiased user preferences:

1. **Multiple dimensions**. MST involves categorising the content based on multiple dimensions or criteria which could be flexible and not predetermined (Barnett, 2008; Canter et al., 1985). For instance, while creating the triads for the urban environment, it was possible to categorise them by the attribute that was common and in the next step participants could sort the same images into categories such as high, moderate or low density. This helped in extracting two sets of information, one that is personal to the participants and the other that addresses the survey's objective.
2. **Subjectivity**. MSTs are subjective in the sense that participants may categorise the same items differently based on their own perspectives and experiences (Canter et al., 1985; Chollet et al., 2014). For instance, the images of the urban environment represent several symbolic cues such as building typologies, trees and cars. Some participants might identify the common element as tall buildings, some might say the presence of trees or some might comment on the overall experience of the urban environs. It represents their perspective and how they make sense of it. This assisted in understanding how they saw urban environments.

3. **Iterative process**. Typically, MSTs are iterative. They involve multiple rounds of sorting which allows the participants to revise and reorganise the categories. In this case, the task was conducted online but the process of sorting was repeated 3 times for 9 different images each time. This aided in extracting diverse categories and minimising the difference between them, which were processed later to identify 65 constructs grouped under 17 categories.

SJT was chosen because it involves the assessment of hypothetical situations such as urban environments represented by images to judge the most qualitative value associated with it. The key characteristics of SJTs include:

1. **Realistic scenarios**. SJTs typically represent realistic scenarios that are relevant to the research. The scenarios for this study were 16 images of urban environments that needed to be judged for having a positive, negative or neutral value.
2. **Multiple options**. SJTs normally provide the participants with multiple choice options, each of which represents a course of action. In this instance, the multiple choices act as justifications for the evaluations.
3. **Tailored to suit the research objective**. The main task was to judge the urban environment. This could have been done by simply asking the participants to judge it as positive, negative or neutral or keeping it open-ended. The former responses would not generate enough information to understand the logic behind the judgement and the latter would be open to interpretation. To improve the relevance and accuracy of the survey and eliminate the bias that could have arisen in interpretation, three binary constructs were used to represent six emotional responses such as comfortable or overwhelming, where comfortable represents the positive pole and overwhelming the negative. One could then record the justification for selecting either. This increased validity and reliability of the survey data.

These methods offer several advantages.

1. **Rich and detailed data**. These methods provide rich and detailed data about

how individuals receive and interpret their experiences. The interpretation of this data can assist in giving insights into beliefs, values and cognitive processes.

2. **Flexibility**. Both these methods are flexible and can be adapted to fit a wide range of questions and situations. For instance, open-ended questions in the MST assisted in gathering data on experiences, while the use of binary constructs in SJT assisted in evaluating the urban environs.
3. **Complementarity with other methods**. Personal construct methods can be used in conjunction with other quantitative or qualitative methods such as surveys or interviews. In this case, however, different types of questions were used to make the task more engaging and to extract effective data.

It was also possible to construct visual open-ended surveys that record succinct responses without requiring respondents to select between binary options, removing the apprehension of making absolute judgements over relative ones.

4.8 Data Analysis

These survey results can be grouped into two categories: textual descriptions and visual appraisal of images. The first cluster consists of the descriptions associated with the images gathered from the MST and for the evaluation of the photographs gleaned from the situation judgement task. These descriptions facilitate an understanding of how individuals perceive urban environments. The MST generates a set of nouns and adjectives that characterise the physical properties of the created form, their composition or the emotional response linked to it. This description requires interpretation to establish the characteristics or variables that affect the perception of density. Thus, content analysis, the most popular method for qualitative analysis, was used. This helped in identifying the themes and categories reflecting those components of the urban environment mostly associated with the participant's perception of density. To identify the important constructs, it was also necessary to estimate the frequency of these descriptions. To identify the most influential with regards to human perception.

Images are crucial to this study and the effect of images on the human perception of density in visual perception cannot be disregarded. Image analysis identifies the frequency of constructs identified in the two surveys and the patterns used by the participants. This can reveal vital information about the visual composition of urban environments and so aid in planning, design and decision-making. All the images in the study were manually analysed using image segmentation to identify eight components of the urban environment that can have a visual impact on human perception. Using magnitude estimation, the segmented images were further analysed to identify the contribution of each of the visual components in high, moderate and low-density urban situations.

4.8.1 Content Analysis

Content analysis is a method of conducting research that involves analysing and interpreting textual or visual data to uncover patterns and themes (Hsieh and Shannon, 2005; Zhang and Wildemuth, 2009; Kleinheksel *et al.*, 2020). The process entails methodically categorising and coding the data according to pre-set categories or topics and then analysing the data to reveal trends, patterns and insights.

Typically, it begins with the selection of a data sample for analysis. This entails selecting a random sample of texts or media content or choosing specific descriptions resulting from the surveys. The next step is to create a coding scheme that will be used to classify the data. This may involve the development of a group of themes or concepts that represent the most important ideas or topics in the data. Once the coding scheme has been developed, the data is systematically coded and evaluated, either manually or through the use of software designed for this purpose. The results of the analysis are then interpreted to generate conclusions and inferences regarding the examined content.

The ability to evaluate vast amounts of data systematically and thoroughly is one of the advantages of content analysis. It also enables researchers to recognise patterns and themes that may not be immediately evident and to draw conclusions based on the data as opposed to subjective interpretations or judgements.

4.8.2 Frequency Analysis

Frequency analysis facilitates the identification of the most influential variables and factors linked with the perception of urban environment and density. It is a method of identifying the most frequent words and phrases in a big corpus of textual data (Randall, 1987; Hulshof, 2005).

In the first step of frequency analysis, all textual descriptions are compiled into a single document or dataset. This stage requires extracting the descriptions from a database or other source or copying and pasting them manually into a single file. After the data has been compiled, there may be a requirement to clean and pre-process the text to eliminate any undesired characters such as punctuation or special letters. The next step is to tokenise the text into individual words or phrases, which entails deleting any meaningless terms. Once the text has been tokenised, a word frequency distribution can be generated to determine the most frequently occurring words and phrases. After generating the frequency distribution, the findings can be analysed to determine the most frequent words or phrases. This can be accomplished by analysing the ten or twenty most frequent words or by constructing word clouds or other visual representations of the data. Which leads to insight into the predominant themes and issues.

4.8.3 Image Segmentation

Image segmentation is a technique for analysing images by splitting them into regions or segments (Ryan, 1985; Debals and Brabandere, 2020). This can assist in identifying and isolating items, structures or areas of interest within a picture, which can then be further studied. Medical imaging, computer vision, remote sensing and robotics are a few of the uses for image segmentation. By segmenting an image, it is possible to extract characteristics such as object boundaries, texture, colour and shape. This data can be used for a variety of image analysis tasks, including object detection, categorisation, tracking and recognition. It is possible to segment an image using both supervised and unsupervised algorithms(Ryan, 1985). Supervised approaches require labelled data in which each pixel or image region is assigned a label or classification. Unsupervised algorithms do not require labelled data and instead categorise pixels or regions based on their similarity.

It is commonly employed in the perception of urban surroundings such as road and lane markers, buildings, pedestrians and vehicles and even urban vegetation and Emo (2017) has used it in determining urban density.

4.8.3.1 Magnitude Estimation

Magnitude estimation can be used to quantify the size, shape and intensity of segmented sections (Howard R. Moskowitz, 1978; Marks, 1988). For this study, magnitude estimation helped determine the contribution of the urban environment's visual components. Methods for estimating the magnitude of segmented images include pixel counting, intensity analysis, texture analysis and form analysis. The pixel counting approach estimates the size and shape of each segmented section by counting the number of pixels within it. The total number of pixels within the image can also be determined to serve as a comparison point.

4.9 Presentation of Findings

The findings of the MST are presented independently for the Glasgow and universal illustration sets. The content analysis procedure and the generation of the coding manual were tabulated to enable comparisons between variables and facilitate the identification of patterns associated with high, moderate and low density. This also facilitates future replication of the investigations and validation of the results by other researchers. These results are shown in Chapter 5.

Chapter 6 discusses image analysis. Using image segmentation and Gestalt principles, the images were evaluated and colour-coded, making it simple to distinguish between image components or regions. This is useful when monitoring the contribution of various image components.

Chapter 5. The Surveys

This chapter presents the process and results of the two surveys (see Section 4.6). It begins with a brief description of the characteristics of the two survey methods and their advantages concerning survey design, result consistency and useability in conjunction with other methods.

Both surveys were based on the personal construct theory, each was tailored to achieve to achieve: 1. MST-Identify the factors influencing the perceived density (research objective 1) and 2. SJT-evaluating the perceived quality (positive/negative) of the urban environment. Hence the process of survey design is explained independently. The survey design process typically involves designing the survey structure pre-survey data collection, a pilot survey and finalising the design for the survey. Both were conducted online to allow people to take the survey at their own convenience and gather a greater number of responses. These surveys were conducted during the COVID-19 pandemic therefore in-person discussion or workshops was not possible.

The results were analysed using descriptive statistical methods. The text descriptions of the first survey were analysed using content analysis and generated 65 constructs that influenced the perception of density. The frequency count of these constructs was analysed separately for Glasgow and universal illustrations which helped identify the most influential constructs for high, moderate and low density. The frequency counts for both steps were compared to derive the most critical constructs which were then selected for the second survey, the SJTs.

5.1 Survey 1 – MST

An MST can be carried out using a variety of applications such as Q-Sort, Optimal Sort and Qualtrics. The custom version used here was based on the belief that the groups created by the people by visualising the images represent the elements of the urban environment that have a greater visual impact. It was an interactive image-sorting task and the considerations for designing this as an online web application are described below. The images are alternatively referred to as cards throughout the chapter.

5.1.1 Survey Design

This survey is designed as an online task, easy to understand, supported by images, and could be taken by anyone from the age of 18 and above. Measuring human perception using visual research methods could be complex, hence the survey design divided the task into simple steps. As verbal description is the richest source of information, each survey at some stage recorded the user's description of their experience of the urban environments with the help of the images. The detailed survey design is attached in the appendix.

5.1.1.1 The Goal of the Survey

The goal of the first survey was to extract a list of all the factors of the built environment (building height, building size and street attributes), the variables (cars and people) and the emotional responses that people choose to describe their perception of urban environment and density.

5.1.1.2 Selecting Card Sorting Type

There are three types of card sorting. The first – open card sort – allows the participant to create their own categories and label them whereas in the second – the closed card sort – the categories are created by the researcher and the participant had to only sort them. The hybrid sort hand allows the participant to sort the cards into given categories and simultaneously create their own.

This study customised the hybrid card sort. The first step of the survey was an open card sort while in the second, the categories (low, moderate and high density) were given, and the participant has to sort them and label them individually.

5.1.1.3 Creating a Card Sort

While creating or designing a card sort one has to decide the number of cards (images) to be used and the scheme of grouping the cards. The number required to deliver consistent and reliable results varies between 15 and 25 cards (Canter D et al., 1985; Chollet et al., 2014). This study used a set of 27 cards of coloured street perspectives that capture the urban environment at a human eye level to form a field of vision. The concept of triads (groups of three) formed the premise for the finalisation of the number of cards used for the survey. A dyad, or set of two, is the smallest group and is easy to form. However, its reliability can be questioned. However, in a triad, the third element is the deciding factor that determines the cohesiveness or similarity of the group (Curtis et al., 2008).

Presenting the 27 cards to the respondent for sorting was a challenge. Considering the difference in understanding capabilities of respondents, the probability of the task being compromised was higher. The success of this task was based on the user involvement and attention span and the ability to recall and recognise to make conscious decisions. Hence the design of the task had to be creative and the presentation of the cards was one major component.

To simplify the task and to not make the sorting activity overwhelming, the number of cards presented at a time was limited to nine, thus making three panels in all (see Figure 5 -1). Each panel consisted of nine cards and was then sorted into three triads by the respondents. Triads are usually defined as a set of three persons, things or attributes. Since they involve an uneven number, they have been considered to be the perfect expressions of unity and proportion, corresponding to a threefold division in nature or, in this case, to the images of a nuclear family. Each panel consisted of 3 low, 3 moderate and 3 high-density images.

5.1.1.4 Identifying Card Content

The intention was to discover how people make sense of the information in the images. Hence the images should be conceptually similar. Images can be as effective as text for representing concepts, but the language of the images needs to be the same.

The cards represented low, moderate and high-density urban environments. The

Figure 5-1. Abstract representation of Panel of 9 images and formation of Triad

images were conceptually similar in the sense that they were all street perspectives representing the human point of view and proxies for the real world which carried non-verbal environmental cues that facilitate the perception of the urban environment (Snow et al., 2014). Hence the images chosen were high-resolution and without text. The similar language implied the consistency of the presence of the urban form in all the images. Although the urban form varies for images that represent high, moderate and low density, it is constant and occupies a certain percentage within the field of human vision.

The first set of images from Glasgow represented high (160dph) (City et al., 2019; Glasgow City Council, n.d.), moderate (75dph) and low (50dph) – density mixed-use urban areas to understand the perception of relative density and wider context. Universal illustrations captured using Google Street imagery represented high (>200dph), moderate (100-200dph) and low (76dph) density mixed-use urban areas. The two sets of images were used for independent surveys to test two hypotheses:

1. The perception of density is relative and is interpreted differently in place-based studies as compared to specific universal illustrations. Consequently, this can test the difference in opinion of the residents versus that of the strangers.
2. The change in viewing angle as an outcome of self-captured images to that of the Google Street imagery does not impact the identification of factors that influence the human perception of density.

5.1.1.5 Sample Selection

The sample selection process employed in this study was designed to encompass a broad range of perspectives on density perception within urban environments. Here is an overview of the key aspects of the sample selection methodology:

Diverse Participant Pool: The study intentionally included participants from various backgrounds, ensuring diversity within the sample facilitating a multidisciplinary perspective. This encompassed architecture students, laypeople, and professionals, representing a spectrum of ages and backgrounds. Laypeople represented the general public, while architecture students and professionals brought specialized knowledge in urban design and planning to the study.

Convenience Sampling and Recruitment: The study utilized a convenience sampling technique, whereby participants were selected based on their accessibility and willingness to participate. Participants were recruited through a variety of channels, including social media platforms, email invitations, and educational institutions.

Sampling Across Urban Environments: Given the study's focus on urban density perception, the sample included participants from various urban settings. This could encompass residents of Glasgow, the chosen case study city, as well as individuals residing in other high-density cities worldwide. This approach aimed to capture variations in density perception across diverse urban contexts.

Demographic Diversity: Although not explicitly mentioned, efforts have been made to ensure demographic diversity within the sample. This involved collecting data on participants' age, gender, cultural backgrounds, and socioeconomic status to gain insights into how these demographic factors influence density perception. However, due to the scope of the thesis, the in-depth analysis of these demographic factors' impact on density perception was beyond its primary objectives.

Online Survey: The primary data collection method employed was an online survey. This approach enabled the study to gather a substantial number of responses from participants located across various geographic regions. The online survey format offered convenience and accessibility, allowing participants to engage with the study remotely.

By adopting this mixed-methods approach to sample selection, the study aimed to comprehensively explore and understand the nuances of density perception, considering the perspectives of both experts and the general public across various urban environments and demographic groups.

5.1.2 Survey Implementation

The multiple-sorting task was designed as an online web application to understand how participants grouped and categorized urban images based on their perceptions of density-related factors and emotional responses. The study consisted of three steps, each aimed at gathering insights into how participants organized and labelled the images. The following describes the steps:

Step 1 – Grouping Images

Participants were presented with 27 urban images, which were divided into 3 groups of nine images each. The participants were instructed to sort the images into three groups based on any similarities they perceived. This similarity may be attributable to particular urban elements, qualities, or characteristics that attracted their attention. For instance, if a participant felt that three images conveyed a sense of "crowding" due to a high building density, they would group those images in this step.

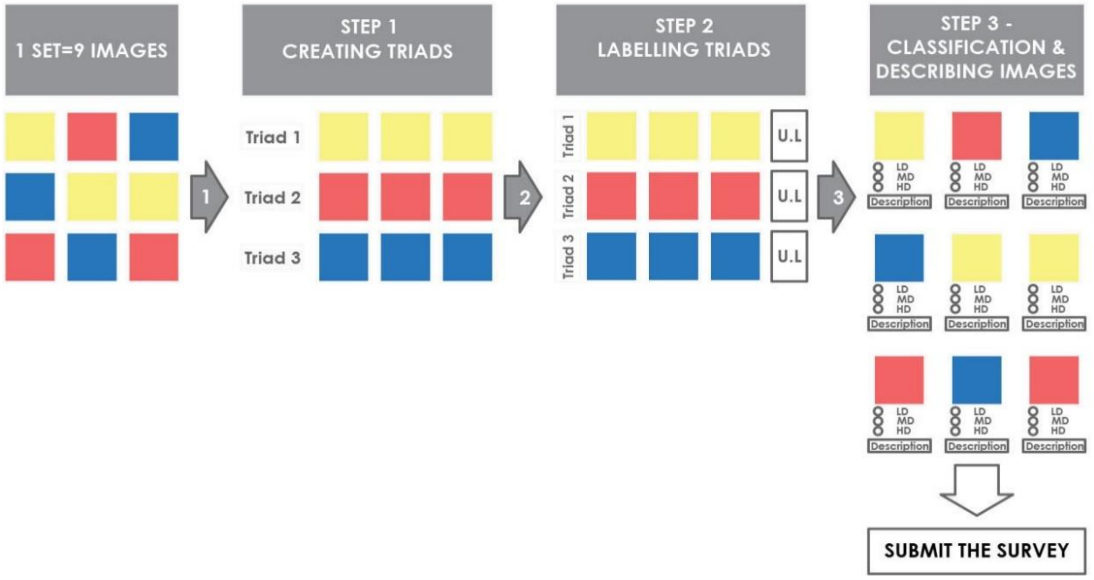


Figure 5-2. Abstract representation of the Survey conducted using Multiple Sorting Task

Step 2 – Labelling Triads

Participants proceeded to the second step after sorting the images into triads. In this step, they were required to assign unique labels to each of the nine triads they had previously created. These labels should reflect what participants identified as the visible element or trait shared by all three images in each triad. Additionally, the label could capture any associated emotional response or factor that influenced their classification. For example, if a participant grouped images based on a sense of "spaciousness" due to open areas and low building density, they would assign a label such as "Open and Airy" to that triad.

Step 3 – Image Classification and Justification

In the final step, participants were presented with individual images, one at a time, in either odd or even numbers, resulting in 13 or 14 images for classification. Participants were required to classify each image into one of the categories: low density, moderate density, or high density. Additionally, participants had to provide justifications for their classification decisions. These justifications should explain why they considered the image to represent a particular density level. For example, if they classified an image as "high density," their justification might mention features like tall buildings closely spaced together and a large number of people, contributing to a sense of crowdedness.

5.1.3 Mode of the Survey

The surveys based on MSTs are generally conducted in person or in workshops to allow the researcher to interact with the participants and understand their thought processes. However, this is time-consuming and the willingness of people to participate is highly questionable. This might also result in a low number of responses. Therefore, to avoid all the limitations, this survey was designed as an online web application. The rationale behind conducting the survey online and some of the considerations are described below:

Efficiency and Convenience: Conducting the survey online offered a more efficient and convenient way to gather responses from a broader and more diverse participant pool. Participants could take the survey at their own convenience without the need for in-person interactions or workshops.

Accessibility: This online survey was accessible to a wider audience, including those who may not be able to attend in-person sessions due to geographical constraints, time limitations, or other factors.

Response Quantity: Online surveys typically have the potential to collect a larger number of responses compared to in-person sessions. This enhanced the robustness of the data and provided more comprehensive insights.

Cost-Effective: Hosting an online survey was cost-effective compared to organizing in-person workshops or interviews, as it eliminated the need for physical space, printed materials, and travel expenses.

The participants were requested to complete the survey on laptops or desktops rather than mobile phones. This decision was a practical one that took into account potential issues related to legibility and the ability to view images simultaneously.

5.1.4 Choosing the Right Type of Question

A combination of open-ended and multiple-choice questions was used. Labelling questions in steps 2 and 3 were open-ended and the participant was asked to describe their experience of the built environment using a few set words. Step 3 also involved the classification of images into degree of density which were fixed, hence the multiple-choice questions (MCQs).

5.1.5 Formulating the Questions

The questions were clear and short. They are accompanied by instructions for each step and an explanation of how to handle the interface.

5.1.6 Introduction to the Survey

The introduction briefly describes the intent of the survey without divulging the details regarding density or what to expect from the survey. This was to ensure that people registered their experiences without any preconceived notions about density. The introduction also mentions the time taken for completion of the survey, which is roughly around 15 mins.

5.1.7 Pilot Study

Before launch, a pilot study was conducted, and the lessons incorporated into the final version. The revisions were in the number of images used. To present a greater number of diverse situations, 45 images were considered initially, and the survey was designed in a similar manner to that described above. The increase resulted in a greater number of triads and increased effort in steps 2 and 3. The survey was found to be too long and people lost interest, increasing the number of incomplete surveys. Hence, the design was shortened to ensure a greater number of completed responses.

5.1.8 Survey Collection

The survey collection strategy employed in this study contributed to the achievement of a high number of responses. This survey was conducted online and circulated to around 300 people. A total of 252 responses were received, 163 for set 1 and 89 for set 2. The following points explain the strategy:

Online Survey: Conducting the surveys online allowed for greater accessibility and convenience for potential participants. People could complete the surveys at their own pace and without the need for physical attendance.

Wide Outreach: To maximize participation, a multi-faceted outreach strategy was employed. This included sharing the survey links through various channels such as email, social media, and academic networks (Strathclyde Doctoral School, Strathclyde Architecture department).

Convenience Sampling: The study utilized a convenience sampling technique, whereby participants were selected based on their accessibility and willingness to participate. The study also encouraged participants to refer others to the study.

Clear Communication: A clear and concise information about the purpose of the study, the importance of participant contributions, and the expected time commitment was provided.

Engaging Content: The visual surveys and research questions were designed to be engaging and exciting to potential participants. Engaging content can lead to higher response rates.

In conclusion, a well-rounded survey collection strategy that combined online convenience, multi-faceted outreach, snowball sampling, clear communication, engaging content contributed to achieving high participation numbers.

5.1.9 Survey Results and Analysis

The raw data comprised text data recorded under unique labels in step 2 and description in step 3. More than 7,000 labels and descriptions were recorded. These labels were coded into categories and then described using statistics using content analysis.

Qualitative content analysis is the subjective interpretation of the text data which involves systematic classification and coding by identifying themes or patterns (Hsieh and Shannon, 2005). It is a controlled method of analysis that does not result in rash quantification (Marying, 2000, cited in Hsieh and Shannon, 2005). It is one of the research methods used to analyse text data to determine social reality in a subjective yet scientific manner (Zhang and Wildemuth, 2009).

5.1.10 Content Analysis and Results

The process of qualitative content analysis is iterative and often begins in the early stages of data collection. The process of content analysis is divided into 8 steps that begin with preparing the data up to reporting the findings of the surveys (Zhang and Wildemuth, 2009). For this study to be replicable, the analytical procedures and process have been described in detail in the following steps.

5.1.10.1 Step 1: Preparing the Data

The raw data or unique labels retrieved from the surveys are in the form of text as a set of common nouns (see Table 5 -1). Each unique label or description might contain more than one quality or element, in which case both elements are considered separately. The data is further sorted for unique labels representing the triads and for descriptions representing each image. Although the labels are similar, the unique labels for triads reflect the common element for grouping three images whereas the description of the image suggests the justification for classification of images as high, moderate or low density.

For instance, people grouped the images in Figure 5-3 and identified 'tall buildings overshadowing the street' as a common feature. The images were classified as high density and tall buildings were the justification provided for the classification.

Table 5-1. Sample of the raw data as received from the survey report

Participant Number	*Unique Labels / Descriptions by the Participants*
P1	City – Tall Buildings
P2	Cars, People
P3	Architectural styles
P4	no gaps between buildings
P5	enclosed by tall buildings
P6	Empty space

Figure 5-3. Sample of triad (three images) as sorted by participants in the survey, classified as high density

This task identifies the factors and variables that people point out while perceiving an urban environment as being low moderate or high density. Hence the descriptions for low, moderate and high density are separately analysed as shown in Table 5-2 to identify the critical factors that determine the degree of density (Refer Appendix A1).

Table 5-2. Descriptions for each image, stated by people under low, moderate and high density

LOW-DENSITY	MODERATE DENSITY	HIGH-DENSITY
Open space	Tall buildings but not so dense	Little sky visible
Empty space	Mostly housing, not too tall	Narrow street – high-rise
Vacant land makes the place look empty	Open area	Building-to-sky ratio
Low buildings but also empty spaces so feel less dense	Medium-sized buildings and medium-sized paths	Verticality
More residential, less vehicle movement	Open pedestrian space	Built-up, city street

5.1.10.2 Step 2: Define the Unit of Analysis

The unit of analysis is the basic unit to be classified during the content analysis to allow the coding of the huge amount of text data (weber 1990, as cited in Zhang and Wildemuth, 2009). The unit of analysis could be objective data such as age or conceptual data such as a set of words. To determine the conceptual unit of analysis for this survey, around 200 text descriptions were scanned and around 50 sets of categories and constructs were identified to further analyse data. The unit of analysis was the construct name derived from the unique labels and descriptions (see Table 5-3).

Table 5-3. Derivation of construct names

Unique Label/ Image Description	*Construct Name*
little sky visible	Amount of sky
narrow street – high-rise	Street width, building typology
Building-to-Sky ratio	Balanced (built/open) development
Verticality	Height of the buildings

built-up city street	Built-up area
High buildings / no natural environment	Height of the buildings, vegetation

5.1.10.3 Step 3: Develop Categories and a Coding Scheme

Coding schemes can be derived from the data, previous studies or theories. The 50 constructs derived from the initial scanning and literature review were sieved to identify themes or categories. These categories were coded with letters and the constructs within those themes as numbers. The categories and constructs were clear and mutually exclusive. To ensure consistency, a coding manual was developed which consisted of category names and code, construct name and construct code (see Table 5-4)

Table 5-4. Coding manual sample

CATEGORY CODE	CATEGORY NAME	CONSTRUCT CODE	CONSTRUCT NAME
A	Building Density along the street	A1	Loose / Scattered urban form
A		A2	Compact urban form
A		A3	Space between the buildings
B	Building Profile	B1	Height of the Buildings
B		B2	Length of the Buildings (Façade)

Some 17 categories were identified, and the description of the categories is as follows.

1. Building density along the street. The visual composition of the built form, as perceived from the viewpoint of a pedestrian. In contrast to a compact urban form, a loose or scattered urban form is characterised by the spacing between adjacent structures.
2. Building profile. The building's basic dimensions, including its height, length and roof.
3. Context. The urban fabric or locality often connotated as urban, suburban or rural (Designing Buildings Ltd., 2021).
4. Degree of density. Low, moderate or high perceived or measured density based on the degree of concentration or compaction of people or development in a city (Cheng, 2010a, 2010b; Churchman, 1999; Rapoport, 1975).
5. Enclosure ratio. The function of ratio and scale which affect user perception

and comfort (Aung, 2020). The enclosure ratio refers to the height-to-width ratio where the first number corresponds to the building's height and the second to the street's width.

6. Human aesthetic response. Mediates between perception and interpretation and is manifested as an emotional reaction to urban or built surroundings such as happiness, sadness, vibrancy and drabness (Nasar, 1989).
7. Intensity of activities. The extent to which the pavements are used for recreational or commercial purposes and the number of people.
8. Land use. The management and distribution of functions (residential, commercial, institutional and industrial) that inform the building typology and contribute to the area's identity. The term also refers to the activities and their level of spatial accumulation which indicates intensity and concentration (Rodrigue, 2020).
9. Massing. The three-dimensional form of the buildings. It relates to the volume, size, scale or proportion of the built-up area. It dictates the character and overall expression of the built form as viewed from the pedestrian point of view (Spacey, 2017).
10. Permeability. The visible connection at ground level is due to the building material's transparency which blurs the boundaries and lowers the perception of a rigid edge (Bentley et al., 1985).
11. Site organisation. The complementing aspects that give a street or urban area its character and value; for example, features of the streetscape, greenery, environmental quality and parking lots (Groat, 1985).
12. Social density. The number of individuals in a fixed space or on-street (Churchman, 1999).
13. Street profile. The street's width, length, form and slope (Marshall, 2005).
14. Street type. The physical and functional characteristics of streets; for example, avenues, boulevards, expressway and lanes (Marshall, 2005).
15. Transitional edge. The active street edges; the pavements or sidewalks or space between the roads and the building edge that stimulate activities and serve as a transition zone between public and private (Thwaites et al., 2020).
16. Urban form aesthetics. The architectural style and physical aspects of the

built environment such as the geometry of the built form, its colour and its shape that has a visual and a significant effect on the residents' daily lives (Lehmann, 2019; Nasar, 1989).

17. Urban form composition. The organisation and structure of the built form, which may be symmetrical (balanced) or asymmetrical (unbalanced) based on building heights, the presence of vegetation or the presence of open spaces and is most usually depicted as built versus open (Živković, 2020).

5.1.10.4 Step 4: Test the Coding Scheme on a Sample of Text

This coding scheme was tested on the first 500 labels and descriptions. Concerns regarding the construct and category names were resolved and the manual was revised. However, coding sample text, checking coding consistency is an iterative process and it continued for a few thousand text descriptions.

5.1.10.5 Step 5: Code All the Text

New constructs emerged as the process of interpretation continued and a number of constructs were added to the list which grew to 63 constructs (see Table 5-4). The coding manual was revised regularly. The complete list of constructs developed after interpretation of all the descriptions is Table 5-5.

Table 5-5. List of constructs and categories

CATEGORY CODE	CATEGORY NAME	CONSTRUCT CODE	CONSTRUCT NAME
A	Building Density along the street	A1	Loose/scattered urban form
A		A2	Compact urban form
A		A3	Space between the buildings
B	Building Profile	B1	Height of the buildings
B		B2	Length of the buildings (façade)
C	Context	C1	Urban/city
C		C2	Sprawl/outskirts/suburbs
C		C3	Neighbourhood
D	Degree of Density	D1	High density
D		D2	Moderate density
D		D3	Low density
D	Residential Density	D4	Occupancy rates
E	Enclosure Ratios	E1	Sense of enclosure
E		E2	Loss of enclosure
E		E3	Semi-enclosed (buildings + vacant land)
		E4	Scale and proportion
F	Human Aesthetic Response	F1	Sad/negative
F		F2	Confused

F		F3	Happy/appreciative
F		F4	Angry
F		F5	Energised
F		F6	Overwhelming
		F7	Comfortable
		FS	Familiar situation
G	Intensity of Activities	G1	Highly Active
G		G2	Non-active
H	Land Use	H1	Residential
H		H2	Commercial
H		H3	Mixed
I	Massing	I1	Volume of buildings
I		I2	Built-up area
J	Permeability	J1	Visual permeability at ground floor level
J		J2	Visual permeability through building
K	Site Organisation	K1	Vegetation
K		K2	Streetscape elements
K		K3	Parking lots
K		K4	On-street parking
K		K5	Open spaces/parks
K		K6	Space qualities
K		K7	Lack of space
		K8	Environment quality
K		K9	Vacant/empty Spaces
L	Social Density	L1	Density of cars on the street
L		L2	Density of people in the street
M	Street Profile	M1	Street length
M		M2	Street width
M		M3	Street markings
N	Street type	N1	Service lanes
N		N2	Avenues
O	Transitional Edge	O1	Pavement width
O		O2	Pedestrian-friendly
P	Urban form Aesthetics	P1	Style of the buildings
P		P2	Materials
P		P3	Colours
P		P4	Texture/pattern
P		P5	Building typology
P		P6	Variety
P		P7	Too many elements
P		P8	Urban canyon
P		P9	Link between old/new building styles
Q		Q1	Balanced (built/open) development

Q	Urban Form Composition	Q2	Uniform built form along the street
Q		Q3	Amount of sky
Q		Q4	Trees on one side
Q		Q5	Unbalanced – buildings on one side
Q		Q6	Non-uniform built form on either side

5.1.10.6 Step 6: Assess Coding Consistency

After coding all the data, it is rechecked for consistency. The possibility of manual error arising due to fatigue always exists. Hence the codes and their categories were rechecked to maintain the essence of the data recorded by people and avoid researcher bias.

5.1.10.7 Step 7: Draw Conclusions from the Coded Data

The raw data represents different mindsets, both conscious (aware of density) and unconscious (unaware of density), hence it was interpreted independently at every stage and then as a whole reviewing the Glasgow and universal illustrations separately. Based on the initial interpretation, the following patterns can be drawn.

1. **Sorting and labelling of triads reflects visual impact elements**. In the first step – the creation of triads – the raw data received is a unique label that represents the elements that show similarity. The respondents were unaware at this stage that the survey was related to density assessment. Hence the labels purely represent the element that has a greater visual impact by virtue of shape, colour, material or any other characteristic.

2. **Perceived degree of density**. The classification of the images into high, moderate or low density based on perception. This classification was then compared to the measured density values to verify if people perceive density differently. This further assists in identifying which building typology is associated with what degree of density.

3. **Correlations between the constructs**. People give a reason for their perceived classification in the second step. These reasons either reflect a physical feature that can be quantified such as buildings, the number of people or the presence of vegetation, or a human response to the urban environment such as feeling comfortable, happy or sad or dull. However,

these constructs are dependent on one another. Establishing correlations would assist in identifying the constructs that influence one another and deducing design implications to control these constructs.

5.1.11 Step 8: Report your Methods and Findings

Qualitative content analysis does not produce counts or statistical data. It uncovers patterns, themes and categories important in understanding the perception of urban environments. The findings from the content analysis are thus further processed using frequency count and Spearman correlation analysis to derive the statistical significance of constructs associated with the perception of density. The four outcomes derived from this survey are presented below.

First, the unique labels of the triads are analysed using the coding manual produced for the content analysis to record 60 constructs for each of the two sets; Glasgow and universal illustrations. These constructs represent the characteristic aspect of the triad. with the help of frequency count, the 30 most frequently occurring constructs are selected and used for further analysis.

Secondly, the top 30 constructs are analysed using two distinct approaches. The first divides the constructs into those that can be quantified and those that represent the character of the urban environment. The second categorises the constructs into those that constitute urban form elements and those that depend on or arise from the former constructs. This includes determining an urban form's contribution relative to other dependent constructs.

Thirdly, using the coding manual, the descriptions of the images were analysed to find 65 components associated with high, moderate and low density. The constructs for triads and image classification into high, moderate and low were the same. Based on the frequency count, the top 20 critical constructs related to all degrees (high, moderate and low) of density were found.

Fourthly, it was discovered that the majority of these constructs comprise urban form aspects and are measurable and controllable. To determine the level of control, a correlation study using the Spearman correlation analysis was undertaken to reveal significant relationships. This study speculates on the causes of these connections and can be expanded to infer design implications. Additionally, these correlations do not always suggest a causal relationship and are contingent on the presence of other components and the environment. Therefore, additional research is required to corroborate these relationships.

In the following sections, these four outcomes and their associated procedures are explained.

Demographics

The MST survey was taken by 263 people in total. The survey for Glasgow (GLA) received 163 responses, 75 male and 85 female. The majority of respondents (107) were in the age range of 18-24, with 40 falling in the age range of 25-34. All participants held a professional degree. The survey for universal illustrations (UI) was responded to by 89 participants, 35 male and 53 female, with 68 respondents being in the age group of 18-24.

The gender distribution of responders was roughly even with slightly more women than men. The majority of respondents were between the ages of 18 and 24, which may limit the generalisability of the results to older populations. Nevertheless, each participant held a professional degree, indicating that they may have had comparable levels of education and professional experience.

The Triads

The primary reason to use triads is to limit the cognitive burden on respondents by giving them a very simple set of tasks which can be analysed to reveal their perceptions of the degree of similarity between all pairs of images (Curtis et al., 2008). Therefore the 27 images were presented in 3 sets of 9. Each set consisted of 3 high density, 3 moderate density and 3 low density images. They were presented in the manner shown in Fig 5.5.

Unique Label Count

Nine unique labels per person were recorded. Some 163 people took the survey for GLA and 89 people for UI; therefore, the expected count of triad labels were 1,467 and 801 respectively. However, respondents often described the triads with more than one element, hence the total number of unique labels recorded for GLA was

1,486 and that for UI was 811.

The following two figures represent the ways in which the images were presented to the people to create triads and label them. this assists in visualising the process of sorting and labelling, the first and second steps of multiple sorting tasks.

Categories and Construct Codes Identified

A total of 1,486 number of unique labels for GLA and 809 for UI were interpretated to identify 65 constructs or themes and the top 30 constructs that form a part of one's perception and experience (see Figure 5-9).

Analysis of the Triads

The top 30 constructs identified in the surveys were analysed to identify the contribution of the urban form elements in human perception and the number of constructs that can be controlled using density measures and building codes.

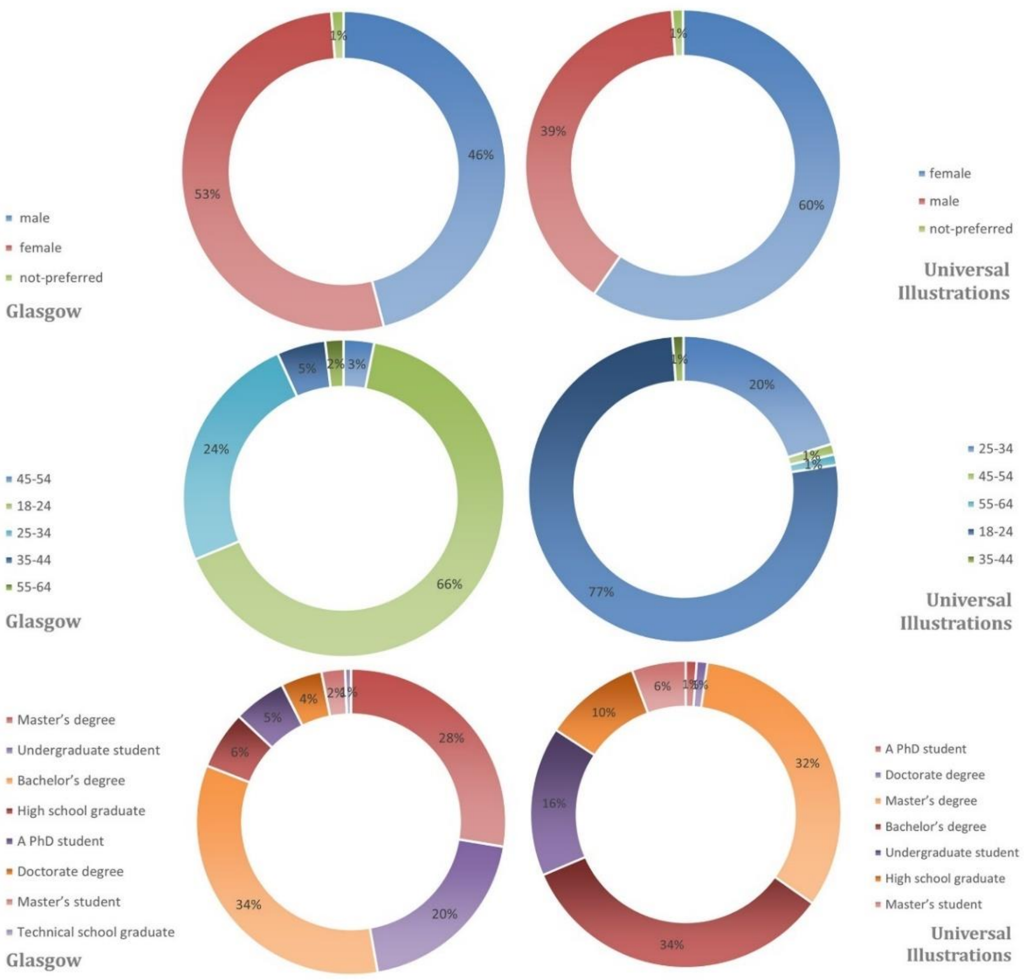


Figure 5-4. Participant information – MST

Typically, the process of creating triads of images by the participant involves identifying similarities and differences between them and then assigning a unique label to define the category or construct. These might involve colour, composition, style, theme, size, orientation, content or context. For perceived density, the constructs characterising the triads were analysed using two approaches.

Approach 1

The urban environment is composed of elements that are measurable or quantifiable and those that reflect its character and quality. The first set of triad descriptions consists of the building height, open space or parks along the streets, street width, volume of the buildings, density of cars, density of people, pavement width and level of activities.

These constructs are quantifiable and signify the intensity or magnitude by virtue of numbers or volume. The frequency count of the constructs defining the triads suggests that the higher the number of elements present, the greater the intensity

Figure 5-5. Triads- Glasgow

or magnitude and thus the higher possibility of getting noticed.

The second set of descriptions comprises land use (residential, commercial and mixed), vegetation, building typology, context (urban or suburban), environmental quality, vacant or empty spaces, space between the buildings, loose or scattered urban form and architectural style of the buildings. These constructs signify a quality, character or function of the built environment which can be noticed visually. Therefore, if these constructs occur frequently, they can affect visual perception. Applying the law of deductive reasoning on both sets, the higher the number of constructs, the greater the visual impact and consequently the higher the influence on human perception.

Table 5-6. Approach 1 – Measurable constructs and constructs with visual impact

Approach 1	
Set 1	**Set 2**
Measurable constructs	**Constructs that reflect character**
Height of the Buildings	Land use
Open spaces	Trees – Vegetation
Street Width	Building Typology
Volume of Buildings	Context – Urban/Suburban
Density of cars on the street	Level of Activity
Density of people in the street	Environmental Quality
Pavement width	Vacant/Empty spaces
Amount of sky	Buildings on one side (unbalanced)
	Compact urban form
	Style of the buildings (architectural style)

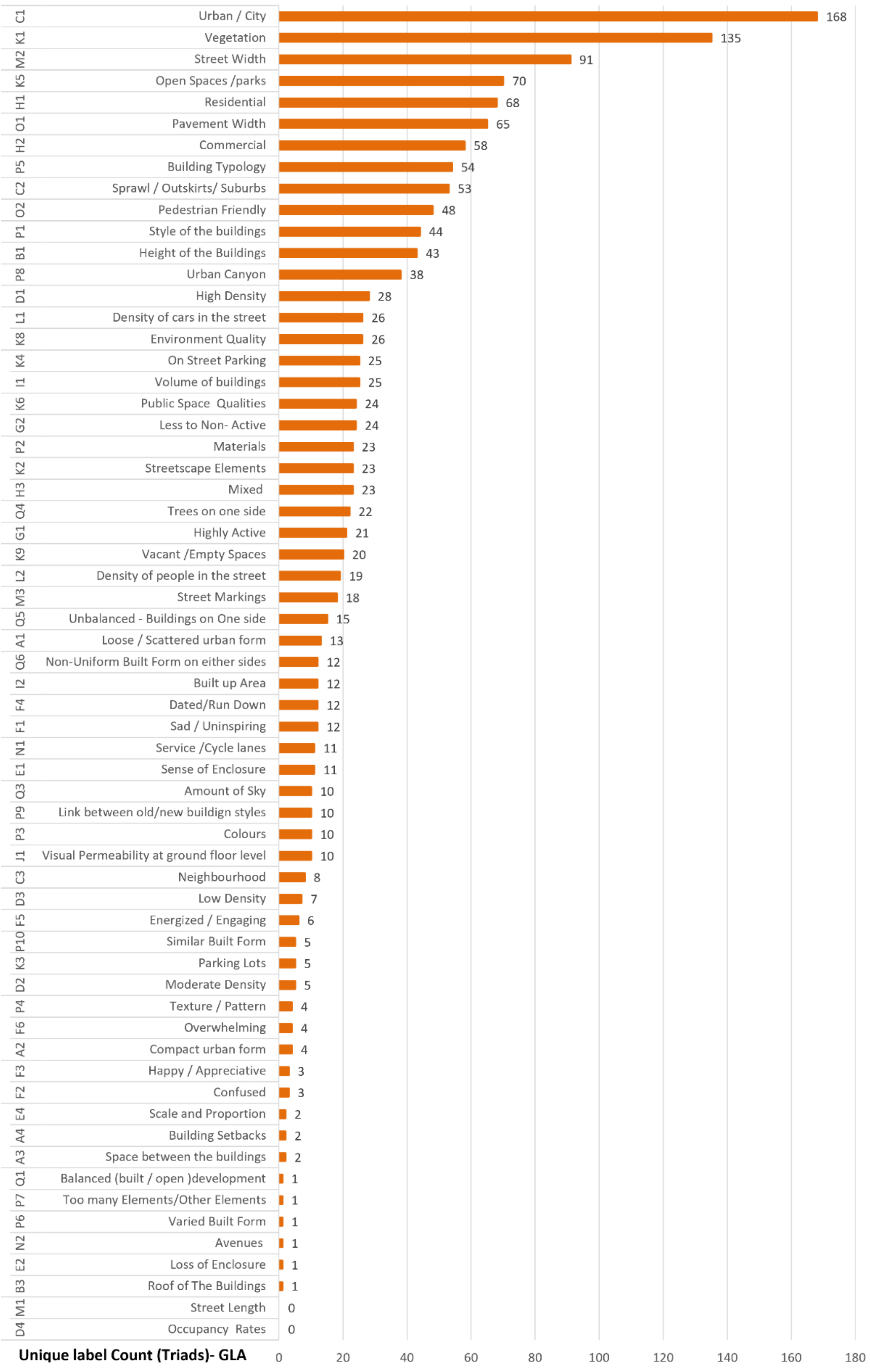


Figure 5-5. Most described construct codes (163 responses)

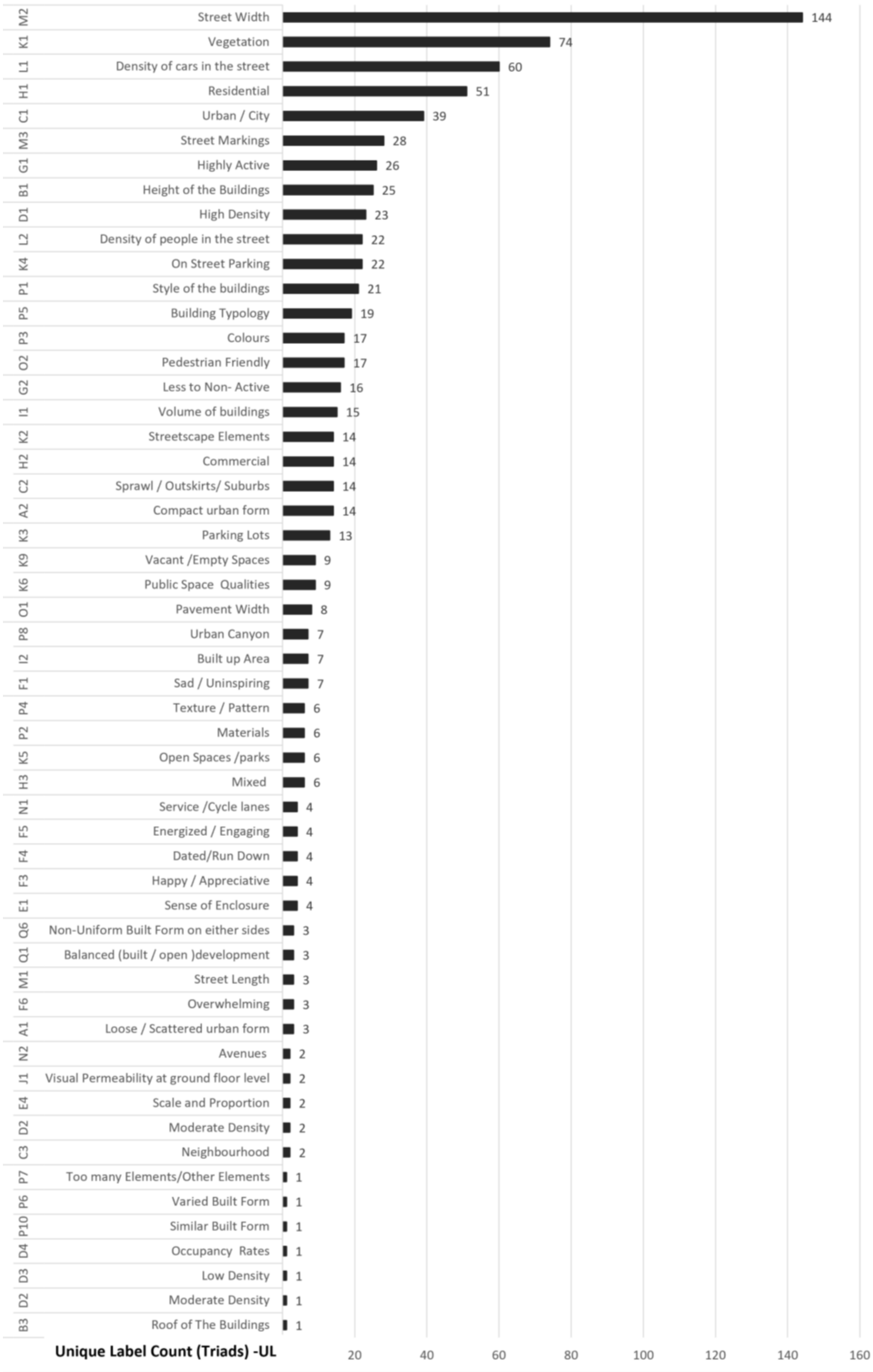


Figure 5-6. Universal illustrations – most described construct codes (89 Responses)

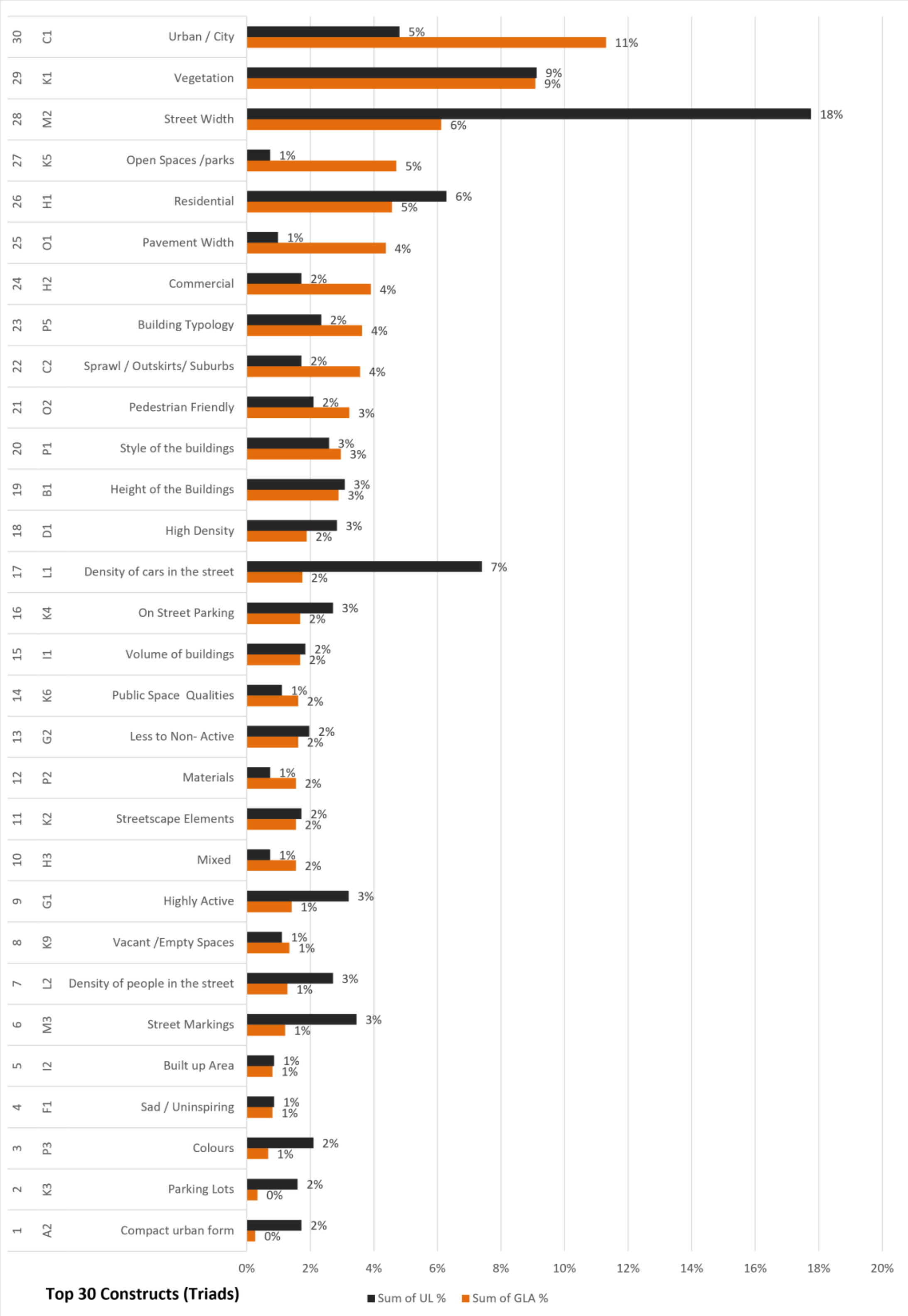


Figure 5-7. Top 30 Constructs (derived from unique labels of triads)

Approach 2

The same constructs can be divided into two sets, one the direct and indirect elements of urban form that can be designed and altered, and the other dependent constructs that are a response to the composition of these elements. Land use, housing type, layout, transport infrastructure and density are elements of urban form (Dempsey et al., 2010). But of these, elements such as layout and transport are systems that are comprised of several other attributes (see Table 5-7). The height, volume, and building typology contribute to building density. Compact or loose urban form determined by the space between the buildings guides the arrangement of buildings within the block, whereas street and pavement width is a part of street systems. The urban or suburban context governs the land use and the density of cars and people and intensity of activities are an outcome of land use and so are listed as dependent constructs. This approach assists in determining the contribution of urban form elements.

Table 5-7. Approach 2 – Constructs that constitute the urban form versus Dependent Constructs

Approach 2	
Set 1	**Set 2**
Constructs that constitute urban form	**Dependent constructs**
Height of the Buildings	Density of cars on the street
Open spaces	Density of People in the street
Street width	Context (urban/suburban)
Volume of buildings	Level of activity (active/inactive)
Land use	Environmental quality (natural light/ shadows)
Building typology	
Pavement width	
Amount of sky	
Vacant or empty spaces	
Compact urban form	
Style of the buildings	
Unbalanced (asymmetrical – buildings on one side)	

Descriptions of the Images

The 27 images were classified into high, moderate and low density according to the participants' perception and the associated descriptions with it were recorded separately for GLA and UI.

Typically, an image description, either written or verbal, consists of aspects of the objects, people, cityscape, colours, textures and patterns that catch the attention

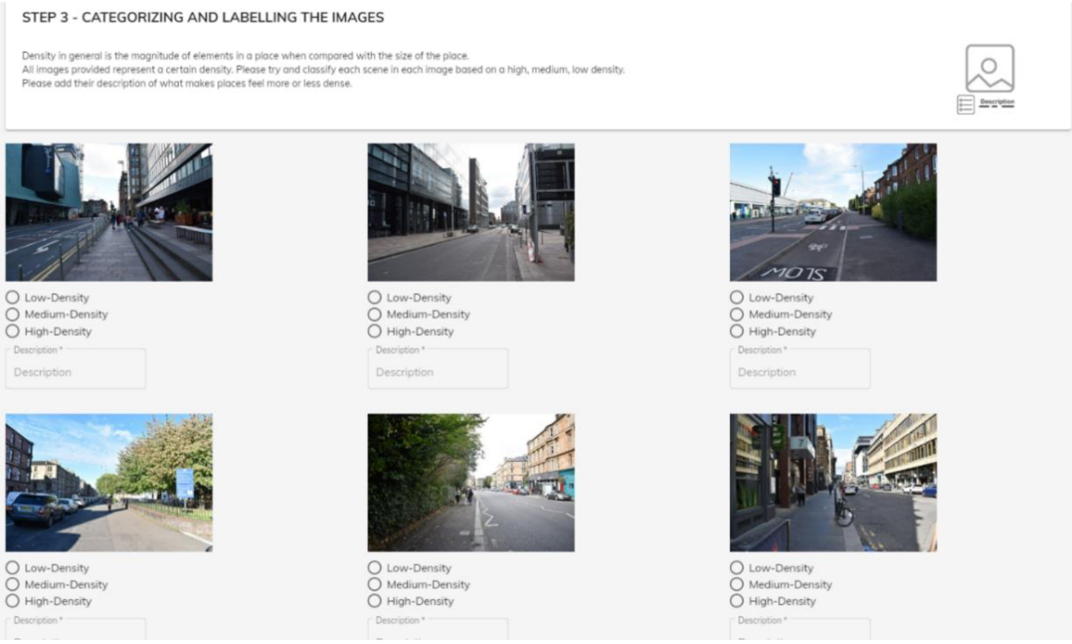


Figure 5-8. Classification and description of Images

(Gestalt, n.d.; Sanoff, 2016). People tend to focus on any noticeable physical features of the images to describe them (Lynch, 1964; Nasar, 1988, 1989b). It involves using a range of adjectives that convey their experience or the impression of what they see. This includes the use of words such as bright or colourful to express happy feelings whereas grey or dull could be used to explain monotonous images. Descriptive terms such as happy, chaotic and comfortable explain the emotional responses or moods (Sanoff, 2016). People might also focus on the details or elements of the image which they find attractive. For instance, they may comment on the composition of the image itself. Overall, the description so the images assist in gathering valuable insights into their perception of visual information.

The descriptions for both the sets identified similar constructs, yet are represented independently below for comparative analysis to:

1. Understand the reasons for the observed similarities and differences between the 2 sets.
2. Verify if the collection of data on two cases can assist in identifying a common framework for assessing perception of density.
3. Test the two hypotheses stated for selecting two different sets.

Construct Code	Construct Name	Construct Count HD	Critical Constructs (High Density)	Construct Count MD	Critical Constructs (Moderate Density)	Construct Count LD	Critical Constructs (Low Density)
K5	Open Spaces /parks	18		126	■	90	■
B1	Height of the Buildings	186	■	125	■	89	■
I1	Volume of buildings	52	■	81	■	85	■
K1	Vegetation	11		73	■	48	■
H1	Residential	10		71	■	47	■
L1	Density of cars in the street	38	■	66	■	41	■
M2	Street Width	63	■	63	■	36	■
H3	Mixed	22	■	58	■	35	■
P5	Building Typology	35	■	57	■	34	■
A1	Loose / Scattered urban form	14		45	■	34	■
H2	Commercial	38	■	38	■	30	■
O1	Pavement Width	15		37	■	27	■
L2	Density of people in the street	40	■	36	■	25	■
Q5	Unbalanced - Buildings on One side			31	■	18	
C1	Urban / City	75	■	24	■	17	
G1	Highly Active	19		23	■	14	
C2	Sprawl / Outskirts/ Suburbs			19		12	
Q3	Amount of Sky	5		17		9	
G2	Less to Non- Active	4		17		8	
K8	Environment Quality	16		14		7	
A3	Space between the buildings	14		10		7	
O2	Pedestrian Friendly	4		10		6	
Q6	Non-Uniform Built Form on either sides	2		10		6	
Q1	Balanced (built / open)development	2		9		5	
Q4	Trees on one side			8		4	
K9	Vacant /Empty Spaces			7		4	
K6	Public Space Qualities	3		7		3	
P1	Style of the buildings	11		6		3	
K3	Parking Lots	1		6		3	
K7	Lack of Space	7		6		3	
K4	On Street Parking	2		5		3	
I2	Built up Area	4		5		2	
D2	Moderate Density			5		2	
A2	Compact urban form	30	■	4		1	
D1	High Density	10		4		1	
P4	Texture / Pattern	7		3		1	
P2	Materials	4		3		1	
F1	Sad / Uninspiring			2		1	
D3	Low Density			2		1	
C3	Neighbourhood	1		2		1	
E1	Sense of Enclosure	6		2		1	
P6	Varied Built Form	1		2		1	
F5	Energized / Engaging	1		2		1	
M1	Street Length			2		1	
E4	Scale and Proportion	3		1		1	
P8	Urban Canyon	17		1			
P9	Link between old/new building styles	3		1			
A4	Building Setbacks	1		1			
B2	Length of the Buildings(Façade)	1		1			
F6	Overwhelming			1			
P3	Colours			1			
K2	Streetscape Elements	4					
M3	Street Markings	3					
P7	Too many Elements/Other Elements	2					

High Density | Moderate Density | Low Density | ■ Critical Constructs - GLA

Figure 5-9. Constructs associated with high, moderate and low density for Glasgow

The individual cases are presented before the comparative analysis to identify the critical constructs associated with the perception of high, moderate and low density in both cases.

Glasgow

805 descriptions were recorded for high density images, 1,155 for moderate density and 769 for low density images. Using frequency analysis, these constructs were organised for high, moderate and low density and are presented in Figure 5 -10. The height and volume of the buildings, density of cars or people in the street, street width, building typology and the building use (mixed, commercial or residential) were associated with all three degrees of density. Moderate and low density areas were characterised by the presence of open spaces, vegetation and trees and residential land use along the street. Additionally, loose or scattered urban form, pavement width and the concentration of built form on either side of the street all indicated moderate or low density.

The critical constructs identified are mostly controllable using measures of density such as FAR or plot ratios in conjunction with the building bylaws. Few of them fall within the purview of urban planning such as the allocation of land use and few can be addressed at the plot level by architects and designers. These constructs are dependent on one another; for instance, social density is dependent on land use. Land use, however, acts as an urban catalyst that triggers the generation and intensity of contextual (urban or suburban) elements.

Universal Illustrations

For the UI, a total of 1,599 descriptions were interpreted. Of these descriptions, 709 corresponded to high density, 669 to moderate density and 221 to low density. Some 51 constructs corresponded to high and moderate density and 35 for low density. Street width, height and volume of the buildings and density of cars and people in the street were common to all three degrees of density. Compact urban form, building typology, high levels of activities and commercial land use characterised the perception of high density. Moderate density included space between the buildings, vegetation, presence of open space or parks, residential

Construct Code	Construct Name	Construct Count-HD	Critical Constructs (High Density)	Construct Count-MD	Critical Constructs (Moderate Density)	Construct Count-LD	Critical Constructs (Low Density)
M2	Street Width	122	■	135	■	35	■
B1	Height of the Buildings	116	■	123	■	26	■
I1	Volume of buildings	22	■	43	■	6	
L1	Density of cars in the street	52	■	33	■	23	■
A3	Space between the buildings	12		32	■	5	
K1	Vegetation	13		27	■	10	■
K5	Open Spaces /parks	8		27	■	6	
H1	Residential	11		21	■	8	
K3	Parking Lots	11		18	■	10	
C2	Sprawl / Outskirts/ Suburbs	6		15	■	2	
L2	Density of people in the street	52	■	14		9	
A2	Compact urban form	36	■	12		1	
A1	Loose / Scattered urban form	2		11		11	
G1	Highly Active	38	■	11			
P1	Style of the buildings	4		10		2	
P5	Building Typology	38	■	10		1	
K9	Vacant / Empty Spaces			9		9	
Q3	Amount of Sky			9			
E1	Sense of Enclosure	11		8		2	
K4	On Street Parking	10		8		2	
O1	Pavement Width	5		7		8	
Q1	Balanced (built / open)development	1		7			
E3	Semi-Enclosed			6		1	
I2	Built up Area	4		6			
C1	Urban / City	9		5		1	
G2	Less to Non- Active	7		5		20	■
O2	Pedestrian Friendly	5		5		2	
E4	Scale and Proportion	2		4		1	
K6	Public Space Qualities	10		4		3	
C3	Neighbourhood	1		3		2	
F1	Sad/ Unispiring			3		3	
H2	Commercial	16	■	3		2	
H3	Mixed	5		3			
K8	Environment Quality	2		3			
P10	Similar Built Form	3		3		0	
P3	Colours	3		3		3	
D4	Occupancy Rates	8		2		1	
F3	Happy / Appreciative	4		2		0	
F6	Overwhelming	8		2		2	
K2	Streetscape Elements	9		2		1	
P2	Materials	2		2		1	
P6	Varied Built Form	6		2			
P8	Urban Canyon	6		2			
Q4	Trees on one side			2			
D2	Moderate Density			1			
E2	Loss of Enclosure			1			
F4	Dated/Run Down	2		1		3	
M1	Street Length	4		1			
M3	Street Markings			1			
P7	Too many Elements/Other Elements	1		1			
Q5	Unbalanced- Buildings on one side			1			
A4	Building Setbacks	1					
D1	High Density	2					
F2	Confused	1					
F5	Energized / Engaging	1					
J1	Visual Permeability at ground floor level	2					
K7	Lack of Space	8					
N1	Service /Cycle lanes	2					
N2	Avenues	1					
P4	Texture / Pattern	4					
Q2	Uniform built form along the street					1	

High Density | Moderate Density | Low Density | Critical Constructs - UL

Figure 5-10. Constructs associated with high, moderate and low density for Universal Illustrations

areas with parking lots and suburban while the presence of vegetation and low level of activities were found to be vital for the perception of low density.

Amongst the critical constructs identified (Figure 10), street width, height and volume of the building, space between the buildings, allocation of land use and planning of green spaces and parking lots are within the purview of the urban planning and design faculties. The other constructs are a response to the manifestation of the planned constructs.

5.1.12 Comparative Analysis

For comparison purposes, the frequencies of the constructs were normalised to percentages. The top 10 constructs identified by both sets (height of buildings, street width, density of cars, presence of open spaces, volume of the buildings, density of people, vegetation, land use, building typology and arrangement of built form) influence the perception of density irrespective of the degree of density. The constructs are the same, but the percentage of the frequency count varies.

The difference in the percentages of the identified constructs can be attributed to the difference in the visual composition of each set of images used for GLA and UI. They are conceptually similar and represent different density levels for urban areas, but they are also different in the sense that GLA represents density as a relative construct where density levels gradually decrease from the city centre towards the peripheral areas while the UI are random samples of urban centres representing high and moderate density throughout the world. Relative density and high density also represent different levels of built form and development intensity in an urban environment. While relative density can be considered a transition between suburban and high-density urban areas, high density areas are characterised by tall, closely spaced buildings and a greater concentration of people and activity. This was a deliberate decision made during the study to verify if the constructs associated with the perception of density are different for relative density as against the high-density urban centres. The other difference in the set of images is with objective density. For instance, a building density of 160 dph which is considered as high for GLA, is moderate for UI.

Even so, the constructs that influence the perception of density identified by analysing both sets are similar. The similarity in the results suggests two things:

1. **Methods of analysis are reliable and valid**. This implies that the datasets, which were measuring the same phenomenon (perception of density), provided consistent findings when analyzed using the chosen methods. Reliability refers to the consistency and stability of measurement, and the fact that the results were similar suggests that the methods used in the study produced consistent findings across different datasets. Validity, on the other hand, pertains to the accuracy and appropriateness of the measurement in capturing the intended construct. The similarity in results indicates that the methods employed in the analysis effectively captured and measured the construct of density perception.

   Need to account for the visual composition of the urban form. This suggests that the frequency of particular constructs may vary, but that this variation may be attributable to the visual composition of the urban form itself, which is not fully captured by content or frequency analysis alone. Consequently, it is necessary to incorporate image analysis techniques in order to further investigate and comprehend the role of visual composition in the perception of density.

   Composition refers to the organisation and arrangement of visual elements within a scene or image. It includes factors such as building height, spacing, architectural styles, green spaces, and other visual elements that contribute to the overall appearance and aesthetics of an urban environment. These visual elements can influence how people perceive and interpret the urban environment's density.

These results also invalidated both *hypotheses* for selecting two sets of images for the task. The similarity of constructs suggests that:

1. The findings suggest that the perception of density is not primarily associated with relative density but rather with the visible urban form elements. This emphasises the significance of visibility as a fundamental concept in the

study of perception. However, it is difficult to determine the role of familiarity in the perception of density given that the responses of the participants did not provide substantial insight into the differences in opinions between strangers and residents.

2. Changing the viewing angle of image capture between the two sets had no significant effect on the perception of density, according to the study. This suggests that participants' perceptions of density were not significantly affected by the perspective or angle from which urban environments were portrayed. In other words, regardless of the viewing angle, participants were able to perceive and evaluate the density of the scenes consistently. This finding suggests that density perception may depend less on a specific viewpoint or angle of observation and more on the overall arrangement and distribution of visible elements within the urban environment.

Thus, it is possible to conduct studies on the perception of density using Google Street imagery which can be extended to different places. Yet, one will always be able to make out the difference between the relative density that is seen in cities versus that of extreme density seen in the metropolis or megalopolis when the images are analysed using image segmentation or other such algorithms.

5.1.13 Constructs Associated with High, Moderate and Low Perceived Density

The intent of incorporating the UI was to explore the constructs associated with high and moderate density and find ways to alter or modify them to achieve the high objective density but a perception of moderate density. The results of the content analysis are thus compared in the following section for high, moderate and low density to identify if a common framework be derived.

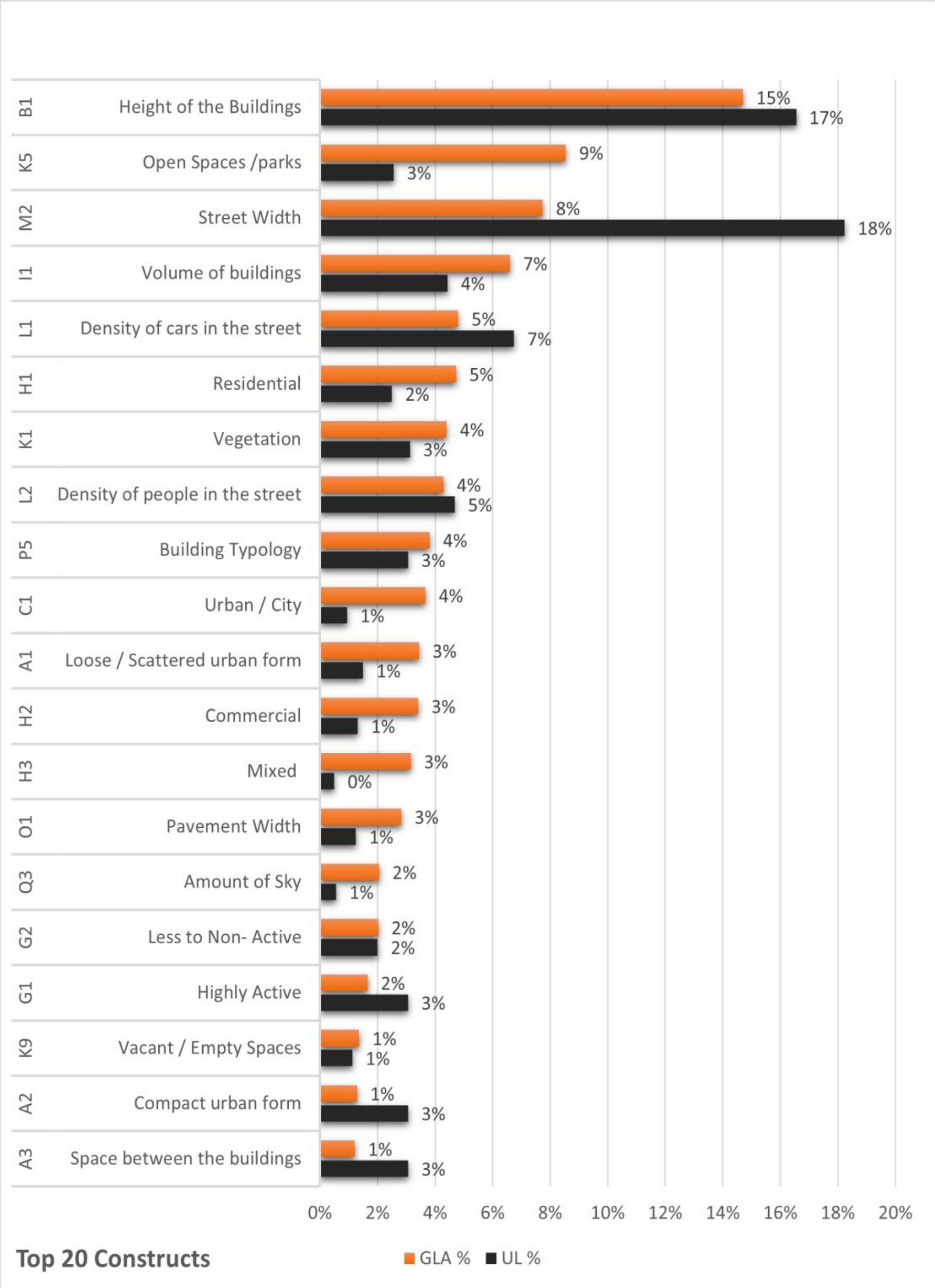


Figure 5-11.Top 20 constructs of image descriptions identified for comparative image analysis.

5.1.14 High Density

High density in urban environments is frequently characterised by the presence of tall buildings, narrow streets, a high concentration of automobiles and people, particular building types, and a compact urban form. Collectively, these factors contribute to the perception of high density. It is essential to recognise that these elements are interdependent and mutually influence one another, ultimately shaping the quality of the urban environment as a whole.

The height of buildings, a prominent physical characteristic of high-density areas, contributes significantly to the perception of density. It contributes to the concept of enclosure ratio, which refers to the feeling of being enclosed or surrounded by tall buildings, when combined with street width. By emphasising the proximity of buildings, the compactness of the urban form contributes to the perception of density.

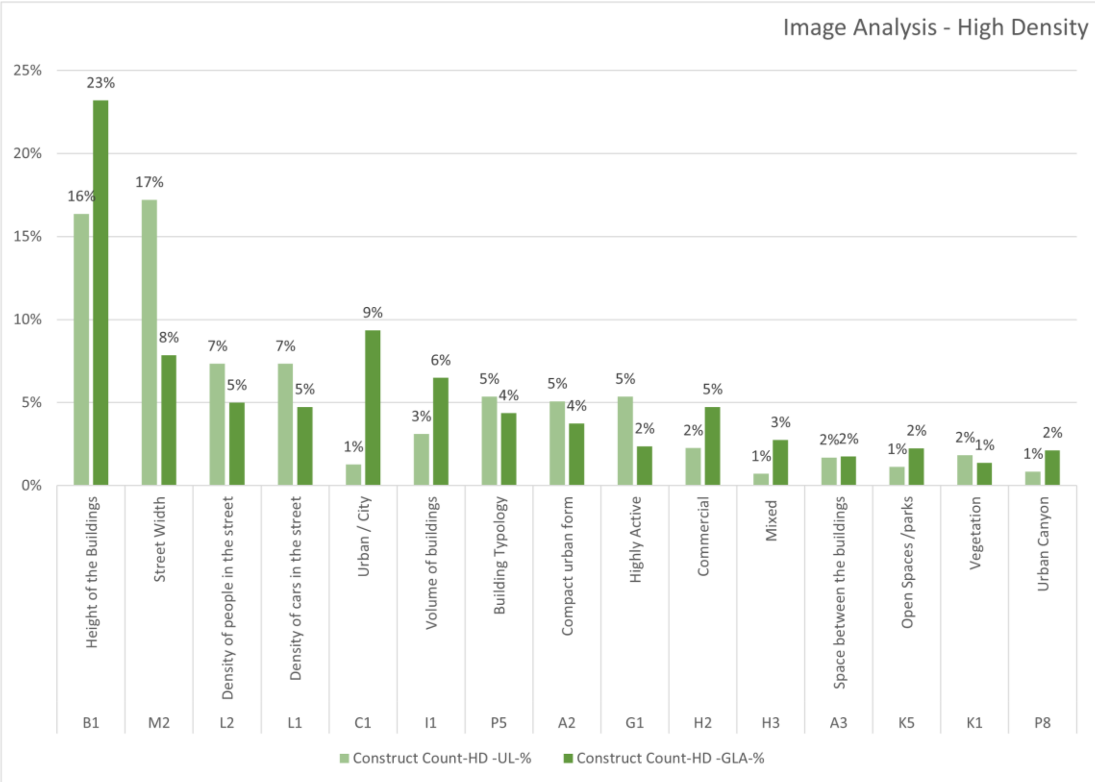


Figure 5-12. Image descriptions – frequency analysis – high density – for GLA and UI

The density of cars in urban areas is affected by a number of variables, including street type (primary, secondary, or tertiary) and the allocation of land use along the streets. These variables influence the overall level of vehicular activity and congestion, thereby contributing to the impression of density.

In addition, building typology, which includes land use allocation, plot ratios, and contextual factors, influences the perception of density. Different types of buildings and their functions contribute to the overall visual and functional characteristics of an area, thereby influencing the perception of density.

Notably, the aforementioned concepts are not only associated with the perception of density, but also with the concept of perceived crowding. In urban environments, the combination of high-rise buildings, narrow streets, dense vehicular and pedestrian activity, specific building typologies, and a compact urban form can create a feeling of congestion.

In conclusion, the concepts of building height, street width, urban form, car density, and building type all contribute to the perception of urban environment density. To comprehend and effectively manage high-density areas, it is essential to comprehend the interdependency of these concepts and their impact on the perceived quality of the urban environment.

5.1.15 Moderate Density

Open spaces, which provide a contrast to dense urban settings, are characteristic of moderate density environments. These open areas can take the form of pocket parks, squares, or green lawns and provide a respite from the built environment. By incorporating these open spaces along the streets, the overwhelming quality of the built form is mitigated, resulting in a more neutral perception of density.

The inclusion of open spaces in areas of moderate population density also contributes to the impression of a dispersed urban form. These spaces contribute to the visual and physical separation of adjacent and opposite buildings, providing the perception of greater distance and diminishing the feeling of density. The width of secondary streets or roads with multiple lanes, flanked by medium-height buildings (typically between four and seven stories), also contributes to the perception of moderate density. The combination of these elements creates a more spacious and airy atmosphere.

Variables such as the number of people and automobiles, as well as the levels of activity, are scaled moderately in environments with moderate population density.

These regions may feature a mixture of land uses, but they may not necessarily reflect the urban context's density. Compared to high-density areas, the level of activity is lower, and the atmosphere and pace may resemble those of a suburban setting.

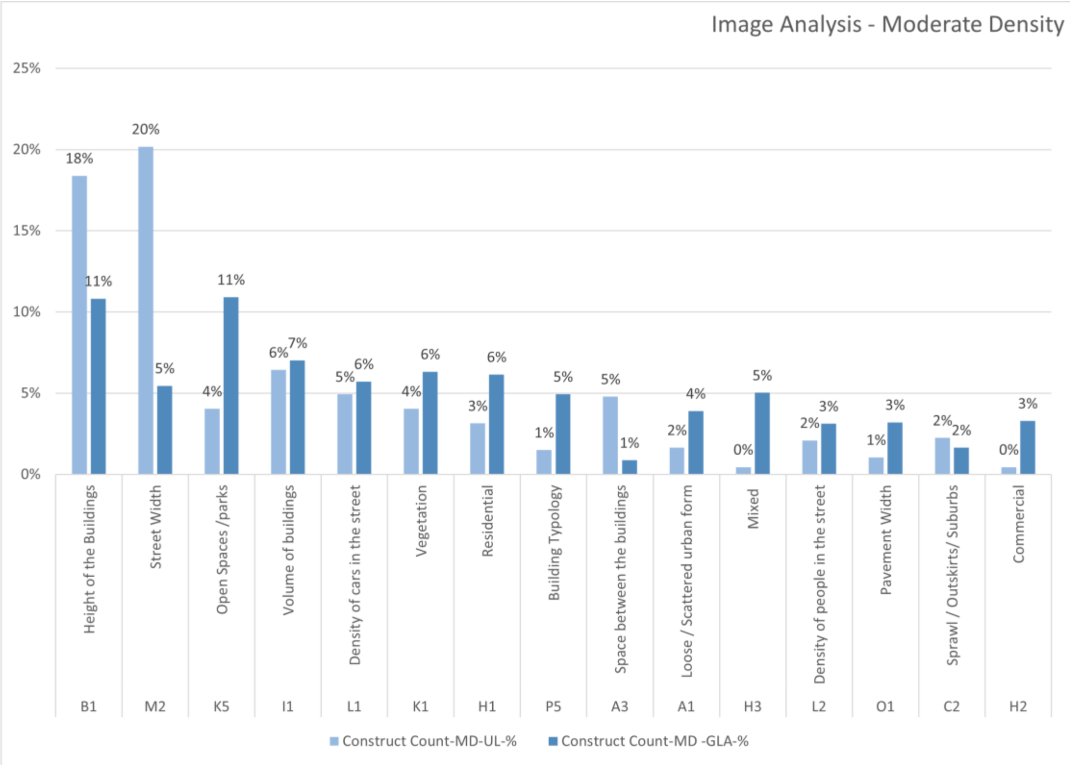


Figure 5-13. Image descriptions – frequency analysis – moderate density– for GLA and UI

Overall, moderate density areas strike a balance between the built environment and open spaces. By incorporating open areas, reflecting a scattered urban form, and ensuring a moderate scale of activities, these environments offer a perception of density that is more relaxed and spacious compared to high-density areas.

5.1.16 Low Density

Numerous factors contribute to the perception of a spacious and less crowded environment, which is indicative of low density. In addition to open spaces, low density areas frequently feature undeveloped land, front setbacks, and designated parking areas. These elements create a sense of physical separation and distance between buildings, thereby enhancing the perception of a lower population density.

Low density areas are distinguished by their lack of vehicular traffic and low levels of activity. This is frequently observed in residential settings where the emphasis is on providing a peaceful and tranquil atmosphere. The lack of heavy traffic and reduced activity levels contribute to a quieter and less bustling environment, which reinforces the perception of a lower population density.

Another characteristic of low density areas is their loose or scattered urban form. The buildings are more dispersed, creating a sense of space between them. This dispersed arrangement of the built environment contributes further to the perception of a lower population density.

The presence of vegetation, trees, and greenery is crucial to the perception of low population density. The presence of green elements creates visual breaks and improves the overall aesthetic appeal. Additionally, the presence of parked cars along the streets contributes to the impression of a lower population density by suggesting a more relaxed and less congested atmosphere.

Additionally, lower building heights in low-density areas contribute to the perception of openness and spaciousness. By avoiding tall structures, the visual impact of the built environment is reduced, and the atmosphere feels more open and less congested.

The perception of low density is influenced by a number of factors, including the presence of open spaces, vacant land, front setbacks, and dedicated parking. The absence of heavy traffic and reduced activity levels, combined with a loose urban form and lower building heights, further contribute to the impression of spaciousness and tranquilly. Additionally, the presence of vegetation, trees, and parked cars along the streets contributes to the perception of a lower population density in these areas.

These constructs are indicators of density that are measurable and objective. The constructs such as street width, the height of buildings, the density of cars and people and vegetation have a considerable visual impact and coincide with the image analysis presented in Figures 5 -16 to 19. Further analysis of the images can assist in determining the threshold for each indicator and a system of measurement can be derived. Based on the results of this survey and the image analysis, a visual assessment framework is proposed in Chapter 6. These results assist in deriving a visual assessment index with a scoring system, where the weights can be assigned to each indicator based on the importance of the construct.

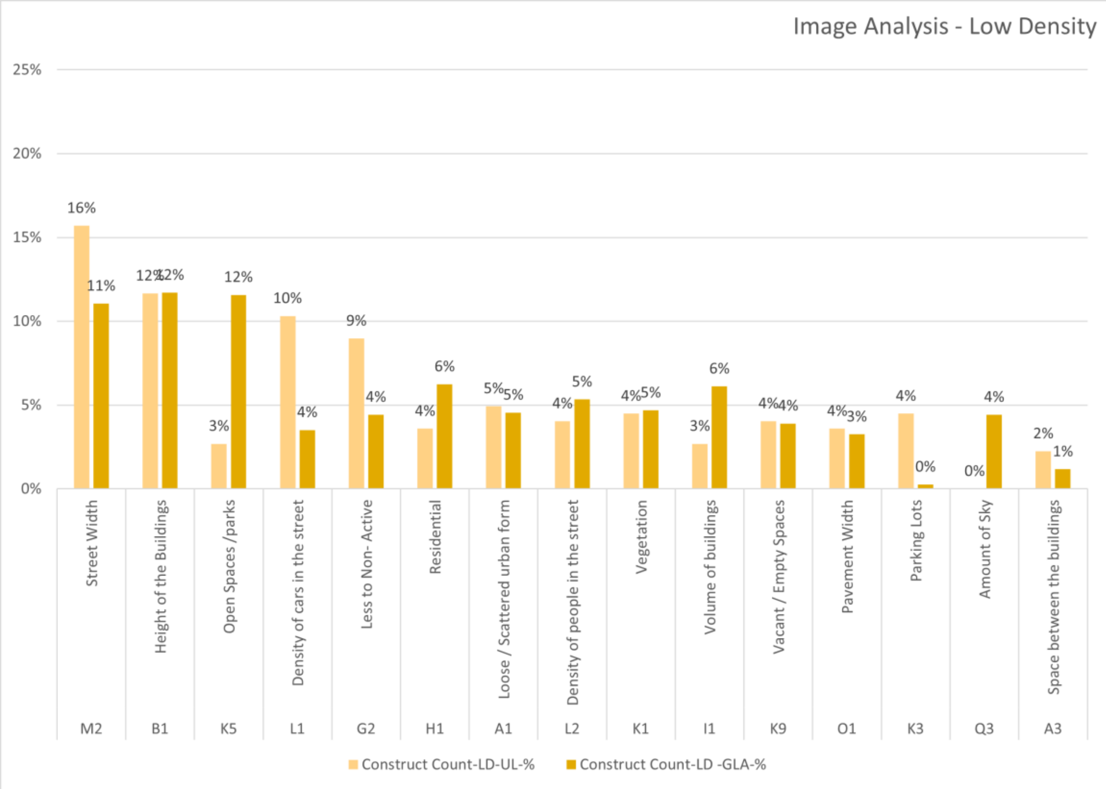


Figure 5-14. Image descriptions – frequency analysis – low density – for GLA and UI

Figure 5-14. HD – Triad – Glasgow – Image Segmentation

Figure 5-15. MD – Triad – Glasgow – Image Segmentation

Figure 5-16. LD – Triad – Glasgow – Image Segmentation

Universal Illustrations - HD - TRIAD = 32 Occurrences in MST

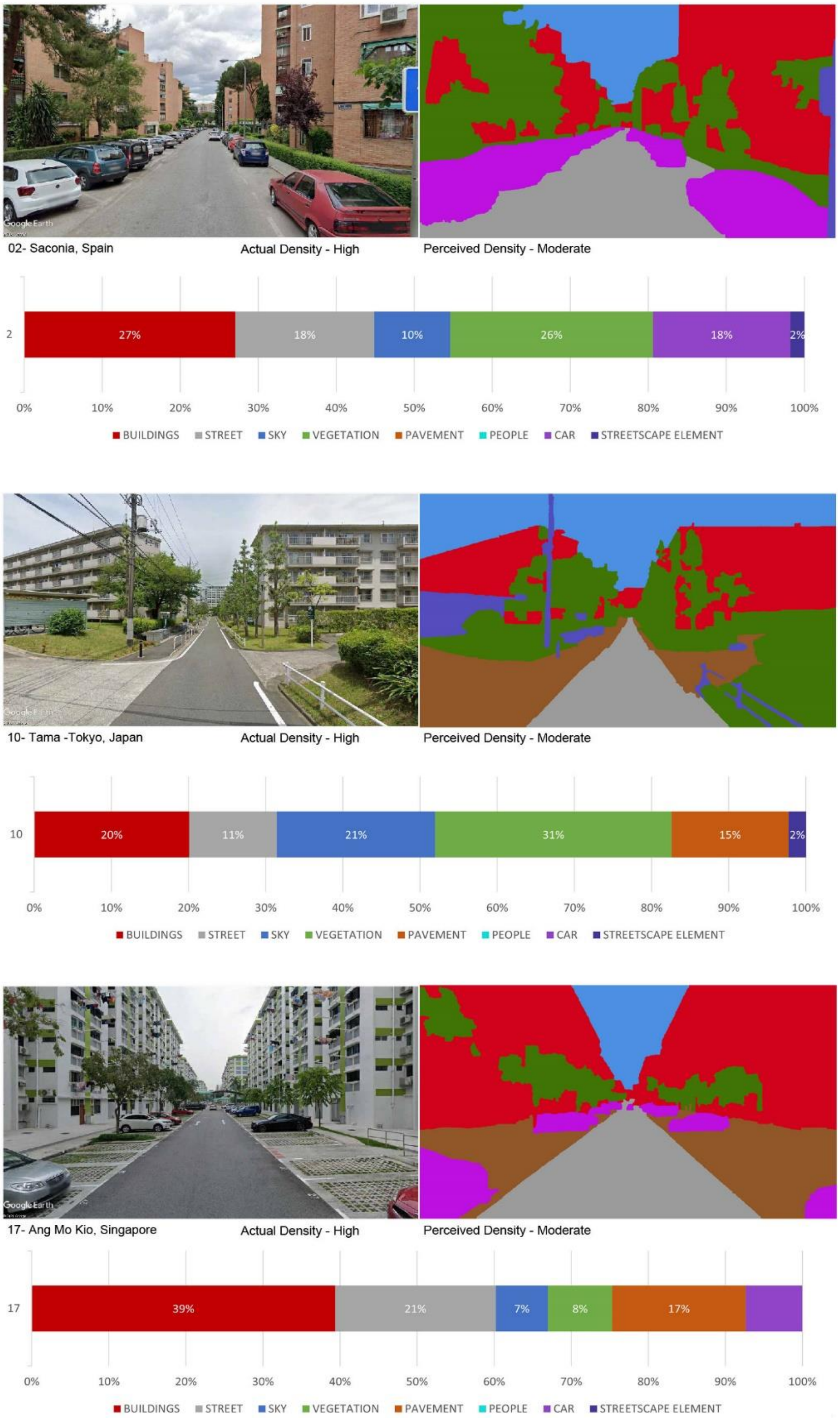


Figure 5-17. HD – Triad – Universal Illustrations – Image Segmentation
(Images from Google Street View ©2023 Google)

5.1.17 Validating the constructs

The validation of constructs was a crucial step in the research process, as it ensured the accuracy and reliability of the classification. One approach to validating the constructs involved developing clear definitions for each category. By providing precise and comprehensive definitions, this research established a common understanding of the constructs, thereby minimizing the risk of misclassification and enhancing consistency for coding. These clear definitions served as a guiding framework for coding the raw data during the data analysis phase.

The evaluation of constructs through the literature review validated the classification of identified constructs by demonstrating their alignment with existing frameworks and research on urban perception and streetscape qualities. By comparing the identified constructs with concepts such as contextual compatibility (Groat, 1985) , perceptual qualities (Clemente *et al.*, 2005; Ewing *et al.*, 2016; Boeing, 2018), urban form aesthetics (Nasar, 1989b; Gjerde, 2010), and visual complexity (Boeing, 2018), along with Rapoport's framework, the study ensured that the constructs were relevant and applicable to the study of density perception in urban environments (see Figure.8-1).

35 design features were mentioned that showed similarity with findings from work on contextual compatibility conducted at a pedestrian scale in residential settings were reviewed. Of these 35, 8 design features that can be perceived by people visually and can create a visual impact– the height of the buildings, the link between old and new buildings, space between the buildings, small-scale site elements (streetscape elements), style, material, texture and colour of the buildings (Groat, 1985) – were identified in the MST. These corresponded with Rapoport's framework of cues.

Second, the perceptual qualities framework to assess the human perception of the physical features of the built environment and walking behaviour was examined (Ewing *et al.*, 2016). Eight physical characteristics and two perceptual qualities were considered. Of these seven features – the height of the building, tree canopy, number of people, transparency (visual permeability), street width, pavement width, enclosure and weather (environmental quality) (Ewing *et al.*, 2016) – were identified in the MST.

Third, built-form characteristics (Gjerde, 2010) and literature on perception, cognition and evaluation of urban spaces and urban form aesthetics (Nasar, 1989) were examined. Twenty-two physical features of the built form that reflect complexity, order, scale, imageability and human scale – were considered. Seven of them – solid/void balance, proximity, landscape elements, permeability, density, enclosure and light and shade (environmental quality) – were identified.

The literature on the interpretations of visual complexity (Boeing, 2018) as a function of disorder that can influence human perception was reviewed. Twelve factors under the dimensions of temporal, visual, spatial and scaling were considered for the study connected to complexity. Seven – tree canopies, signage, building façades, unity in variety, land use, human activity and sunlight patterns – were identified. Out of the 63 constructs identified, 20 constructs were from the literature review and 43 were newly identified through the surveys. The factors and design features identified by reviewing four frameworks, overlap with one another (common factors or shared characteristics) were merged and represented as 1 construct. This task assisted in compiling a list of constructs that influence the perception of density, however not all the factors are critical (common factors for high, moderate and low density). The critical 20 constructs associated with high, moderate and low density were identified and recommended for future studies on the perception of density.

By organising these validated constructs within Rapoport's (1975c) framework of visual cues (see- Table 8-1), this study established a systematic and comprehensive method for understanding density perception. This alignment with established frameworks and concepts enhanced the constructs' credibility and reliability, ensuring that they effectively capture the qualitative and experiential aspects of density perception. Overall, the evaluation of constructs through a review of the literature provided a solid validation of the classification and demonstrated the framework's ability to comprehend the complex nature of perceived density.

5.1.18 Contribution of Urban Form Elements in the Perception of Density

The 65 constructs identified as unique labels and the constructs that represented the three degrees of density using image descriptions were further categorised to identify the contribution of urban form elements in the perception of density. These constructs are represented in comparison for GLA and UI by Figures 5-7 and 5-8 for triads and image descriptions. The categories classified under urban form elements can be measured, determined and controlled by the designers or planners, whereas the other category represents the constructs that are dependent on or are a response to an action or by virtue of some elements. The contribution of urban form elements in the perception of density makes up an average of 70 per cent in both cases. This percentage might vary depending on the context, location and time when the images were taken.

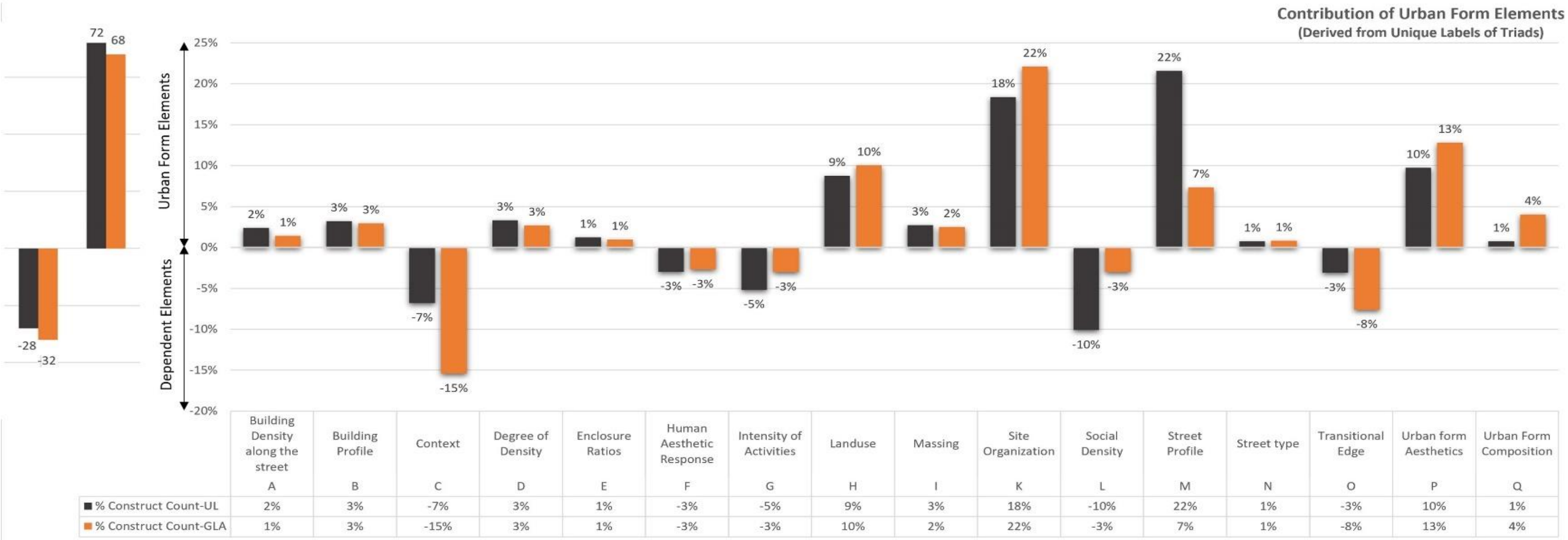
The frequency count suggests that the most common constructs identified are street profile, site organisation and building profile. The street profile includes street width and building profile includes building height. Both these constructs occupy a larger area than other components such as people, vegetation, cars and streetscape, not only while analysing the images, but also in real life. The buildings and the street feel overwhelming from a pedestrian point of view (Flachsbart, 1979; Zacharias and Stamps, 2004). The street profile and building profile can work together to create a cohesive and visually appealing urban environment. For example, a well-designed street profile with varied building heights and styles can create a dynamic and interesting visual experience, while a poorly designed street profile with monotonous buildings can be visually unappealing and uninviting. Therefore, these two constructs could have a considerable visual impact on human perception.

Site organisation has the second-highest frequency count. The most common constructs within site organisation are presence or absence of opens spaces or parks and vegetation. Both can create a visual impact. The presence of open spaces adds to the feeling of spaciousness and the colour green which is in contrast with all the other elements of the other environment (Lilli, 2013). The presence of trees or vegetation along the streets adds a layer of three-dimensionality and the colour green gets noticed easily, again adding to the visual impact. The presence of open spaces such as parks, plazas and squares can also create a feeling of spaciousness and openness and provide opportunities for social interaction and recreation. They can also serve as visual landmarks within a cityscape, helping to break up the monotony. Vegetation can also be used to soften the hard edges of buildings and streets, creating a more welcoming and inviting urban environment (Aiden et al., 1988; Lilli, 2013).

The next categories of constructs are that of land and building use, urban form aesthetics and context, the land use allocated to a block or urban area dictates the building use, while building use, location and context govern building typology and style (Cheng, 2010b). Urban form aesthetics refers to the visual appearance and design of the built environment in an urban area. This includes the arrangement of buildings, the size and scale of the buildings and the materials and colours used in their construction. Similar builds stand out because of repetition and diverse built forms can be the focal point or point of interest. All of these constructs define the street character which affects the imageability and memorability of the area.

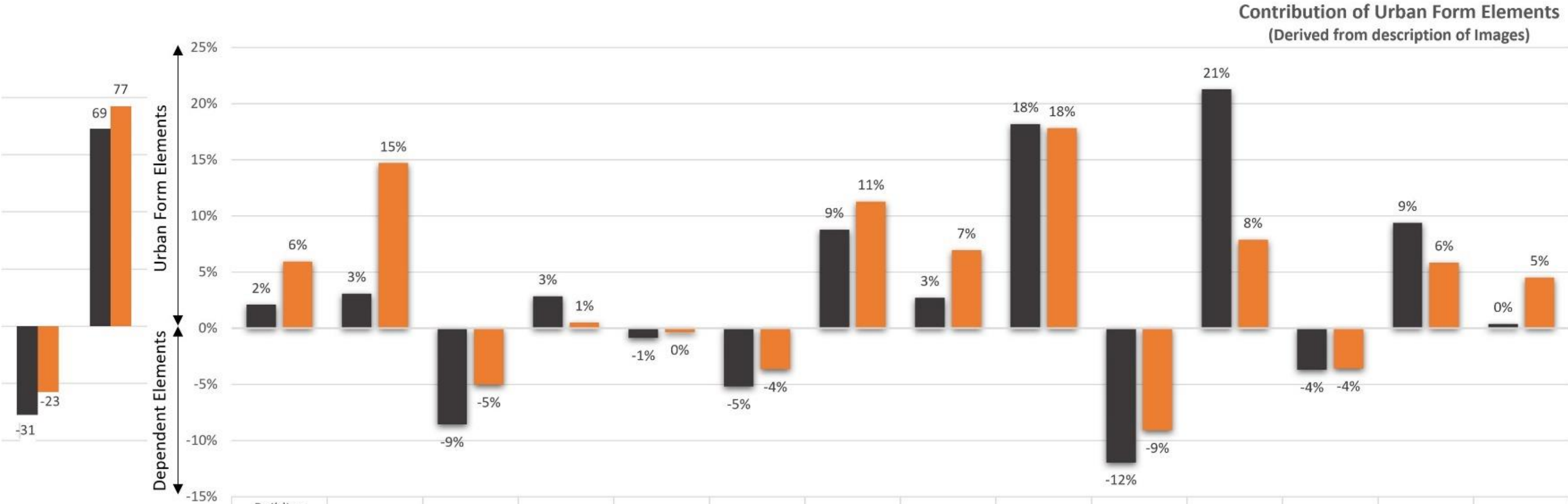
The building density along the street, whether compact or spacious, depends on the presence of open spaces. Urban form composition refers to how different elements of the urban environment such as buildings, streets and public spaces are arranged and combined to create a cohesive whole. The urban form composition reflects the visual experience of the urban environment and is usually described as balanced or unbalanced, symmetrical or asymmetrical, visually appealing or non-appealing by virtue of the presence of buildings on one side and openness on the other.

Social density covers the variables such as people and cars and their density in the street. They are temporal and hence the cityscape changes continuously. But they are an integral part of the experience and their presence and density cannot be controlled. The presence of a large number of people and cars can also create a sense of vibrancy and energy or one of chaos and congestion. Thus, they have a role to play in the visual perception of the urban environment.



	Building Density along the street	Building Profile	Context	Degree of Density	Enclosure Ratios	Human Aesthetic Response	Intensity of Activities	Landuse	Massing	Site Organization	Social Density	Street Profile	Street type	Transitional Edge	Urban form Aesthetics	Urban Form Composition
	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q
% Construct Count-UL	2%	3%	-7%	3%	1%	-3%	-5%	9%	3%	18%	-10%	22%	1%	-3%	10%	1%
% Construct Count-GLA	1%	3%	-15%	3%	1%	-3%	-3%	10%	2%	22%	-3%	7%	1%	-8%	13%	4%

Figure 5-18. Contribution of urban form derived from the unique labels of triads



	Building Density along the street	Building Profile	Context	Degree of Density	Human Aesthetic Response	Intensity of Activities	Landuse	Massing	Site Organization	Social Density	Street Profile	Transitional Edge	Urban form Aesthetics	Urban Form Composition
	A	B	C	D	F	G	H	I	K	L	M	O	P	Q
% Construct Count-UL	2%	3%	-9%	3%	-1%	-5%	9%	3%	18%	-12%	21%	-4%	9%	0%
% Construct Count-GLA	6%	15%	-5%	1%	0%	-4%	11%	7%	18%	-9%	8%	-4%	6%	5%

Figure 5-19. Contribution of urban form derived from image descriptions

There is no specific ratio of built form to the other elements of the urban environment. Typically, urban design principles focus on achieving a balance between the built environment, nature and social encounters. This involves designing human-scale environments that are walkable, accessible and visually appealing with diverse activities and amenities. Therefore, the percentage derived from this comparison cannot be viewed as higher or lower. However, this exercise proves that most of the factors associated with human perception belong to the physical environment and that change in one construct might lead to the variation in visual composition and affect the function of the area and thus social encounters, thus identifying the need for correlation analysis.

Quantifiable and nonquantifiable factors also contribute to the character and quality of the urban environment. When attempting to develop a lively, liveable and sustainable city, it is important to include both quantitative and non-quantitative components.

5.2 Survey 2 – SJT

SJTs assist in evaluating the response of a participant to different scenarios Click or tap here to enter text. In this study, SJT assisted in assessing individuals' emotional responses to a number of real-world urban density situations represented by images. The SJT designed as the second survey was as an assessment strategy that interprets the qualitative value (positive or negative) based on human emotional responses. This design of this task considers that people perceive urban environments differently owing to personal and cultural differences. It also considers that the same density can be represented in different urban forms based on the designer's interpretation of building guidelines and hence can influence emotional response.

The intent of this survey was:

1. To identify the value (positive or negative) associated with urban environments and identify the constructs associated with it.
2. To verify that the constructs of the urban environment determined by people in the first survey influence the quality of the urban environment and in turn the human perception of density.

The first survey identified the list of constructs influencing the perception of density and those constructs corresponding with low, moderate and high density. But low, moderate or high density is a quantitative classification system that categorises something based on a scale or range of values or its intensity. It does not state the qualitative value, whether positive or negative, associated with urban environments where a high intensity feeling can be positive or negative depending on the specific emotion being experienced. However, in urban environments, it is difficult to determine directly the value associated with the perceived density. The results of the first survey suggest that the percentage of human emotions recorded as constructs are fewer when compared to the urban form factors. Hence it is important to understand which of the urban environs are perceived as positive or negative and why.

5.2.1 Design of the SJT

5.2.1.1 Step1 – Role Analysis and Test Specification

Role analysis is the first step to ensure the competent performance of the participants while evaluating it. A typical role analysis includes collecting and analysing role-related information such as responsibilities, tasks, knowledge, skills and abilities relevant to any given role. For this study, the most important quality considered was the cognitive ability of an individual to distinguish and judge real-life scenarios based on individual and cultural differences and preferences. Role analysis includes conducting interviews with participants to understand challenging and salient information that is likely to occur. However, this step was skipped in this study since the relevant information required to conduct this survey had already been gathered by the first survey.

Role analysis is followed by determining the test specification. This includes a description of the actual test content of the SJT, the types of items and the response format (multiple choice, rank order or rating). The SJT for evaluating the urban environment includes (1) images that represent different urban environs with varying levels of density; (2) three bipolar constructs that assist in recording the emotional response to the urban environs; (3) a multiple choice question that determines the constructs justifying the selection of emotional response; and (4) a

Likert scale question to understand the frequency of visits to the selected urban environs.

A total of 16 images were selected for this task drawn from the GLA and UI sets in which the images had been perceived differently from their actual objective density. They not only represented different levels of density but also had a different visual composition that assisted in identifying the different constructs associated with the particular urban environment. Using images perceived by people to represent a certain degree of density rather than relying on the objective number ensures integration of user perspective.

The use of bipolar constructs ensured the psychometric quality of the task. The bipolar constructs were derived from the personal construct theory (Kelly, 2017) which states that all human thinking is dichotomous in nature. These constructs employed here are polar opposites that assist participants in making sense of the situation or interpreting the scenarios. In this case, the opposites are emotional responses such as comfortable/overwhelming, cheerful/depressing and vibrant/dull. This is based on the principle that one cannot know something unless one knows what contrasts with it. In simple terms, there can be no good without an awareness of the bad.

The 13 options provided for this task were amongst the top 15 critical constructs identified in the first survey. These included physical attributes of the built form, the visual elements of the urban environment and the variables. They are a crucial part of the visual composition of the urban environs and consequently of visual perception. The Likert scale question was introduced to understand the duration or frequency of visits that one would like to make to urban environments. This response to this question was correlated to the bipolar construct in the first stage.

5.2.1.2 Step 2 – Item Development, Scoring Key and Initial Reviews

The test specification developed in the first step was discussed with 10 people, including a supervisor, who was familiar with the purpose of the survey. This was done to ensure that the scenarios developed were realistic, appropriate and plausible. The scenarios were presented in the form of images. It was agreed that one cannot make an informed decision by just looking at the image once. Hence each question was accompanied by an image to ease the burden on the participant and to facilitate the effective and quick generation of the response.

A discussion on the type of questions for the survey was initiated and critical incidents that might arise while answering the questions were identified. For instance, 14 choices were presented to the participants. Whether to allow them to select as many or to restrict it to the first three that are most relevant was decided. Deciding to use a 5-point Likert scale to understand the frequency of visitation to a certain urban environment was also a part of the discussion. A thorough systematic review was undertaken to ensure each element used to design the survey was fair, relevant and realistic. The scoring pattern informed the methods of analysis. Hence deliberating on how the responses will be measured was an important step.

Selection of the 13 Constructs for Multiple Choice

The 13 constructs provided for MCQs as justifications were derived from the top 20 constructs deduced from the MST. These constructs were ranked based on the frequency count and assigned weights based on their ranking. This approach assumes that the constructs that are ranked higher are more important in the evaluation. Each construct weights 1/13th or approximately 0.08 and then is multiplied by the corresponding rank.

Table 5-8. Ranking and weights table for top 13 constructs

Features	Ranking	Weights
Enclosures created by buildings	3	0.33
Number of buildings	4	0.25
Building heights	1	1.00
Similarity of the built form	9	0.11
Variety of built form	9	0.11
Building use (residential, commercial, mixed)	6	0.17
Building-to-sky ratio	11	0.09
Activities along the street	12	0.08
Number of cars	5	0.20
Number of people	8	0.13
Street width	2	0.50
Pavement width	10	0.10
Amount of vegetation	7	0.14

5.2.1.3 Step 3 – Test Construction

Qualtrics was chosen to construct the survey. It was designed to be computer and mobile-friendly and the ability to access it on a phone facilitated a greater number of responses.

5.2.1.4 Step 4 – Piloting

After constructing the SJT, the next step was piloting to ensure that the design was fair and measured what was intended to be measured; that is that it had construct validity. The design was circulated to 10 people to identify if there were any performance issues such as order effects. Three performance issues were raised and the design of the SJT was modified accordingly.

1. The choice of constructs may be influenced by the order in which the options are presented in an MCQ. The options presented near the beginning and end of a list are most likely to be chosen due to primacy and regency effect (Practical Psychology, 2022). The primacy effect refers to the tendency to select the first seemingly satisfactory option a respondent sees, whereas the regency effect describes how the last or most seen option in a list is freshest in the mind. To prevent this effect, the constructs for the MCQs were shuffled.

2. Other performance issues may arise due to current mood or emotional state bias. A participant's emotional state will affect the response to the survey. If someone is rushed, tired or apathetic they are unlikely to begin the survey in the first place. Therefore, the survey was designed as a simple interactive task which could be taken on mobile phones whenever convenient for them.

3. If the participants become aware of the researcher's aims and objectives, they are more likely to change their responses, and this could influence the outcome. Hence, anonymity was maintained regarding the term density. The participants were asked to register their emotional response to the represented urban environments and later select the constructs that reflect the perceived density.

5.2.1.5 Step 6 – Psychometric Analysis and Quality Assurance

After the SJT has been piloted, a psychometric analysis of the pilot data was conducted. This stage enabled the examination of the reliability and validity of the test and that each step of SJT was performing well psychometrically. The responses registered were converted to charts to see if there were any patterns in the response selection and whether the selection justified the degree of density that the image represented.

5.2.1.6 Step 7 – Launching the Survey

After going through a series of revisions, the SJT was launched to gather public responses. The links to the survey were distributed to 150 people. The participants included the general public, architecture students and professionals between 18 and 65, the same as for the first survey.

5.2.2 Situation Judgement Task - Implementation

The SJT was designed to determine the quality (positive or negative) of the urban environments as perceived in the form of the images and was divided into three steps (see Figure 5-20). Some 16 images used for the task were presented to the participant with a set of 3 questions. These images represent high, moderate and low-density urban environments selected from GLA and UI.

Step 1. Observation and Description

Participants are presented with an image representing an urban environment with either high, moderate or low degree of density. Participants are instructed to carefully observe the image to form an impression of the urban environment. Participants are then asked to describe their experience in that environment using three bipolar constructs: comfortable/overwhelming, cheerful/depressing, and vibrant/dull.

Step 2. Selection of Relevant Choices

After describing their urban environment experience using the three bipolar constructs, participants are presented with 14 choices. Participants are required to select, for each of the three constructs (comfortable/overwhelming, cheerful/depressing, vibrant/dull), the three options that correspond most closely to their Step 1 description. If a participant selected "comfortable" as one of their descriptions, they would select three options that indicate the presence of elements typically found in "comfortable" environments. Similarly, if they selected "dull," they would select options that reflect the presence of elements typically found in "dull" environments. If a participant chose "neutral" for any construct, they are prompted to provide reasons for their selection using a text box.

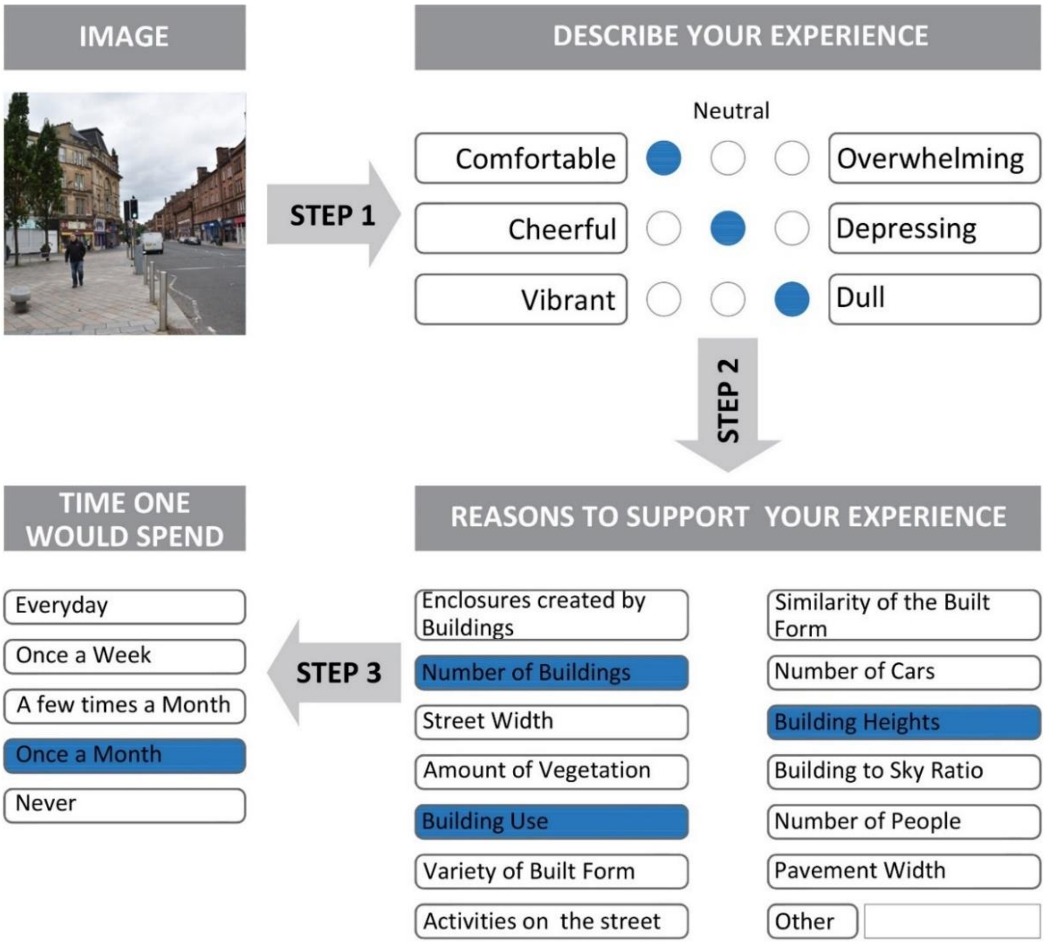


Figure 5-20. Abstract representation of the second survey- Situation Judgement Task

Step 3. Frequency of Visits

Participants are asked to select the number of times they would visit the urban environment depicted in the image. This question seeks to determine how frequently respondents would choose to visit or avoid such urban environments based on their previous descriptions and construct selections.

This procedure is repeated for each of the sixteen images, each of which represents a unique urban environment with varying density and visual characteristics. The objective is to ascertain the participants' perceptions and emotional responses to each of these environments, as well as their preferences regarding the frequency of their visits.

5.2.3 Results and Analysis

The task was answered by 82 participants of whom 54 were female and 26 male. One participant preferred not to disclose their gender. Some 50 were between 25 and 34 years, 16 were between 18 and 24 years and the remainder over 35. Forty-nine had a Master's degree, 14 had a Bachelor's degree and the other 28 were students, high school graduates or with professional or doctorates.

The 82 responses were assessed to derive two sets of information. The first set revealed the evaluation of the urban environment derived using bipolar constructs and the second was the set of constructs associated with a positive or negative perception. The first involved judging images as positive, neutral or negative based on the choice of the construct. Using the method of frequency count a value for each construct is determined and a bipolar construct profile for 16 images is created and is presented in the table below.

Of the 16 images, 9 were perceived as positive, 2 as neutral and the remaining 5 images negative (see Table 5-9). The constructs associated with the positive or negative evaluation of these urban environments are presented in the second set of information. Figures 5-28 and 29 show the positive and negative evaluations, respectively.

The features were analysed using two approaches. The first involved using frequency counts to measure the number of times a feature occurred in the judgement of images. The second employed weighting the 13 features based on their ranks to measure the significance of a construct in the survey. The values derived from the frequency counts and weights were plotted separately on the column chart. The features and weights associated with the positive (comfortable, cheerful, vibrant) and negative constructs (overwhelming, depressing, dull) were plotted on a dual-axis chart. The positive values are shown above the horizontal axis and negative values are shown below the horizontal axis.

Table 5-9. Bipolar construct profile

Image No	Positive Pole Comfortable/ Cheerful/ Vibrant	Neutral	Negative Pole Overwhelming/ Depressing/ Dull	Value
1	58	108	56	Neutral
2	105	45	13	Positive
3	53	57	24	Neutral
4	46	29	47	Negative
5	52	50	15	Positive
6	19	34	63	Negative
7	63	22	25	Positive
8	22	29	56	Negative
9	53	30	21	Positive
10	62	15	24	Positive
11	47	28	27	Positive
12	18	27	53	Negative
13	63	19	17	Positive
14	62	9	25	Positive
15	31	30	35	Negative
16	42	27	27	Positive

5.2.3.1 Approach 1

Frequency count is a simple way of understanding the distribution of features and identifying patterns and trends. The frequency count measured the number of times the features occurred in either positive or negative constructs.

Positive Perception

Images with a positive evaluation or judgement may suggest that the urban environment is desirable, successful and well-managed. Positive images may include modern, innovative and sustainable infrastructure, public spaces and amenities. A positive valuation may also suggest that the community is prosperous, inclusive and cohesive.

1 - Perceived Density : High
Value: Neutral

2- Perceived Density : Moderate
Value: Positive

3 - Perceived Density : Moderate
Value: Neutral

4- Perceived Density : High
Value: Negative

5 - Perceived Density : Moderate
Value: Positive

6- Perceived Density : Moderate
Value: Negative

7- Perceived Density : High
Value: Positive

8- Perceived Density : Moderate
Value: Negative

Figure 5-21. Perceived value of the urban environment (first 8 images)
(Images 2, 4 & 6 ©2023 Google)

9 - Perceived Density : Low
Value: Positive

10 - Perceived Density : High
Value: Positive

11 - Perceived Density : High
Value: Positive

12 - Perceived Density : Moderate
Value: Negative

13 - Perceived Density : Low
Value: Positive

14 - Perceived Density : High
Value: Positive

15 - Perceived Density : Low
Value: Negative

16 - Perceived Density : Moderate
Value: Positive

Figure 5-22. Perceived value of the urban environments (next 8 images)
(Images 9, 11, 14, 16 ©2023 Google)

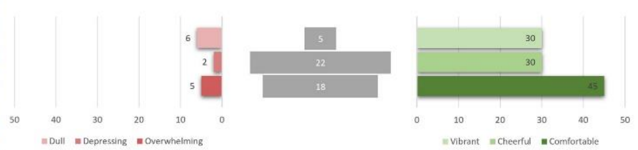
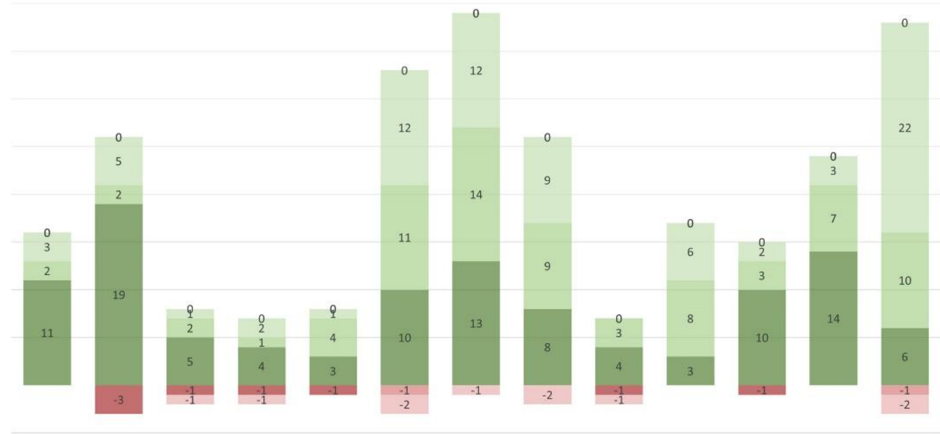


Image 2 - Positive

28- Manhattan, New York
Objective Density Extreme
Perceived Density Moderate

IMAGE 2_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	0	0	-1	-1	0	-2	-1	-2	-1	0	0	0	-2
Depressing	0	0	0	0	0	-1	0	0	0	0	0	0	-1
Overwhelming	0	-3	-1	-1	-1	0	0	0	-1	0	-1	0	0
Vibrant	3	5	1	2	1	12	12	9	0	6	2	3	22
Cheerful	2	2	2	1	4	11	14	9	3	8	3	7	10
Comfortable	11	19	5	4	3	10	13	8	4	3	10	14	6

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 2_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	16.00	13.00	2.67	1.75	1.60	5.50	5.57	3.25	2.67	1.50	2.18	3.17
N_WEIGHTAGE	0.00	-1.50	-0.67	-0.50	-0.20	-0.50	-0.14	-0.25	-0.22	-0.10	0.00	-0.25

Figure 5-23. Situation judgement task – example of positive evaluation
(Image 28 ©2023 Google)

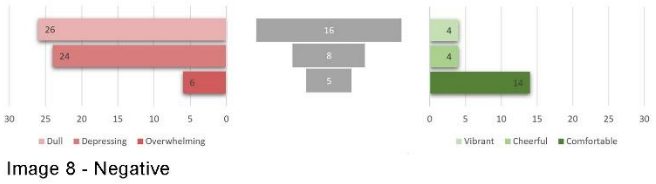
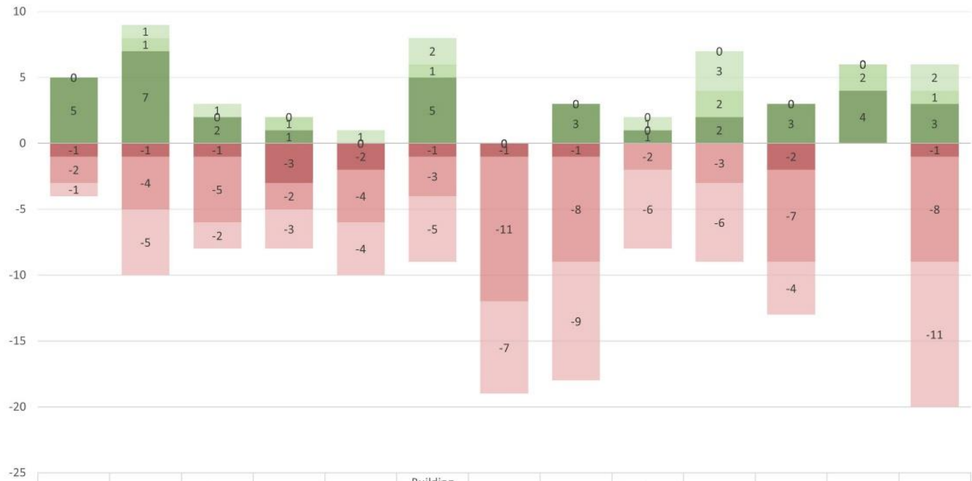


IMAGE 8_FREQUENCY COUNT



	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-1	-5	-2	-3	-4	-5	-7	-9	-6	-6	-4	0	-11
Depressing	-2	-4	-5	-2	-4	-3	-11	-8	-2	-3	-7	0	-8
Overwhelming	-1	-1	-1	-3	-2	-1	-1	-1	0	0	-2	0	-1
Vibrant	0	1	1	0	1	2	0	0	1	3	0	0	2
Cheerful	0	1	0	1	0	1	0	0	0	2	0	2	1
Comfortable	5	7	2	1	0	5	0	3	1	2	3	4	3

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 8_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	5.00	4.50	1.00	0.50	0.20	1.33	0.00	0.38	1.00	0.30	0.55	0.50
N_WEIGHTAGE	-4.00	-5.00	-2.67	-2.00	-2.00	-1.50	-2.71	-2.25	-1.89	-1.30	0.00	-1.67

Figure 5-24. Situation judgement task – example of negative evaluation

The features associated with positive (comfortable, cheerful, vibrant) urban environs were:

1. **Activities along the street**. The presence of diverse and interesting activities along the street such as street performances, outdoor dining or shopping can create a lively and engaging atmosphere that is conducive to social interaction and community building.

2. **Amount of vegetation**. The presence of vegetation such as trees, plants and flowers can enhance the aesthetic appeal of urban spaces and contribute to a sense of tranquillity and relaxation.

3. **Building use**. The way that buildings are used can have a substantial bearing on the overall character of urban spaces. Buildings that are well-maintained and used for a variety of purposes such as housing, retail and offices can create a dynamic and diverse urban environment.

4. **Building-to-sky ratio**. The ratio of building height to the open sky can affect the perception of urban spaces. A balance between tall buildings and open sky can create a visually interesting and dynamic environment, while too many tall buildings can create a sense of oppression and claustrophobia.

5. **Number of people**. The presence of people in urban spaces is essential to creating a sense of vitality and community. Crowded spaces can create a sense of energy and excitement, while too few people can create a sense of emptiness and isolation.

6. **Street width**. The width of streets can affect the overall character of urban spaces. Narrow streets can create a sense of proximity and security, while wider streets can create a sense of spaciousness and grandness.

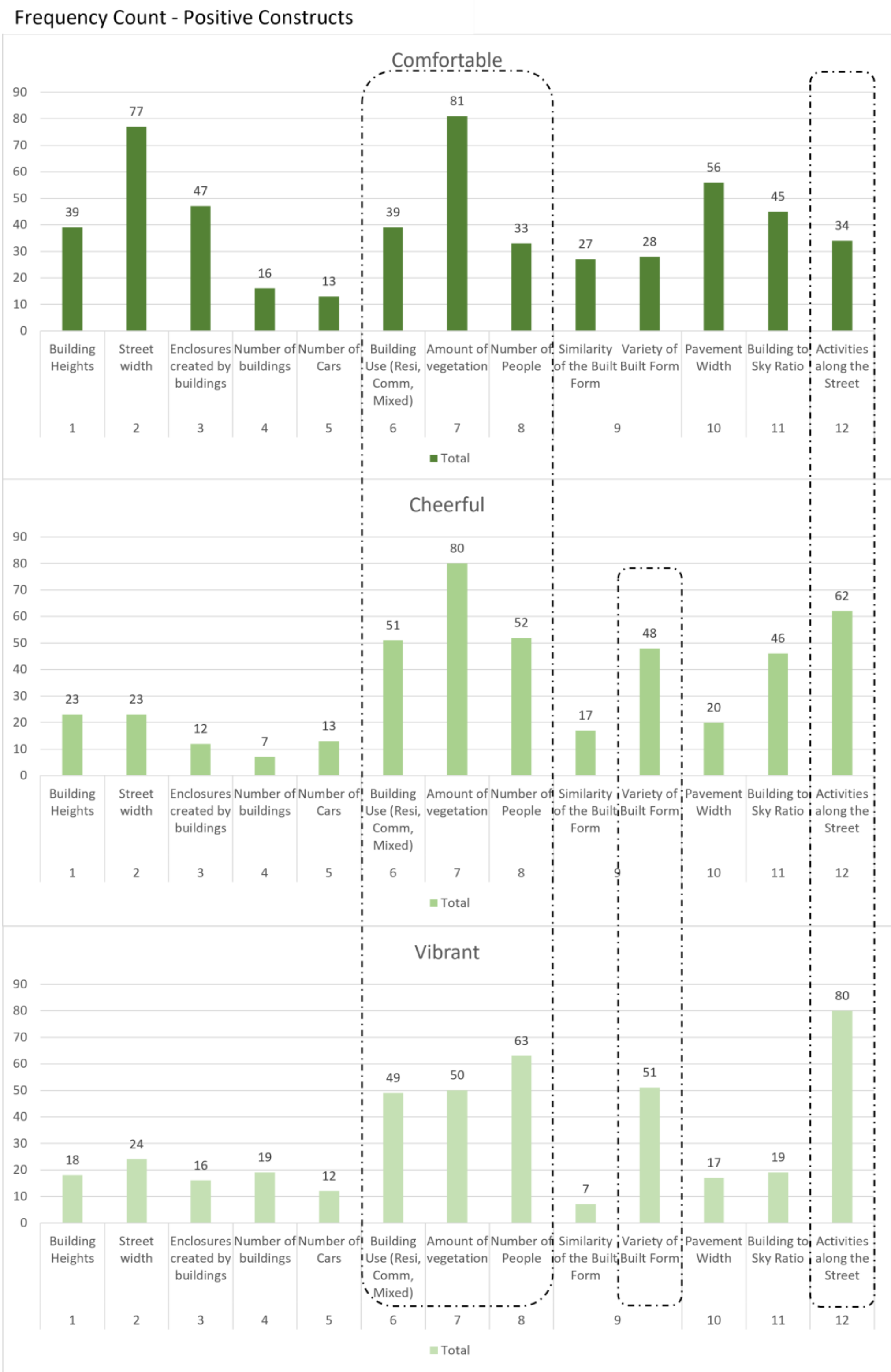


Figure 5-25. Frequency analysis of positive constructs

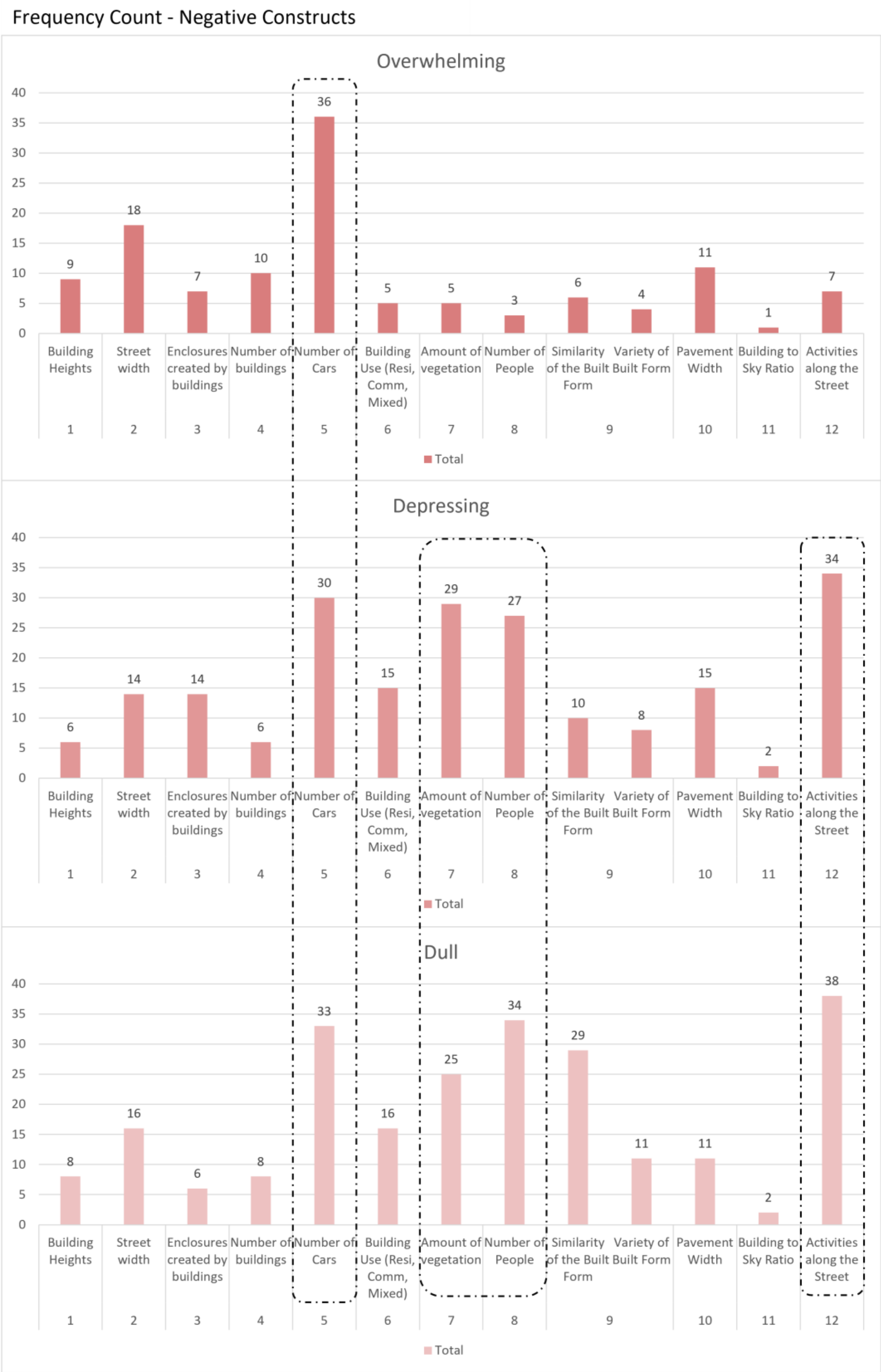


Figure 5-26. Frequency analysis of negative constructs

Negative Perception

Images with a negative analysis may suggest that the urban environment is visually unappealing, unsafe or unpleasant to be in. Negative images may include dilapidated buildings, rubbish, pollution, graffiti and crime. A negative analysis may also suggest that the community is disengaged, marginalised or struggling.

Overwhelming, depressing and dull urban environs were characterised by the following factors:

1. **A high number of cars**. The presence of a high number of cars and traffic congestion can create a noisy and polluted environment that is unpleasant and unsafe for pedestrians and cyclists.
2. **Lack of people**. The absence of people in urban spaces can create a sense of emptiness and isolation, which can be especially pronounced in areas that are designed primarily for car traffic.
3. **Lack of activities and vegetation**. The absence of diverse and interesting activities and a lack of vegetation can create an unappealing and uninviting urban environment that is lacking in colour, texture and visual interest.
4. **Similarity of built form**. The uniformity and monotony of the built form such as the prevalence of repetitive and indistinguishable buildings can create a sense of monotony and dullness that is unappealing and uninspiring.

Neutral

All 16 images received at least one neutral judgement but 2 were perceived as neutral by the majority of participants. The selection of neutral suggests that the respondents found the images neither appealing nor unappealing and hence the respondents have registered an objective evaluation. The neutral evaluation also suggests that judgement of the urban environment can be influenced by factors other than the 13 presented for multiple choice. Hence, participants were allowed to enter their text descriptions as the reasons for neutral judgement. These descriptions were analysed using the content analysis method and the number of constructs responsible for neutral judgement.

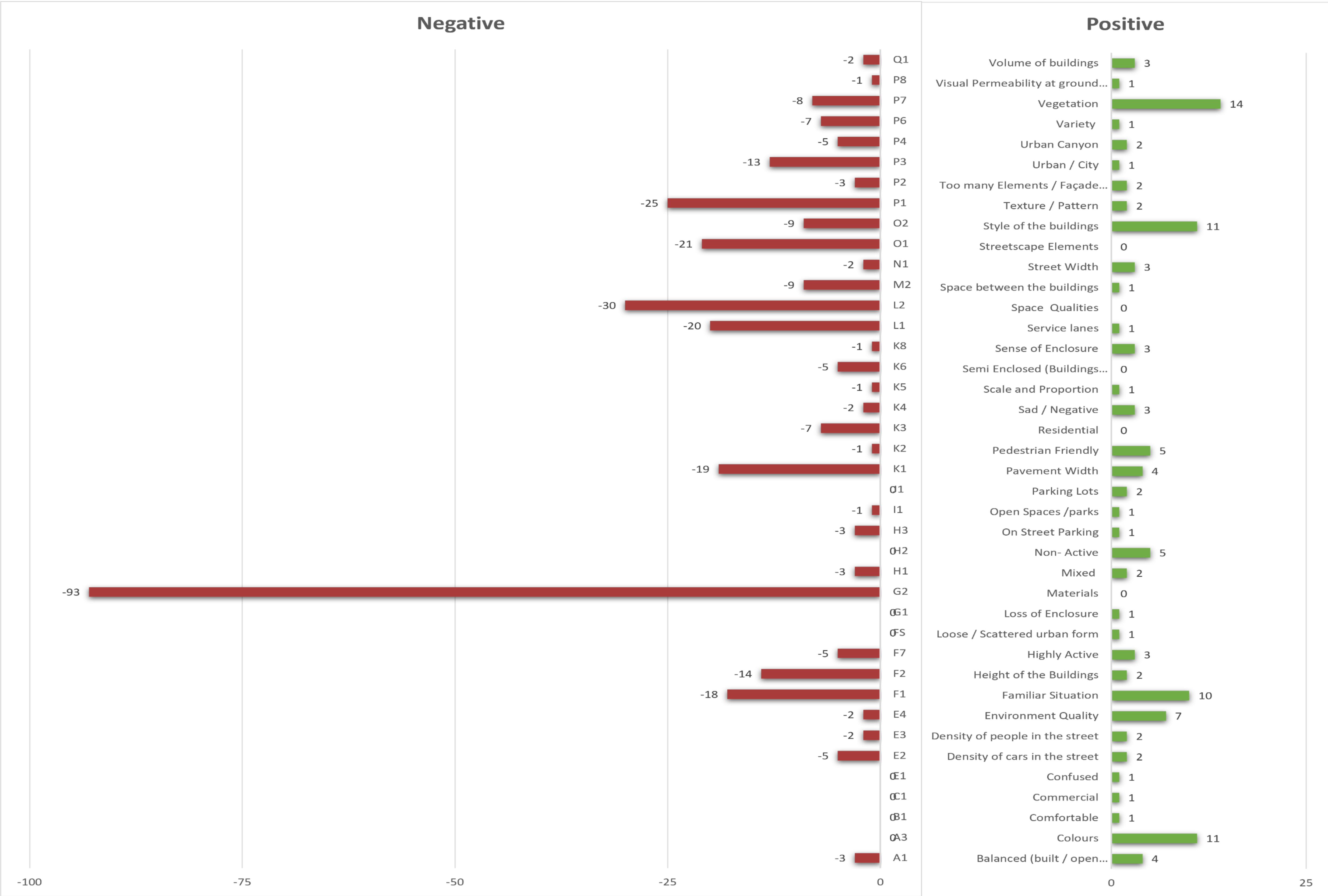


Figure 5-27. Constructs associated with neutral judgement

Around 40 constructs associated with neutral judgement were identified. Those mentioning the lack of a construct were plotted on the left side as negative and those describing the presence of constructs were plotted on the right side as positive (see Figure 5-32). Despite this exercise, no definite explanation for the neutral evaluation could be drawn.

5.2.3.2 Approach 2

The weighting approach allowed the assignment of numerical values to establish the relative importance of the 13 features used in this survey. This approach helped in estimating the effect impact of the features that were identified by people to have a significant influence on the perception of density. The features were derived from the content analysis and frequency analysis of the data from the MST survey. Two pointers that explain the rationale for weighting are as below:

1. **Statistical Analysis**. The weighting for these 13 descriptions was based on the frequency analysis. The frequency of each feature was calculated and weights were assigned based on the relative frequency of each feature.

2. **Prior Research**. Some of the 13 descriptions such as the height of the building, the number of people or visible sky were found in previous studies to influence the perception of density. Hence the weighting allocation considers the findings of the prior studies to verify the weighting allocation for this study using the frequency analysis.

The determination of the constructs that influence the perception of density was not enough; it was also important to determine the effect of the most influential.

1. **Relative importance**. The occurrence of the same constructs and their higher frequency in the MST in triads and image descriptions established their relative importance in the perception of urban environments and density and this assisted in focusing on those aspects that were the most significant.

2. **Trend analysis**. The weighting allocation facilitated the trend analysis by providing a more accurate measure of the features that have a greater effect on positive and negative perceptions of the urban environment. The

weighting charts show the change in the magnitude of 13 descriptions for positive and negative evaluations.

5.2.3.3 Results of Weighting Analysis

The results of the weighting analysis for positively perceived urban environments suggest that building height, street width, building use and amount of vegetation have higher weights. This means that these features are perceived to be more important or influential in shaping positive perceptions of urban environments.

1. Building height is an important feature since it has the potential to influence the visual aesthetics of the urban environment. Tall buildings can provide striking visual features that can enhance the overall attractiveness of an urban landscape.

2. Street width is also an important feature since it can affect the experience of pedestrians and drivers. Wider streets can provide a more spacious and comfortable environment for pedestrians, while also allowing for greater flexibility in terms of vehicular traffic.

3. Building use or land use is another important feature because it can influence the overall function and vibrancy of an urban area. Buildings that are used for commercial or cultural purposes can create a more dynamic and interesting environment that can attract people and create a sense of community.

4. Finally, the amount of vegetation is an important variable because it can enhance the aesthetic quality and liveability of the urban environment. Vegetation can provide shade, improve air quality and create a more natural and pleasant environment for people to enjoy.

The results of the weighting analysis for negatively perceived urban environments suggest that building height, street width, number of cars and people and amount of vegetation are more significant. Building height is a significant factor in urban environments. High-rise buildings may create a feeling of being boxed in and can be oppressive, which can contribute to a negative perception of the environment. Taller buildings may also block natural light, which can affect the environmental quality and perceived liveability of an area. Street width can affect the perception of the urban environment. Narrow streets can create a feeling of congestion which can contribute to a sense of being boxed in and a lack of space. Narrow streets can also be difficult to navigate, contributing to a negative perception of the area. Wider streets with low building heights on either side might result in the loss of enclosure.

The number of cars on the road can affect the perceived quality of the environment. Cars can contribute to the tempo and pace of the area, which can affect its liveability. High traffic volumes can also contribute to a sense of congestion and frustration, which can contribute to a negative perception of the environment.

The amount of vegetation in an urban environment can also play a role in the perceived quality of the area. A lack of green space can make the built form feel more overpowering and a lack of natural beauty.

Finally, the number of people in an area can affect the perceived quality of the environment. A high number of people can result in overcrowding which can lead to a lack of privacy and social space, whereas a low number might make the area feel deserted and also affect the sense of safety which can contribute to a negative perception of the environment.

Overall, both frequency analysis and weighting analysis can assist in providing valuable insights for designing urban environments with a particular density and a positive perception. Frequency analysis assisted in identifying the most visually dominant features and their association with positive or negative evaluation and the weighting analysis helped in determining the most significant features associated with people’s perceptions.

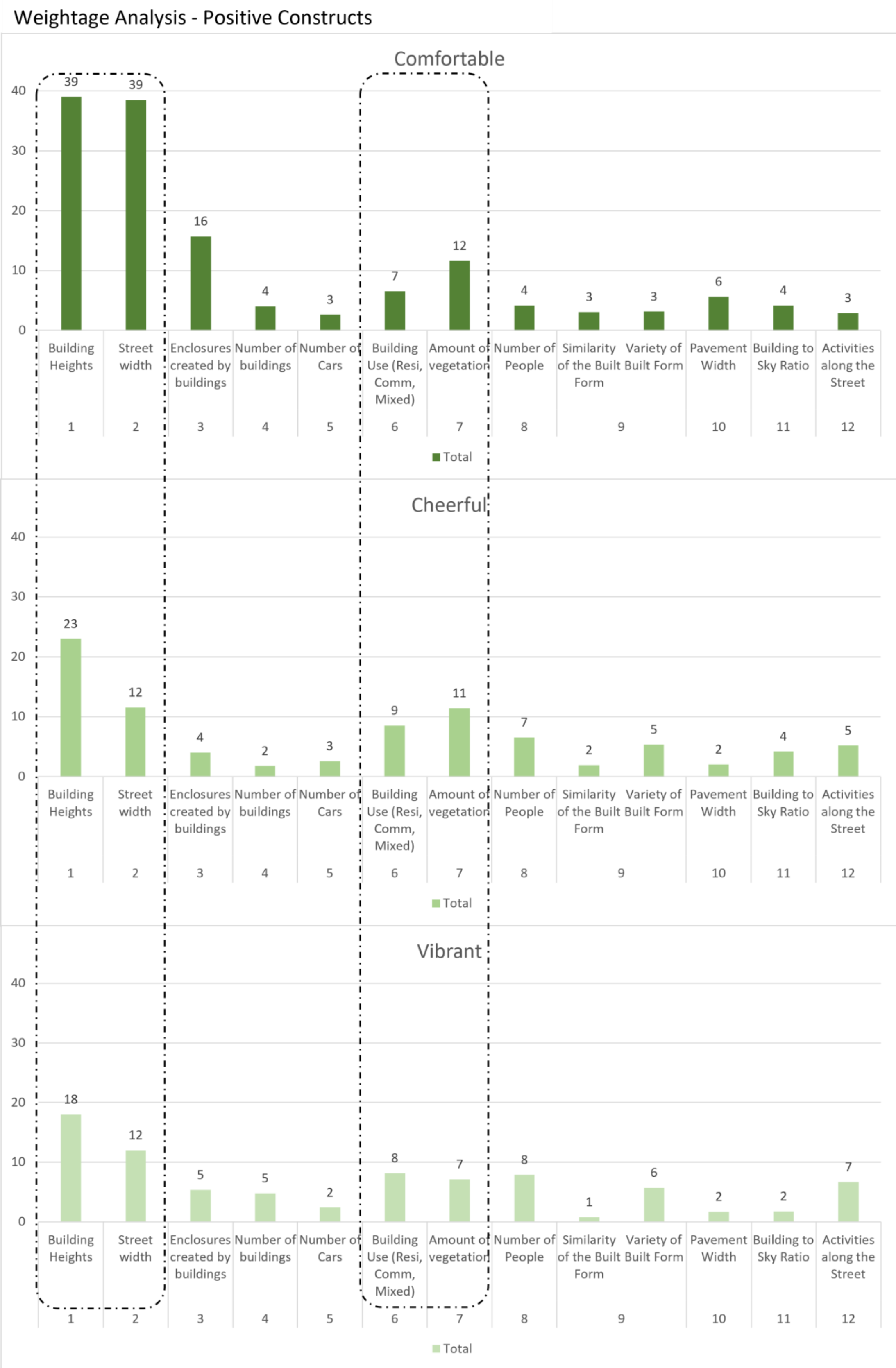


Figure 5-28. Weighting analysis – positive constructs

Weightage Analysis - Negative Constructs

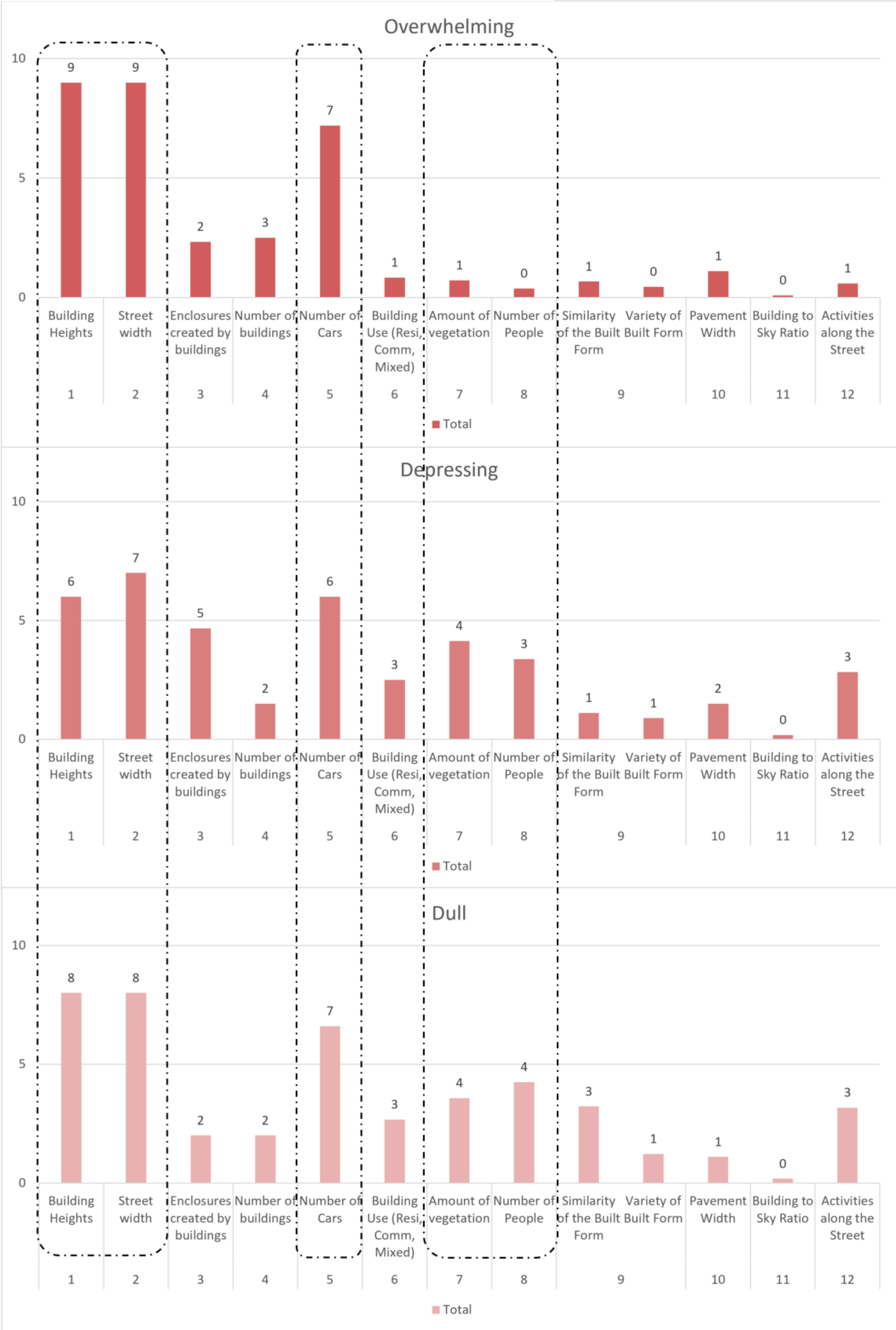


Figure 5-29. Weighting analysis – negative constructs

5.3 Chapter Summary

The objective of this study was to identify the factors associated with the perception of density and compile a comprehensive list. This objective has been achieved with the help of the first survey, an MST.

The MST aided in deriving the 65 constructs classified under 17 categories representing physical attributes of the built form, urban form composition, elements of site organisation, social density, urban form aesthetics and human aesthetic response. More than 7,000 constructs were coded using content analysis. Frequency analysis was conducted on this coded data to identify the most identified constructs associated with perceived density. The results were analysed separately for GLA and UI.

The height of the buildings, street width, open spaces, density of cars and people and volume of the buildings were found to have a higher frequency than others both in the analysis of the unique labels (triads) and descriptions (images). The analysis of these constructs using two approaches suggested that people's perception of the urban environment and density is influenced by the object's capacity to create a visual impact and these constructs are measurable and controllable and within the purview of the architect, urban designer and urban planner. The content analysis and frequency analysis helped in identifying the constructs particularly associated with high, moderate and low-density urban environments.

The comparative analysis assisted in identifying 20 critical constructs that were then used in the second survey and the contribution of urban form elements amongst other constructs. This suggests that the perception of density and the urban environment can be designed by determining the appropriate composition of the urban form elements both in plan and elevation. For this, the urban form needs to be assessed for its visual composition as seen in perspective. This involves the components that have a visual impact and the estimation of their magnitude. It is also important to determine which construct influences which and whether causal relationships can be established.

The 20 critical constructs were narrowed down to 13 constructs, ranked, assigned a weight and used as multiple choices to evaluate the value of the urban environment in the second survey. This was designed as an adaptation of the repertory grid technique that uses 3 bipolar constructs to record the experience of the public with the urban environment: comfortable/overwhelming, cheerful/depressing, and vibrant/dull. The 16 images which were often sorted together in triads were then presented for evaluation. The results identified the presence of high levels of activities, vegetation and people to be the reasons for the positive perception and their absence to be the reasons for the negative. The weighting analysis found the height of the buildings, street width and the amount of vegetation to be associated with both positive and negative evaluation.

The surveys identified eight visual components that constitute the urban environment when seen in elevation: the buildings, street, sky, vegetation, pavements, people, cars and streetscape.

Chapter 6. Image Analysis

Image analysis can be a highly effective method for understanding how people perceive and respond to visual stimuli. This technique has proven to be useful in fields including marketing, advertising, design and psychology. Typically, image analysis is done whenever there is a need to extract information or gain insights from an image. In this case, it is used to verify and quantify data from the surveys such as the frequency count of the constructs.

The first survey identified a list of critical constructs associated with the perception of density. Although the constructs identified for both sets were common, their frequency count varied significantly. This variation may be due to the variation in visual composition. Therefore, to be able to derive measures for the perception of density, analysing the visual composition with the help of images is essential.

The image analysis assists in achieving two objectives:

1. **Determining the visual thresholds for density**. The 54 images were analysed using image segmentation to determine the visual area covered by each component and its consequent effect. The results were categories based on perceived high, moderate and low density in the first survey. The histograms for each image falling under each category are compared independently for 2 sets to derive thresholds for the perception of density.

2. **Deriving visual indexes for quantitative and qualitative assessments**. The images were analysed using the results from the image segmentation and by judging the possible FAR ratio based on the building typology to derive a quantitative index. The principles of Gestalt psychology were employed to derive the qualitative index for the perception of density.

Image analysis is also used to determine human perception by analysing how people interpret or respond to visual stimuli. The image analysis was used to:

1. **Identify patterns or trends in how people respond to different types of images or visual stimuli**. By analysing large datasets from survey responses, researchers gain insights into how people perceive and respond to different

visual stimuli such as urban environments.

2. **Measure the emotional impact of visual stimuli**. By analysing self-reported emotions, researchers can gain insights into how people perceive and respond to different visual stimuli. For example, image analysis can be used to measure the emotional impact of different types of urban environments with different density levels.

3. **Analyse the visual characteristics of images that are most likely to elicit a certain type of perception**. For example, researchers can use image analysis to identify the visual features of the urban environment that are most likely to elicit a perception of comfort or high density.

6.1 Three Approaches to Image Analysis

Images are static representations of the urban environments but a meaning resides in them which can be extracted Click or tap here to enter text.. A dynamic perspective on images would reveal what they do and what they contain. An SJT revealed that the images have the power to elicit human emotional responses and the features responsible for the response. However, analysing the images to identify the compositional elements and patterns that have a greater effect on visual perception will assist in defining the process of assessing the perception of density. One might consider analysing images using machine learning or conventionally.

In this study, the images were analysed using three approaches:

1. **Visual complexity of the images**. The first approach examined the images to check their heterogeneity. This involved identifying the visual characteristics and properties of the images including colour, texture, composition, lighting and style. But for the perception of density, the images needed to account for the number and intensity of all the visual components that are a part of the urban environment. Hence the 54 images were analysed to determine the visual variety.

2. **Image segmentation to determine visual thresholds**. The primary goal of image segmentation is to simplify the representation of an image into

meaningful patterns that are easier to analyse. The images classified into perceived high, moderate and low density in the first survey were analysed using image segmentation to separate the 8 components of the urban environment: buildings, people, streets, sky, vegetation, pavements, vehicles and streetscape elements. These elements are consistent in every urban environment although their proportion varies with density and context. The magnitude of these components was calculated and the thresholds for each were determined for high, moderate and low density.

3. **Image analysis using principles of Gestalt psychology**. The image analysis using Gestalt principles assisted in deriving the quantitative and qualitative visual indexes which can be used for on-site assessment of the perception of the density of urban environments. Gestalt principles are a part of our cognitive processes so when an image is presented, an individual naturally tries to assess its qualities based on similarity and contrast, proximity, closure, continuity and figure. The values for these principles are derived by analysing the images and indexes are formulated. These indexes are iterative and can be developed in future studies.

These approaches and the processes are described below.

6.2 Approach 1 – Visual Complexity of the Images

The difference in frequency count suggests the relative prevalence of different items or events in a given dataset or context. Frequency count refers to the number of times a particular item or event occurs within a set of data, such as the number of times a word appears in a text document, the number of times a particular behaviour is observed in a group of people or the number of occurrences of a particular outcome in a series of trials or experiments. When there is a significant difference in frequency counts between two or more items, this may suggest that the concept represented by that word is particularly important or salient to the study subjects.

However, differences in frequency counts alone do not necessarily indicate causality or meaningful relationships between variables. Additional analysis such as statistical testing or qualitative interpretation may be necessary to fully understand the implications of the differences.

Determining the heterogeneity or homogeneity of images is a form of preliminary image analysis. Homogeneity and heterogeneity refer to the similarity or dissimilarity of images. Homogeneous images have a uniform appearance, while heterogenous images have a varied appearance. For the urban environment, the general factors associated with homogeneity or heterogeneity are colour, texture, style, composition and lighting. The colours in the urban environments exist mainly due to the materials of the buildings added to by the green of the vegetation, hence they stand out. The texture is determined by the building materials. The composition refers to the arrangement of the built form along the street, where the style is the street perspective and is consistent. The lighting determines the environmental quality of the urban environment. All these factors influence the perception of the urban environment. Hence the images used for the study were examined in detail to account for the variation and number of visual elements. For density, there could be many more factors that could determine homogeneity or heterogeneity. These factors are described for both sets by examining the images.

The two sets of images were examined to determine the heterogeneity in visual composition and the number of visual components. The heterogeneity of the images was determined by virtue of the factors listed below.

1. **Vegetation**. Vegetation can affect the colour, texture and overall aesthetic quality of an image, and influence the perception of depth and scale. Therefore, when analysing images, the presence and distribution of vegetation is important as it may affect the interpretation and analysis of the image. Fourteen of the 27 GLA images and 20 out of 27 images in UI had trees along the roads and 14 of the 57 images had small parks or green patches.

2. **Building typology**. The presence and arrangement of building typologies such as point blocks, tenement buildings and high-rises can significantly affect the visual and spatial characteristics of an image and provide valuable

information about the density and land use practices in a particular area Click or tap here to enter text.. The mixed-use built form in GLA was represented by point blocks, apartment blocks and tenement buildings with retail on the ground floor or a combination of blocks and tenements on either side of the street. In addition to the point blocks and tenements, the UI included high-rise building typology.

3. **Cars in the street**. The number of cars and their arrangement (on-street parking) can affect the perception of scale, depth and visual clutter (Rapoport,1975). Therefore, when analysing images, it is important to consider the presence and distribution of cars and how they can affect the interpretation and analysis of the image. Ninety per cent of the images in both GLA and UI had cars in the street which reflects the vehicular movement captured in the images and the on-street parking.

4. **Height of the building**. The height of the buildings might significantly affect the visual appearance of the image (Rapoport,1975, Cheng 2010, Emo 2017). It may suggest a dense urban environment with a high concentration of commercial and residential activities. Fifty per cent of the images both in GLA and UI had similar building heights but different building typologies on each side of the street, whereas the rest had varied building heights on the side of the street. The variation affected the enclosure ratios.

5. **Style of the buildings**. The style of the buildings can affect the perception of scale, depth and visual interest and provide valuable information about the cultural and historical context of an area (Flachsbart,1979). The arrangement of buildings of different styles in an image can also provide valuable information about the diversity of building types and architectural styles. Therefore, when analysing images, it is important to consider the style of the buildings and how it can affect the interpretation and analysis of the image. Fourteen GLA and 5 UI images had both traditional and modern building styles, establishing a link between the old and new architectural styles. The majority of the UI images represented contemporary architecture.

6. **Building materials**. The choice of materials can significantly affect the visual appearance and texture of an image. The tenements and buildings of traditional building style in GLA were clad with red or yellow sandstone. The buildings in the city centre had artificial cladding materials and some were a combination of artificial cladding for the retail units but the residential floors above had natural building materials. Most of the images in the UI had artificial building materials.
7. **Pavement width**. Wide pavements may suggest a more pedestrian-friendly or open character, while images with narrow pavements may indicate a more congested or closed-in character. The arrangement of pavements of different sizes and widths in an image can also provide valuable information about the diversity of transportation modes and pedestrian accessibility. In both cases, few pavements were wide enough to host outdoor eating, seating and activities. Some pavements were narrow, but wide enough to allow pedestrian movement.
8. **Land use**. The combination of land use types in an image can also provide valuable information about the diversity of social and economic activities and their interactions in a particular area. The majority of images represented mixed-used areas but some images showing low density were perceived as residential and suburban.
9. **Context**. Urban images may suggest a more dense and bustling character, while rural images may indicate a more open and peaceful character. The surrounding environment in an image can also provide valuable information about the natural and built features of the area and the social and cultural context of the location. Therefore, when analysing images, it is important to consider the context and consider how it can affect the perception of an area. The images considered for this study represent the urban context.
10. **Activity levels**. Images with high levels of activity and movement such as images of crowded streets or busy public spaces may suggest a more vibrant and dynamic character, while images with low levels may indicate a more

serene and peaceful character (Rapoport,1975). Therefore, when analysing images, it is important to consider activity levels and how they can affect interpretation. The images represented different levels of activity, some due to pedestrian movement and some to the retail activity on the pavements.

This exercise of determining the heterogeneity of the images presented for the surveys assisted in verifying three aspects. The images presented for the surveys were capable of developing different visual patterns by virtue of intensity or number but similar visual patterns due to building typology, street width and other urban form elements. This supports the formation of triads in the MST (Survey 1) either because of the presence of an element such as vegetation or the high intensity of elements such as the number of cars or building volume. The images were clear enough to identify disparities in the built environment by virtue of the unequal distribution of green spaces, pavements and the number of people to trigger the emotional response to the unique urban environments. This supports the evaluation of certain images as having a positive or negative perception. The images reflecting the density of GLA and UI samples were diverse enough to represent every element and its manifestation. This diversity of images did not justify the identification of 65 constructs influencing the human perception of density.

On similar lines, 27 images representing the density scenarios around the world were examined to determine the heterogeneity and see in what respects they differed from the GLA sample.

6.3 Approach 2 – Image Segmentation

People are capable of instantly evaluating the visual complexity of elements (Kyle-Davidson, Bors and Evans, 2022). They are capable of assessing the complexity that varies from textures to the details or physical attributes of the objects nut their evaluation of the urban environments falls short. A logic behind that evaluation should be established and one way is using visual perception done using image analysis.

GLASGOW (GLA)																													
Categories	**Sub - Categories**	**Image 1**	**Image 2**	**Image 3**	**Image 4**	**Image 5**	**Image 6**	**Image 7**	**Image 8**	**Image 9**	**Image 10**	**Image 11**	**Image 12**	**Image 13**	**Image 14**	**Image 15**	**Image 16**	**Image 17**	**Image 18**	**Image 19**	**Image 20**	**Image 21**	**Image 22**	**Image 23**	**Image 24**	**Image 25**	**Image 26**	**Image 27**	**Total Number of Images**
Vegetation	Trees				1	1	1	1	1	1				1	1	1	1								1	1	1	1	**14**
	Open Spaces / Parks						1	1							1		1	1								1	1	1	**8**
Building Typology	Point Blocks / Apartment Blocks	1		1																						1			**3**
	Tenements							1	1	1	1			1	1	1	1	1	1									1	**11**
	Blocks + Tenements		1		1	1	1					1	1							1	1	1	1	1	1		1		**13**
Cars in the Street	Cars in the Street		1	1	1	1		1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1	1	**23**
Height of the Building	Similar on both sides	1	1	1					1		1	1	1				1	1	1	1	1	1							**13**
	Varied on both sides				1	1	1	1		1				1	1	1							1	1	1	1	1	1	**14**
Style of the Buildings	Traditional							1	1	1				1	1	1	1	1									1	1	**10**
	Modern / Contemporary	1		1								1																	**3**
	Traditional + Modern		1		1	1	1				1		1						1	1	1	1	1	1	1	1			**14**
Building Materials	Natural							1	1	1				1		1	1	1									1	1	**9**
	Artificial	1		1																									**2**
	Natural + Artificial		1		1	1	1				1	1	1		1				1	1	1	1		1	1	1			**15**
Pavement Width	Narrow		1		1		1		1	1	1	1		1						1	1					1			**11**
	Comfortable	1		1		1		1					1		1	1	1	1	1			1	1	1	1		1	1	**16**
	Pedestrain Friendly	1		1		1		1	1	1		1	1		1	1	1	1	1		1	1	1	1	1		1	1	**20**
Landuse	Residential																												**0**
	Commercial																												**0**
	Mixed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**27**
Context	City / Urban	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**27**
	Suburban																												**0**
Activity Levels	High	1										1	1						1		1			1	1				**7**
	Low/ None		1	1	1	1	1	1	1	1	1			1	1	1	1	1		1		1	1			1	1	1	**20**

Figure 6-1. Quantifying the visual components of the images – Glasgow

UNIVERSAL ILLUSTRATIONS

Categories	Sub - Categories	Image 1	Image 2	Image 3	Image 4	Image 5	Image 6	Image 7	Image 8	Image 9	Image 10	Image 11	Image 12	Image 13	Image 14	Image 15	Image 16	Image 17	Image 18	Image 19	Image 20	Image 21	Image 22	Image 23	Image 24	Image 25	Image 26	Image 27	Total Number of Images
Vegetation	Trees	1	1		1	1	1	1	1	1	1		1	1	1	1		1	1	1	1			1	1	1			20
	Open Spaces / Parks						1			1						1		1		1					1				6
Building Typology	Point Blocks / Apartment Blocks	1	1	1	1		1				1	1									1		1	1		1			11
	Tenements					1		1	1	1												1							5
	High Rises												1	1	1	1	1	1	1	1					1		1	1	11
Cars in the Street	Cars in the Street	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	25
Height of the Building	Similar on both sides	1	1	1	1	1	1	1	1	1	1				1		1					1	1					1	15
	Varied on both sides											1	1	1		1		1	1	1	1			1	1	1	1		12
Style of the Buildings	Traditional				1	1	1	1			1											1							6
	Modern / Contemporary	1	1						1	1		1	1	1	1	1		1	1	1					1	1	1	1	16
	Traditional + Modern			1													1				1		1	1					5
Building Materials	Natural		1		1	1	1	1			1									1		1	1						9
	Artificial	1		1					1	1		1	1	1	1	1									1	1	1	1	13
	Natural + Artificial																1	1	1		1			1					5
Pavement Width	Narrow	1	1	1	1			1	1	1	1	1	1	1	1	1					1	1	1					1	17
	Comfortable					1	1										1	1	1	1				1	1	1	1		10
	Pedestrain Friendly						1											1	1					1	1	1	1	1	8
Landuse	Residential	1	1			1			1	1	1	1			1	1				1		1	1						12
	Commercial																												0
	Mixed			1	1		1	1					1	1			1	1	1		1			1	1	1	1	1	15
Context	City / Urban	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	27
	Suburban																												0
Activity Levels	High																1	1	1					1		1	1	1	7
	Low/ None	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	1	1	1		1				20

Figure 6-2. Quantifying the visual components of the images – Universal Illustrations

The results derived from the MST and SJT identified the critical constructs that people perceive in the urban environment. These constructs are the urban form elements and are common to every urban environment. This raises the question of what the distinguishing criteria between high, moderate and low density could be and whether there could be a quantitative measurement for the perception of density with the help of images. The answer to these questions lies in image analysis using machine learning.

There are many methods of image analysis, which vary depending on the type of image data and the specific analysis goals. Some common methods are listed below.

1. **Feature extraction**. This involves identifying and extracting relevant characteristics or features from raw data such as images(Ryan, 1985; Debals and Brabandere, 2020). These features can then be used to identify patterns or objects in the data. In image processing, feature extraction may involve identifying edges, corners or other distinctive parts of an image that can be used to identify objects or patterns within the image.

2. **Pattern recognition**. Pattern recognition involves identifying patterns or objects within data based on predefined criteria or algorithms(Debals and Brabandere, 2020). This process can involve using features extracted from the data to identify objects or patterns and can be used for tasks such as object detection or classification.

3. **Image analysis using deep learning**. This involves training neural networks to recognise and analyse images(Debals and Brabandere, 2020). It involves feeding large amounts of data to a algorithm and allowing it to learn to identify patterns and features in the data. Deep learning can be used for object identification, classification, and segmentation, among other applications.

4. **Image segmentation**. This involves dividing an image into multiple segments or regions based on similarities or differences between the pixels(Debals and Brabandere, 2020). This process can be used to identify objects within the

image or to separate different areas of interest. Image segmentation can be used in a variety of applications, such as medical imaging or remote sensing.

Of these four methods, Image segmentation is preferred because it can be done manually without the use of algorithms or knowledge of programming languages. It is useful for object detection, segmentation, labelling and classification of objects within the images, reduces the complexity of the image and improves the efficiency of subsequent analysis.

6.3.1 Image Segmentation

Images have been central to how researchers, urbanists and professionals understand cities. They are means of understanding the aesthetic experience of urban environs(Debals and Brabandere, 2020). Conventionally, the images used for surveys are interpreted by eye, which is a laborious and intensive process. The limitations arising due to fatigue in analysing large amounts of visual data put a cap on the scale of research. Image processing techniques address these limitations and assist in analysing larger amounts of visual data and make large-scale studies possible.

The examination of the cityscapes reveals that more than 30 visual objects can be identified and segmented. However, the detail of segmentation depends on the

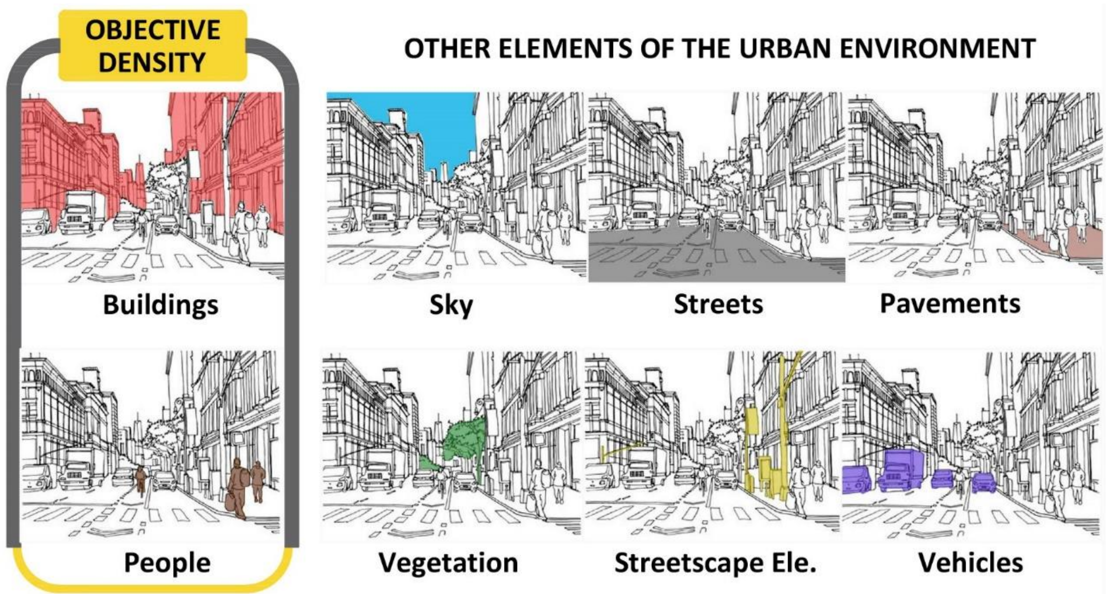


Figure 6-3. Eight visual components of the urban environment

research objectives. For the perception of density, it was important to identify the elements that can create a visual impact and whose presence or absence is noticeable. Variation in the intensity of these objects must also be evident, which assists in identifying the influence that intensity has on human perception. The urban environs consider eight objects – buildings, people, sky, streets, pavements, vegetation, streetscape elements and vehicles – whose presence and intensity can have a significant impact on the human perception of density (see Figure 6-3).

This study employed a classical image segmentation method used by Segments.ai, which is based on super-pixel and auto-segment technology. This software is available to researchers and allows the segmentation of any component of the image. This deep learning segmentation method can also classify semantics of the objects in an image such as sky, roads or buildings to the pixel level.

6.3.2 The Process of Image Segmentation

Image segmentation is used to extract the visual elements of the streetscape. This process has three steps.

Step 1 – Pre-processing the Image. Before the image segmentation can begin, the image is pre-processed to enhance its quality and ensure accurate segmentation. Sometimes an image needs smoothing, filtering or colour correction to avoid errors while processing.

with Segment-AI, the high-resolution image is uploaded and segmentation type bitmap is selected. This type is based on the super-pixel technology which recognises objects, colours and textures. It is possible to label the minutest details in the images using this technique. For this study, the image segmentation was limited to object recognition and the two sets of 27 images uploaded and analysed independently.

Step 2 – Feature extraction. To enable segmentation, it is necessary to extract the features of the images. These may be based on colour, texture, shape or other properties. These features here were the eight visual components identified by examining the urban environment using eye observation. Labels for the eight components were created and colour-coded to maintain same visual language and to enable reading 54 images.

Figure 6-4. Segmentation using superpixel

Step 3 – Segmentation: Using the extracted features the images is segmented into multiple regions. This can be done using various algorithms; however, this process was done manually for 54 images. The process of segmentation is represented in the Figure 2.

Step 4 – Post-processing. After segmentation the images were exported in .jpeg format for pixel counting. This is a simple method used to estimate the size or area of an object in an image. The process involves counting the number of pixels that belong to the object. The basic steps involved in pixel counting are as follows:

1. **Choose an object to measure**. This step involved the selection of objects by colour within the image.

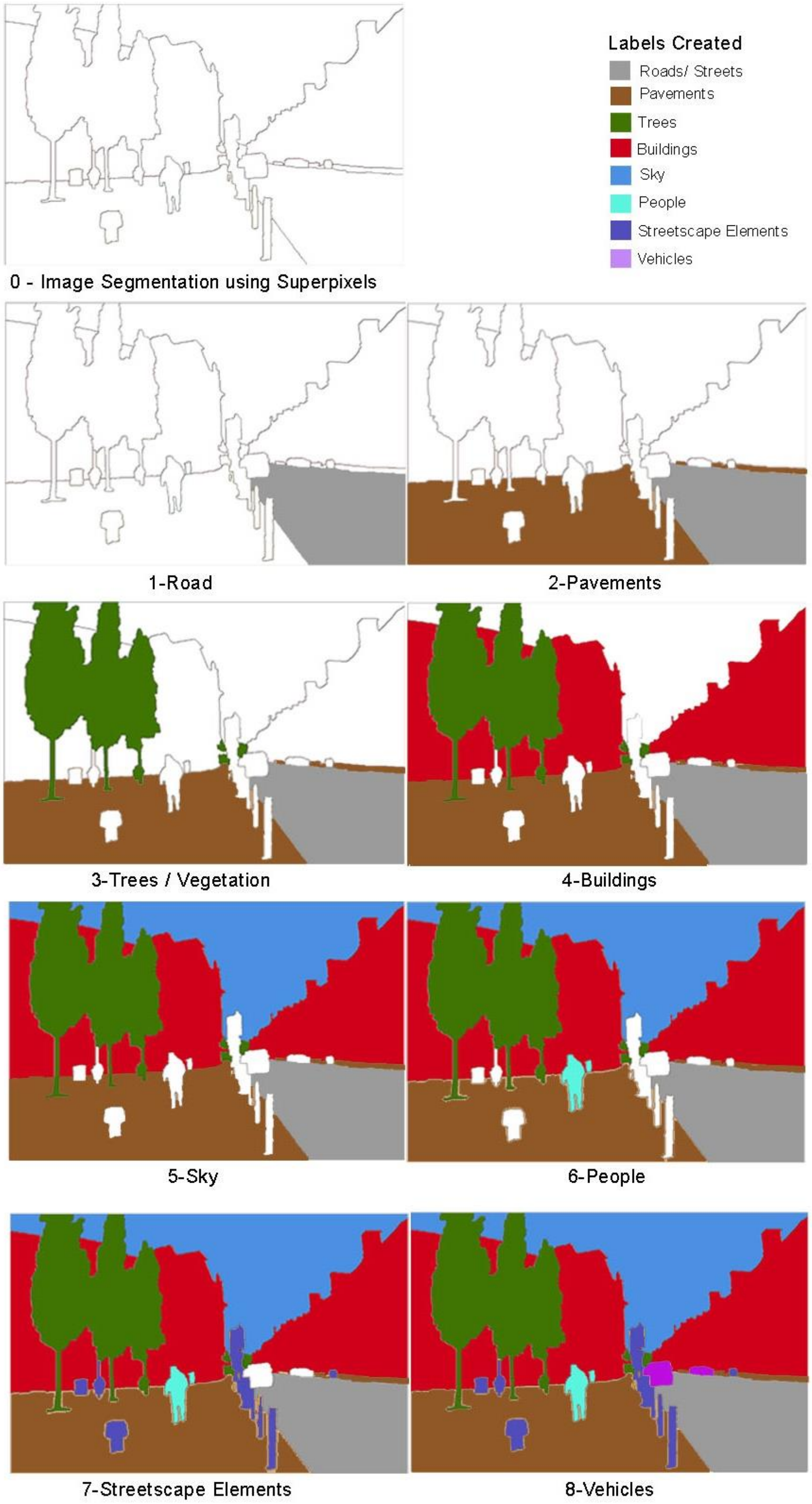


Figure 6-5. Sample of image segmentation – labels

2. **Count the pixels**. Once the object has been identified, the pixels for that object can be counted manually or by using image analysis software. The algorithms that use Python can determine the area covered by each object after segmentation. However, for this study, pixel counting was done using Adobe Photoshop.
3. **Measuring the size of each pixel**. The size of each pixel depends on the resolution of the image and the size of the area it represents. The details of the image are easily available in Photoshop once imported. Alternatively, the size of each pixel can be determined manually by dividing the total height of the image by the number of pixels in that dimension.
4. **Total area**. The total area of the object was calculated by multiplying the number of pixels in the object by the area of each pixel.

6.3.3 Image Segmentation Results

The results of image segmentation were used for magnitude estimation. Once the image is segmented and the intensity of pixels calculated, the perceived intensity or magnitude of each region is estimated in percentages using magnitude estimation (mathematical calculations) followed by histogram analysis. The examples of segmented images and their magnitudes are represented in Figures 6.6 and 6.7. The image segmentation of all the images is included in the Appendix to Chapter 6.

6.3.3.1 Magnitude Estimation

Magnitude estimation is a psychophysical method used to measure the perceived intensity or magnitude of a sensory stimulus such as colour, sound, light or touch, or, in this case, the colour of the eight visual components. It relies on the principle that the perceived intensity of a stimulus is related to its physical intensity Moskowitz, 1977). A typical process of magnitude estimation involves five steps.

- **Step 1 – Stimulus selection**. The first step chooses a set of sensory stimuli that is central to the research.
- **Step 2 – Instructions and training**. This step involves giving clear and precise instructions to the participants about the task and the rating scale. A

demonstration of how to estimate magnitudes can be included at this stage.

- **Step 3 – Magnitude estimation task**. Participants are presented with the stimuli and asked to assign a rating that reflects the perceived magnitude.
- **Step 4 – Repetition and normalisation**. The task of magnitude estimation could be repeated to normalise the data by dividing each estimate by the participant's average estimate across all stimuli.
- **Step 5 – Data analysis**. Once all the participants have completed the task, the data is analysed to determine the relative magnitudes and similarities of the stimuli.

However, the approach to magnitude estimation for this study differs in two ways. First, the participants were asked to judge the degree of density in the first survey and the qualitative value in the second based on the visual impact of the components of the urban environment. Hence an additional survey was not conducted after segmenting the images for estimating magnitude and the process of magnitude estimation after image segmentation was a part of the analysis and so the participants were not involved.

Second, magnitude estimation was done for the two sets of images. The lower and upper limits of the magnitude for the eight visual components were recorded independently for high, moderate and low densities. These magnitudes were statistically analysed to derive the visual threshold for each component for the corresponding density.

6.3.3.2 Histogram Analysis

Histograms can be used to represent magnitude estimation by showing the frequency of values within specific ranges. For example, if we have a dataset of magnitudes ranging from 0 to 100, we could divide it into 10 bins of size 10 each and then plot the frequency of observations falling within each as the height of the bars. This would give us a histogram that shows the distribution of magnitudes across the entire range and any peaks or gaps in the distribution.

Histograms can also be used to compare the distribution of magnitudes across different datasets or conditions. By plotting multiple histograms on the same graph, we can compare the frequency of observations falling within each bin for each dataset or condition and look for differences or similarities in the distribution.

Histogram analysis was used in this study to represent the estimated magnitude (pixel count) derived from image segmentation for each of the 8 components for the 54 images. It was possible to identify the upper and lower limits of each component which assisted in comparing the results of image segmentation for high moderate and low-density images. For instance, certain components such as buildings have a consistently higher pixel count in high-density images, indicating that they are more prevalent in the images. On the contrary, the vegetation had a consistently lower pixel count in high-density images, indicating they are less prevalent and more difficult to identify. In addition, histogram analysis assisted in detecting the outliers or anomalies in the data, which assisted in identifying the images that are an exception and should not be considered for deciding the upper and lower limits. The histogram analysis for the eight components are presented in Figures 6-8 to 6-10 for high, moderate and low density, respectively. The pixel count was converted to square centimetres to represent the area covered by the component in the image.

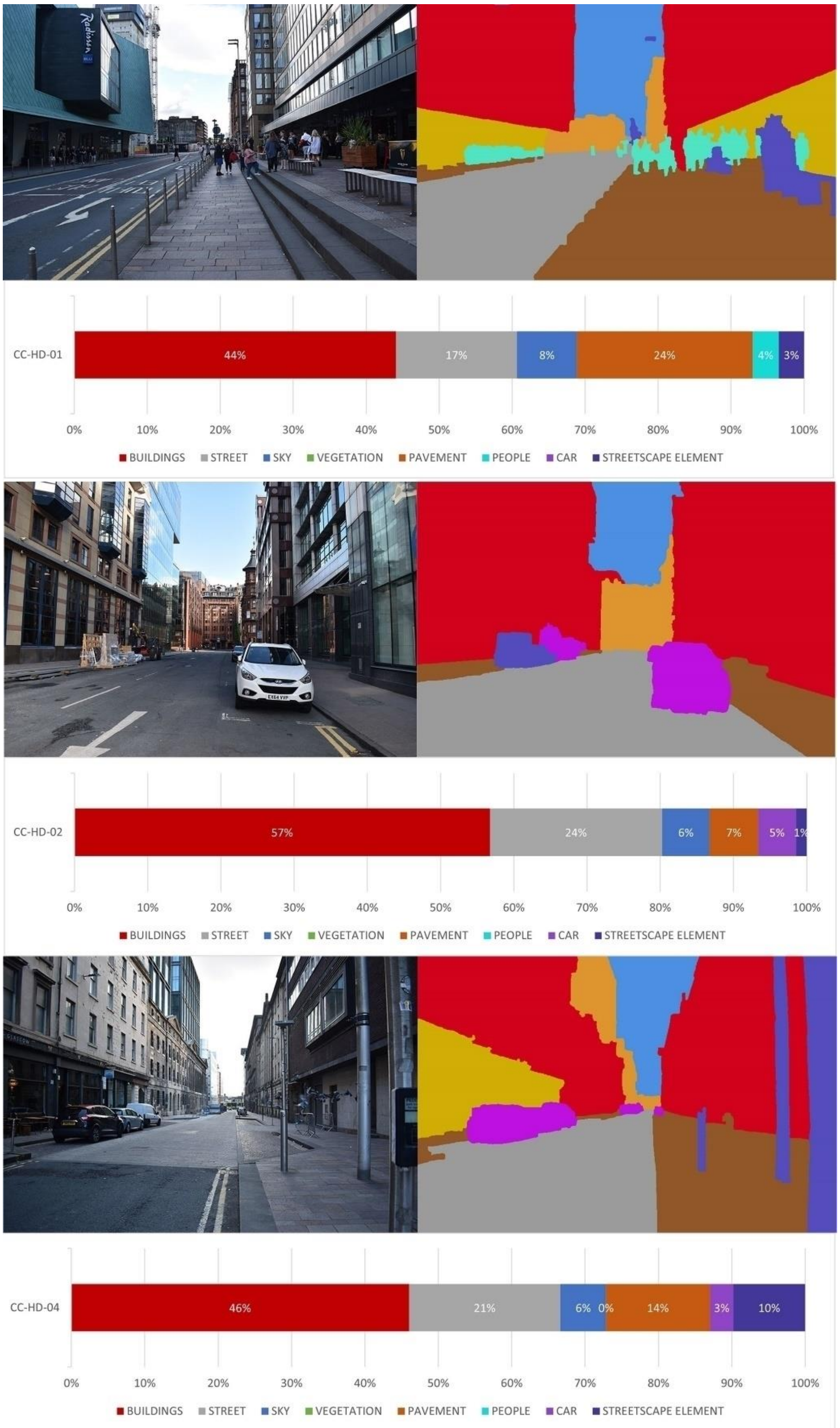


Figure 6-6. Image segmentation – Glasgow – 1

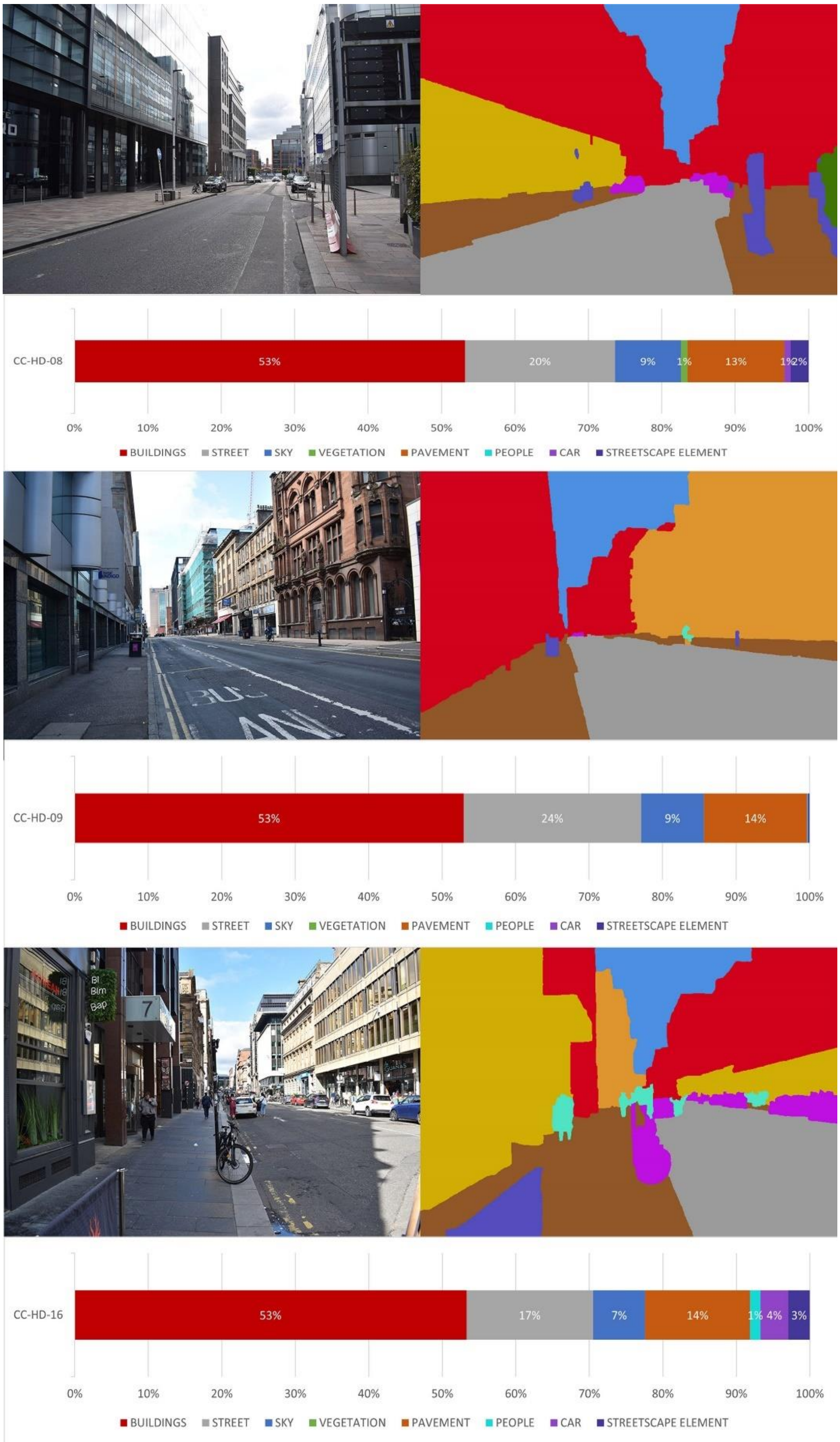


Figure 6-7. Image segmentation – Glasgow – 2

6.3.3.3 Glasgow (GLA)

High Density

The results of the histogram analysis for the high-density group for GLA are presented in Table 6 -1.

Table 6-1. Histogram analysis – high density – GLA

Upper and Lower Limits of Visual Components – High Density – GLA		
Component	Lower limit %	Upper limit%
Building	44	59
Street	16	24
Sky	5	9
Vegetation	0	1
Pavement	7	24
People	0	2
Car	0	8
Streetscape Elements	0	5

Moderate Density

The results of the histogram analysis for the medium-density group for GLA are presented in Table 6-2.

Table 6-2. Histogram analysis – moderate density – GLA

Upper and Lower Limits of Visual Components – Moderate Density – GLA		
Component	Lower limit %	Upper limit%
Building	12	38
Street	1	23
Sky	10	32
Vegetation	0	40
Pavement	9	33
People	0	1
Car	1	10
Streetscape Elements	0	10

Low Density

The results of the histogram analysis for the low-density group for GLA are presented in Table 6-3.

Table 6-3. Histogram analysis – low density – GLA

Upper and Lower Limits of Visual Components – Low Density – GLA		
Component	Lower limit %	Upper limit%
Building	7	21
Street	10	19
Sky	18	30
Vegetation	6	23
Pavement	12	27

People	0	1
Car	0	3
Streetscape Elements	0	8

6.3.3.4 Universal Illustrations (UI)

The process was repeated for the 27 UI images.

High Density

The results of the histogram analysis for the high-density group for UI are presented in Table 6-4.

Table 6-4. Histogram analysis – high density – UI

Upper and Lower Limits of Visual Components – High Density – UI		
Component	Lower limit %	Upper limit %
Building	19	75
Street	0	36
Sky	2	16
Vegetation	0	14
Pavement	0	8
People	0	8
Car	0	14
Streetscape Elements	0	12

Moderate Density

The results of the histogram analysis for the medium-density group for UI are presented in Table 6-5.

Table 6-5. Histogram analysis-moderate density – UI

Upper and Lower Limits of Visual Components – Moderate Density – UI		
Component	Lower limit %	Upper limit %
Building	14	58
Street	11	35
Sky	4	12
Vegetation	0	34
Pavement	0	8
People	0	0
Car	0	16
Streetscape Elements	0	9

Table 5.

Low Density

The results of the histogram analysis for the low-density group for UI are presented in Table 6-6.

Table 6-6. Histogram analysis – low density – UI

Upper and Lower Limits of Visual Components – Low Density – UI		
Component	Lower limit %	Upper limit %
Building	21	51
Street	21	45
Sky	7	18
Vegetation	2	28
Pavement	4	23
People	0	0
Car	1	3
Streetscape Elements	0	8

6.3.3.5 Summary

The intention of this exercise was threefold.

1. To verify that the classification of images into high, moderate and low perceived density by the participants in the MST can be supported by a quantitative equivalence.
2. Determine a way to measure the visual impact of the visual components of the perception of the density identified in the surveys.
3. To verify whether the perception of the urban environment is dependent on the magnitude of the component as seen from a pedestrian perspective and whether the major contribution is that of the built form.

The results of the image segmentation for the eight visual components derived from the critical constructs correspond to the classification of images into high, moderate and low perceived density. This implies that people identify those constructs which have a considerable visual impact and a higher magnitude to be associated with perceived density. The presence or absence of components also characterised the degree of density and value of the urban environment.

The upper and lower limits for the eight components for both sets are different. This is because each mixed-use urban environment, in any context is unique. Therefore, the variance was anticipated. Other reasons for disparity include.

1. **Variation in objective density**. The place-based study in GLA represents density as a relative concept where the density is gradually seen to decrease

within the city limits whereas the UI represents distinct high and moderate density areas throughout the world. Thus, what is considered high density for GLA could be considered moderate for other regions.

2. **Visual complexity of the images**. The variation can also be explained by the heterogeneity of the images. The presence and absence and complexity of visual components have a considerable impact on the evaluation of the urban environments as seen from the results of SJT.

3. **Image capturing method**. The methods used to capture the images are different. The images for GLA are captured from eye level and thus from the pedestrian point of view from the pavements and so the opposite side of the building is viewed clearly. Google Street imagery was used for the UI images and so were taken from the centre of the street and the two sides of the street are presented as even.

6.4 Thresholds for visually assessing High, Moderate and Low-Density Using Image Segmentation

Human perception can be a valuable tool for assessing density in urban areas as it can capture the qualitative and experiential aspects of density that may not be captured by objective measures alone. However, deriving thresholds for population and building density based on human perception has limitations that must be carefully considered.

One is the potential for observer bias and subjectivity. Different people may have different perceptions and preferences regarding density and these factors can influence their assessments. Therefore, it is important to ensure that the observers are representative of the population of interest and are trained on the methods for assessing density.

Another is the difficulty of generalising the results to other situations or populations. Human perception of density may vary across cultural, social and environmental circumstances and the thresholds derived from one may not apply to another. Therefore, it is important to validate the thresholds in different contexts and to consider the contextual factors that may influence the perception of density.

The data were further analysed to derive visual thresholds for the eight visual components. The statistical calculations are in the appendix.

Visual thresholds in this study refer to the percentage of area of the component present in the image from which an urban environment can be perceived to be highly, moderately or lower density. In this sense, a visual threshold would be the point above which an urban environment could be perceived to have a higher density and below which the density would be perceived as lower.

Table 6-7. Threshold Values for high, moderate and low density – GLA

Threshold Analysis – GLA			
Component	Threshold-HD	Threshold-MD	Threshold-LD
Buildings	53.33	27.16	18.66
Streets	18.22	11.08	17.5
Sky	7.11	23.75	28
Vegetation	0.55	15	17.33
Pavement	14.77	21	22
People	1.44	0.67	0.58
Car	3.77	4.13	1.91
Streetscape Elements	3.05	7.5	5.25

Table 6-8. Threshold values for high, moderate and low density – UI

Threshold Analysis – UI			
Components	Threshold-HD	Threshold – MD	Threshold – LD
Building	47	36	36
Street	16.2	23.85	33
Sky	11.8	11.21	12.5
Vegetation	9.8	15.78	15
Pavement	4	7.03	13.5
People	5.7	0.03	0
Car	12.6	8.57	2
Streetscape Elements	8.4	6.53	4

High Density- GLA

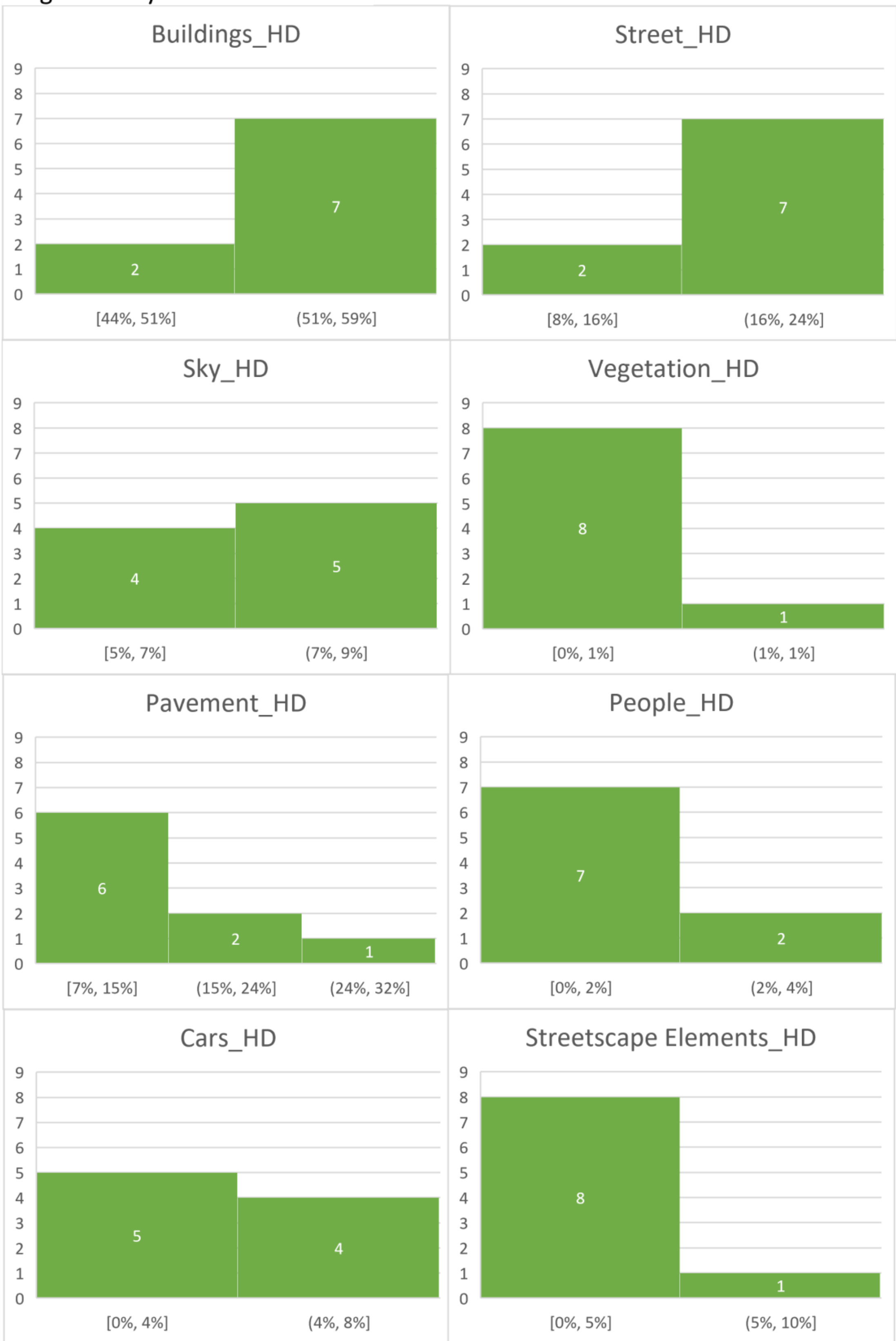


Figure 6-8. Histograms for the eight visual components – High Density – Glasgow

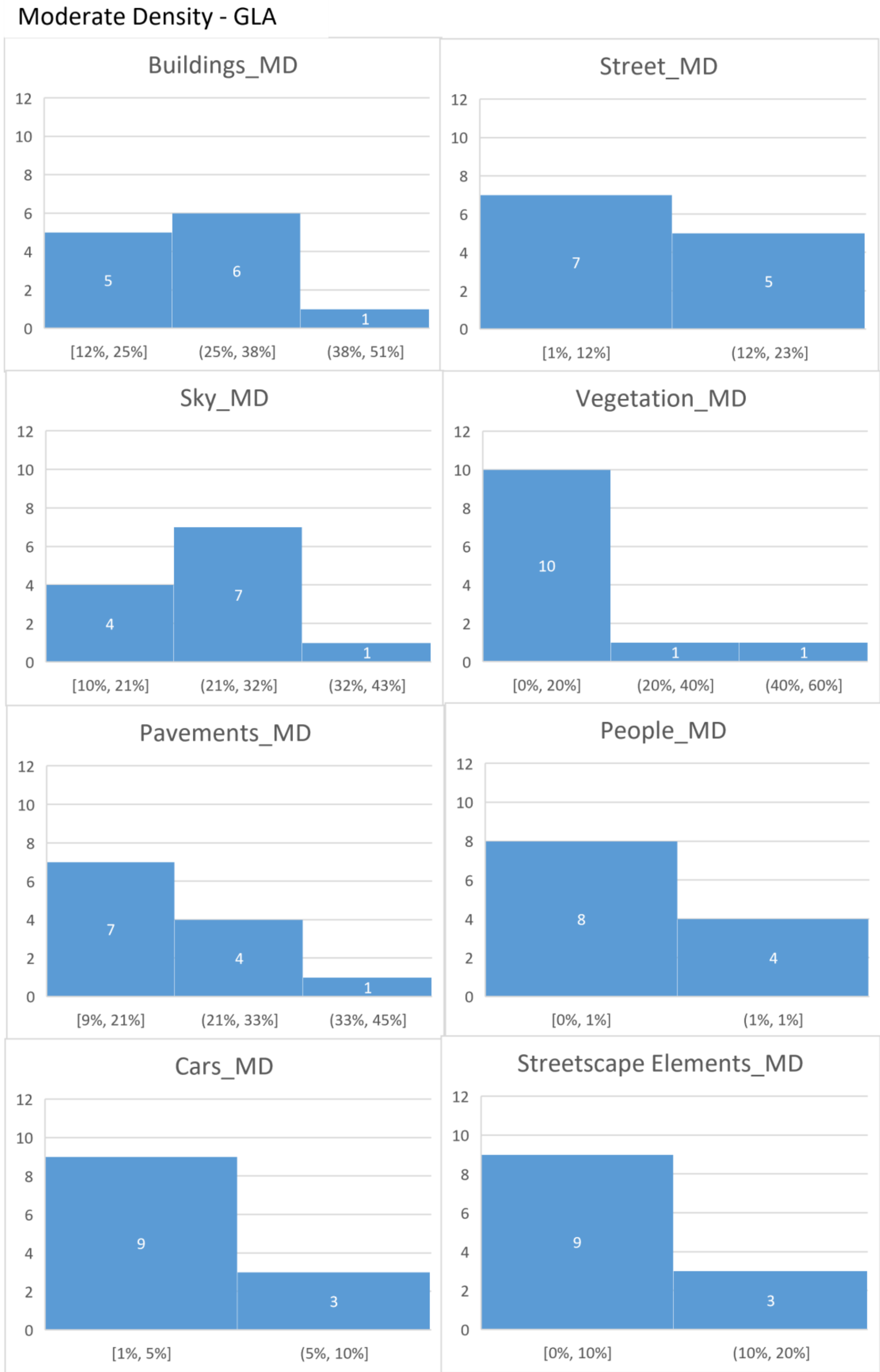


Figure 6-9.Histograms for 8 visual components – Moderate Density - Glasgow

Figure 6-10. Histograms for 8 visual components – Low Density - Glasgow

Despite, these challenges, deriving thresholds for population and building density based on human perception can prove to be of valuable guidance for urban planners, architects and policymakers to design and plan urban environments that are more aligned with human preferences and needs. The thresholds derived from human perception can complement objective measures of density and provide a more holistic understanding of the complex dynamics of urban density and those derived in this study can be tested in other situations using the image segmentation technique followed by magnitude estimation and histogram analysis.

6.5 Approach 3 – Image Analysis Using Gestalt Psychology

The Gestalt principles (Wertheimer, 1938; Wertheimer and Riezler, 1944) play an important role in visual perception by helping to explain how we organise and interpret the visual information around us (Gilchrist, 2012; Wagemans et al., 2012). These principles describe how our brains perceive visual information as organised wholes rather than as isolated parts and provide a framework for understanding how we perceive and make sense of complex visual scenes.

Gestalt psychology includes two main organisational principles: grouping and figure-ground (Koffka, 1935; Wagemans, Elder, Kubovy, Palmer, Peterson, Singh, von der Heydt, *et al.*, 2012; Yang and Yuan, 2022). Individuals group similar elements to form an organic whole which is recognised as a grouping principle. The figure-ground relationship suggests that, when an individual observes an object, they can perceive only a part of the information. This information from the image and the unperceived information forms the background.

6.5.1 Principles of Perceptual Grouping

Perceptual grouping is a cognitive process that is closely associated with the organisation of sensory information mostly visual into meaningful patterns or objects (Koffka, 1935; Wagemans, Elder, Kubovy, Palmer, Peterson, Singh, von der Heydt, *et al.*, 2012). Grouping is an organisational phenomenon that determines the qualitative elements of perception. The grouping principles described below assist in establishing the logic behind the visual assessment of the urban environments for perception.

1. **Proximity or relative distance**. Elements that are close together tend to be grouped (Wagemans et al., 2012). From a pedestrian point of view, the buildings with similar styles aligned on either side tend to be grouped. If the buildings along the entire block are close together, it appears like a street wall and creates the effect of an 'urban canyon', the effect created when tall buildings are closely spaced on both sides of the street, creating a narrow, funnel-like enclosed space. The term is used in architecture and urban planning to describe the visual or spatial experience of walking or driving and can have both positive and negative effects on the urban environment. On the positive side, it can create a dramatic and memorable sense of place and enhance the sense of urban density. On the negative, it can affect the environmental quality of the street and induce feelings of being uninviting, claustrophobia and lack of access to light. It can be mitigated by managing the buildings' heights along the street and introducing space between adjacent buildings.

2. **Similarity**. Elements that are similar by colour, shape and texture tend to be grouped (Wagemans et al., 2012). The principle of similarity refers to the degree to which two or more objects or entities share common characteristics or attributes. In an urban environment, the built form is constant and therefore has specific physical attributes. The similarity of built form along the street would tend to present similar colours or textures and will tend to be grouped. Buildings with similar heights also would read as similar.

3. **Continuity**. Elements that are arranged in a smooth, continuous manner tend to be grouped (Wagemans et al., 2012). Streets and pavements are important elements that not only reflect movement but also continuity. A built form without articulating façades (recesses or extrusions from the façade) provides a smooth surface and tends to be continuous. Continuity

due to built form can create an urban canyon that might be perceived as positive or negative by the user. This principle is closely related to proximity and similarity.

4. **Symmetry**. Symmetry refers to the balanced or harmonious relationship between two or more elements. One can judge the urban environment as symmetrical or balanced due to the presence of similar volumes or heights of buildings on either side as seen from the centre of the street. Symmetry might exist due to the presence of trees or building shape and size. Symmetrical patterns are often pleasant to the eye and can assist in creating a positive perception but too much similarity can make the cityscape monotonous and dull. Unlike objects, the urban environment is hardly symmetrical.

5. **Common fate**. Elements that move together or are perceived as part of a common motion tend to be grouped. In an urban environment, this principle is only applicable to the movement of cars or people in a group.

6.5.2 Figure-Ground Organisation

The figure-ground organisation is the cognitive ability to organise visual information into distinct objects (figures or buildings) and their background (ground or sky) (Wagemans et al., 2012). It separates the objects of interest from their surroundings. This organisation is influenced by factors such as contrast, size, orientation and shape. Objects such as buildings having a distinctive shape or orientation are perceived as figures. The background is the sky against which the buildings are seen. The figure-ground organisation is an important perceptual mechanism that assists in understanding complex visual information and extracting relevant information.

6.5.3 Qualitative Visual Index

The Gestalt principles provide a powerful framework for understanding how our brains process and make sense of visual information. By applying these principles to analyse the images, it is possible to create more effective and engaging visual experiences that are easier for people to perceive and understand. To be able to derive a visual index for the perception of density, the images were examined using the Gestalt principles.

Deriving a visual index for the assessment of urban environments can be a useful tool for urban planners, architects and designers to evaluate the quality and attractiveness of a given urban space. A visual index can help to identify the strengths and weaknesses of an urban environment and provide guidance for future development and improvements. The key steps in the process of deriving a visual index for urban environments are described below.

6.5.3.1 Process of Deriving Visual Index

Deriving a visual assessment index based on the perception of density can be a useful tool for evaluating the perceived density of urban environments. The key steps in the process of deriving a visual assessment index based on the perception of density.

1. **Identify key visual features**. The first step in deriving a visual assessment index based on the perception of density is to identify the key visual features that contribute to the perceived density of urban environments. This may include elements such as building height, building massing, street width and building setback.
2. **Develop a scoring system**. Once the key visual features have been identified, a scoring system can be developed to evaluate the perceived density of each. This may involve assigning a score based on factors such as the visual weight of the feature, the degree of enclosure or openness and the amount of negative space.
3. **Establish weighting factors**. To develop an accurate visual assessment index, it may be necessary to establish weighting factors. This involves assigning relative importance to each feature based on its impact on the perceived density of the urban environment.

4. **Collect data**. To establish a baseline for the visual assessment index, data can be collected through site visits, surveys or other methods to collect data on the visual features of the urban environment and subjective assessments of the perceived density of the space.
5. **Analyse and refine**. Once the data have been collected, they can be analysed to identify areas of high and low perceived density in the urban environment. The scoring system and weighting factors can be refined based on the data to improve the accuracy of the visual assessment index.
6. **Apply the index**. Finally, the visual assessment index can be applied to future urban projects. By using the index to guide decision-making, urban planners, architects and designers can create more visually appealing and functional urban spaces that are perceived as less dense, more open and less claustrophobic.

6.5.3.2 Step 1 – Identifying Key Visual Features

Gestalt psychology believes that while perceiving graphics to suit their own cognitive abilities, an individual prefers to simplify the graphics. Therefore, the 54 images used for the study were examined to determine the key visual features for the perception of density and urban form. The examination identified 12 physical attributes of the built form for which either quantitative or relative measurements can be derived. Based on the principles of grouping, two features that describe the visual composition of the urban environment were identified which also assisted in identifying the spatial relationships between the features. They are described below.

Measurable Urban Form Attributes

Building height. Measuring building height visually requires some estimation. It can be done using reference points. The reference points could be the height of the known object such as the height of the person or the height of the building storey.

Measuring building height with reference to building storeys is a common method used in the construction industry. A storey (or floor) is defined as a level of a building that is above the ground floor, with its own floor and ceiling. One could simply count the building storeys and calculate it with the average floor height (3.2 metres) to determine the height of the building. However, this method only provides an estimate of the building's height based on the number of storeys and the actual height may vary depending on the design and construction of the building.

The ratio of the ground floor to the superstructure. This can vary depending on the type and design of the building. In general, the ground floor area of a building is typically larger than the upper floors due to the need for public spaces such as lobbies, retail areas and common areas like staircases and elevators. The exact ratio can depend on several factors including the building's function, location and architectural style. For example, a residential building may have a smaller ground floor area compared to a commercial building, while a building with a traditional architectural style may have a larger ground floor area compared to a modern building.

As a rough estimate, a typical ratio for the ground floor area to superstructure area could be around 1.3 to 1.5, but this can vary significantly and can be influenced by many factors including the requirements of the building's occupants and the local building codes and regulations.

Space between the opposite buildings. The distance between opposite buildings is typically determined by the width of the street and pavements. This can range from narrow alleyways in old towns to wide avenues flanked by wide pavements in modern cities. It can also be influenced by the arrangement of buildings within the plot. For example, commercial or mixed-used buildings are built to the plot edge without setbacks, whereas residential buildings may have setbacks.

The distance between the opposite buildings can be estimated by counting the number of lanes and multiplying them by the average lane width (3.75 metres) and the average width of the pavements (1.2 metres).

Setbacks. In urban planning and zoning, building setback is the distance between a building and the plot or property line or street. They are typically required by local building codes or zoning regulations to promote safety, aesthetic appeal and functional use of land. Setbacks can be inconsistent and hence estimating them could be difficult.

The ratio of foreground to background. Determining the ratio of foreground to background visually involves estimating the relative amount of space occupied by each in an image or scene. This can be accomplished by visually comparing the size and prominence of the foreground and background objects or elements.

The image can be mentally divided into thirds both horizontally and vertically to create a 3x3 grid. The foreground and background elements should be compared in each of the nine sections of the grid, with a higher weight given to sections that contain more prominent elements.

Style of the buildings. The style of a building refers to the specific architectural design or aesthetic that characterises its form, structure and decorative elements. There are many different styles of buildings, each with its own unique features and history, but this study considered the traditional or classical style of architecture, the modern or contemporary style, and a combination of both.

Overall, the style of a building can reflect the cultural, historical and artistic influences of its time and place and can evoke a sense of identity, tradition and innovation and can influence the perception of the urban environment.

Contrast in the built form along the street. This refers to the visual and architectural differences between buildings and structures along a particular stretch of road. Contrast can be created by variations in building materials, height, style, colour or other factors and can add visual interest and complexity to a streetscape. For example, a street with buildings of different architectural styles, such as a mix of modern and traditional styles can create a dynamic contrast that draws the eye and adds character to the area. Similarly, a street with buildings of varying heights can create a sense of rhythm and movement as the eye is drawn up and down the different façades. Contrast in the built form along a street can create a sense of variety, interest, and visual excitement, thereby enhancing the character and perception of the area as a whole.

Variety of built forms. This refers to the diversity of building shapes, sizes and arrangements in a particular plot or property. Buildings with different shapes and configurations can add visual appeal and break up a streetscape's monotony. This study refers to two types of forms: regular geometric form and non-geometric or parametric form. The third category is the combination of both. The variety of built form can enhance the aesthetics and functionality by creating a diverse and visually interesting built environment.

Building typology. Recognising building typologies involves understanding the different types or categories of buildings based on their design, construction and function. Building typologies can vary depending on the context and location and most importantly FAR or plot ratios. This study refers to the 50 building typologies published by A+T (Aurora, 2015) to identify different building typologies associated with FAR, FSI and plot ratios. For visual analysis, on-site identification of the building typology as similar or diverse will suffice.

Complimentary elements. These are the physical components of a city that work together to create a functional, cohesive and attractive urban environment. Buildings are considered as primary elements and trees, vegetation, streetscape elements, people and cars are complementary elements. These elements in a coordinated and integrated manner can enhance the experience of the urban environments.

Activity levels. This is the amount and type of human activity that takes place in a particular street or public space. The level of activity on the street can vary depending on a range of factors such as the time of day, day of the week and the season. Common indicators of activity levels on the street include pedestrian traffic, sidewalk activities such as street performance and outdoor eating. The number of people walking along the street is an important indicator of activity levels. High pedestrian traffic can indicate a popular and active area with a range of amenities and attractions. The presence of outdoor dining or seating areas or street performers can add to the vibrancy and activity of the street and create a unique and interesting atmosphere.

Building use. This is the purpose for which a building was designed and used. Building use can vary widely depending on factors such as location, size and zoning regulations. The typical building uses include residential, commercial, industrial, institutional, recreational and mixed-use. The building typology is closely linked to building use. For instance, one experiences and sees a number of buildings daily and develops a system that distinguishes a residential building from a commercial one. Some building typologies such as detached houses or townhouses are associated with residential use.

Measurable Attributes of Visual Composition

Arrangement of buildings along the street – spatial density. The spatial arrangement of buildings along a street can have a significant impact on the overall experience and character of the neighbourhood. Several factors influence the spatial arrangement of buildings including zoning regulations, building codes and architectural styles.

In urban areas, buildings are typically arranged linearly along the street, with little space between them. This creates a dense, compact urban environment that is common in cities around the world. In suburban areas, buildings may be set back from the street with more space between them and larger yards. This creates a more spacious (scattered or loose) and relaxed environment.

Balance – symmetry and asymmetry. The arrangement of buildings along a street can be either symmetrical or asymmetrical and both have their own unique visual appeal and benefits.

Symmetrical arrangements are characterised by an even and balanced distribution of buildings on both sides of the street with buildings of similar size, shape and types. This creates a sense of order and harmony and can be visually striking and aesthetically pleasing.

Asymmetrical arrangements are characterised by an uneven and varied distribution of buildings with buildings of different sizes, shapes and types. This can create a more dynamic and livelier visual environment with more opportunities for architectural diversity and creativity. The perception of symmetry or asymmetry and also be influenced by the presence of vegetation and open or vacant spaces on either side of the building. Ultimately, the arrangement of buildings along a street should be carefully considered and planned to achieve the desired visual impact and functional outcomes.

Enclosure ratios. This is the relationship between the height of buildings and the width of the street or public space they face. It is a measure of how enclosed or open a space feels. An enclosure can be seen as an outdoor room in which large vertical objects such as buildings or trees form the walls and the horizontal area of the street provides a floor (Harvey, 2009a).

In urban design, full enclosure refers to a design strategy in which buildings or other structures completely enclose a public space or street with a ratio of 1:1. This creates a highly intimate and enclosed space with little or no visibility beyond the immediate surroundings.

Threshold enclosures are often designed to create a sense of separation and privacy, while still maintaining a connection to the surrounding public space with a ratio of 1:2. They can also help to define the boundaries of the public and private spaces and can create a clear visual transition between the two.

Minimum enclosure with a ratio of 1:3 is often used where the goal is to create a more open and welcoming environment such as in parks, plazas or other public spaces. It can also be used in residential or commercial developments where the goal is to create a more visually open and accessible environment. While minimum enclosure can create a sense of openness and accessibility, it can also have drawbacks. Buildings that are set back from the street or public space can create a feeling of disconnection and isolation and may make it more difficult for individuals to navigate and orient themselves. It may also limit the sense of intimacy and enclosure that can be created in more tightly enclosed spaces.

In urban design, loss of enclosure with a ratio of 1:4 or more refers to a situation where the sense of enclosure that is created by the arrangement of buildings and other structures around a public space is reduced or lost altogether. This can be caused by a variety of factors, including the demolition of buildings, the widening of streets or the introduction of new buildings that do not conform to the existing arrangement. Loss of enclosure can have negative effects on the character and functionality of a public space. It can create a sense of disorientation and disconnection as the visual and physical cues that once defined the space are lost. It can also reduce the perceived sense of safety and security as the space becomes more open and exposed.

6.5.3.3 Step 2 – Assigning Scoring Systems

Assigning scores to the 15 measurable attributes identified above can be subjective and situation-dependent. However, the results of the SJT and MST assist in assigning scores for each feature based on the participants' perceptions of the urban environments presented to them. These visual features can create visually engaging or non-engaging urban environments. Hence the scoring system designed considers visual engagement and visual non-engagement as two main criteria for scoring.

Building Height

Building height is the critical construct identified in both surveys and for both GLA and UI and was associated with high, moderate and low densities; the lack of tall buildings characterised the moderate and low density and its presence signified high density. Varied built forms produced a positive perception whereas similar built forms gave a negative perception. Built forms on either side of the street can either have a similar or varied building height. Both similar and varied building heights could be visually engaging or visually non-engaging.

Criteria. The urban environs with building heights relative to the surroundings and context could be visually engaging and could have a higher score. Conversely, a different building does not match the height of the surrounding built form and is perceived as out of proportion might not be of visual interest and can be scored low. The scoring criteria are shown below.

Table 6-9. Scoring key – Building Height

Criteria	Visually Engaging		Visually Non-Engaging	
Building height	Similar	Varied	Similar	Varied
	1	1	-1	-1

The scores are accompanied by the data table on the average building height on either side of the street, which can be counted with the help of building floors.

Table 6-10 Building height – visual measurement

	Left	Number of Floors	Right
Building Height		1-4 floors	
		5-7 floors	
		7 floors and above	

Building Setbacks

Although building setback was identified as a construct that can influence the perception of density, its frequency compared to the critical constructs was negligible. However, building setbacks alter enclosure ratios and so are important. The setbacks could be a part of the pavement or semi-private spaces separated by some kind of boundary. Its direct role in influencing the perception of the urban environment is unclear.

Criteria. The setbacks that merge with the pavements to create an attractive and functional streetscape along with a proportionate relationship with the plot could be visually engaging, whereas a setback which is cordoned off and restricts visibility can be perceived as non-engaging and could have a lower score.

Table 6-11. Scoring key – Building Setback

Criteria	Visually Engaging		Visually Non-Engaging	
Building Setback	Front setback	Built to Edge	Front setback	Built to Edge
	1	1	-1	-1

Space Between Buildings

Space between the buildings is one of the top 20 constructs identified by the participants in the MST. Given that it is difficult to recognise the space between the adjacent buildings from a pedestrian perspective, the participants' annotation of space between the building is interpreted as space between the opposite buildings which is separated by the street. This feature also includes the attributes of the street.

Criteria. Higher scores are given to the built form that is spatially arranged to create interesting and functional spaces while maintaining a good environmental quality between the buildings such as allowing for adequate light and air. Closely spaced built form creates a dark and dull environment and will be scored lower.

Table 6-12. Scoring key – Space between the Buildings

Criteria	Visually Engaging	Visually Non-Engaging
Space between the Buildings	1	-1

The scores can be accompanied by the data that results in calculating the average carriage width.

The carriage and the building height can assist in determining the enclosure ratios.

Table 6-13. Space between the buildings – visual measurement

Space between the buildings	Number of Lanes	Number of pavements	Calculations	Carriage Width
Example	3	2	(3x3.75) + (2 x 1.2)	

Ground Floor-to-Superstructure Ratio

The articulation of the ground floor was not exclusively identified as a construct in either of the surveys (MST or SJT). However, from the pedestrian point of view, the activities at ground level can influence the perception of social density and consequently the perception of the urban environment. In addition, the scale and proportion of the ground floor as against the other floors of the buildings can create a visual impact (Gehl, Kaefer Johansen and Solvekg, 2016).

Criteria. A building with a very small ground floor area relative to the overall building mass would receive a lower score, while a building with a ground floor that is in proportion to the superstructure and creates a welcoming and functional streetscape would receive a higher score.

Table 6-14. Scoring key- Ground floor – Superstructure

Criteria	Visually Engaging		Visually Non-Engaging	
Ground floor superstructure	Left	Right	Left	Right
	1	1	-1	-1

It is possible to visually differentiate between the ground floor and the upper floors. The height of the ground floor might not be equal to other floors and this can be accounted for using the multiples of floors.

Table 6-15. Ground floor: Superstructure – visual assessment

	Left		Right	
Ground floor superstructure	Height of the Ground Floor	Number of floors	Height of the Ground Floor	Number of floors
	1	10	1.5	10

Background vs Foreground

The built-to-open ratio was not identified as a construct in the MST but participants described the urban environments to have too much built-up area and openness due to visible sky. These constructs were translated to identify the built-to-open relationship or determine the ratio of background to foreground using the rule of thirds used in photography. The rule of thirds is a photography compositional guideline that divides an image into thirds (9 parts). It assists in visual and instant assessment and the results can later be validated using image segmentation.

Criteria. Higher scores are given to developments that have a strong and clear built-open relationship and that create an attractive and visually engaging urban environment. An urban environment with an ambiguous figure-ground relationship in which it is unclear where the buildings end and the open space begins would receive a lower score.

Table 6-16. Scoring – key- Background vs Foreground

Criteria	Visually Engaging	Visually Non-Engaging
Built – Open	1	-1

For instance, the built-to-open ratio can be determined as 9:1 in high density or 3:2 in moderate density with reference to the frame of vision.

Building Style

The style of the buildings was one of the top 20 constructs identified by the participants as influencing the perception of density. The building style, whether traditional or modern, has a considerable impact on the aesthetics of the urban environs. The impact of both styles, positive or negative, depends on how effectively they are linked together.

Criteria. Higher scores are given to urban environs that have a unique and attractive building style that is appropriate to the context and surroundings and that creates a cohesive and visually engaging urban environment. Multiple styles that might not create a cohesive urban environment might be scored lower.

Table 6-17. Scoring key – Style of Building

Criteria	Visually Engaging			Visually Non-Engaging		
Style of the Building	Traditional(T)	Modern (M)	T +M	Traditional(T)	Modern(M)	T +M
	1	1	1	-1	-1	-1

Contrast in Built Form

Contrast in built form refers to the differences in building styles, colours, textures and materials. These elements did not appear in the top 20 constructs derived from the MST, but they are visual features and can affect the visual quality of the urban environs.

Criteria. Higher scores are given to developments that have a variety of building heights, architectural styles and materials that create an interesting and visually engaging streetscape, whereas something uniform and similar can appear monotonous and would receive a lower score.

Table 6-18. Scoring key – Contrast in built form

Criteria		Visually Engaging	Visually Non-Engaging
Contrast in the built form	Building style	1	-1
	Colour	1	-1
	Texture	1	-1
	Material	1	-1

Variety of Built Forms

The variety of built forms was identified as one of the criteria associated with the positive perception of urban environments in the situation judgement task. It could be by virtue of the building's size, shape or style. It also refers to the geometric versus parametric built form.

Criteria. Higher scores are given to developments that have a variety of building sizes, shapes and styles that create an interesting and visually engaging streetscape. A similar size, shape and style of built form would receive a lower score. However, this terminology is technical. When describing their experience people may get confused between contrast, style, variety and building typology and register it under whatever adjectives come to mind.

Table 6-19. Scoring key – Variety of built form

Criteria	Visually Engaging			Visually Non-Engaging		
Variety of built form	Geometric	Parametric	Both	Geometric	Parametric	Both
	1	1	1	-1	-1	-1

Building Typology

Building typology refers to building forms associated with residential, commercial or mixed-use. There are as many as 50 building typologies, but detached or semi-detached houses, row houses, townhouses, apartment blocks and high-rises are most common. People associate these with a specific use.

Criteria. Higher scores are given to developments that have a mix of building types that serve different purposes and create a vibrant and diverse community, whereas developments with one building type could appear to be dull and monotonous and could receive a lower score.

Table 6-20. Scoring key – Building Typology

Criteria	Visually Engaging		Visually Non-Engaging	
Building Typology	Similar	Varied	Similar	Varied
	1	1	-1	-1

Complimentary Elements

The presence and quality of complementary elements such as trees, people, cars and streetscape elements contribute to the overall character and liability of the street. The surveys show that the presence of trees is a determinant of positive perception whereas cars create a perception of high density and a negative quality. Therefore, complementary elements have been identified to influence the perception of density to a certain extent.

Criteria. Higher scores are given to developments that have well-designed and well-maintained streetscape elements, such as pavements, lighting, street furniture and greenery and a diverse and active mix of people and vehicles that create a lively and safe environment. The intensity and number of these elements could have a favourable or adverse effect on the perception of density.

Table 6-21. Scoring key – Complementary elements

Criteria		Visually Engaging	Visually Non-Engaging
Complimentary elements	Vegetation	1	-1
	Streetscape elements	1	-1
	Cars	1	-1
	people	1	-1

Activity Levels

Activity levels refer to the activities and vibrancy along the street, such as pedestrian traffic, commercial activity, community events, spillover of retail activities, outdoor dining and sitting and being social.

Criteria. Higher scores are given to developments that have a high level of activity and vibrancy that create a lively and engaging environment for residents, workers and visitors, whereas an urban environment with low pedestrian and vehicle traffic, limited commercial activity and few community events would receive a lower score.

Table 6-22. Scoring key - Activity levels

Criteria	Visually Engaging			Visually Non-Engaging		
Activity levels	High	Low	None	High	Low	None
	1	1	1	-1	-1	-1

Arrangement of Buildings Along the Street and Spatial Density

The arrangement of buildings along the street includes their spacing, orientation and relationship to the street and adjacent buildings. The results of the MST show that high-density urban environments are characterised by the compact arrangement of buildings whereas moderate and low-density urban environments were described as having loose or scattered urban form.

Criteria. The urban environs that have a well-designed arrangement of the built form, either compact or loose, that creates an attractive and engaging street frontage and a comfortable pedestrian environment can be given higher scores. Built form that appears to be far apart and lacks consistent orientation would receive a lower score.

Table 6-23. Scoring key – Spatial Density

Criteria	Visually Engaging		Visually Non-Engaging	
Arrangement of buildings along the street / Spatial Density	Compact built form	Spacious/ loose built form	Compact built form	Spacious/ loose built form
	1	1	-1	-1

Balance or Symmetry

Symmetry refers to the degree to which the buildings along the street are arranged with consistent building heights, setback distances and façade details. People might also perceive the urban environment as symmetrical due to the presence of vegetation or open spaces.

Criteria. Higher scores are assigned to developments that have a high degree of symmetry and create a visually harmonious streetscape. Built forms with varying heights, and setback distances that would not be visually harmonious would receive a lower score.

Table 6-24. Scoring key – Symmetry

Criteria		Visually Engaging	Visually Non-Engaging
Symmetry	Vegetation	1	-1
	Open/vacant spaces	1	-1
	Building typologies	1	-1
	Building height	1	-1

Table 6-25. scoring Key – Asymmetry

Criteria		Visually Engaging	Visually Non-Engaging
Asymmetry	Vegetation	1	-1
	Open/vacant spaces	1	-1
	Building typologies	1	-1
	Building height	1	-1

Enclosure Ratios

Enclosure ratio refers to the degree to which the buildings along a street create a sense of enclosure and define the street edge. It is measured as a ratio of building height to street width.

Criteria. Higher scores are assigned to developments that have a high degree of enclosure and create a strong sense of place and identity for the street.

Table 6-26. Scoring key – Enclosure ratios

Criteria			Visually Engaging	Visually Non-Engaging
Enclosure Ratios		1.1 – Full Enclosure	1	-1
		1.2 – Threshold Enclosure	1	-1
		1.3 – Minimum Enclosure	1	-1
		1.4 – Loss of Enclosure	1	-1

Building Function or Use

Building use refers to residential, commercial or mixed functions. The context governs the building use, whereas the building use hints at the building typology, building style and the activities that follow.

Table 6-27. Scoring key – Building use

Criteria		Visually Engaging	Visually Non-Engaging
Building Function	Residential	1	-1
	Commercial	1	-1
	Mixed-use	1	-1

6.5.3.4 Step 3 – Establishing Weighing Factors to the Visual Features

Establishing weighting factors to visual features is an important step in image analysis as it allows for the prioritisation of certain visual features over others. This can help to improve the accuracy and effectiveness of visual indexes that rely on visual information. On the basis of their frequency or distribution in the dataset, statistical methods can be employed to determine the significance of visual features.This study uses frequency-based weighting. In this approach, weights are assigned based on the frequency of occurrence of each visual feature in the dataset. Features that occur more frequently are assigned higher weights.

Few of the visual features correspond to the critical constructs identified in the MST and the remaining visual features derived from the Gestalt theories represent the spatial relationship between the two constructs. Therefore, the visual features were categorised as per the groups formulated for MST in the coding manual and with reference to the frequency count of the constructs and weighting derived for the categories, the weighting for the visual features was deduced.

The frequency count for street profile, site organisation and building profile was highest in the MST. Site organisation included vegetation and streetscape elements which are covered under the category of complementary elements of the visual index. Complimentary elements also include the number of people and cars which are grouped under social density in MST and whose impact is measured in visual assessment by the level of activity along the street. People and cars are temporal and continuously in flux hence are added to complimentary elements to the built form which is static and constant. Building profile includes building height and length and the street profile includes street width and street length as constructs. The results of the MST determine building height and street width as a common and critical construct for the perception of high, moderate and low density. While building height can independently signify the density and volume of the buildings, street width does not. Hence, it makes sense to see them in correlation. The proportion of building height to street width suggests that enclosure ratios play an important role in the perception of space and density. Therefore, the highest weights were assigned to building profile, site organisation and enclosure ratios.

The categories with frequency counts in the second tier were land use, urban form aesthetics, urban form composition and building density. Land use for visual assessment refers to the building function (residential, commercial or mixed) of the majority of buildings. Constructs such as balanced or unbalanced development, the amount of visible sky and the presence of buildings only on one side were covered under urban form composition in the MST code manual and correspond to Gestalt principles of symmetry and figure-ground or built-open in visual assessment. Urban form aesthetics includes all the physical attributes of the built form such as building style, material, colour and texture. They also create contrast and introduce variety in the built form. These constructs are translated into four visual features: the style of the building, variety of the built form, contrast in the built form and building typology. Building density refers to the special arrangement of the built form due to setbacks or space between the buildings. The visual features covered under this category are arrangement of buildings along the street, spatial density, building setback and space between buildings. These categories are assigned a weighting of 10% with an exception of 15% for urban form aesthetics since it has a greater visual impact from a pedestrian point of view.

The visual indexes with the assigned scores and weighting are shown in Table 6-28.

Table 6-28. Qualitative Index for Visual Assessment

Building profile			Weighting	15 %
Criteria	Visually Engaging		Visually Non-engaging	
Building Height	Similar	Varied	Similar	Varied
Scores	1	1	-1	-1
Ground Floor. Superstructure	Left	Right	Left	Right
Scores	1	1	-1	-1
Urban Form Composition			Weighting	10%
Criteria	Visually Engaging		Visually Non-engaging	
Built – Open	1		-1	
Criteria	By virtue of		Visually Engaging	Visually Non-engaging
Symmetry	Vegetation		1	-1
	Open / vacant spaces		1	-1
	Building Typologies		1	-1
	Building Height		1	-1
Asymmetry	Vegetation		1	-1
	Open / vacant spaces		1	-1
	Building Typologies		1	-1
	Building Height		1	-1
Urban Form Aesthetics			Weighting	15%
Criteria	By virtue of		Visually Engaging	Visually Non-engaging
Style of the Building	Classical/ Traditional		1	-1
	Modern/Contemporary		1	-1
	Classical + Modern		1	-1
Variety of Built form	Geometric built form		1	-1
	Parametric built form		1	-1
	Geometric + Parametric		1	-1
Contrast in the built form	Building style		1	-1
	Colour		1	-1
	Texture		1	-1
	Material		1	-1
Building Typology	Similar	Varied	Similar	Varied
Scores	1	1	-1	-1

Site Organisation			Weighting	15%
Criteria	By virtue of		Visually Engaging	Visually Non-engaging
Complimentary elements	Vegetation		1	-1
	Streetscape elements		1	-1
	Cars		1	-1
	People		1	-1
Intensity of Activities			Weighting	10%
Criteria	Level of Activity		Visually Engaging	Visually Non-engaging
Level of activities	High		1	-1
	Low		1	-1
	No Activity		1	-1
Building density along the Street			Weighting	10%
Criteria	Visually Engaging		Visually Non-engaging	
Arrangement of buildings along the street / Spatial Density	Compact built form	Spacious/ Loose built form	Compact built form	Spacious/loose built form
	1	1	-1	-1
Building Setback	Front setback	Built to Edge	Front setback	Built to Edge
	1	1	-1	-1
Space between the Buildings	1		-1	
Enclosure Ratios			Weighting	15%
Criteria	Types of Enclosures		Visually Engaging	Visually Non-engaging
Enclosures	1.1 – Full Enclosure		1	-1
	1.2 – Threshold Enclosure		1	-1
	1.3 – Minimum Enclosure		1	-1
	1.4 – Loss of Enclosure		1	-1
Building Use			Weighting	10%
Building Use	Residential		1	-1
	Commercial		1	-1
	Mixed-Use		1	-1

6.6 Chapter Summary

This chapter examined the image analysis and assists in achieving the second and third objectives of the study. It began by presenting an analysis of the 54 images using three approaches. The first assessed the visual complexity of the images and validated the number of constructs identified in the MST. It proves that the images representing mixed land use represent different densities, intensities and numbers of visual elements, architectural styles and built form, thus providing images with different visual compositions that trigger different elements of the urban environment.

The second approach – image segmentation – assists in achieving the second objective which is determining the contribution of visual components to the perception of density. It identified the magnitude of the eight visual components within the frame of vision that characterises perceived density. Magnitude estimation and analysis of this data assisted in deriving the range (expressed in percentages) that represents the area of the eight visual components for high, moderate and low-density urban environments. A further threshold analysis of this data aided in deriving the critical points above and below which the degree of density would increase or decrease.

The ranges and threshold for GLA and UI were different owing to the visual complexity of the images and probably the angle at which the images had been captured. The ranges for GLA can be considered guidelines for assessing other similar urban environments.

The third approach analyses the images with the help of Gestalt principles since they explain the way we select, organise and interpret urban environments subconsciously. This assists in achieving the third objective of the study, the development of the qualitative index for the visual assessment of the urban environments.

The 20 critical constructs (including the eight visual components) that include the physical attributes of the built form, their spatial organisation and the way we perceive them with the help of Gestalt principles such as the law of symmetry, built-vs-open and enclosure ratios were considered for developing the index. These factors can be measured using the relative measurements of the building floors or width of the street. Using the frequency analysis, contribution of urban form elements were allocated scores and assigned weights to measure the positive or negative perception of the urban environment.

Chapter 7. Correlation Analysis

Chapter 5 identified the critical constructs associated with the perception of density. design and planning establish a degree of correlation amongst them but in regard to their role in the perception of density, these needs are verified to meet four objectives:

1. **Identify associations**. To identify the association between two or more constructs and determine if they are positively or negatively correlated with the perception of density.

2. **Predict outcomes**. To identify the spatial properties described by constructs that can be acted upon by design to maintain the benefits of high objective density whilst maintaining the benefits of a moderate perception of density.

3. **Identify causal relationships**. To identify potential causal relationships between constructs. For instance, mixed-use urban environments would imply high levels of activity and consequently a high density of people. Thus, it can be implied that land use influences the presence or absence of other constructs.

4. **Make informed decisions**. To deduce design implications that can pinpoint the constructs that are most influential and controllable and assist in changing the negative correlations to positive ones.

The correlations were established using Spearman's correlation analysis.

7.1 Urban Design Principles

Urban designers constantly reflect on the elements of urban form that can aid in the creation of successful places and spaces. Several frameworks have been derived for successful urban design and place-making (Lynch, 1981; Jacobs and Appleyard, 1987; Bentley, 1985; Tibbalds, 1989; Ellin, 2006; Gehl and Carmona, 2010). They assess urban environments using different approaches to establish correlations between space and human behaviour. Some refer to the links between perception, cognition, human behaviour and the evaluation of the physical built environment

(Nasar, 1989c; Gehl, Kaefer Johansen and Solvekg, 2016). Some urban design principles that assist in understanding the correlations established in this study are described briefly below.

1. The people-place principles emphasise designing environments with people in mind (Nasar, 1989; Carmona et al., 2010; Gehl, Kaefer Johansen and Solvekg, 2016). This involves designing settings that are welcoming, accessible and conducive to social interaction. This approach, when applied to the design of public spaces can help to create well-used spaces that foster a sense of community. When individuals feel more comfortable and engaged in a space, they are more inclined to spend time there which might contribute positively to the perception of density. Good enclosures are the physical limits that define and enclose public places, such as walls, buildings and other urban components (Harvey, 2009b; Aung, 2020). They offer a sense of intimacy and privacy in public places, making them more comfortable and inviting. Urban designers can generate a sense of density in areas where the real density is not particularly great by defining and enclosing public spaces.

2. The diversity principle (Cabe, no date; Steemers, Ramos and Sinou, 2004) emphasises the development of diversified mixed-use communities that provide a variety of amenities and activities. This may comprise a combination of residential, commercial and institutional functions and a variety of public places. When an area offers a variety of purposes and activities, it entices people to spend time there, leading to a positive perception of density.

3. Activity-based design focuses on designing environments for particular activities or functions. This can include parks, plazas and other public areas designed to promote social interaction and community involvement. When a space is designed to accommodate particular activities, it might attract more people.

4. The idea of a scaled approach to density (Angel, Lamson-Hall and Blanco, 2021; Godoy-Shimizu, Steadman and Evans, 2021; Burger *et al.*, 2022) considers the human experience of density. It implies that density should be considered not only as a quantitative measure of people per unit area but also as a qualitative measure that considers the size of the built environment and the human experience of that space (Rapoport, 1975a; Alexander, Reed and Murphy, 1988; Churchman, 1999; Cheng and Vicky, 2010; Kent and Madden, 2016). This implies that density should be proportional to the size and character of the urban environment and that the design of public spaces and structures should be adapted to the conditions, requirements and preferences of the individuals who use them.

5. The term 'curated ground floor experiences' refers to the design and programming of the ground floor level of urban buildings. The ground floor is the most significant component of the building in terms of its influence on-street life and the urban experience as a whole (Araldi and Fusco, 2016; Gehl, Kaefer Johansen and Solvekg, 2016; Kent and Madden, 2016). Urban designers can generate a bustling street life that contributes to a feeling of density by building ground floor spaces that are appealing, practical and accessible to the public. Street life refers to the activities and relationships that occur on the street. This involves walking, socialising, business and other urban activities. By bringing people together and fostering a sense of community, a bustling street life can create a sense of density. Urban designers may create a dynamic and engaging atmosphere by designing public areas and structures that promote street activity.

The overview of these principles assists in understanding the positive and negative correlations found in the case studies, the dependencies and causal relationships between the constructs.

7.2 Spearman Correlation Analysis

Spearman correlation which measures the relationship between two ranked constructs (Laerd Statistics, 2018). The relationship suggests one of the following: (1) as the value of one construct increases, so does the value of the other – a positive correlation; or (2) as the value of one construct increases, the other value of the other construct decreases – a negative correlation. The ordinal data (hat represents variables with values that have a natural order or ranking) used for this test was derived from the frequency analysis of the constructs conducted for the MST.

In Spearman correlation, each factor is correlated with every other factor in the dataset. The Spearman correlation coefficient measures the intensity of the relationship between two variables. It provides a measure of how closely the ranks of the variables are related to each other.

For example, if one has had variables A, B, C, and D, one can calculate the Spearman correlation between A and B, A and C, A and D, and so on. This allows to examine the relationships between each pair of variables and assess the strength of their monotonic association.

This study conducted Spearman correlation analysis using SPSS. The output table of the analysis is a matrix that represents the correlation coefficient and the p-values (probability of obtaining a correlation coefficient as extreme). In the output matrix of a Spearman's rho analysis in SPSS, the 'Correlation coefficient' column displays the correlation coefficient values (r) for each pair of variables. This measures the strength and direction of the relationship between the variables and ranges from -1 to 1, where -1 represents a negative correlation, 1 represents a positive correlation and 0 represents no correlation.

The 'Sig. (2-tailed)' column represents the p-value for each correlation coefficient. The p-value measures the likelihood of obtaining the observed correlation coefficient by chance, assuming that there is no true correlation between the variables. A p-value less than or equal to 0.05 (typically chosen as the threshold for statistical significance) indicates that the correlation coefficient is statistically significant, and it is unlikely to have occurred by chance.

The ‘2-tailed’ part of the Sig. column indicates that the p-value is calculated assuming a two-tailed test, which means that the test is sensitive to both positive and negative deviations from the null hypothesis. It thus takes into account the possibility of obtaining both positive and negative correlations between two variables.

If the p-value is high (close to 1), it may indicate that the sample size is too small or that there is too much variability in the data to detect a significant correlation. It may also suggest that the variables being analysed are not related or that other variables need to be considered in the analysis.

The p-value of 0.000 in a Spearman correlation suggests that there is a statistically significant correlation between the two variables being studied. A p-value of 0.000 suggests that the correlation observed is unlikely to have occurred by chance and that there is a high level of confidence that the correlation between the two variables is real and not due to random variation in the data.

These guidelines assist in interpreting the Spearman correlation matrix attached in the Appendix of Chapter 5.

7.3 Results

To be able to summarise the results of Spearman correlation, colour-coded matrix for Glasgow and Universal Illustrations is presented below, that highlights R-values of +1 and -1 that indicate the perfect positive and negative correlations between the constructs, respectively. It was also found that the constructs with perfect correlation have a p-value of 0.000 which indicates a strong statistical significance for the observed correlation and that the correlation is extremely unlikely to have occurred by chance.

Perfect positive correlations refer to the situation where the constructs have a correlation value (R-value) of +1.000. This indicated that there exists a linear relationship between the two constructs in a positive direction. This means, as the value of one variable increases, the value of other increases proportionally. Negative correlations refer to a situation where two constructs have a correlation coefficient (R-value) of -1.000, indicating that there is a strong negative linear relationship between them. This means that, as one variable increases, the other variable proportionally decreases.

The correlation matrices for the 20 critical constructs of the two sets are presented independently in this chapter. However, the comparative analysis of the matrices revealed that most of the constructs with positive correlation and negative correlations are similar in both sets. Hence, they are described once to avoid repetition.

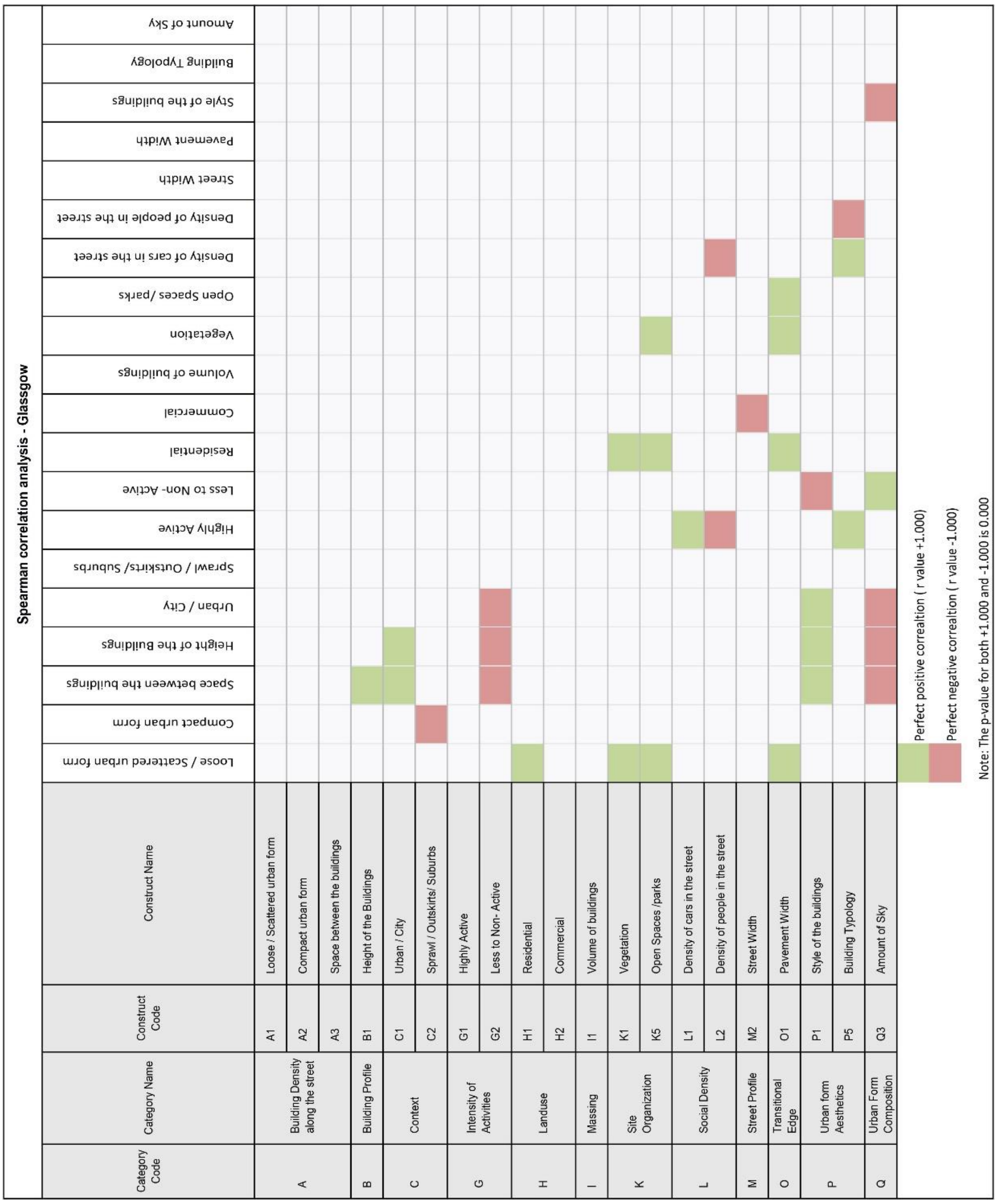


Figure 7-1. Spearman correlation analysis – Glasgow

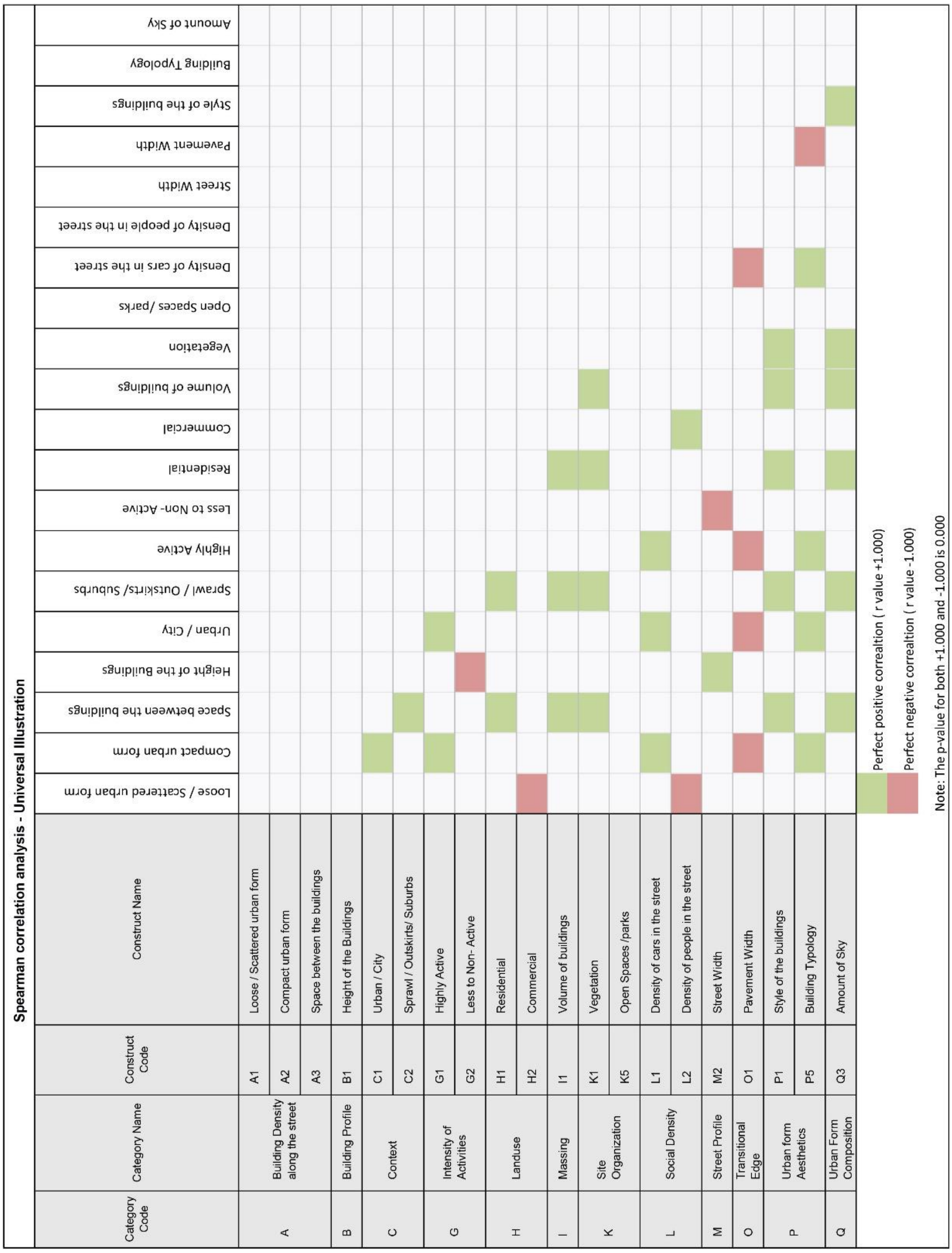


Figure 7-2. Spearman correlation analysis – Universal Illustrations

7.3.1 Correlation 1. Correlation of Height of the Building with other constructs

Table 7-1. Correlation 1 – Height of the building

Construct	SET	Construct	R-value	p-value
Height of the building	GLA	Space between the buildings	+1.000	0.000
	GLA	Style of the buildings	+1.000	0.000
	GLA	Urban/city Context	+1.000	0.000
	UI	Street width	+1.000	0.000
	GLA	Amount of sky	-1.000	0.000
	GLA	Little to no activity	-1.000	0.000

In the provided correlation table, each row represents a construct (variable), and the columns provide information about the correlation between that construct and other constructs. For instance, the first row shows the correlations of the "height of the building" with space between the buildings; style of the buildings and so on.

A perfect positive correlation between height of the building and space between the buildings, style of the buildings, urban and city context and street width indicates a thoughtfully designed urban setting. In case of Glasgow (GLA-CC-HD-16, 22, 28; UI-02, 06,22,29,28), as the height of buildings increases, the space between them also increases. This correlation suggests that taller buildings are situated farther apart, allowing for more open spaces, green areas, or public plazas. This design approach aims to create a sense of spaciousness, visual relief, and improved views within the urban environment. A positive correlation between building height and style indicates that as buildings get taller, their architectural style becomes more prominent and distinctive. This correlation may involve incorporating unique design elements, innovative façades, or iconic features that enhance the visual identity of the buildings (GLA-CC-HD-01,02,09,28,16; UI-28,22,03,33). It contributes to creating a visually striking skyline and an aesthetically pleasing urban landscape. The positive correlation between building height and urban/city context suggests that taller buildings are strategically located in specific areas within the city. This correlation recognises that certain zones or districts are more suitable for high-rise development due to factors such as transportation hubs, commercial centres, or designated urban growth areas. It reflects a conscious effort to shape the urban fabric in alignment with the city's overall vision and development goals. As building height increases, the street width also tends to widen. Taller buildings often require wider streets to maintain a sense of proportion and avoid a canyon-like effect. The wider streets provide more breathing space, accommodate pedestrian movement, and allow for adequate light penetration (GLA-CC-HD-16, 22, 28; UI-02, 06,22,29,28). This correlation contributes to creating a balanced and harmonious urban environment.

A perfect negative correlation between the height of the building and amount of sky indicates that, as the height of buildings decreases, the amount of visible sky increases (GLA-CC-HD-04, 16, 22, 24, 28; UI-05, 22, 29, 33, 34). Lower buildings allow for a larger portion of the sky to be visible from street level. This correlation aims to create a more open and expansive perception of the sky, providing a sense of visual spaciousness and connection to the natural environment. A negative correlation between building height and activity levels suggests that as buildings become shorter, the level of activity in the surrounding area decreases. Lower buildings may indicate less intense urban development, resulting in quieter and less bustling streets (GLA-EE-MD-09, SE-MD-13, WE-MD-06 16; UI-01, 02, 06, 10). This correlation may be desired in certain contexts where a more tranquil and relaxed environment is sought, such as residential neighbourhoods or areas with a focus on green spaces.

These correlations can be explained using the following urban design principles:

1. Scale and Proportions: The height of buildings relative to the surrounding space can influence the sense of scale and proportions (Jacobs, 1961; Lynch, 1964; Cullen, 1971b; Rapoport, 1975c, 1982; Alexander, 1978; Nasar, 1989a; Gehl and Koch, 2001). Taller buildings may create a sense of grandeur or dominance, while lower buildings can provide a more intimate and human scale environment. The spacing between buildings can also affect the perceived scale and rhythm of the urban fabric. The scale and proportions of buildings play a crucial role in human perception. Buildings that are in proportion to the human body and provide a sense of human scale tend to

be more inviting and relatable. People may feel more comfortable and connected in environments where the buildings are designed with their proportions and spatial needs in mind. The relationship between building height and the scale of the urban context is important. In a dense urban environment with buildings of varying heights, the juxtaposition of tall and shorter buildings can create a sense of scale and depth. This interplay between different building heights can contribute to a visually dynamic and engaging streetscape, providing a diverse range of spatial experiences for pedestrians.

2. Symbolism and Impression: Tall buildings often convey a sense of power, prestige, and modernity (Lynch, 1964; Cullen, 1971a; Norberg Schultz, 1980; Nasar, 1989a; Gehl and Gemzøe, 2003; Gifford, Steg and Reser, 2011). They can become iconic symbols of a city or a particular era. The height of buildings can leave a lasting impression on people and shape their perception of a place (Evans, 2003; Salingaros and van Bilsen, 2005; Gifford, Steg and Reser, 2011) . Similarly, architectural styles, such as classical, modernist, or contemporary, carry cultural and historical associations that can evoke specific emotions and perceptions.

3. Aesthetics and Visual Appeal: The design and style of buildings greatly contribute to the aesthetic quality of a cityscape. Unique and visually appealing buildings can enhance the overall attractiveness of an area and create a sense of visual interest (Kaplan and Kaplan, 1982; Nasar, 1998; Herzog, 2006; Gehl, 2010) . Different architectural styles can evoke different moods and elicit varied emotional responses from individuals.

4. Visual Enclosure and Openness: The spacing between buildings determines the degree of visual enclosure or openness in urban spaces. Closer spacing can create a sense of enclosure and intimacy, while wider spacing can provide a more open and expansive feel (Bosselmann and Gilson, 1977; Appleyard, Gerson and Lintell, 1981; Bosselmann, Macdonald and

Kronemeyer, 1999; Gehl and Svarre, 2013). These spatial qualities can influence people's comfort, sense of safety, and their overall experience of the urban environment. Building height and street width contribute to the visual enclosure of a street. Narrow streets with tall buildings create a sense of verticality, as the buildings visually frame the street and narrow the field of view. This can create a more intimate and enclosed atmosphere, evoking a sense of contentment and pedestrian-scale experience. In contrast, wider streets with lower buildings may provide a more expansive and open feeling.

5. Environmental Quality (sunlight and shadow): The height and spacing of buildings affect the distribution of sunlight and shadows in urban areas (Gehl, 2011; Gehl, Kaefer Johansen and Solvekg, 2016). Taller buildings can cast longer shadows and potentially reduce the amount of sunlight reaching the street level and open spaces affecting the perceived brightness and ambiance of the street. The spacing between buildings too, can determine the penetration of sunlight into the urban fabric, impacting the visual quality, thermal comfort, and overall ambiance.

6. Visual Connections and Views: The spacing between buildings can create visual connections and framed views within the urban environment (Lynch, 1964; Appleyard and Lintell, 1972; Lozano, 1974; Alexander, 1978; Norberg Schultz, 1980; AECOM, 2016). Strategic spacing and orientation of buildings can frame important landmarks, vistas, or focal points, enhancing the visual interest and legibility of the cityscape. Views of natural elements, such as parks or water bodies, can contribute to a sense of well-being and connection to the environment.

7. Sense of Place and Identity: The collective arrangement of building height and spacing contributes to the unique character and identity of a place. Different urban morphologies, such as dense skyscraper clusters or low-rise historic neighbourhoods, evoke distinct perceptions and associations. The built environment, including the interplay of building height and spacing,

shapes the sense of place and can influence people's emotional attachment to their surroundings (Lynch, 1964; Cullen, 1971a; Relph, 1976; Tuan, 1977; Madani-Pour, 1996) .

8. Psychological Impact: The height and style of buildings and the context can have psychological effects on individuals (Rapoport, 1975c, 1982). Tall buildings can induce feelings of awe, inspiration, or even anxiety, depending on personal preferences and experiences. In some cases, tall buildings may invoke a sense of power, progress or innovation, while in others, they might be perceived as dominating or intimidating (V Cheng, 2010). Additionally, people's perceptions can be influenced by their personal preferences, cultural background and previous experiences with similar urban contexts (Taylor, 1981a; Evans, Lepore and Allen, 2000; Evans, 2003). Architectural styles that align with people's cultural or personal preferences may evoke a sense of familiarity, comfort, or nostalgia. Moreover, visual access to the sky and open space is often associated with feelings of freedom, tranquillity, and connection to nature.

9. Walkability and Pedestrian Comfort: The combination of building height and street width can impact the overall walkability and pedestrian comfort (Appleyard and Lintell, 1972; Appleyard, Gerson and Lintell, 1981; Gehl and Gemzøe, 1996). Narrow streets with tall buildings can provide shade and wind protection, creating a more sheltered and comfortable pedestrian environment. In contrast, wide streets with low-rise buildings may offer more exposure to sunlight and natural ventilation, potentially enhancing the comfort level for pedestrians.

10. Visual Access to the Sky: Building height affects the amount of visible sky from street level or public spaces. Taller buildings can obstruct the view of the sky, limiting the visual access to open space and natural elements. In contrast, lower buildings may provide a more expansive view of the sky, giving a sense of openness and spatial freedom (V Cheng, 2010). This can

create a sense of enclosure and restrict the perceived openness of the urban environment.

11. Activity Generators: Higher buildings, such as commercial or mixed-use developments, can act as activity generators in the urban environment. They can accommodate a larger number of businesses, offices, or residential units, attracting more people and generating a higher level of street activity (Carmona *et al.*, 2010; Gehl, 2010). This can create a bustling and vibrant atmosphere, contributing to the perception of a lively and thriving urban area.

7.3.2 Correlation 2. Correlation of Open Spaces with Other Constructs

Table 7-2. Correlation 2 – Open spaces

Construct	to	Construct	R-value	p-value
Open Spaces/ Parks	GLA	Residential Use	+1.000	0.000
	GLA	Vegetation	+1.000	0.000
	GLA	Loose/Scattered Urban Form	+1.000	0.000

A perfect positive correlation between the open space/parks and the residential use suggests that as the presence and size of open spaces and parks increase, there is a corresponding increase in residential use (GLA-EE-MD-09, SE-MD-05, 06, WE-MD-06 16; UI-01, 10, 25). Open spaces and parks are strategically integrated within residential areas, providing residents with accessible green spaces for recreational activities, social interaction, and a closer connection to nature. The proximity of these spaces to residential developments promotes a higher QoL and contributes to the overall well-being of residents. A positive correlation between open spaces/parks and vegetation implies that as the amount of open spaces and parks increases, so does the presence of vegetation (GLA-EE-MD-09, SE-MD-05, 06, WE-MD-06 16; UI-01, 10, 25). These green areas are carefully designed and landscaped, incorporating trees, shrubs, and other forms of vegetation. The abundance of vegetation within open spaces and parks enhances their aesthetic appeal, provides shade, improves air quality, and supports biodiversity. A loose/scattered urban form refers to a spatial arrangement where buildings and structures are dispersed and not tightly clustered. In a perfect positive correlation, as the urban form becomes more loose/scattered, the presence of open spaces and parks increases (GLA-SE-LD-09, SE-MD-06, EE-MD-07, EE-LD-10; UI-10,12, 25). This design approach allows for the integration of open spaces throughout the urban fabric, promoting a sense of spaciousness, visual relief, and opportunities for recreation and relaxation. A positive correlation between open spaces/parks and pavement width suggests that wider pavements induce a feeling of spaciousness and openness. Wider pavements provide ample pedestrian pathways and create a sense of openness and accessibility (GLA-CC-LD-01, EE-LD-05, SE-MD-05,06, SE-LD-04; UI-07,21, 22, 28). This encourages walking, cycling, and social interaction while also allowing for the integration of green spaces and seating areas along the pavements, enhancing the overall urban experience.

These correlations can be explained using the following urban design principles:

1. Aesthetics and Visual Appeal: Open spaces and parks provide visually appealing and natural environments that enhance the overall aesthetic quality of an area (Alyari, 2018). The presence of greenery, trees, flowers, and well-maintained landscapes creates a pleasing visual atmosphere, which positively influences human perception and evokes feelings of beauty and serenity. Open spaces with well-designed landscapes, pathways, and amenities create an attractive, safe and inviting ambiance. The wider pavements provide a sense of spaciousness and allow for comfortable pedestrian movement. The visual appeal of these elements enhances the overall perception of the urban surroundings, making it more visually pleasing and enjoyable for pedestrians.
2. Psychological Impact: Open spaces and parks with abundant vegetation create a sense of tranquillity, relaxation, and a connection with nature (Kaplan and Kaplan, 1989; Velarde, Fry and Tveit, 2007) . The presence of greenery, trees, and plants has a calming effect on the human mind, reducing stress, anxiety, and promoting positive emotions. Being in these environments enhances mental well-being, uplifts mood, and provides a respite from urban settings.

3. Environmental Quality: Vegetation in open spaces provides shade, reduces temperatures, and mitigates the urban heat island effect. Trees and plants act as natural air purifiers, filtering pollutants and improving air quality. The cooler and cleaner environment created by vegetation enhances the comfort of outdoor spaces and promotes a sense of well-being.
4. Visual Variety and Aesthetics: The scattered arrangement of buildings and the presence of open spaces create visual variety and aesthetic appeal (Lynch, 1964; Nasar, 1998; Lilli, 2013). This urban form offers diverse views and vistas, with a mix of buildings, green spaces, and natural elements. The visual richness and variety contribute to a more engaging and stimulating environment, capturing people's attention and creating a positive perception of the surroundings.
5. Sense of Spaciousness: The presence of open spaces and a more dispersed arrangement of buildings in a loose/scattered urban form creates a perception of spaciousness (Appleyard, 1971; Gehl, 2010; Lilli, 2013). This feeling of ample space enhances comfort and reduces feelings of congestion or claustrophobia that can be associated with denser urban environments. The perception of spaciousness contributes to a more positive and pleasant experience of the urban surroundings.

7.3.3 Correlation 3. Correlation of Volume of the Buildings with Other Constructs

Table 7-3. Correlation 3 – Volume of the building

Construct	SET	Construct	R-value	p-value
Volume of the buildings	UI	Vegetation	+1.000	0.000
	UI	Sprawl/Outskirts	+1.000	0.000
	UI	Residential use	+1.000	0.000
	UI	Style of the Buildings	+1.000	0.000
	UI	Amount of Sky	+1.000	0.000

As the volume of buildings increases, there is a greater potential for incorporating green spaces and vegetation within and around the built environment. This correlation suggests that there is a conscious effort to integrate natural elements, such as trees, gardens, and green roofs, alongside taller buildings (UI-05, 02,29, 25). The presence of abundant vegetation enhances the visual appeal, ecological sustainability, and overall well-being of the urban area. A positive correlation between building volume and sprawl/outskirts indicates that larger buildings are more commonly found on the periphery of urban areas or in suburban developments (UI-01, 17, 10, 25). This correlation suggests that there is a tendency for expansive, low-density development patterns with larger buildings in these areas. The aim is to accommodate residential or mixed-use developments in spacious surroundings, often characterised by larger setbacks, ample parking, and a more spread-out urban form. A positive correlation between building volume and residential use suggests that taller buildings are predominantly designed for residential purposes (UI-17,20, 33, 34). This correlation signifies a focus on vertical development to accommodate a larger number of housing units within limited land areas. High-rise residential buildings allow for efficient land use and promote urban density, providing housing options for a larger population in a compact and sustainable manner. A positive correlation between building volume and style of the buildings implies that taller buildings often exhibit distinctive architectural styles and design features (UI-06,17, 29,16). This correlation suggests that architectural expression and aesthetic considerations are taken into account when constructing larger buildings. The style of buildings may vary based on cultural, historical, or contemporary influences, adding visual diversity and creating iconic landmarks within the urban fabric. A positive correlation between building volume and the amount of sky refers to the potential for taller buildings to occupy more vertical space and reduce the visible sky area (UI-05, 08, 20, 21). This correlation suggests that as buildings become taller, the sky becomes less visible from ground level. It indicates a denser urban environment with increased building coverage, resulting in a different skyline and altered perception of the sky in the urban context.

These correlations can be explained using the following urban design principles:

1. Human Scale and Proportions: The volume of buildings, in relation to the surrounding environment, can impact the perception of human scale and proportions (Cullen, 1971b; Alexander, 1978; Gehl and Koch, 2001; Gehl, Kaefer Johansen and Solvekg, 2016). Buildings that are in proportion to the

street width and adjacent structures create a harmonious and comfortable environment. This can enhance the sense of walkability, create pleasant pedestrian experiences, and foster social interaction.

2. Visual Appeal and Aesthetics: The volume of buildings in densely developed areas can create a visually stimulating environment, showcasing architectural diversity and iconic structures (Lynch, 1964; Gehl, 2010; Gehl, Kaefer Johansen and Solvekg, 2016). This can leave a lasting impression on residents and visitors, contributing to a sense of vibrancy and excitement. Additionally, the combination of tall buildings with abundant vegetation creates a visually pleasing and diverse urban landscape. The contrast between the built form and the natural element of vegetation enhances the overall aesthetics and can evoke positive emotional responses. The presence of greenery softens the urban environment, adds colour and texture, and creates a more inviting and attractive setting, contributing to a more pleasant perception of the surroundings. Buildings designed in a particular architectural style, whether it is classical, modern, vernacular, or contemporary, can convey a sense of heritage, tradition, and local identity. This can foster a connection to the history and cultural values of a community, evoking a sense of place and belonging.
3. Sense of Connection and Place Identity: The volume of buildings in urban areas can contribute to the perception of scale and create a sense of place (Alexander, 1978; Gehl, 2010). When buildings are taller and more prominent, they can establish a distinctive character and identity for a city or neighbourhood. On the other hand, sprawl or low-density development in the outskirts often lacks a cohesive urban fabric and may give a sense of disjointedness. This can lead to a perception of an impersonal or disconnected environment, diminishing the sense of place and community. The integration of vegetation within the volume of buildings fosters a sense of connection to the local environment and enhances place identity. Green spaces provide opportunities for social interaction, recreation, and

relaxation, creating gathering places that foster a sense of community (Gehl and Gemzøe, 1996; Carmona *et al.*, 2010). When people can perceive a harmonious blend of building volume and vegetation, it contributes to a stronger sense of place, pride in the neighbourhood, and an enhanced perception of the overall liveability and quality of the urban environment (Tuan, 1977; Whyte, 1980).

4. Environmental Considerations: The volume of buildings in urban areas can have implications for resource efficiency and environmental sustainability. Higher building volumes often allow for compact development, reducing land consumption and supporting efficient infrastructure provision (Bramley and Power, 2009). In contrast, sprawl or low-density development in the outskirts may lead to urban sprawl, increased land consumption, and higher infrastructure costs. This can influence perceptions of sustainability and environmental responsibility.
5. Urban Density and Vibrancy: The volume of residential buildings, particularly in denser urban areas, can contribute to a sense of vibrancy and urban vitality (Gehl, 2010, 2011; Gehl, Kaefer Johansen and Solvekg, 2016). Higher volumes of residential units within a given area often translate to a larger population density, which can support a wide range of amenities, services, and cultural offerings. This can create a dynamic and lively atmosphere, providing residents with convenient access to various amenities and fostering a sense of excitement and opportunity.
6. Symbolic Significance: The amount of sky visible in the urban environment can carry symbolic significance (Fisher-Gewirtzman and Wagner, 2003; V Cheng, 2010). In dense urban areas with limited sky visibility, seeing the sky can be seen as a precious and rare occurrence, adding a sense of wonder and appreciation. It can serve as a reminder of the broader world beyond the built environment and create a sense of transcendence.
7. Urban Identity: The volume of buildings and the amount of visible sky can contribute to the identity and character of a city. Skylines with a mix of

building heights and an adequate amount of sky can become iconic representations of a city's identity and create a lasting impression on residents and visitors.

7.3.4 Correlation 4. Correlation of Amount of Sky to the Other Constructs

Table 7-4. Correlation 4 – Amount of sky

Construct	SET	Construct	R-value	p-value
Amount of Sky	UI	Sprawl	+1.000	0.000
	UI	Residential	+1.000	0.000
	GLA	Space between the Buildings	-1.000	0.000
	GLA	Urban / City	-1.000	0.000

A perfect positive correlation between amount of sky and sprawl, residential use suggest that areas characterised by sprawl and a predominantly residential land use pattern, there tends to be a larger amount of sky visible in the urban environment (UI-05, 08, 20, 21). The low-density development, typically found in suburban or outskirts areas, allows for more open spaces and a greater expanse of sky to be seen. The presence of single-family homes, townhouses, or low-rise buildings with spacious yards and setbacks contributes to a more spread-out development pattern, enabling wider views of the sky.

A perfect negative correlation between amount of sky and space between the buildings in an urban context suggests that densely built urban areas with limited space between buildings, there is a reduced visibility of the sky (GLA -CC-HD-04, 24,; UI-05, 21, 26, 27) . The urban/city context, characterised by high-rise buildings, narrow streets, and a compact layout, contributes to the restricted view of the sky. The close proximity and tall structures obstruct the line of sight to the sky, resulting in a decreased amount of visible sky in the urban environment.

These correlations can be explained using the following urban design principles:

1. Sense of Space: The larger amount of visible sky in sprawling residential areas can create a sense of spaciousness and openness (Cheng, 2010). The low-density development allows for more breathing room and a greater visual distance between buildings, enhancing the perception of a less

congested and more expansive environment. The positive correlation between the amount of sky, sprawl, and residential use reflects the typical characteristics of suburban living. Sprawling residential areas often offer a more car-oriented lifestyle, with larger lots and more separation between residential units. The increased visibility of the sky aligns with the suburban lifestyle's emphasis on space, privacy, and a connection to nature.

2. Sense of Enclosure: The limited visibility of the sky in densely built urban areas can create a sense of enclosure. The tall buildings, narrow streets, and compact layout create a more enclosed and confined environment(Harvey, 2009a; Aung, 2020). This can result in a perceived sense of restricted space and a potentially claustrophobic feeling.
3. Urban Intensity: The negative correlation reflects the intense and bustling nature of urban/city contexts. The dense arrangement of buildings, streets, and infrastructure is often associated with vibrant city life, with a high concentration of activities, amenities, and social interactions. The reduced visibility of the sky contributes to a visually dynamic and bustling urban environment.

7.3.5 Correlation 5. Correlation of Density of People in the Street with Other Constructs

Table 7-5. Correlation 5 – Density of people in the street

Construct	SET	Construct	R-value	p-value
Density of people in the street	UI	Commercial Land use	+1.000	0.000
	GLA	Density of cars on the street	-1.000	0.000
	GLA	Building typology	-1.000	0.000
	GLA	Mixed land use	-1.000	0.000
	UI	Loose Scattered Urban Form	-1.000	0.000

When there is a high density of people in the street, it indicates a vibrant and bustling urban environment with a significant level of pedestrian activity (GLA-CC-HD-01, 22; UI-30, 33, 34). This density of people in the street often occurs in areas where commercial land use is prevalent. Commercial areas, such as shopping districts, marketplaces, or business centres, tend to attract a large number of people due to the presence of various retail stores, restaurants, offices, and other commercial establishments.

The positive correlation between density of people in the street and commercial land use is driven by several factors. Firstly, commercial areas tend to offer a diverse range of goods and services, attracting people from both the local community and visitors from other areas. This concentration of commercial activities leads to increased foot traffic and a higher density of people in the street. Secondly, the presence of commercial land use often results in a mixed-use urban environment, where people live, work, and engage in leisure activities in close proximity. This integration of residential and commercial spaces encourages people to walk or use public transportation, contributing to a higher density of people in the street. Lastly, a loose and scattered urban form characterised by low building densities, large setbacks, and wide roadways can contribute to a lower density of people in the street. Such urban forms prioritise vehicular movement and create a sense of disconnectedness, making it less conducive for pedestrians to navigate and engage with the street environment.

In areas where there is a low density of people in the street, it is often accompanied by a high density of cars (GLA-; UI-05, 20, 28, 33) . This can be attributed to several factors, such as sprawling suburban development patterns, reliance on private automobile transportation, and limited pedestrian-friendly infrastructure. The high density of cars creates a less inviting and pedestrian-unfriendly environment, resulting in fewer people walking or spending time in the street. Higher density of people in the street can create a sense of vibrancy, liveliness, and social interaction. It contributes to a bustling atmosphere, where individuals feel connected to the urban environment and experience a sense of community. The presence of a diverse crowd can enhance the perception of a vibrant and dynamic place. Conversely, a high density of cars in the streets can have negative effects on human perception. It can lead to increased traffic congestion, noise pollution, and reduced pedestrian comfort and safety. Excessive car density can create a sense of chaos and make the urban environment feel less inviting for pedestrians.

When the density of people in the street outweighs the density of cars, human perception tends to be more positive. People feel more engaged, connected, and at ease in areas where they can freely move around and interact with others. However, if the density of cars becomes overwhelming, it can detract from the overall experience and create a less desirable urban environment.

Additionally, the building typology in these areas often leans towards car-oriented designs, such as large-scale shopping malls, parking structures, or office complexes with expansive surface parking lots. These building typologies prioritise car accessibility and convenience, which can deter pedestrians and contribute to a lower density of people in the street.

Moreover, the presence of a predominantly single-use land pattern, where residential, commercial, and recreational activities are separated, can lead to a reduced density of people in the street. without a mix of land uses, there is limited incentive for people to walk or spend time in the area, as they need to travel longer distances to access different amenities.

Lastly, a loose and scattered urban form characterised by low building densities, large setbacks, and wide roadways can contribute to a lower density of people in the street. Such urban forms prioritise vehicular movement and create a sense of disconnectedness, making it less conducive for pedestrians to navigate and engage with the street environment. The lower density of people in the street can limit opportunities for spontaneous encounters and community engagement. However, this can also be perceived positively by individuals seeking more solitude or privacy.

These correlations can be explained using the following urban design principles:

1. Vibrancy and Social Interaction: Higher density of people in the street creates a sense of vibrancy and liveliness. It fosters social interactions, encourages engagement, and contributes to a lively urban atmosphere (Whyte, 1980; Gehl and Gemzøe, 1996; Carmona *et al.*, 2010; Gehl, 2010). The presence of a diverse crowd, including shoppers, pedestrians, and individuals enjoying street activities, can make the environment feel more

dynamic and appealing.

2. Sense of Safety and Security: Increased density of people in the street can enhance the perceived sense of safety and security (Newman, 1972; Tuan, 1977). A well-populated street with active commercial establishments tends to deter criminal activities and create a sense of collective surveillance. People feel more comfortable and confident walking in areas where there are others around, contributing to a positive perception of safety.
3. Diversity and Cultural Expression: Commercial areas often exhibit a variety of businesses, representing different cultures, cuisines, and experiences (Gehl and Gemzøe, 1996; Gehl, 2010; Gehl, Kaefer Johansen and Solvekg, 2016). This diversity adds richness to the urban environment and can enhance human perception by providing opportunities for exploration, exposure to new ideas, and the celebration of local culture and traditions.
4. Aesthetics and Visual Appeal: Building typology plays a key role in shaping the visual appeal of the street (Lynch, 1984; Nasar, 1989b, 1998; Gehl, 2010). Well-designed buildings with architectural diversity, interesting façades, and appropriate scale can create an aesthetically pleasing environment. The combination of people density and visually appealing buildings contributes to a positive visual experience and enhances the overall perception of the street.
5. Sense of Individuality: In a less densely populated street, people may have a stronger sense of individuality and personal space (Proshansky, 1976; Canter, 1977; Altman and Chemers, 1984; Gifford, Steg and Reser, 2011). This can lead to a perception of greater independence and the ability to freely move and navigate through the surroundings without feeling crowded or restricted.

7.3.6 Correlation 6. Correlation of Street Width with Other Constructs

Table 7-6. Correlation 6 – Street width

Construct	SET	Construct	R-value	p-value
Street width	GLA	Commercial	-1.000	0.000
	UI	Less to No Activity	-1.000	0.000

When the street width decreases, it creates a more intimate and narrow space that tends to discourage commercial activity. The limited space may not accommodate a significant number of pedestrians or provide sufficient room for commercial establishments such as shops, cafes, or restaurants. Additionally, a narrower street may lack the necessary infrastructure, such as wider sidewalks or designated areas for outdoor seating, which can hinder the presence and viability of commercial activities.

Furthermore, a narrower street often leads to lower levels of activity, as it may deter people from frequenting the area. The reduced space may make pedestrians feel crowded or uncomfortable, leading to fewer individuals choosing to walk or spend time in the vicinity. The lack of pedestrian activity can also discourage businesses from establishing themselves in the area, as there may be limited foot traffic and potential customers.

These correlations can be explained using the following urban design principles:

1. Accessibility and Convenience: Wider streets with commercial land use often offer better access to goods, services, and amenities. The presence of shops and businesses in close proximity to each other can make it easier for people to meet their needs and desires. In areas with low levels of activity and limited commercial land use, access to amenities may be more challenging, requiring people to travel longer distances.
2. Walkability and Comfort: Street width directly affects the pedestrian experience (Gehl, 2010). Wider streets often provide more space for sidewalks, allowing for comfortable walking and promoting pedestrian activity. In areas with active commercial land use, wider streets can accommodate larger numbers of people, creating a lively and enjoyable walking environment. Narrower streets with low levels of activity may feel cramped and less inviting for pedestrians.
3. Safety and Security: The perception of safety can be influenced by street width and the presence of commercial activities. Wider streets with active

commercial land use tend to have more eyes on the street, creating a perception of safety and security (Newman, 1972; Gehl, 2010). In contrast, narrower streets with low levels of activity may be perceived as less safe, especially in dimly lit or isolated areas.

4. Social Interaction and Community: The street width and presence of commercial activities can shape social interactions and community engagement (Whyte, 1980; Gehl and Gemzøe, 1996; Carmona *et al.*, 2010; Gehl, 2010). Wider streets with active commercial land use can create opportunities for socialising, interacting with others, and fostering a sense of community. In contrast, narrower streets with low levels of activity may limit social encounters and reduce community cohesion.

7.3.7 Correlation 7. Correlation of Vegetation Along the Street with Other Constructs

Table 7-7. Correlation 7 – Vegetation

Construct	SET	Construct	R-value	p-value
Vegetation	GLA	Loose/ Scattered Urban Form	+1.000	0.000
	GLA	Pavement Width	+1.000	0.000
	UI	Space between the buildings	+1.000	0.000
	GLA	Sprawls	+1.000	0.000
	GLA /UI	Residential	+1.000	0.000
	UI	Style of the Buildings	+1.000	0.000
	UI	Amount of Sky	+1.000	0.000

A perfect positive correlation between vegetation and various urban factors can create a harmonious and appealing urban environment. In a loose/scattered urban form, where buildings are spaced out and interspersed with green areas, the presence of vegetation enhances the overall aesthetic and creates a pleasant visual experience (GLA-SE-LD-04, 09, SE-MD-06, SE-MD-13; UI-02, 06, 06, 17). Trees, shrubs, and green spaces contribute to a sense of natural beauty and tranquillity within the urban fabric.

When there is a wider pavement width accompanied by abundant vegetation, it provides a more inviting and comfortable pedestrian experience. Trees and greenery alongside the pavement can offer shade, reduce heat island effects, and create a refreshing environment for pedestrians.

Vegetation in the spaces between buildings adds a touch of greenery and softness to the urban landscape. It helps to break up the built environment and provides visual relief, promoting a sense of openness and natural elements within the urban fabric.

In sprawling urban areas, the inclusion of vegetation helps counterbalance the negative impacts of expansive development. Green spaces, parks, and tree-lined streets can mitigate the visual monotony and offer residents and visitors opportunities for recreation, relaxation, and connection with nature.

The presence of vegetation in open spaces and parks enhances their appeal and functionality. Trees, lawns, and gardens provide shade, improve air quality, and create a welcoming environment for recreational activities, social gatherings, and leisure pursuits.

Incorporating vegetation into residential areas has numerous benefits. It improves the QoL for residents by providing green spaces for relaxation and outdoor activities. Vegetation also contributes to a healthier and more visually appealing living environment, creating a sense of serenity and well-being.

Vegetation complements different architectural styles and building designs. When buildings are adorned with green façades, rooftop gardens, or balconies with plants, it adds an element of natural beauty and connection to the surrounding environment. This symbiotic relationship between vegetation and building style enhances the overall aesthetic value and human perception of the urban landscape.

Vegetation contributes to the amount of sky visible within the urban context. Tall trees, green roofs, and vertical gardens can create a visual contrast against the buildings and allow for glimpses of the sky, providing a sense of openness, connection with nature, and relief from the built environment.

1. Visual Appeal: Vegetation in a loose/scattered urban form adds visual interest and enhances the overall aesthetics of the environment. Green spaces, trees, and plants create a softer and more natural look, breaking up

the monotony of buildings and concrete. This visual diversity promotes a sense of beauty, tranquillity, and harmony with nature.

2. Psychological Impact: The presence of vegetation in a loose/scattered urban form has a positive impact on people's psychological well-being. Access to green spaces and natural elements has been linked to reduced stress levels, improved mood, and increased feelings of relaxation and calmness (Kaplan, 1987; Kaplan and Kaplan, 1989). Being surrounded by vegetation in an urban environment can provide a sense of connection with nature, which has been shown to have numerous psychological benefits.
3. Sense of Openness: In a loose/scattered urban form, vegetation helps to create a sense of openness and spaciousness. Green spaces and trees provide a visual break, allowing people to perceive the environment as less congested and more expansive. This sense of openness can positively impact human perception by promoting a feeling of freedom, relaxation, and a closer connection to nature.

7.3.8 Correlation 8. Correlation of Density of Cars in the Street with Other Constructs

Table 7-8. Correlation 8 – Density of cars in the street

Construct	SET	Construct	R-value	p-value
Density of cars on the street	GLA/UI	Building typology	+1.000	0.000
	GLA	Mixed-Use	+1.000	0.000
	GLA/UI	High levels of Activity	+1.000	0.000
	UI	Compact Urban Form	+1.000	0.000
	UI	Urban/City	+1.000	0.000
	UI	Pavement Width	-1.000	0.000
	UI	Building Typology	-1.000	0.000

A perfect positive correlation between the density of the cars in the street and building typology can be explained in areas with a high density of cars in the street, there tends to be a mix of building typologies, including commercial buildings, residential complexes, and office spaces (GLA-EE-MD-07, SE-MD-06, 13, EE-LD-05; UI-03, 05, 20, 28, 34). The presence of a variety of building types indicates a vibrant and active urban environment.

The density of cars in the street is often associated with mixed-use development, where different land uses, such as residential, commercial, and recreational, are integrated into a compact area. This mix creates a dynamic and bustling atmosphere, with people using cars to access various amenities conveniently.

A high density of cars in the street signifies a bustling urban environment with high levels of activity. It suggests a vibrant economy, lively street life, and a variety of businesses and services that attract people and contribute to a vibrant urban atmosphere.

The density of cars in the street is often found in areas characterised by a compact urban form. This means that buildings are situated closer together, and streets are designed to accommodate a higher volume of traffic. The compact form fosters accessibility, efficiency, and a sense of urban vitality.

The density of cars in the street is typically observed in urban city contexts, where the population is concentrated, and the demand for transportation is high. Urban areas with a significant number of cars on the streets reflect the mobility needs of residents and the presence of a well-connected transportation infrastructure.

1. Perception of Accessibility: The density of cars in the street, particularly in areas with mixed-use building typologies, can enhance the perception of accessibility. It suggests that various amenities, services, and activities are easily reachable by car, promoting convenience and mobility for individuals.
2. Functional Diversity: Different building typologies in conjunction with a density of cars in the street can signify functional diversity (Metropolitian Council, no date; Steemers, Ramos and Sinou, 2004; Vormann, 2015). It implies that there are opportunities for work, leisure, shopping, and social interactions within a relatively compact area. This diversity can enrich the urban experience and provide a range of options for individuals.
3. Perception of Urban Vitality: The presence of cars in the street and varied building typologies can contribute to the perception of urban vitality. It signifies an active and thriving environment, where people, commerce, and daily activities intersect. This can enhance the attractiveness of an area and

create a positive impression of its liveliness and energy.

4. Vibrant and Active Environment: The presence of a density of cars in the street, combined with mixed-use developments, can contribute to a vibrant and active urban environment. It signifies a diverse range of activities happening simultaneously, such as commercial transactions, social interactions, and cultural events. This can create a sense of liveliness and energy, making the area more engaging and enjoyable for residents and visitors.

7.4 Summary

The correlation analysis is the culmination of all the analyses done so far in the study. This analysis assists answer the research question which is to identify ways to manipulate the urban from using the objective measures of density to achieve a positive perception. This analysis identified the correlations with the most frequently mentioned constructs which include eight visual components measured using the image segmentation method. These correlations can be linked to objective density measures and urban planning concepts to derive meaningful associations.

7.4.1 FAR/ Plot Ratios

FAR or plot ratios can be linked to the correlation between building height and space between buildings, as well as building height and street width (Vicky Cheng, 2010). Higher FAR or plot ratios often result in denser development patterns with taller buildings situated closer together and narrower streets. Conversely, lower FAR or plot ratios allow for more open spaces between buildings and wider streets. FAR or plot ratios, for example, can be linked to the correlation between building volume and the presence of green spaces. Higher FAR or plot ratios often result in denser built environments with less space for green areas. Conversely, lower FAR or plot ratios provide opportunities for incorporating more green spaces alongside taller buildings. FAR or plot ratios can be linked to the correlation between the amount of sky and sprawl/residential use. Higher FAR or plot ratios are often associated with denser development patterns, where buildings are closer together, resulting in less visible sky. In contrast, lower FAR or plot ratios, typically found in sprawling residential areas, allow for more open spaces and a larger expanse of visible sky. FAR or plot ratios can be linked to the correlation between the density of people in the street and commercial land use. Higher FAR or plot ratios, which indicate more intense development and higher building densities, are often associated with commercial areas. The concentration of commercial activities attracts a larger number of people, resulting in a higher density of people in the street.

FAR or plot ratios can be associated with the correlation between street width and commercial activity. Higher FAR or plot ratios, indicating more intense development and higher building densities, often require wider streets to accommodate the increased population and commercial activities. In areas with higher FAR, there is a greater potential for commercial establishments and pedestrian activity, which may necessitate wider streets to accommodate the flow of people and provide space for commercial uses.

FAR or plot ratios can be associated with the correlation between car density and building typology. Higher FAR or plot ratios indicate more intense development and higher building densities. In areas with higher FAR, there is a greater potential for mixed-use development, which can attract a diverse range of building typologies and contribute to a higher density of cars in the street.

7.4.2 Site Coverage

Site coverage, which refers to the percentage of land covered by buildings, can be associated with the correlation between building height and space between buildings (Cheng, 2010; Angel, Lamson-Hall and Blanco, 2021). Lower site coverage typically allows for more open spaces and larger distances between buildings, accommodating a sense of spaciousness and green areas. The correlation between building volume and sprawl/outskirts can be linked to site coverage, which refers to the percentage of land covered by buildings. Larger setbacks and more spread-out development patterns in suburban areas are often associated with lower site coverage, allowing for more open space between buildings. Site coverage, representing the percentage of land covered by buildings, can also be associated with the correlation between the amount of sky and sprawl/residential use. Lower site coverage in sprawling residential areas allows for more open spaces, creating a greater visibility of the sky. In denser urban areas, higher site coverage limits the availability of open spaces, resulting in a reduced amount of visible sky. Site coverage, representing the percentage of land covered by buildings, can also be associated with the correlation between the density of people in the street and commercial land use. Higher site coverage in commercial areas accommodates a larger number of commercial establishments, attracting more people and leading to a higher density of people in the street.

Site coverage, representing the percentage of land covered by buildings, can also be linked to the correlation between street width and commercial activity. Higher site coverage can limit the available space for wider streets, especially in areas with a high density of buildings. As a result, narrower streets may have limited room for commercial activities and pedestrian infrastructure, potentially discouraging commercial development. Site coverage, representing the percentage of land covered by buildings, can also be linked to the correlation between car density and building typology. Higher site coverage often results in a more compact urban form with a mix of building typologies. The higher density of buildings can attract more people and businesses, leading to a higher density of cars in the street.

7.4.3 Social and Spatial Density

Social density and spatial density measures can be linked to the correlation between building height and activity levels. Higher social density, which represents the number of people per unit of residential space, is often associated with taller buildings and more intense urban development. Lower building heights may indicate lower social density and a quieter, less bustling environment. Spatial density, which represents the intensity of development in a given area, can be associated with the correlation between pavement width and open spaces/parks. In areas with wider pavements, there is generally more space for pedestrian pathways and the integration of green spaces and seating areas. This can enhance the overall urban experience and promote social interaction, particularly in areas with higher spatial density. Spatial density, reflecting the intensity of development in a given area, can be associated with the correlation between the amount of sky and space between buildings/urban context. Higher spatial density in urban areas leads to taller buildings, narrower streets, and a compact layout, resulting in a restricted view of the sky. In sprawling residential areas with lower spatial density, there is more room between buildings, allowing for a greater visibility of the sky.

Social density, which measures the number of people per unit of residential or commercial space, can be linked to the correlation between the density of people in the street and commercial land use. Higher social density in mixed use areas, contributes to a higher density of people in the street. The proximity of residences, workplaces, and commercial establishments encourages pedestrian activity and increases the density of people in the street.

Spatial density, reflecting the intensity of development in a given area, can be associated with the correlation between the density of people in the street and the density of cars. Higher spatial density, resulting from compact urban forms with higher building densities and less emphasis on vehicular movement, is often associated with a higher density of people in the street and a lower density of cars. Conversely, lower spatial density, characterised by sprawling suburban development patterns and car-oriented designs, contributes to a lower density of people in the street and a higher density of cars.

Social density, measuring the number of people per unit of residential or commercial space, can be associated with the correlation between street width and commercial activity. Higher social density often supports a vibrant commercial environment, as it provides a larger customer base and more foot traffic. In areas with high social density, wider streets may be necessary to accommodate the influx of people and support a thriving commercial scene.

Spatial density, reflecting the intensity of development in a given area, can also be linked to the correlation between street width and commercial activity. Higher spatial density, resulting from compact urban forms and higher building densities, may require wider streets to handle increased pedestrian and vehicular traffic. In contrast, lower spatial density, associated with sprawling or low-density development, may not prioritise commercial activity or require wider streets. Social density, measuring the number of people per unit of residential or commercial space, can be associated with the correlation between car density and building typology. Higher social density, often found in areas with mixed-use development, can lead to a higher demand for transportation, including cars. The presence of a variety of building typologies in areas with high social density can contribute to a higher density of cars in the street.

Spatial density, reflecting the intensity of development in a given area, can also be linked to the correlation between car density and building typology. Higher spatial density, resulting from compact urban forms and higher building densities, can support a mix of building typologies and generate a higher density of cars in the street.

The correlation of building height with context, style of the building, space between the buildings and land use suggests that one factor informs the character of the other. Mixed urban land use determines the style and height of the building, and the FAR or plot ratios along with building bylaws decide the spacing between buildings. This suggests that the planning systems need to lay urban form design guidelines for the entire block length or the perimeter of the block why? And don't you think they do so already? Although the built form can be controlled and measured at the plot level, it needs an overarching framework that guides its development for the user's perception.

These correlations were developed to provide a framework to develop performance guidelines drawing on the results of image segmentation to achieve a visually engaging urban environment with a positive perception of density. However, that is not within the scope of this study. These correlations do not necessarily always identify causal relationships and are influenced by more than one factor in the urban environment. These constructs are dependent on one another, therefore modification of one aspect of the built environment can result in changing the visual appearance either positively or negatively. Therefore, this study identifies multiple ways to assess the perception of the urban environment and density to arrive at definite ways to measure this impact. Further research is required in different contexts to validate these correlations.

Chapter 8. Conclusions

This concluding chapter summarises the findings of this study, discusses its limitations and suggests directions for future research.

8.1 Summary of the Findings

This research has addressed several issues dealing with the concept of perceived density and the need for its integration into the design of urban environments. The main question that the study addressed was whether it was possible to find ways to manipulate design features of the urban environment to alter perception of density in positive ways. This question was broken down into 3 questions: what factors (spatial or personal) of the urban environment influence the perception of density; what the contribution of the spatial characters of urban form in the perception of density is; and how can the knowledge gained from the two questions support place-making to maximise the benefits of density while mitigating its perceived pitfalls. These questions correspond to the three objectives.

8.1.1 Objective 1: Comprehensive List of Factors That Influence the Perception of Density

The first objective of the study was to develop a comprehensive list of characteristics and variables of an urban environment that people perceive through the application of personal construct theory methods. The content and frequency analysis of the raw data received from the MST assisted in achieving the first objective of compiling a list of factors that influence the perception of density and updating the existing framework of visual cues produced by Rapoport (1975b).

The evaluation of constructs through a literature review validated their classification by demonstrating alignment with existing frameworks and urban perception research. Comparing the identified constructs with contextual compatibility (Groat, 1985), perceptual qualities (Boeing, 2018), urban form aesthetics (Gjerde, 2010), and visual complexity concepts (Nasar, 1988, 1989b) ensured their relevance to density perception in urban environments (see Section 5.1.13).

The factors and design features identified by reviewing four frameworks, that overlap with one another (common factors or shared characteristics) were merged and represented as 1 construct. This task assisted in compiling a list of constructs that influence the perception of density, however not all the factors are critical (common factors for high, moderate and low density). The critical 20 constructs associated with high, moderate and low density were identified and recommended for future studies on the perception of density.

These critical constructs were classified as per the framework of visual cues proposed by Rapoport (1975b) and the framework was updated. He identified several factors classified under perceptual, symbolic/associational and temporal categories. Perceptual cues refer to the features or attributes in the urban environment about the objects and the landscapes that are perceived and used by an individual in a particular situation or setting to identify and make judgements about that stimulus and its properties (APA Dictionary of Psychology). These cues help in understanding the depth, shape, size and position of these objects. The symbolic or associational cues refer to visual or non-visual elements that represent or communicate an idea, concept or meaning (Swansburg and Neyedli, 2019). Symbolic cues of the urban environment include skyscrapers, street art, public transportation, streetscape elements, parks and green space (Rapoport, 1975c). Temporal cues refer to those elements or features that are continuously in flux and vary with time (Rapoport, 1975c). These include traffic patterns, and pedestrian footfall at various times of the day. These descriptions aided in classifying first the 65 constructs into the three categories and consequently updating Rapoport's framework. The reduction from the 65 to the final 20 critical constructs, done by frequency analysis, is presented in Figure 5-11 (Glasgow), 5-12 (Universal Illustrations) and a complete list is presented in the Appendix to Chapter 5.

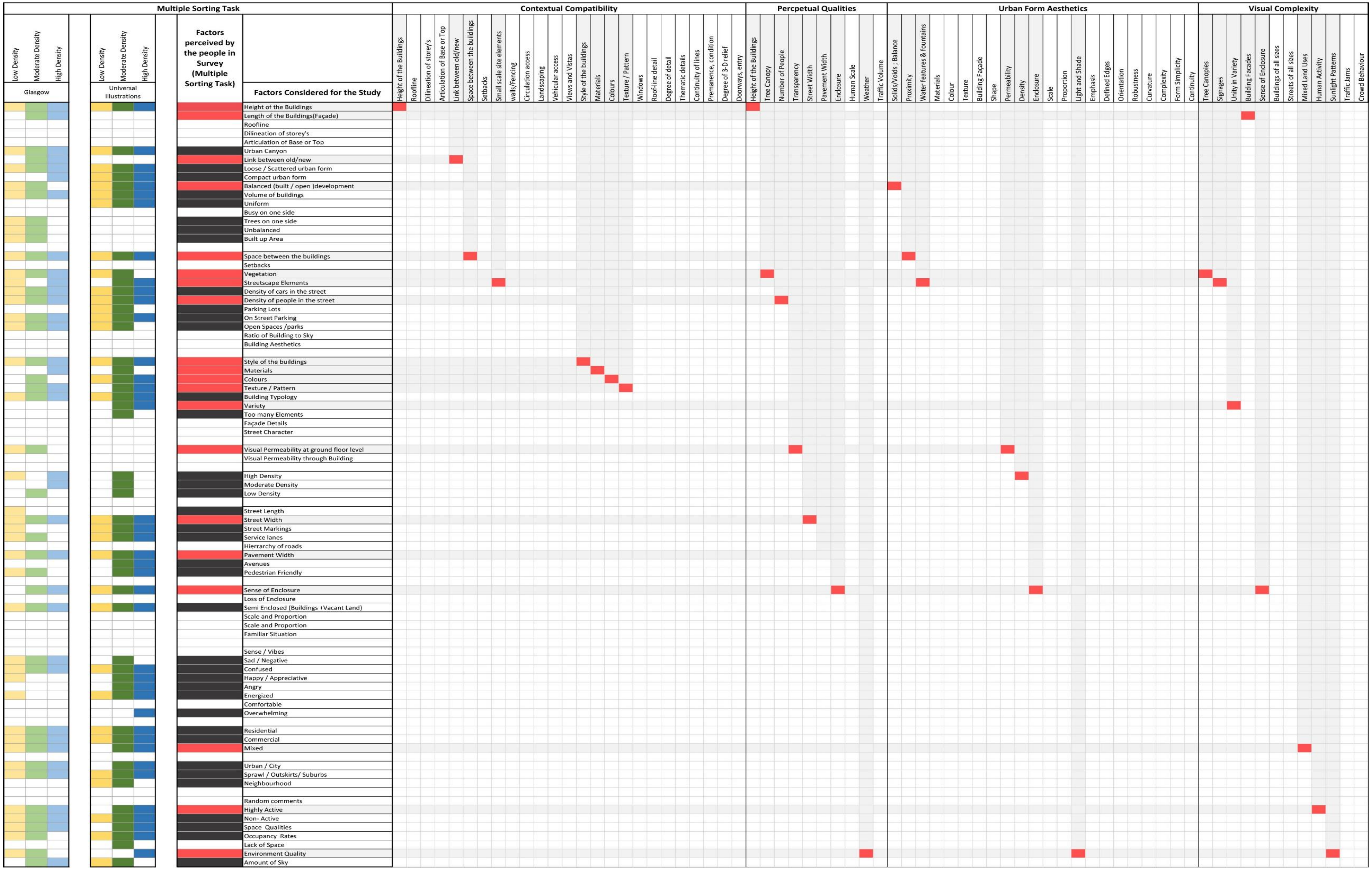


Figure 8-1. Assessment of existing frameworks on perceptual studies

The final 20 critical constructs can be manipulated using objective density measures and are interdependent. The positive and negative correlations between these constructs were identified using the Spearman correlation method (see Chapter 7). These correlations can be considered as a framework to develop guidelines for designing high-density user-friendly urban areas with a positive perception.

Correlations developed with perceived density have revealed important relationships between perceived density and various factors. Some key correlations that have been identified include:

1. Building Height: Studies have shown a positive correlation between the height of buildings and perceived density. Taller buildings are often perceived as more dense compared to shorter buildings.

2. Open Spaces: The presence of open spaces, such as parks or plazas, has been found to have a negative correlation with perceived density. More open spaces tend to be associated with lower perceived density.

3. Building Volume: The volume or bulkiness of buildings has shown a positive correlation with perceived density. Larger and more massive buildings are typically perceived as denser.

4. Amount of Sky: The amount of sky visible from a given location has been found to have a negative correlation with perceived density. Greater visibility of the sky is associated with lower perceived density.

5. Density of People: The density of people in a given area has shown a positive correlation with perceived density. Higher concentrations of people are often associated with higher perceived density.

6. Street Width: Narrower streets have been found to have a positive correlation with perceived density. Wider streets tend to be perceived as less dense.

7. Vegetation: The presence of vegetation along streets or in public spaces has shown a negative correlation with perceived density. More greenery is often associated with lower perceived density.
8. Density of Cars: The density of cars in a street or parking area has shown a positive correlation with perceived density. More cars in an area are typically perceived as higher density.

These correlations highlight the complex interplay between physical characteristics, social factors, and individual perceptions in shaping the perception of density. Understanding these correlations can inform urban design, planning, and policy decisions aimed at creating environments that meet the desired levels of perceived density and associated outcomes.

These constructs are not only physical attributes but are also objects and can have a significant visual impact on perception. Thus, the second survey, the SJT, sought to understand this impact by recording the emotional response associated with it. It also confirmed that not all high-density urban environments are perceived as negative.

Building use, activities along the street and number of people were commonly cited in relation to both positive and negative perceptions. Temporal variations in the number of people and activities also contribute to the dynamic nature of urban environments. Different times of the day may bring about changes in the character, vibrancy, and perceived density of urban spaces. For example, a street that is bustling with pedestrians and vibrant commercial activities during daytime may feel significantly different and less dense during the night time when the activity level decreases. Therefore, the temporal aspect of urban environments, including the fluctuations in the number of people and activities throughout the day, can significantly influence the perception of density.

Table 8-1. Frameworks on perceptual qualities of built form

Sr. No	Critical constructs	Controllable measures of density	According to Rapoport's Framework of cues
1	Height of the buildings	FAR/ Plot Ratios	Symbolic Cue
2	Volume of buildings	FAR/ Plot Ratios	Symbolic Cue
3	Building typology	FAR/ Plot Ratios	Symbolic Cue
4	Compact urban form	FAR/ Plot Ratios; Building Byelaws; Development Plans	Symbolic Cue
5	Space between the Buildings	FAR/ Plot Ratios; Building Byelaws	Perceptual Cue
6	Urban canyon	FAR/ Plot Ratios; Building Byelaws	Perceptual Cue
7	Land use	Development Plans	-
8	Open spaces/parks	Development Plans	Perceptual Cue
9	Street width	Development Plans	Symbolic Cue
10	Vegetation along the street	Streetscape design	Perceptual Cue
11	Density of people on the street	Dependent on building use	Perceptual Cue
12	Density of the cars on the street	Dependent on building use	Perceptual Cue
13	Context (urban/city)	Land use	Perceptual Cue

The other constructs associated with building attributes are symbolic cues. They are physical objects whose intensity and magnitude have a direct effect on visual perception. The colour, style, material and design features of the façade can influence the perception of density. Repetition of these elements suggests similarity whereas difference brings out the contrast. Diverse built form will give more than one object to look at, but similar built form might appear overwhelming and monotonous.

The number of elements or their magnitude in the urban environment can have a significant impact on the perception of density. The arrangement, quantity, and size of buildings, streets, public spaces, and other elements shape the visual landscape and influence how individuals perceive the density of an urban area. Considering the perception of density in urban design and planning, there are several design implications that can help shape a more humanised experience of engaging with cities.

This suggests that contextual and density requirements will help design professionals alter or design urban environments to give a positive perception.

Again, the two surveys did not establish the threshold for high-density positive perception or high-density negative perception. Based on the constructs alone it is difficult to decide when the positive density might turn to negative and due to the presence of which element and at what intensity. To address this issue and derive indicative thresholds, each image was analysed using an image segmentation technique. This helped in developing indexes for visual assessments which are indicative and can be developed further in future studies.

8.1.2 Objective 2: Threshold Values for the Eight Visual Components Using Image Segmentation

The second objective of the study was to quantify the contribution of different visual components in the urban environment to the perception of density and determine the percentage representation of each component in high, moderate, and low density scenarios. To be able to do so, 54 images were analysed and segmented manually using the super-pixel method provided by segment.ai and the eight visual components were represented by different colour codes (see Figure 8-1) (see Section 6.3). Magnitude estimation and histogram analysis assisted in determining the upper and lower limits for each component corresponding to the images of high, moderate and low density.

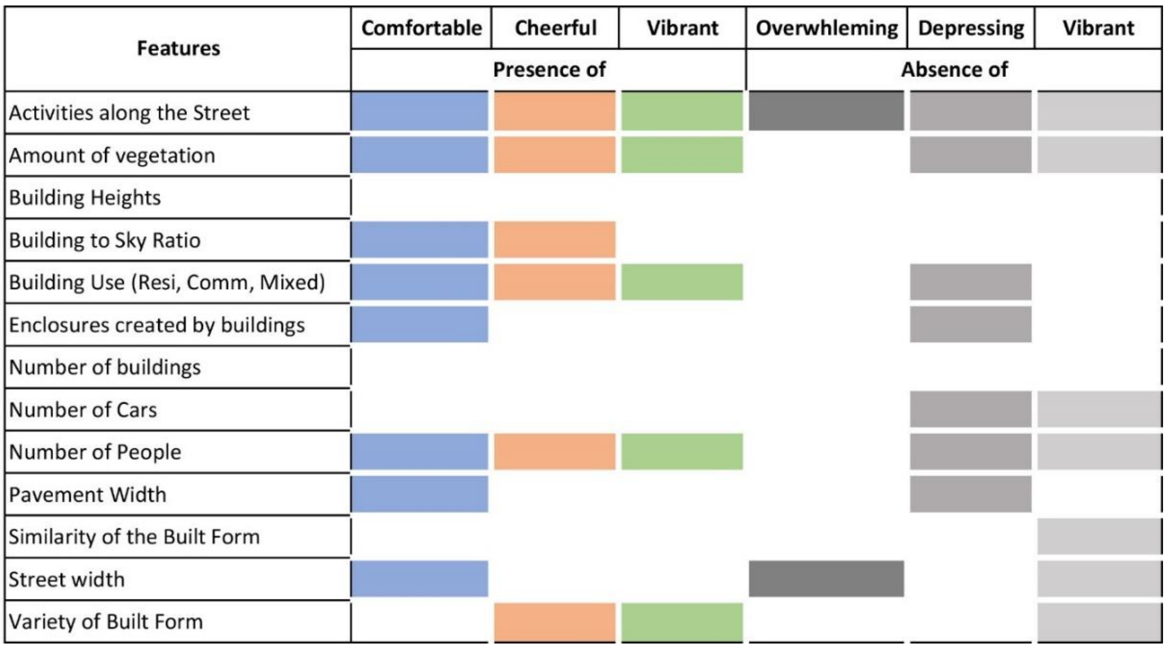


Figure 8-2. Evaluation of urban Environments – bipolar constructs – SJT

These limits act as indicators which can assist in predicting how dense an environment will be perceived. This data was further processed using threshold analysis to determine the threshold for each visual component for the urban environment for high, moderate and low density. These values differed for GLA and UI because of how the image was captured; GLA from the perspective of a pedestrian and UI from Google Street imagery. It was felt that to be able to derive the generic values for thresholds of upper and lower limits, more samples would be needed. Currently, 27 images included 9 images each of high, moderate and low density were used. However, there would be a need to train an AI-based segmentation model based on a much larger number of samples to identify more reliable ranges for each of the eight components.

Table 8-2. Magnitude estimation of the images

Upper and Lower Limits of Visual Components – High Density – Glasgow						
Component	High Density		Moderate Density		Low Density	
	Lower limit %	Upper limit%	Lower limit %	Upper limit%	Lower limit %	Upper limit%
Building	44	59	12	38	7	21
Street	16	24	1	23	10	19
Sky	5	9	10	32	18	30
Vegetation	0	1	0	40	6	23
Pavement	7	24	9	33	12	27
People	0	2	0	1	0	1
Car	0	8	1	10	0	3
Streetscape Elements	0	5	0	10	0	8

8.1.3 Objective 3: Visual Assessment Index

The third objective was to develop a visual assessment index of perceived density by developing a quantitative and qualitative database of images representing low, moderate and high levels for the evaluation of environments of different densities. This was achieved by analysing the images using Gestalt principles, which help identify the associations between critical constructs and visual components. By applying these principles, it becomes possible to understand how the urban environment is perceived and develop methods for recording and measuring it on-site (see Section 6.5.3). Using the critical constructs (Figure 5-11, 5-12) and the principles of Gestalt psychology such as symmetry, contrast, figure-ground and continuity, a visual index (Table 6-28) was developed which aided in presenting the complex data derived from the two surveys in a more accessible and effective way.

This index is iterative and can be tested on the site to determine whether the urban environment is visually engaging and whether it will be perceived overall in positive or negative terms (Table 6-28). By applying image segmentation techniques, the upper and lower limits of density can be derived from the images. To ensure the accuracy and validity of the findings, the results obtained from image segmentation can be compared with the outcomes of this study. This comparison helps to verify and validate the results obtained through the analysis of the images. It is important to note that the images considered in this study were specifically captured from the sidewalks, providing a clear view of the length of the street and the buildings along it. The focus is primarily on the visual elements related to density perception, and the nodes or intersections of the street are not directly investigated in this particular study. Furthermore, the development of an index related to density perception is one of the outcomes of this research. However, it is important to highlight that the index itself has not been tested or validated within the scope of this study.

8.2 Design Implications

These principles, rooted in critical constructs and visual factors impacting density perception, enable the creation of visually pleasing and efficiently designed urban spaces. Employing these principles enhances the quality of the urban environment, enriching the experiences of both residents and visitors.

1. **Variation in Plot Size and Building Typology:** Designers should ensure variation in plot size and consider diverse building typologies within urban blocks. This approach guarantees a diverse built form, preventing monotonous streetscapes. Mixed-use developments with different building types can add visual interest.
2. **Building Height Considerations:** At the conceptual design stage of individual buildings, designers should assess building height to avoid overwhelming

perceptions of density. Balancing height with other design elements can lead to more favorable density perceptions.

3. **Creating Visual Breaks:** Introducing small public spaces, plazas, or pauses along the street can break the monotony of continuous building facades. These spaces provide visual relief and create a sense of openness within dense urban areas.

4. **Staggered Building Arrangements:** Staggering buildings' positions or alignments along streets can create varied streetscapes. This intentional deviation from strict alignment or setback requirements adds diversity to the visual environment and avoids monotony.

5. **Addressing Compact Urban Form:** Designers can consider varying setbacks or plot configurations along streets or within blocks to influence the perception of compact urban form. These variations should align with the specific context of the site, such as block length and street type.

6. **Strategic Distribution of Retail:** Distributing retail land strategically can disperse concentrations of people in certain areas, reducing overall perceived density. This approach aims to create a more balanced and harmonious urban environment.

7. **Visual Harmony and Coherence:** Designers should aim for visual harmony and coherence in the streetscape by considering architectural styles, materials, and colors that complement each other. Consistency in design elements can contribute to a more visually pleasing and less overwhelming environment.

8. **Pedestrian-Friendly Streets:** Creating pedestrian-friendly streetscapes with wider sidewalks, street furniture, and amenities can enhance the perception of density. Well-designed pedestrian spaces encourage social interactions and contribute to a vibrant urban atmosphere.

9. **Transitional Spaces:** Incorporating transitional spaces or buffer zones

between different building types or land uses can help individuals adjust to changes in density gradually. These spaces provide a visual and psychological transition, reducing the abrupt perception of density changes.

10. **Cultural and Historical Context:** Design should consider the cultural and historical context of the area. Incorporating elements that resonate with the local culture and heritage can create a sense of identity and uniqueness, positively impacting density perception.

11. **Art and Public Installations:** Integrating public art and installations into the urban environment can serve as focal points and landmarks, breaking the visual monotony. Artistic elements can enhance the aesthetic appeal of densely populated areas.

12. **Transparency and Openness:** Incorporating transparent facades and windows in buildings can create a sense of openness and transparency. Visual connections between indoor and outdoor spaces can alleviate feelings of confinement in dense areas.

13. **Greenery and Urban Vegetation:** Introducing greenery, such as street trees, parks, and urban gardens, can mitigate the perceived density by providing visual relief and enhancing the overall quality of the environment.

14. **Lighting Design:** Thoughtful lighting design, including street lighting, façade illumination, and accent lighting, can influence the perception of density during nighttime. Well-lit urban areas can feel safer and more inviting.

15. **Community Engagement:** Involving the community in the design process and seeking their input can lead to urban environments that align with the preferences and needs of the residents. Engaged communities are more likely to perceive density positively.

8.3 Proposed Framework for Conducting Perception Studies

Based on findings from the systematic literature review, this research proposed a framework to conduct perception studies on density involving several key steps including identifying the target population, the sampling strategy, the type of environmental simulation to record, the type of questions, the methods of site selection, criteria for street selection, data collection and analysis. The proposed framework was tested in this study to determine the perception of density. The success of the framework is determined by the factors listed below.

- **Quality of data collected**. This framework produced high-quality relevant (accurate, reliable and directly applicable) data that assisted in identifying the factors influencing the perception of density which reflected accurately the perception of the target population.
- **Validity of the results**. The constructs derived from the analysis of the first survey were validated by triangulation against the existing framework of factors influencing perception of density (see Section 8.1) and findings from the empirical studies on perceived density (see Section 3.10). The results of the survey conducted as a part of the study show similar patterns to Rapoport's (1975) framework of visual cues (see Section 3.9), perceptual qualities of physical features of the built environment (Ewing *et al.*, 2016) and literature on perception, cognition and evaluation of urban spaces (Nasar, 1989).
- **Relevance of the findings**. The constructs derived from the raw data identify the physical attributes and spatial qualities of the built form that people use to make sense of space; the emotional responses suggest different ways in which people perceive the urban environment. These two sets of info can be traced back to theories of Gestalt psychology and help understand the visual impact of space.
- **Reproducibility**. The framework is reproducible. It can be used by other researchers to conduct similar studies on the perception of the urban environment and achieve similar results.

This framework is iterative and other researchers can determine its overall success and identify areas for improvement to make it more effective and derive meaningful results.

8.4 Redefining Perceived Density

The analysis of the results from the MST and SJT surveys, combined with image analysis techniques like image segmentation, and insights from Gestalt psychology and visual complexity, provides evidence that the perception of density in the urban environment is influenced by several visual factors. These factors include visual cues, visual complexity, spatial navigation, and aesthetics.

Visual Dominance: The visual system allows the public to quickly and efficiently gather information about the density and height, size, volume of buildings, spaces in their vicinity and variables such as people and cars (Gifford and Ng, 1982; Nasar, 1989a).

Immediate and Salient Perception: Visual Cues related to density, such as the proximity and arrangement of the buildings, or density of people in space, are immediately apparent. Individuals tend to make immediate judgements about density based on these visual cues alone, without requiring additional sensory inputs (Nasar, 1989a).

Visual Complexity: The built environment, with diverse architectural styles, building heights, urban design features, spatial configurations present a visually complex urban landscape. These visual cues stand out and contribute to individuals' perception of density (Wohlwill, 1982; Nasar, 1989a).

Spatial awareness and navigation: People perceive and interpret visual cues related to density and can assist people navigate through spaces, identify patterns of movement and assess the overall legibility of the urban environment (Lozano, 1974).

Aesthetics and Preference: People may have subjective preferences for certain visual qualities associated with density, such as balance between open spaces and built structures or the visual coherence of urban environment (Kaplan and Kaplan, 1982; Nasar, 1989a).

These visual factors collectively shape individuals' perception of density and influence their experiences in urban settings. Incorporating visual factors into the definition of perceived density and perceptual armature allows for a more nuanced understanding of how individuals perceive and interact with density in the urban environment.

8.4.1 Perceptual Armature of Density

In a recent study, a new spatial unit known as a proximity band was defined to explore pedestrian perception by considering two elements – the street network and the space along the street – connected by the transitional edge (Araldi and Fusco, 2016). Another study examined streetscape qualities using the skeletal streetscape as the spatial unit, which identifies the geometric features of buildings and trees along the roadway (Harvey and Aultman-Hall, 2016). Both these studies demarcated the human field of vision in plan which can be considered for perception studies.

This study proposed a spatial unit, *perceptual armature*, which in regard to perceived density refers to the underlying framework or structure of visual elements and spatial characteristics that shape individuals' perception and interpretation of density in urban streetscapes when viewed from the pedestrian perspective. By defining perceptual armature, this study establishes a clear understanding of the spatial unit under consideration.

In this context, perceptual armature represents the arrangement and configuration of visual cues and features that contribute to the perceived density when observing streets and buildings from a particular vantage point or elevation. It encompasses elements such as building heights, widths, setbacks, façade designs, and their spatial relationships within the streetscape (Harvey and Aultman-Hall, 2016).

The gross density seen in elevation measured using image segmentation, which refers to the overall visual density of buildings, streets, sky, vegetation, pavements, people, vehicles and streetscape elements when observed from a particular perspective, is a key aspect of the perceptual armature. It involves the aggregation of vertical elements and their spatial distribution within the urban fabric. The arrangement of buildings, their heights, and the spacing between them contribute to the perceived mass and density when viewed from a specific elevation.

Perceived density can thus be defined as the subjective assessment an urban environment based on visual cues and physical characteristics. It encompasses the visual perception and interpretation of the arrangement, scale, magnitude, spatial qualities, and architectural features of the built environment experienced at an eye level from the pedestrian point of view.

This study proves that as much as objective density is essential for the success of the place, determining its visual impact is essential in creating a memorable experience. The research methodology, therefore, focuses on assessing the street perspectives of different urban environments to measure the contribution of the components of the perceptual armature.

8.5 Original Contributions of this Research

This research study makes multiple contributions to knowledge, including methodological approaches, data and findings, and implications for practical applications. The proposed framework for conducting perception studies serves as a foundational contribution with far-reaching implications for urban design and planning.

Framework Proposed for Conducting Perception Studies

This research study significantly contributes to the field by introducing a prototype tool specifically designed to analyze qualitative perceptions of density in urban environments. This tool represents an innovative approach to understanding how people perceive and interact with urban density, addressing a critical gap in current urban design and planning practices.

The development of this prototype tool represents a significant methodological breakthrough in the field of urban density perception research. It introduces a structured framework that encompasses a wide range of methodological aspects, ensuring the rigor and quality of perception studies conducted in urban environments.

One crucial component of this framework is the site selection criteria. By providing clear guidelines for choosing study sites, the prototype tool ensures that researchers select locations that are representative of various urban contexts. This consideration is vital because density perception can vary significantly depending on the characteristics of the urban environment. Researchers can use the specified criteria to identify study sites that align with their research objectives, facilitating a more focused and meaningful investigation.

In addition to site selection, the prototype tool offers guidance on data collection methods. It outlines best practices for gathering data related to density perception, whether through surveys, interviews, or other data collection techniques. By standardizing data collection procedures, researchers can ensure the consistency and reliability of their findings, making it easier to compare results across different studies and locations.

Furthermore, the prototype tool addresses data analysis techniques. It provides recommendations on how to analyze the collected data effectively, whether through statistical methods, qualitative analysis, image analysis or a combination of approaches. This guidance assists researchers in extracting meaningful insights from their data, uncovering patterns and trends that can inform our understanding of density perception.

By embracing this framework, design practitioners gain a powerful tool to evaluate and enhance the perceived density of urban spaces. Understanding the intricate relationship between specific design elements and density perception allows them to make informed decisions during the design and planning phases. These decisions extend to the arrangement of buildings, the choice of architectural styles, and the incorporation of various visual cues. With this knowledge at their disposal, practitioners can craft urban environments that are not only functionally efficient but also visually appealing and inviting.

Moreover, the framework empowers practitioners to create user-friendly urban spaces. By optimizing density perception, designers can influence how people experience and interact with their surroundings. A more positively perceived density can lead to environments that feel more comfortable and accessible, encouraging greater public engagement and use of urban spaces.

Updated Framework of Visual Cues

This study enhances Rapoport's framework of visual cues for density perception. This revised framework provides a more nuanced and current understanding of how various design elements influence the perception of density. The process of updating the framework included content and frequency analysis of raw survey data. This methodology ensures that the framework accurately reflects the constructs that influence density perception in the present context. The revised framework classifies visual cues as perceptual, symbolic/associational, and temporal. It identifies the most influential critical constructs on density perception. These findings provide a valuable resource for urban designers, offering insights into how specific design elements can be manipulated to create positive density perceptions.

Threshold Values for Visual Components

This research developed a systematic approach to delineating threshold values for visual components influencing density perception within urban environments. The methodology hinged on image analysis and the meticulous segmentation of visual constituents. This process allowed for the precise quantification of visual factors that contribute to how density is perceived, culminating in the establishment of these crucial threshold values.

By discerning specific values corresponding to varying density perceptions, this empirical evidence becomes instrumental in guiding designers and planners. These identified threshold values serve as practical benchmarks within the realm of urban design and planning. They offer a tangible means for practitioners to gauge and adjust the visual components within their projects to align with the desired perceptions of density. In doing so, these environments become not only visually appealing but also resonate positively with the public, enhancing their overall reception. However, it's essential to note that the findings obtained from this research are context-specific. To strengthen the validity and generalizability of the established threshold values, further testing and validation in various urban environments are imperative. These additional studies will help ensure that the thresholds remain applicable and relevant across diverse contexts and settings.

Visual Assessment Index

The research introduces a visual assessment index that combines critical constructs and visual components, providing a comprehensive tool for evaluating and predicting how dense urban environments will be perceived. The visual assessment index was developed using Gestalt psychology principles and image segmentation techniques. This novel method quantifies the intricate relationship between critical constructs and visual elements. The visual assessment index provides a practical and accessible method for assessing the visual impact of urban environments on density perception. It simplifies the evaluation process and enables more precise predictions of how spaces will be perceived. Urban designers and planners can use the visual assessment index to evaluate and refine their design proposals. By employing this index, practitioners can make informed decisions regarding design elements and their impact on density perception, resulting in urban environments that are ultimately more successful.

8.6 Balancing Objective Density Metrics with Perceived Density: Strategies for Urban Design and Planning

Several of the design strategies mentioned (see Section 8.2) can assist in manipulating the perception of density while aligning with objective measures of density such as floor area ratio (FAR), plot ratio, or floor space index (FSI). For Instance:

Variation in Plot Size and Building Typology. While FAR, plot ratio, or FSI provide quantitative measures of density, varying plot size and building typology can influence how that density is perceived. By strategically placing different building types with varying heights and architectural styles within the same development, you can create a visually diverse and less monotonous environment, even if the objective density measures remain consistent.

Building Height Considerations. Balancing building height with other design elements, as suggested, can help manage the perception of density. For example, if you have a high FAR or FSI, designing buildings with setbacks or architectural features that reduce the perceived height from street level can mitigate the feeling of overwhelming density.

Creating Visual Breaks. Introducing small public spaces or plazas within high-density areas can provide visual relief and break up the built environment. While FAR or FSI may indicate high density, the presence of these open spaces can create the perception of greater spaciousness and lower density.

Staggered Building Arrangements. Staggering building positions along streets or within blocks can vary the streetscape, making it visually more interesting. Even if the FAR or FSI suggests high density, this staggered arrangement can give the impression of diversity and reduce the sense of monotony.

Addressing Compact Urban Form. Varying setbacks or plot configurations can be used to influence the perception of compact urban form. Even with a high FAR or FSI, thoughtful design can make the environment feel less cramped and more inviting.

Strategic Distribution of Retail. While FAR, plot ratio, or FSI measures overall density, strategically distributing retail can disperse crowds and reduce perceived density. By guiding pedestrian flow and creating focal points, you can create a sense of balance within a dense area.

Transitional Spaces. Incorporating buffer zones between different density zones can help individuals adjust gradually to changes in density. This can make the transition smoother and reduce the abrupt perception of density changes indicated by FAR or FSI.

Greenery and Urban Vegetation. Integrating greenery into dense areas can provide visual relief and improve the overall quality of the environment. Even with high FAR or FSI, green spaces can create a perception of lower density.

By integrating these design strategies, urban planners and designers can effectively manage the perceived density of an area while maintaining or even optimizing the objective measures of density like FAR, plot ratio, or FSI. This approach ensures that densely populated areas remain visually appealing and conducive to positive urban experiences.

8.7 Utilizing Research Findings to Enhance Urban Planning and Development: A Roadmap for planning Authorities

The research findings can play a significant role in guiding planning authorities and regulatory bodies in their assessment and review of development applications. Few ways in which planning authorities can use the research findings are as follows:

Informed Decision-Making. Using the research findings, planning authorities can make more informed decisions when evaluating development applications. Authorities can determine whether a proposed development aligns with the community's preferences and expectations by analysing the factors and visual components that influence the perception of density.

Design Guidelines. This research can contribute to the creation of design guidelines for particular urban areas. Planning authorities can establish design standards that take into account the research-identified critical constructs and visual factors. These guidelines can help developers create urban environments that are more likely to be positively perceived by residents and visitors.

Zoning and Land Use Planning. The research can inform decisions regarding land use and zoning. Using factors such as building height, open space, and streetscape design, planning authorities can zone areas according to their desired perception of density. This can aid in maintaining a balance between various densities within a city or region.

Public Engagement. The research findings can be utilised by planning authorities to effectively engage the public. When presenting development proposals to the community, authorities can cite the research to demonstrate how design choices align with the factors that contribute to a favourable perception of density. This can increase openness and community support.

Density Incentives. Some cities offer density bonuses to developers who incorporate community benefits, such as affordable housing or public spaces, into their projects. The research can help authorities establish the criteria for density bonuses, ensuring that bonus projects contribute positively to the perception of density.

Visual Impact Assessments. Planning authorities typically conduct environmental impact assessments when reviewing development applications. The research can be used to evaluate the potential visual impact of a proposed development on the surrounding area, enabling authorities to conduct more thorough evaluations.

Urban Renewal and Redevelopment. Planning authorities typically conduct environmental impact assessments when reviewing development applications. The research can be used to evaluate the potential visual impact of a proposed development on the surrounding area, enabling authorities to conduct more thorough evaluations.

Monitoring and Evaluation. After a project has been completed, planning authorities can use the research findings as criteria for monitoring and evaluating the project's success. This can include determining if the development achieved the desired perception of density and if it adheres to research-based guidelines.

Design Validation. The research findings can be utilised by urban designers and architects to validate their design proposals. Using the identified critical constructs and visual factors, designers can determine if their designs align with the elements that contribute to positive density perception. This validation can occur at various stages of design, from initial concepts to comprehensive plans.

Visualization Tools. According to the research, designers can create visualisation tools and simulations that incorporate the perceptual armature of density. These tools can assist stakeholders, such as urban planners, community members, and developers, in gaining a better understanding of how proposed designs will be perceived in terms of density. Immersive experiences can be produced using virtual reality (VR), augmented reality (AR), or 3D modelling.

Post-Occupancy Evaluation. After a design has been implemented, post-occupancy evaluations can determine if the perceived density corresponds with the design intent. This evaluation can inform future project adjustments and enhancements.

Planning authorities and regulatory bodies can promote urban development that not only meets functional requirements but also improves the overall quality of life in urban areas by incorporating research findings into their decision-making processes. This strategy can result in more sustainable and inhabitable cities.

8.8 Limitations of the Study

A city is a composition of many unique urban environments that are perceived differently by the public. cultural diversity (Rapoport, 1975b; Lynch, 1981) individual differences (Taylor, 1981) experiences, gender, age and the form of space itself play a part in this and a complete understanding of the perception process is beyond the scope of this study. Still, density is a factor known to play a considerable role on the overall experience of space; being it in the design and planning remit, it is a useful means through which to make advancements in the overall study of visual perception of the built environment with the aim of supporting the creation of more efficient and desirable environs.

This study is therefore an attempt to advance understanding of the perception of density. Whilst was systematically conducted and executed, some limitations arising from the methods adopted and variables and issues specific to urban location must be taken into account as noted below.

8.8.1 Contextual Variability

The research recognized that the perception of density is context-dependent. It varies based on the specific characteristics of urban environments. For example, the presence of certain visual elements like skyscrapers, street art, public transportation, and parks can influence how people perceive density. This implies that the findings may not be universally applicable and could vary in different urban contexts. The contextual variation can be explained by the following factors:

- **Visual Elements and Features.** Diverse urban contexts contain a variety of visual elements and features that can significantly affect perceptions of density. In a city dominated by skyscrapers and high-rise buildings, for example, high density may be perceived as the norm, whereas in a city dominated by low-rise structures and green spaces, even moderate levels of density may be perceived as high. Street art, vegetation, public transportation, and architectural styles also play important roles in shaping perceptions of density.
- **Land Use and Zoning.** Regulations regarding urban planning, land use, and zoning can vary significantly between cities and regions. These variables can determine the proportion of residential, commercial, and industrial areas in an urban setting. The spatial arrangement of these land uses can influence the density of development and, consequently, the perception of density.
- **Temporal and Seasonal Variations.** Density perception is also susceptible to temporal and seasonal changes. During rush hour, weekends, and holidays, the same urban area may be perceived differently. Additionally, weather, lighting, and even the presence of special events can affect how individuals perceive density.
- **Built Environment Configuration.** The physical layout of streets, buildings, and

public spaces can influence how individuals navigate and interact with their environment. Street width, building setbacks, and the presence of pedestrian-friendly amenities can influence the perception of density.

8.8.2 Cultural Factors

The research acknowledged the influence of cultural factors on perceptions of density. Cultural backgrounds, socioeconomic standing, and societal norms may influence preferences and emotional responses to urban environments. This implies that research on density perception must account for cultural diversity and its influence on findings. This is explicable by the following elements:

- **Cultural Preferences.** Different cultures have distinct urban environment preferences. Some cultures may value close-knit, bustling urban communities with high population density, while others may prioritise spaciousness, privacy, and lower density. For instance, in certain densely populated Asian cities such as Tokyo and Hong Kong, high-rise living and crowded streets are culturally accepted and appreciated. In contrast, there may be a preference for suburban living in certain Western cultures.
- **Socioeconomic Status.** Often, cultural factors and socioeconomic status intersect. Individuals from diverse socioeconomic backgrounds may perceive density differently. People from affluent backgrounds may perceive density as a sign of vitality and economic activity, whereas those from low-income backgrounds may associate density with overcrowding and limited resources. This intersection of culture and socioeconomic status can have a substantial impact on the desirability of high-density living.
- **Societal Norms and Values.** Culture-specific societal norms and values can also influence density perception. Some societies may prioritise communal living and social interactions in densely populated urban neighbourhoods, whereas others may prioritise individualism and private space. These cultural values can influence how individuals interpret and respond to a region's density.
- **Migration and Cultural Diversity.** Cities with a high level of cultural diversity

may be perceived differently by different cultural communities in terms of population density. Immigrants and expatriates may contribute to the multicultural fabric of a city by bringing their own cultural perspectives on density.

8.8.3 Image Selection

The research relied on a set of images to represent urban environments. Although this is a practical approach, the selection of images may influence the perceptions of the participants. Future research could expand the image selection to include a greater variety of urban environments and visual characteristics. Utilizing a particular set of images to represent urban environments in the research methodology raises a number of concerns regarding the potential influence of image selection on participants' perceptions:

- **Image Subjectivity.** The selection of images is inherently subjective, as it depends on the researcher's preferences and selection criteria. This subjectivity may introduce bias into the study, as the images may not adequately capture the visual diversity of urban environments. A participant's perceptions could be influenced by the images they are exposed to.
- **Limited Representativeness.** A limited collection of images may not adequately represent the vast variety of urban settings found in cities, regions, and cultures across the globe. In terms of architectural styles, historical contexts, natural elements, and human activities, urban environments can vary greatly. Concentrating on a limited number of images may result in findings that are less applicable to actual urban settings.
- **Image Context.** Images presented in isolation may lack the context that participants would ordinarily have during actual urban experiences. Factors such as weather, time of day, the presence of people, and ambient sounds can have a significant impact on perceptions of density, which may not be fully conveyed by static images.
- **Visual Characteristics.** Different images may emphasise distinct visual

characteristics, such as building height, street width, green spaces, or pedestrian presence. These visual cues can influence the density judgments of participants. Variations in image content can therefore result in variations in perceived density, potentially influencing the study's findings.

- **Variability in Image perspective**. In this study, Glasgow was selected as the case study city to investigate the perception of density among local residents. Additionally, examples from other high-density cities around the world were considered. The research findings from the visual image survey revealed similar results across both the case study city and the high-density examples.

  However, it is important to note that the findings derived from the image segmentation method may not be easily generalised to a broader context. This is because the ranges for the eight visual components used in the study can vary depending on how the images were captured. For instance, if the images were taken from the edges of the blocks, similar ranges of visual components may be observed. On the other hand, if Google Street imagery or other sources are used, the determination of ranges will depend on factors such as the position on the street from where the image was captured.

  Therefore, it is crucial to clarify the viewing position and angle, as well as the image capturing position, at the outset of the study. This is necessary because the public typically perceives and experiences urban environments while walking on the pavements or sidewalks, rather than from the centre of the street, unless the street is specifically designed as a pedestrian-only area.

8.8.4 Lack of previous research

This study recognises that the research on perceived density is fairly recent and hence there are only a few studies that can be relied on. The lack of previous research can be a limitation for current research in several ways:

- **Limited theoretical background**. Previous research on perceived density provides a limited foundation of knowledge and understanding on which current research can build. Only one theoretical premise by Rapoport and seven empirical studies exist. This made developing a theoretical framework for this study challenging, as was the interpretation and contextualisation of findings.

- **Limited comparability**. The lack of empirical studies to compare findings against made the evaluation of the significance and generalizability of results a challenge. as well as drawing meaningful conclusions, correlations and developing design implications.
- **Experimental artificiality**. People are asked to record their perception of the urban environment by viewing images that are representative of real-life scenarios. However, images are not inclusive of all stimuli affecting other senses (hearing, smell, touch) which could also influence the perception of density. However, accounting of them would require conducting on-site detailed interviews, which is time-consuming and would impact the sample size reached. they are both effective and will be useful in the future to validate the online work done in this research with real life cases.
- **Participant bias**. The participants for the survey were architecture students, lay people and professionals with different backgrounds, cultures and ages and diverse socioeconomic backgrounds. It is suspected that the perception of density might vary between people of different socioeconomic backgrounds and cultures, but it has not been investigated in this study. with a larger number of respondents, it would be interesting to check trends in responses and how these correlates with persona and social characteristics, to establish more clearly their role in the experience of space.

8.9 Recommendations for Future Research

The most significant finding of this research is how to measure the perception of density using image segmentation reflecting the magnitude of the eight fundamental components of the urban environment that affect the visual perception of the urban environment and density. This study will hopefully give way to more detailed research that can be conducted using the same method. This study identified around 65 constructs used to read environments, of which 30 constitute are strongly related to spatial qualities of the urban environment. It also identified categories in which the 65 constructs are classified, and each category can be a research project on its own. For instance, urban form aesthetics involves similarity and diversity of built form, variation in architectural style, the building typology and the visual appearance of the built form. By conducting a detailed study only involving this it is possible to determine the role of the aesthetic qualities of built form alone in the perception of density.

Image segmentation can be a valuable tool in such studies as it allows for the precise analysis and measurement of visual components. By applying image segmentation techniques to specific categories or constructs, researchers can gain deeper insights into how these factors influence the perception of density in the urban environment. This can contribute to a more comprehensive understanding of the complex relationship between visual cues and the perception of density.

However, conducting the image segmentation process manually is a laborious task. Although image segmentation algorithms are available, they need to be adapted to identify these components using Python or some other programming language. Thus, to be able to successfully determine the perception of density, this process needs to be automated to access a large number of samples from different environments and locations. This will allow the generalisation of the results and further assist in developing the performance guidelines for positive perception of density which achieves high objective density.

The other suggestions for future research based on the findings of this study include:

1. **Replication studies**. Researchers may want to replicate this study using similar methods but different samples to confirm the findings and improve the generalisability of the results.
2. **Longitudinal studies**. Researchers may want to conduct longitudinal

studies to examine the effects of the constructs over time and to identify how these vary across age groups, and at different times of day, or in relation to other urban fluxes.

3. **Cross-cultural studies**. Researchers may want to conduct cross-cultural studies to examine the extent to which the findings are generalisable across different cultural situations.
4. **Methodological comparisons**. Researchers may want to explore alternative methods of data collection to address the limitations of this study. Future research could compare the results of the new method with traditional methods to determine reliability and validity. This could help identify any limitations of the new method and improve its accuracy.
5. **Extension of the study**. Researchers may want to extend the study to examine other variables or to explore the research question in different contexts.
6. **Collaborative research**. Future research could involve collaboration with other researchers across disciplines (environmental psychology, cognitive sciences) in different cities to build on previous studies on perceived density.
7. **Constructing the same research in a new environment, location or culture**. Perception of density is highly influenced by context. Therefore, when conducting research in different environments, there may be unique challenges and limitations that arise.
8. **Comparative studies**. Future research could conduct comparative studies to examine the similarities and differences between contexts. This could help to identify any contextual factors that may affect the results and provide a better understanding of the generalisability of the findings.

9. **Adaptation of methods**. Future research could adapt the research methods to fit the specific context. This could include modifying the survey questions, adjusting the sample size, or using different data collection methods. This could help to ensure the validity and reliability of the findings in the new context.
10. **Collaboration with local experts**. Future research could involve collaboration with local experts in the new context to ensure that the research is culturally sensitive and appropriate for the specific context. This could help to improve the validity and reliability of the findings in the new situation.
11. **Diverse Geographic Selection.** Future studies should aim for a broader selection of case study cities to capture a more comprehensive range of urban environments. This will help ensure that findings are not limited to a specific geographic context.
12. **Random Sampling.** Employ random sampling techniques to reduce self-selection bias. Random sampling ensures that all potential participants have an equal chance of being selected, leading to a more representative sample.
13. **Stratified Sampling.** Consider stratified sampling to ensure that participants from different demographic groups are adequately represented in the sample. This will facilitate a more nuanced understanding of how demographic factors influence density perception.
14. **In-Depth Demographic Analysis.** Allocate resources and research efforts to conduct a thorough analysis of the influence of demographic factors on density perception. This can provide valuable insights into variations in perception based on age, gender, cultural backgrounds, and socioeconomic status.

Understanding how density is perceived can be useful in a variety of ways. It can help designers and architects create more comfortable and efficient living and public spaces. For example, by understanding how people perceive the density of a public space, designers can optimise the layout and arrangement of spatial factors and other visual features to create an environment that feels more spacious, less cluttered and more engaging whilst maximising their density efficiency.

Perception of density can also be important in fields like transportation planning and urban design. By understanding how people perceive the density of a city, planners can make more informed decisions about where to locate public transit stations, how to design pedestrian and bicycle infrastructure and how to optimise the benefits of objective density to achieve a balance between the needs of various modes of transportation. It allows for more informed decision-making, leading to the creation of inclusive, sustainable, and people-centric cities.

It can also be useful in fields like psychology and neuroscience. Research in these areas can shed light on how the brain processes and interprets sensory information related to density and how this information contributes to our overall perception of the physical world around us.

A comprehension of design perception will challenge the techniques of design thinking. Advanced tools for building 3D models of built environments such as agent-based modelling, virtual and augmented reality and other simulation techniques will be able to evaluate the designs from a pedestrian perspective by taking into account the elements affecting the perception of density. This will bridge the gap between the city's conception and user interpretation.

8.10 Value Addition

The value of the new knowledge generated by this study lies in the development of a framework for assessing perceptions of density within urban environments. This framework is a prototype that represents a significant step forward in the field of urban design and planning. The value of the prototype can be explained in the following ways:

Innovation in Assessment. The tool developed in this study is pioneering in its approach to assessing density perception. Traditional methods for evaluating urban density typically rely on objective measurements such as population density or building density. Nonetheless, this study adds a new dimension by focusing on how individuals perceive and experience density subjectively.

Addressing a Gap. Prior to this study, there was a significant gap in the literature regarding the subjective perception of density. This void is filled by the prototype, which provides a structured methodology for comprehending how individuals interact with and react to dense urban environments.

Prototype for Future Research. This framework, while acknowledged as a prototype in its present form, lays the groundwork for future research endeavours. Researchers, urban designers, and planners now have a framework for conducting density perception studies. It can be adapted and refined for specific contexts, locations, and research questions.

Interdisciplinary Application. Architecture, urban design, and psychology, among others, contributed to the development of this tool. This multidisciplinary approach increases its adaptability and utility. Different types of professionals can use it to gain insight into how individuals perceive density.

Enhancing Urban Design and Planning. This tool's capacity to inform and direct urban design and planning practises is one of its most significant implications. Using the results of perception studies, designers and planners can optimise the layout, aesthetics, and functionality of urban spaces. This can result in the development of more attractive, user-friendly, and livable cities.

Tailored Interventions. Practitioners can implement targeted interventions when they have knowledge of how specific design features affect density perception. For instance, they can strategically incorporate elements such as green spaces, public art, and architectural diversity to influence how individuals perceive density.

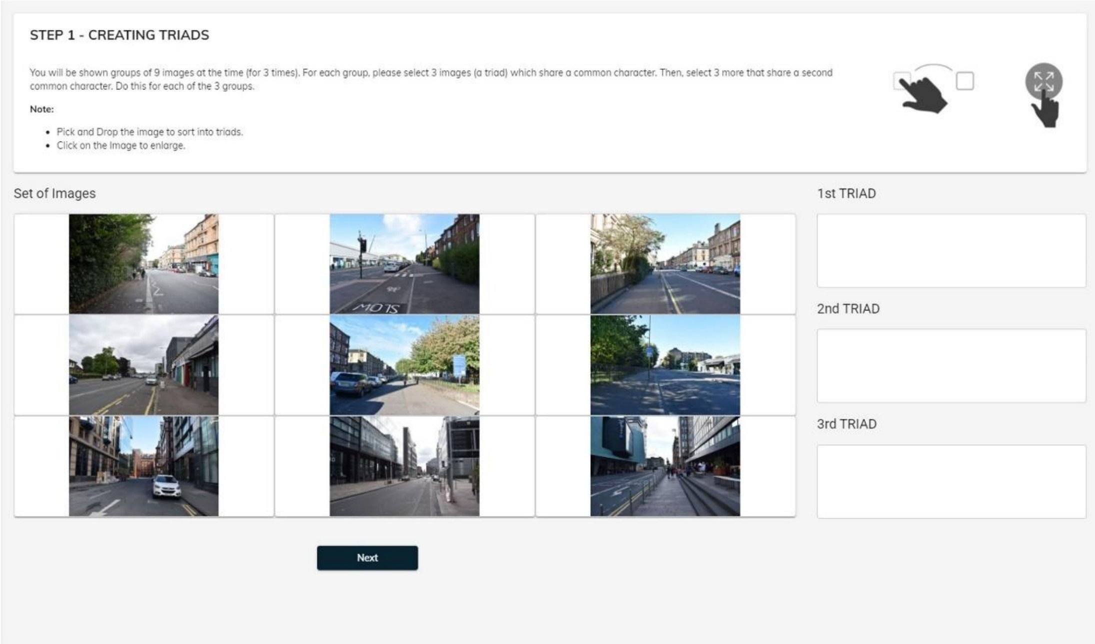
Data-Driven Decision-Making. The tool promotes data-driven urban development decision making. By systematically collecting and analysing data on density perception, stakeholders can make decisions that are in line with the community's preferences and needs.

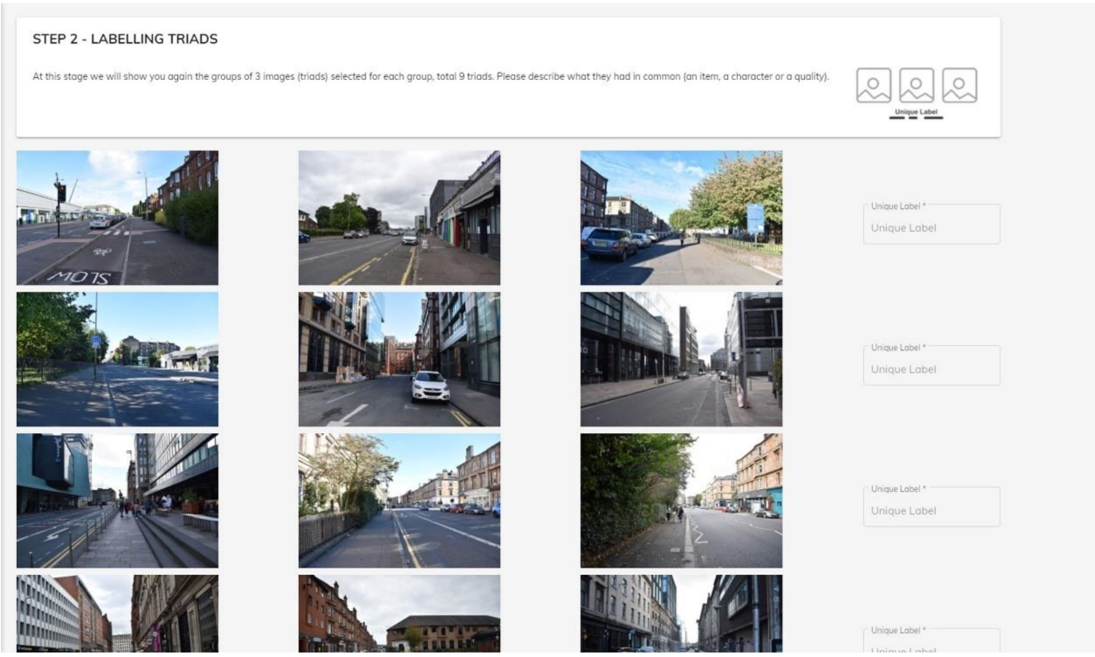
Iterative Improvement. As a prototype, this instrument is open to future refinement and improvement. Researchers can expand the framework's applicability to diverse contexts and improve its precision and dependability.

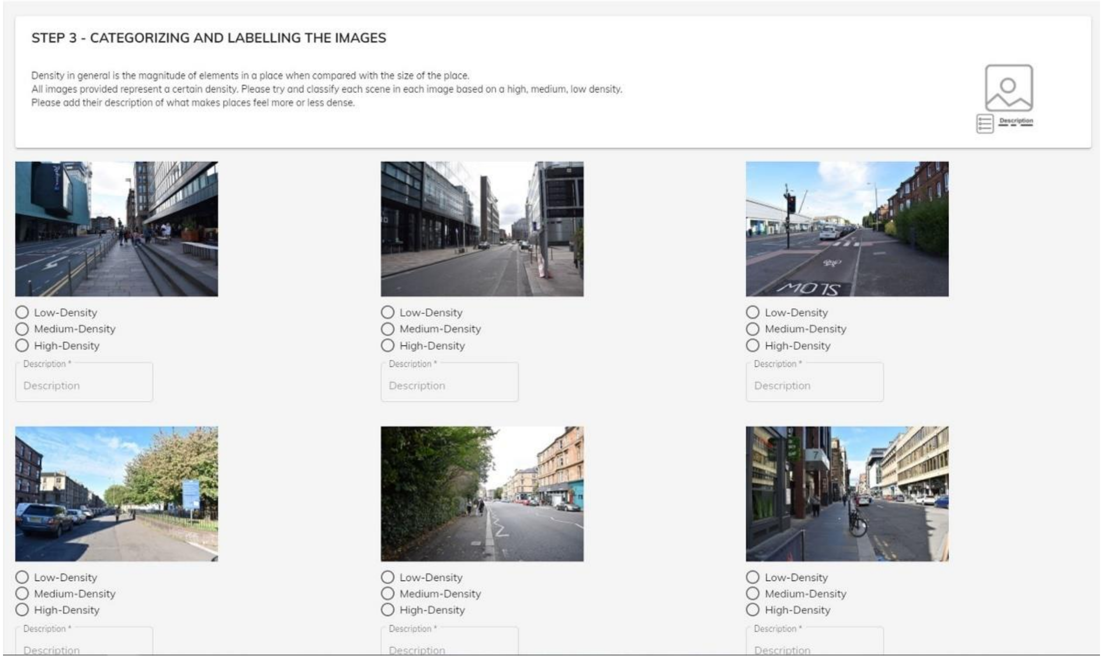
In essence, the value of this new knowledge lies in its potential to transform the way urban density is understood, assessed, and designed. It bridges the gap between objective density measures and the subjective experiences of individuals, offering a promising path towards more inclusive, people-centered, and effective urban planning and design.

Appendix A1 – Supplementary Material to Chapter 5

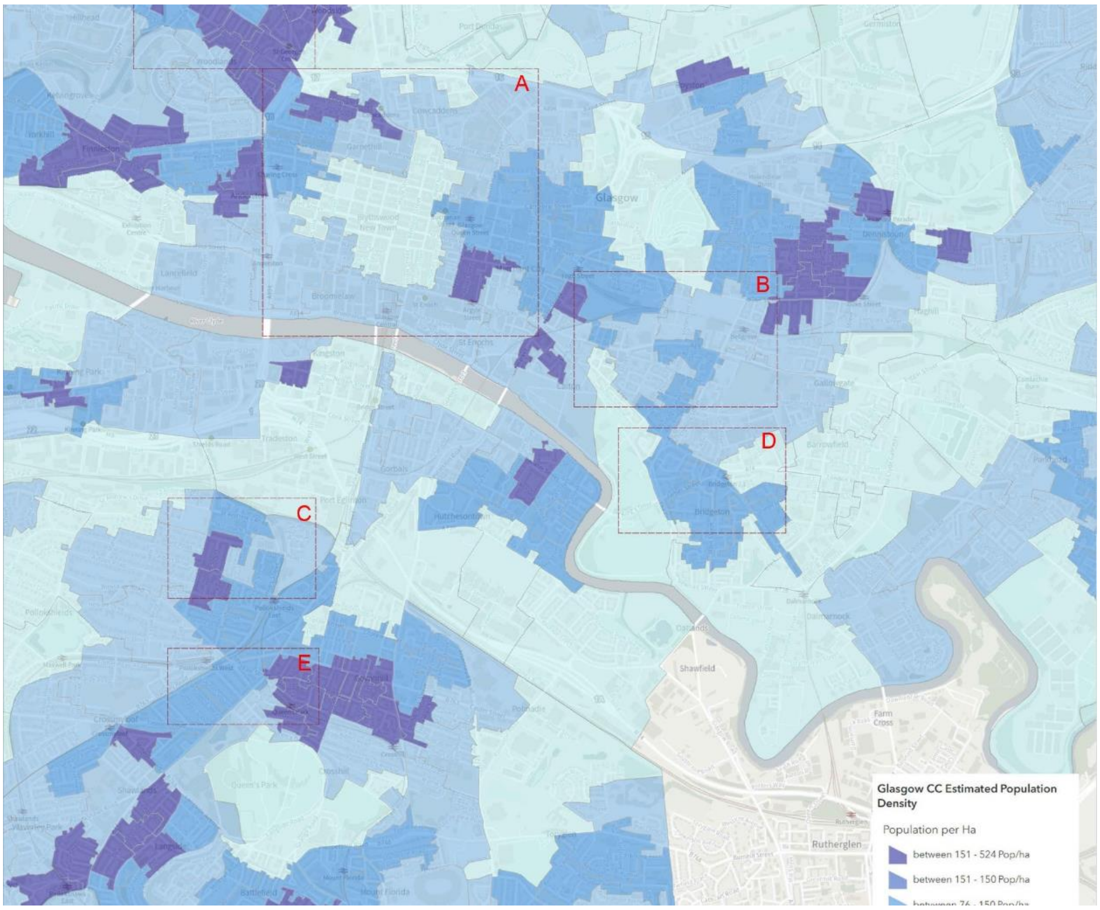
Multiple Sorting Task (MST)- Survey



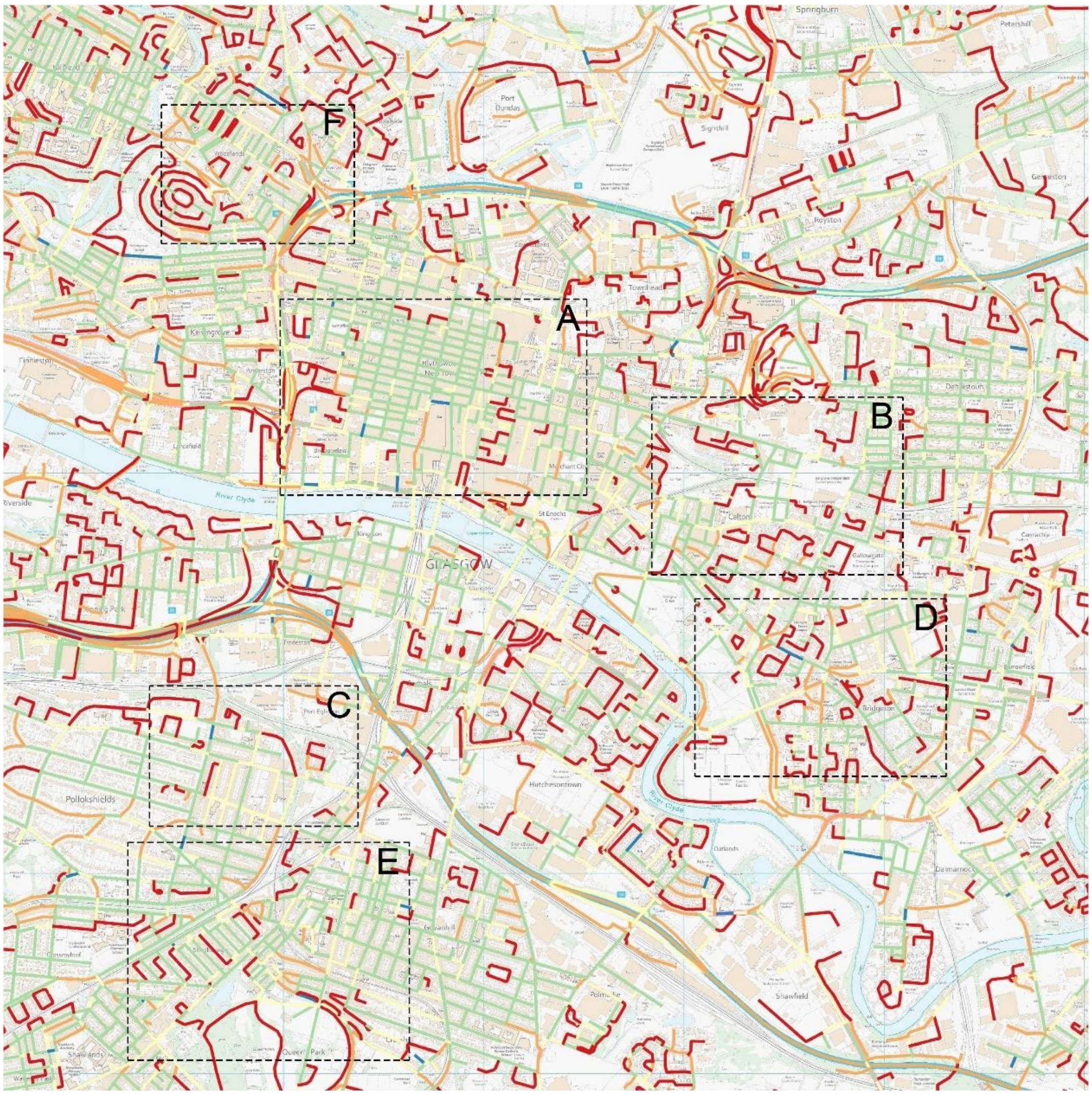


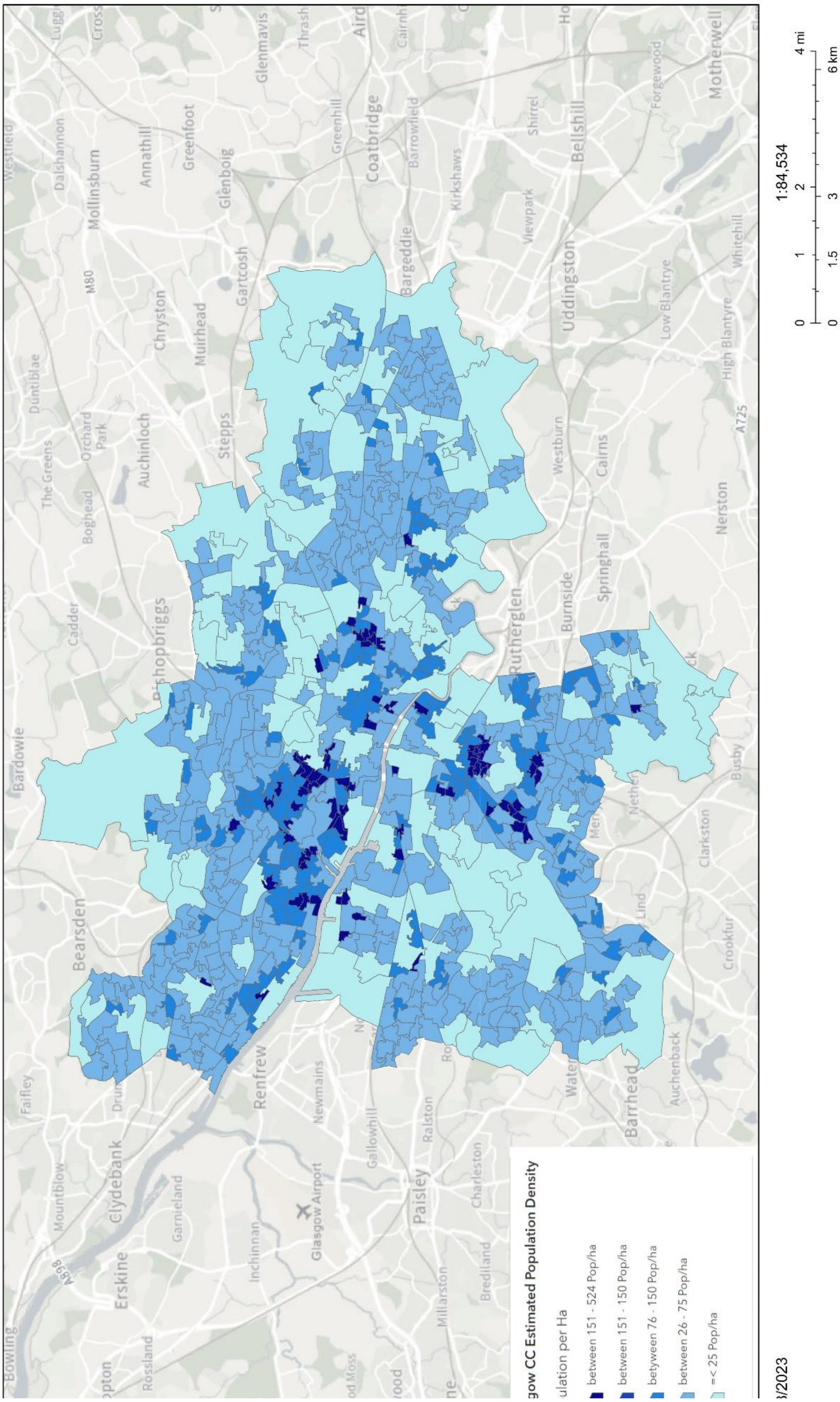


Reference Map- Street Selection



Multiple Centrality Assessment



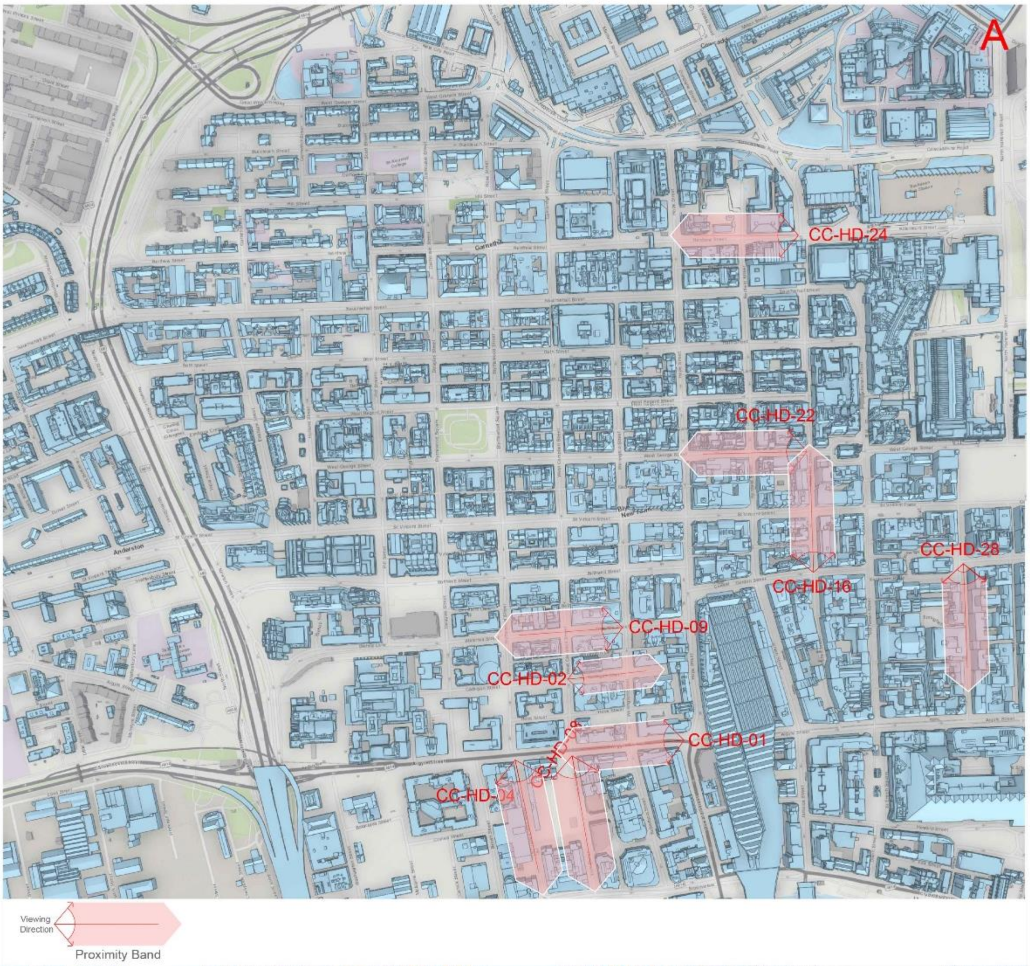


Glasgow Population Density

Source: Glasgow Cityc Council

Street Selection

(Map data from *Glasgow Open Data: Glasgow Urban Model*, reused under the Open Government Licence)



CC-HD-01
Argyll Street
Density- 76-150 pph

CC-HD-02
Cadogan Street
Density- 76-150 pph

CC-HD-08
York Street
Density- 76-150 pph

CC-HD-04
James Watt Street
Density- 76-150 pph

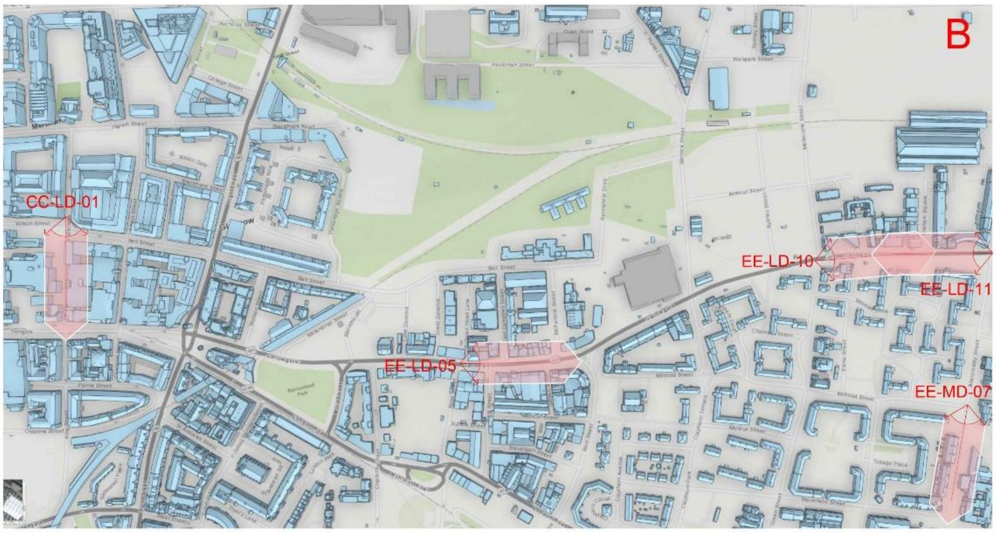
CC-HD-16
West Nile Street
Density- < 25 pph

CC-HD-28
Queens Street
Density- 151-160 pph

CC-HD-09
Waterloo Street
Density- 76-150 pph

CC-HD-22
West George Street
Density- < 25 pph

CC-HD-24
Renfrew Street
Density- 76-150 pph



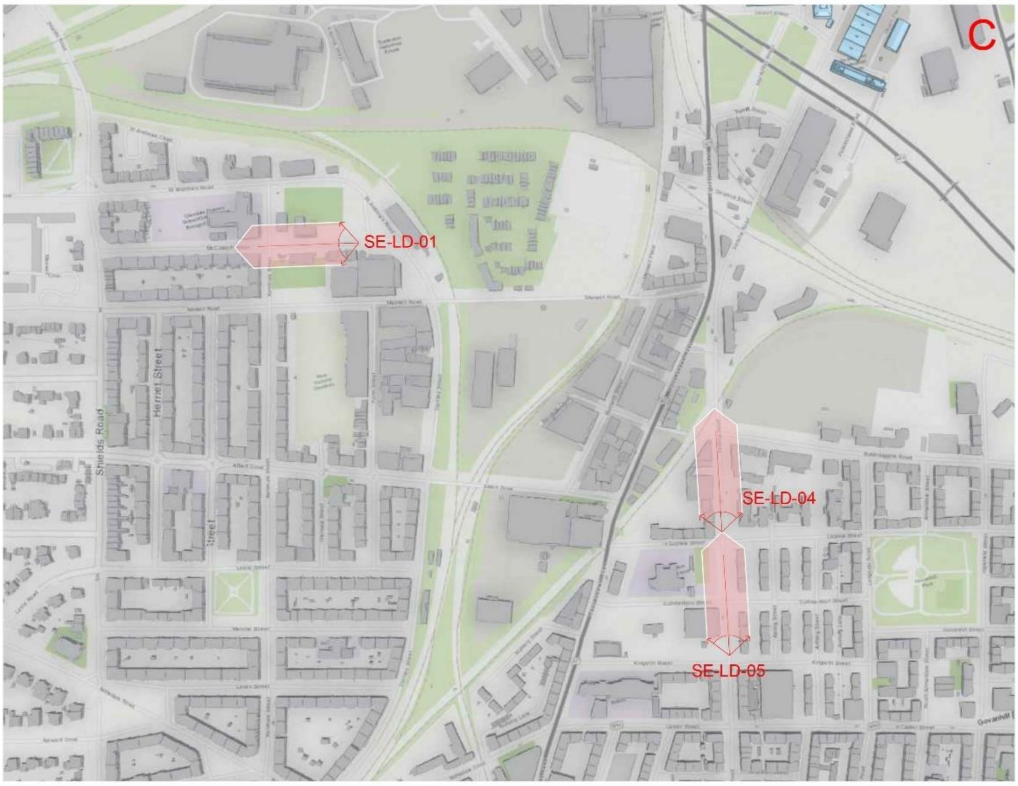
CC-LD-01
Candleriggs
Density- 26-75 pph

EE-LD-05
Gallowgate
Density- 26-75 pph

EE-LD-10
Gallowgate
Density- 26-75 pph

EE-LD-11
Gallowgate
Density- 26-75 pph

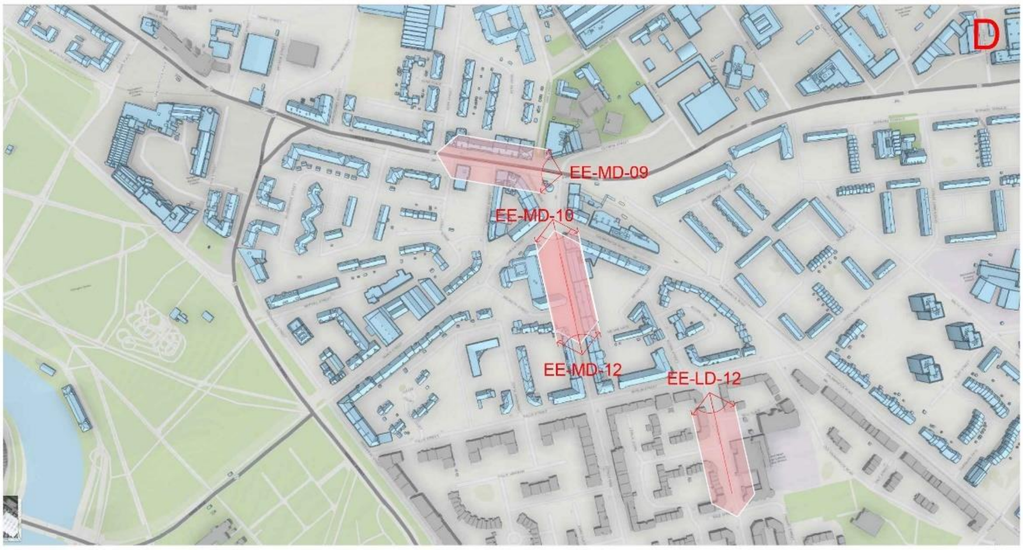
EE-MD-07
Abercromby Street
Density- 26-75 pph



SE-LD-01
Mc Culloch Street
Density- 26-75 pph

SE-LD-05
Victoria Road
Density- 26-75 pph

SE-LD-04
Victoria Road
Density- < 25 pph



EE-MD-09
London Road
Density- 76-150 pph

EE-MD-10
Main Road
Density- 76-150 pph

EE-MD-12
Main Road
Density- 76-150 pph

EE-LD-12
Reid Street
Density- 76-150 pph


SE-MD-05
Calder Street
Density- 151-160 pph


SE-MD-06
Calder Street
Density- 151-160 pph


SE-MD-13
Pollowkshaws Road
Density- 76 -150 pph


SE-LD-09
Pollowkshaws Road
Density- 26-75 pph


WE-MD-06
Woodlands Road
Density- 26 -75 pph

WE-MD-09
St Georges Road
Density- 151 -160 pph

Glasgow-Triads-Unique labels

Triads - Glasglow (GLA) - 3

Frequncy Count

EE-MD-07
Actual Density - Moderate
Perceive Density - Moderate

EE-MD-12
Actual Density - Moderate
Perceive Density - Moderate

SE-MD-05
Actual Density - Moderate
Perceive Density - Moderate

19

EE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

EE-MD-10
Actual Density - Moderate
Perceive Density - Moderate

WE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

40

EE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

SE-LD-01
Actual Density - Low
Perceive Density - Low

WE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

16

EE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

SE-LD-04
Actual Density - Low
Perceive Density - Low

WE-MD-09
Actual Density - Moderate
Perceive Density - Moderate

9

SE-LD-05
Actual Density - Low
Perceive Density - Low

SE-MD-13
Actual Density - Moderate
Perceive Density - Moderate

WE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

10

SE-LD-09
Actual Density - Low
Perceive Density - Low

SE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

SE-MD-13
Actual Density - Moderate
Perceive Density - Moderate

10

Triads - Glasglow (GLA) - 4

Frequncy Count

SE-LD-09
Actual Density - Low
Perceive Density - Low

SE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

WE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

42

SE-LD-09
Actual Density - Low
Perceive Density - Low

SE-MD-13
Actual Density - Moderate
Perceive Density - Moderate

WE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

10

SE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

SE-MD-13
Actual Density - Moderate
Perceive Density - Moderate

WE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

39

CC-LD-01
Actual Density - Low
Perceive Density - Moderate

EE-MD-07
Actual Density - Moderate
Perceive Density - Moderate

EE-MD-12
Actual Density - Moderate
Perceive Density - Moderate

15

CC-LD-01
Actual Density - Low
Perceive Density - Moderate

EE-MD-07
Actual Density - Moderate
Perceive Density - Moderate

SE-MD-05
Actual Density - Moderate
Perceive Density - Moderate

6

CC-LD-01
Actual Density - Low
Perceive Density - Moderate

EE-LD-05
Actual Density - Low
Perceive Density - Moderate

EE-LD-10
Actual Density - Low
Perceive Density - Low

16

Triads - Glasglow (GLA) - 5

Frequncy Count


CC-LD-01
Actual Density - Low
Perceive Density - Moderate


EE-LD-05
Actual Density - Low
Perceive Density - Moderate


EE-MD-07
Actual Density - Moderate
Perceive Density - Moderate

6


CC-LD-01
Actual Density - Low
Perceive Density - Moderate


EE-LD-05
Actual Density - Low
Perceive Density - Moderate


SE-MD-05
Actual Density - Moderate
Perceive Density - Moderate

21


CC-LD-01
Actual Density - Low
Perceive Density - Moderate


EE-LD-10
Actual Density - Low
Perceive Density - Low


EE-MD-07
Actual Density - Moderate
Perceive Density - Moderate

9


CC-LD-01
Actual Density - Low
Perceive Density - Moderate


EE-LD-10
Actual Density - Low
Perceive Density - Low


SE-MD-05
Actual Density - Moderate
Perceive Density - Moderate

6


EE-LD-05
Actual Density - Low
Perceive Density - Moderate


EE-LD-10
Actual Density - Low
Perceive Density - Low


EE-MD-12
Actual Density - Moderate
Perceive Density - Moderate

10


EE-LD-05
Actual Density - Low
Perceive Density - Moderate


EE-LD-10
Actual Density - Low
Perceive Density - Low


SE-MD-05
Actual Density - Moderate
Perceive Density - Moderate

21

Triads - Glasglow (GLA) - 6

Frequncy Count


EE-LD-11
Actual Density - Low
Perceive Density - Low


SE-LD-05
Actual Density - Low
Perceive Density - Low


SE-LD-09
Actual Density - Low
Perceive Density - Low

37


EE-LD-11
Actual Density - Low
Perceive Density - Low


SE-LD-05
Actual Density - Low
Perceive Density - Low


SE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

10


EE-LD-11
Actual Density - Low
Perceive Density - Low


SE-LD-05
Actual Density - Low
Perceive Density - Low


SE-MD-13
Actual Density - Moderate

43


EE-LD-11
Actual Density - Low
Perceive Density - Low


SE-LD-05
Actual Density - Low
Perceive Density - Low


WE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

8


EE-LD-11
Actual Density - Low
Perceive Density - Low


SE-LD-09
Actual Density - Low
Perceive Density - Low


SE-MD-06
Actual Density - Moderate
Perceive Density - Moderate

10


EE-LD-12
Actual Density - Low
Perceive Density - Low


EE-MD-10
Actual Density - Moderate
Perceive Density - Moderate


SE-LD-01
Actual Density - Low
Perceive Density - Low

9

Triads - Glasglow (GLA) - 7

Glasgow – Unique labels for Triads – MST-Step 2

High Density -Triads

Triads	Unique Labels	Perceived Density	Construct Code
CC-HD-08, CC-HD-01, CC-HD-02	Tall buildings, they overshadow the street	HD	B1,K8
CC-HD-08, CC-HD-01, CC-HD-02	tall buildings	HD	B1,K8
CC-HD-02, CC-HD-08, CC-HD-01	Narrow street -Modern Architecture -High rise	HD	M2,P1,P5
CC-HD-08, CC-HD-02, CC-HD-01	City/Modern	HD	C1,P1
CC-HD-01, CC-HD-08, CC-HD-02	Central, Imposing	HD	C1,F6
CC-HD-01, CC-HD-08, CC-HD-02	Glazed facades, city centre	HD	P2,C1

	atmosphere		
CC-HD-02, CC-HD-01, CC-HD-08	low quality of light, sense of desertion, large scale forms imposing on pedestrians	HD	K8,K9
CC-HD-08, CC-HD-01, CC-HD-02	Modern, city centre. commercial	HD	P1,C1,H2
CC-HD-08, CC-HD-02, CC-HD-01	Dark urban centres	HD	C1,K8
CC-HD-08, CC-HD-01, CC-HD-02	CBD High modern buildings	HD	C1,P1
CC-HD-02, CC-HD-01, CC-HD-08	They look like dense city images and the buildings have similar styles.	HD	C1,D1,P1
CC-HD-01, CC-HD-08, CC-HD-02	No greenery, only grey roads and buildings	HD	K1,M2,I1
CC-HD-02, CC-HD-01, CC-HD-08	Inner City -High Rise	HD	C1,P5
CC-HD-01, CC-HD-02, CC-HD-08	tall buildings either side/city centre	HD	P8,C1
CC-HD-08, CC-HD-01, CC-HD-02	High Rise Glass buildings	HD	P2,P5
CC-HD-02, CC-HD-08, CC-HD-01	Narrow	HD	M2,P1,P5
CC-HD-02, CC-HD-08, CC-HD-01	High Buidlings in the built up area	HD	B1,I2
CC-HD-02, CC-HD-01, CC-HD-08	very urban/ built-up	HD	C1,I2
CC-HD-02, CC-HD-01, CC-HD-08	central, high, dense	HD	C1,B1,D1
CC-HD-01, CC-HD-08, CC-HD-02	pedestrian in between two busy city street	HD	O2,G1
CC-HD-01, CC-HD-08, CC-HD-02	city centre, urban, more 'modern' styles of architecture	HD	C1,P1
CC-HD-02, CC-HD-08, CC-HD-01	large scale buildings and sense of enclosure	HD	I1,E1
CC-HD-08, CC-HD-02, CC-HD-01	High Density, City Centre	HD	D1,C1
CC-HD-08, CC-HD-02, CC-HD-01	dense new built city centre commercial	HD	D1,C1,H2
CC-HD-08, CC-HD-01, CC-HD-02	city centre/glass/modern	HD	C1,P2

Moderate Density-Triads

Triads	**Unique Labels**	**Perceived Density**	**Construct Code**
SE-LD-09, WE-MD-06, SE-MD-06	Trees	MD	K1
WE-MD-06, SE-MD-13, EE-LD-11	Lines	MD	M3
SE-MD-06, SE-LD-09, WE-MD-06	Trees	MD	K1
SE-MD-06, SE-LD-09, SE-MD-13	wide roads + Greenery	MD	M2+K1
WE-MD-06, SE-MD-06, SE-LD-09	Greenery	MD	K1
SE-MD-13, SE-MD-06, WE-MD-06	tenements	MD	P5
SE-MD-06, WE-MD-06, SE-MD-13	Medium Density, Mixed use	MD	D2,H3
SE-MD-06, WE-MD-06, SE-LD-09	green living	MD	K1
SE-MD-06, SE-LD-09, WE-MD-06	Trees	MD	K1

SE-MD-06, SE-LD-09, WE-MD-06	Green	MD	K1
WE-MD-06, SE-MD-13, SE-MD-06	residential, trees	MD	H1,K1
SE-LD-09, SE-MD-13, SE-MD-06	House	MD	H1,K1
WE-MD-06, SE-LD-09, SE-MD-06	greenery	MD	K1
SE-LD-09, WE-MD-06, SE-MD-13	Shady walkway	MD	O1
SE-MD-06, WE-MD-06, SE-MD-13	tenement flats	MD	P5
WE-MD-06, SE-MD-06, SE-MD-13	Glasgow vernacular	MD	P1
SE-MD-06, SE-LD-09, WE-MD-06	Park	MD	K1
WE-MD-06, SE-MD-13, SE-MD-06	Green in road sections	MD	K1
WE-MD-06, CC-HD-01, SE-MD-06	people on sidewalk	MD	L2
SE-MD-06, WE-MD-06, SE-LD-09	balanced greenery	MD	K1
WE-MD-06, SE-MD-06, CC-HD-08	open	MD	K5
SE-LD-09, SE-MD-13, WE-MD-06	Trees	MD	K1
WE-MD-06, SE-MD-06, SE-MD-13	Residential, Greenery	MD	H1,K1
SE-MD-06, WE-MD-06, SE-LD-09	wide pavements/next to green space	MD	O1
SE-MD-13, WE-MD-06, SE-MD-06	classic	MD	P1

Low Density-Triads

Triads	Unique Labels	Density	Construct Code
SE-LD-05, SE-MD-13, EE-LD-11	no people	LD	L2
SE-MD-06, EE-LD-11, SE-LD-09	wide streets	LD	M2
SE-LD-05, SE-LD-09, EE-LD-11	a quality	LD	K8
SE-MD-13, EE-LD-11, SE-LD-05	pedestrian	LD	O2
SE-MD-13, SE-LD-09, SE-LD-05	Sidewalk	LD	O1
EE-LD-11, CC-HD-01, SE-LD-05	curb on right side of image	LD	K2
EE-LD-11, CC-HD-08, SE-LD-05	The orientation of the street, ration of buildings to sky	LD	Q1
EE-LD-11, SE-LD-05, SE-LD-09	Shops	LD	H2
SE-LD-05, EE-LD-11, SE-MD-13	bike lane	LD	N1
SE-LD-05, EE-LD-11, SE-MD-13	Low-Rise	LD	B1
SE-MD-06, SE-LD-05, SE-LD-09	Signs	LD	K2
WE-MD-06, SE-LD-05, EE-LD-11	small commercial +wide roads	LD	H2,M2
SE-LD-05, SE-LD-09, EE-LD-11	Low Density	LD	D3
SE-LD-05, SE-LD-09, EE-LD-11	Less Busy Area	LD	G1
SE-LD-09, SE-LD-05, SE-MD-13	Inner Urban / pre-1919 tenement form	LD	C1,P5
SE-LD-09, EE-LD-11, SE-LD-05	Wide Street	LD	M2
SE-LD-05, SE-MD-13, EE-LD-11	Public / semi-public	LD	K5
SE-MD-13, SE-LD-05, EE-LD-11	Road Lanes	LD	N1
EE-LD-11, SE-LD-05, CC-HD-02	wating to pass	LD	K6

SE-LD-05, EE-LD-11, SE-LD-09	suburb high street	LD	H2
SE-LD-05, EE-LD-11, SE-LD-09	Business and retail	LD	H3
EE-LD-11, SE-LD-05, SE-MD-13	low rise	LD	B1
SE-LD-05, SE-LD-09, EE-LD-11	Residential	LD	H1
SE-MD-13, EE-LD-11, SE-LD-05	suburb/neighbourhood	LD	C3
SE-LD-05, SE-LD-09, EE-LD-11	outside city	LD	C3

Glasgow -Classification of Images into High, Moderate or Low density –

MST-Step 3

Sr. No	Images (Thumbnails of Images)	IMG NO.	LOW DENSITY			MEDIUM DENSITY			HIGH DENSITY		
			MALE	FEMALE	DO NOT PREFER	MALE	FEMALE	DO NOT PREFER	MALE	FEMALE	DO NOT PREFER
1		CC-HD-01	4	4	0	5	9	0	38	38	1
2		CC-HD-08	8	7	0	9	15	1	30	29	0
3		WE-MD-06	4	11	0	39	32	0	1	6	0
4		SE-LD-05	26	28	0	18	21	0	0	0	0
5		EE-LD-12	38	34	0	5	14	0	1	1	0
6		CC-HD-02	1	1	0	12	5	0	18	31	2
7		SE-MD-13	9	5	0	19	29	1	3	3	1
8		CC-HD-04	7	4	0	11	8	1	13	25	1
9		SE-LD-01	17	21	0	11	15	2	3	1	0

10		SE-LD-09	25	33	0	5	4	1	1	0	1
11		EE-MD-10	13	23	0	30	24	0	1	2	0
12		CC-HD-09	4	4	0	3	16	0	40	31	1
13		CC-HD-28	3	1	0	5	8	0	24	28	1
14		EE-MD-12	11	11	0	18	26	1	1	1	1
15		EE-LD-05	6	14	0	30	31	0	11	6	1
16		SE-MD-05	11	14	0	31	32	0	2	3	0
17		EE-LD-10	18	23	1	10	12	0	0	0	0
18		CC-HD-24	0	1	0	7	12	0	40	38	1
19		CC-LD-01	5	6	0	19	28	1	7	3	1
20		EE-MD-07	15	16	0	29	31	0	0	2	0
21		SE-LD-04	25	20	0	18	26	0	1	3	0
22		CC-HD-22	1	1	0	3	7	0	24	27	1

23		SE-MD-06	11	11	0	32	33	0	1	5	0
24		EE-LD-11	24	32	1	5	5	0	2	0	1
25		WE-MD-09	4	2	0	23	29	0	4	6	2
26		EE-MD-09	10	2	0	17	29	1	4	6	0
27		CC-HD-16	1	2	0	4	18	0	39	29	0

Image descriptions sample of 100 descriptions for High density, Moderate Density and low Density used for developing coding manual in content analysis.

High Density-Image Descriptions-Glasgow (GLA) – MST-Step 4

High-Density	Construct Code	Category Code	Construct Name
Event space	K5	K	Open Spaces /parks
Roads with cars is not good	L1	L	Density of cars in the street
wide quite streets	M2	M	Street Width
Its a city where lots of people travel to for work	L2	L	Density of people in the street
lots of large buildings.	I1	I	Volume of buildings
city	C1	C	Urban / City
little sky visible	Q3	Q	Amount of Sky
Building to Sky ratio	Q1	Q	Balanced (built / open) development
Verticality	A1	A	Loose / Scattered urban form
built up city street	I2	I	Built up Area
windows make things look house y	P4	P	Texture / Pattern
silence	G2	G	Less to Non-Active
compactness	A2	A	Compact urban form
city	C1	C	Urban / City
high buildings close together	P8	P	Urban Canyon
High rise buildings	P5	P	Building Typology
A lot of buildings	I1	I	Volume of buildings
lots of tall buildings	A1	A	Loose / Scattered urban

			form
Cars on the street -busy area	L1	L	Density of cars in the street
letting some nature be	K1	K	Vegetation
Architectural styles	P1	P	Style of the buildings
buildings	I1	I	Volume of buildings
no gaps between buildings	A3	A	Space between the buildings
verticality and distance of view	B1	B	Height of the Buildings
high rise	P5	P	Building Typology
tall buildings	B1	B	Height of the Buildings
Shops	H2	H	Commercial
taller buildings	B1	B	Height of the Buildings
Access to amenities	K6	K	Public Space Qualities
Look like a busy street	G1	G	Highly Active
Fancy Building like Offices	P1	P	Style of the buildings
City Centre	C1	C	Urban / City
building size	I1	I	Volume of buildings
busy	G1	G	Highly Active
central business district	H2	H	Commercial
mall	H2	H	Commercial
shop and restaurant fronts	H3	H	Mixed
Roads small with parking	K4	K	On Street Parking
big buildings	B1	B	Height of the Buildings
city	C1	C	Urban / City
lots of cars	L1	L	Density of cars in the street
high buildings both sides	P8	P	Urban Canyon
Main street	M2	M	Street Width
A lot of these buildings feature places of work as well as recreational activities,	H2	H	Commercial
height	B1	B	Height of the Buildings
lots of different transport	L2	L	Density of people in the street
tall buildings on each side of road	P8	P	Urban Canyon
Its a city where lots of people travel to for work	C1	C	Urban / City
A lot happening between buildings and pedestrians.	G1	G	Highly Active
cramped pavement	O1	O	Pavement Width
lots of large buildings.	B1	B	Height of the Buildings
Packed commercial space	H2	H	Commercial
Assortment of offices and storefronts	H3	H	Mixed
city	C1	C	Urban / City
closely packed commercial and offices	H2	H	Commercial
Tall buildings	B1	B	Height of the Buildings

Community	H3	H	Mixed
Town Square	K5	K	Open Spaces /parks
Housing and retail	H3	H	Mixed
tenement terrace alludes to high density	P5	P	Building Typology
pedestrian area dominating the place	O2	O	Pedestrian Friendly
open precinct	K5	K	Open Spaces /parks
public square	K5	K	Open Spaces /parks
tenements	P5	P	Building Typology
busy built up town	G2	G	Less to Non-Active
no air	K8	K	Environment Quality
Typical city centre street	M2	M	Street Width
City Centre	C1	C	Urban / City
Chain restaurant	H3	H	Mixed
city centre grid	C1	C	Urban / City
Housing and retail again	H3	H	Mixed
busy	G2	G	Less to Non-Active
amount of ppl	L2	L	Density of people in the street
busy traffic	L1	L	Density of cars in the street
This is another dark city centre image caused again by the height of the buildings and narrowness of the street	K8	K	Environment Quality
city	C1	C	Urban / City
narrow street with bus stops, shopping and cars	M2	M	Street Width
building scale and form	I1	I	Volume of buildings
Tall Buildings makes the area look dense	B1	B	Height of the Buildings
buildings close together	A1	A	Loose / Scattered urban form
a lot of traffic	L1	L	Density of cars in the street
full tall street -cars, people, buildings	B1	B	Height of the Buildings
Closer to the buildings	A3	A	Space between the buildings
Never any parking spaces	K3	K	Parking Lots
Typical grid of streets in Glasgow	M2	M	Street Width
Central	C1	C	Urban / City
silence	K8	K	Environment Quality
high	D1	D	High Density
narrow street	M2	M	Street Width
Massing of buildings	I1	I	Volume of buildings
Tal	B1	B	Height of the Buildings
built up	I2	I	Built up Area
High buildings / no natural environment	B1	B	Height of the Buildings

So many windows	P4	P	Texture / Pattern
high rise buildings	P5	P	Building Typology
silence	G2	G	Less to Non-Active
Tight layout	A2	A	Compact urban form
high rise both sides of the street	P8	P	Urban Canyon
high buildings give high density impression	P5	P	Building Typology

Moderate Density-Image Descriptions-Glasgow (GLA)-MST-Step 4

Medium-Density	**Construct Code**	**Category Code**	**Construct Name**
tall buildings but not so dense	A1	A	Loose / Scattered urban form
open area	K5	K	Open Spaces /parks
open pedestrian space	K5	K	Open Spaces /parks
Housing	H1	H	Residential
medium-height buildings	A1	A	Loose / Scattered urban form
mixed use -commercial and residential	H3	H	Mixed
More Residential	H1	H	Residential
Inner urban mixed	H3	H	Mixed
tenemental, poor open space	P5	P	Building Typology
windows	P4	P	Texture / Pattern
very small road	M2	M	Street Width
open	K5	K	Open Spaces /parks
More open	K5	K	Open Spaces /parks
Deprived suburbs (Less people with less space)	C2	C	Sprawl / Outskirts/ Suburbs
It is a place where people live so there will be people but there not all travelling so it is not as dense as a city	H1	H	Residential
tenement buildings.	P5	P	Building Typology
Has both commercial and residential space	H3	H	Mixed
residential	H1	H	Residential
plenty open space but otherwise fairly developed with little greenery	K5	K	Open Spaces /parks
A lot of space to walk but tall things sticking out of the road add density	O1	O	Pavement Width
Wide open street	M2	M	Street Width
big pathway	O1	O	Pavement Width
mixture of heights make the place look less dense	A1	A	Loose / Scattered urban form
Different heights on different sides	Q5	Q	Unbalanced -Buildings on One side

pedestrian space	O2	O	Pedestrian Friendly
mixed tall and low buildings	A1	A	Loose / Scattered urban form
Access to public amenities and entertainment	K6	K	Public Space Qualities
Empty space in image makes the place feel less dense even though the area could be quite busy	K5	K	Open Spaces /parks
more of a commercial district	C2	C	Sprawl / Outskirts/ Suburbs
tenemental buildings	P5	P	Building Typology
residential	H1	H	Residential
High-to-low	P6	P	Varied Built Form
Open, quiet space	K5	K	Open Spaces /parks
Lower buildings but still feels busy	I1	I	Volume of buildings
Older buildings on the right and newer smaller shops on the left	P9	P	Link between old/new building styles
sky	Q3	Q	Amount of Sky
Local shops	H2	H	Commercial
busy road	G1	G	Highly Active
Med	D2	D	Moderate Density
Modern flats	P5	P	Building Typology
Possible places of work as well as residential	H1	H	Residential
open	K5	K	Open Spaces /parks
closed in	A2	A	Compact urban form
busy but lower buildings on one side	Q5	Q	Unbalanced -Buildings on One side
single story buildings	A1	A	Loose / Scattered urban form
big pavements	O1	O	Pavement Width
building are high on one side.	Q5	Q	Unbalanced -Buildings on One side
Mostly open to the sky	Q3	Q	Amount of Sky
not too busy	G2	G	Less to Non-Active
Has a mix of commercial and residential	H3	H	Mixed
Storefronts & residences	H3	H	Mixed
City-Living	C1	C	Urban / City
The on street parking might increase density	K4	K	On Street Parking
Office Street	H2	H	Commercial
high rise buildings, but not a lot of traffic	P5	P	Building Typology
Canyon	P8	P	Urban Canyon
commercial for public in the city	H2	H	Commercial
average street activity	G2	G	Less to Non-Active
tight street but doesn't look busy	A2	A	Compact urban form
Cars parked on the side, make it seem more unified and less	K4	K	On Street Parking

unorganised.			
Parks	K5	K	Open Spaces /parks
only one occupied side	Q5	Q	Unbalanced -Buildings on One side
mixed edges	O2	O	Pedestrian Friendly
open but still buildings	A1	A	Loose / Scattered urban form
Housing	H1	H	Residential
Accessible social space	K8	K	Environment Quality
More Residential feel	H1	H	Residential
tenemental properties	P5	P	Building Typology
Large space and park areas	K5	K	Open Spaces /parks
not too many people	L2	L	Density of people in the street
nature	K1	K	Vegetation
lost space	K8	K	Environment Quality
only one side has buildings	Q5	Q	Unbalanced -Buildings on One side
open	K5	K	Open Spaces /parks
More open	K5	K	Open Spaces /parks
Housing next to a park so different use of space to fill	H1	H	Residential
Small Buildings	A1	A	Loose / Scattered urban form
trees	K1	K	Vegetation
suburban area	C2	C	Sprawl / Outskirts/ Suburbs
It is a place where people live so there will be people but there not all travelling so it is not as dense as a city	H1	H	Residential
Trees create some movement.	K1	K	Vegetation
Open spaces but car filled street	K5	K	Open Spaces /parks
tenement buildings.	P5	P	Building Typology
Wide street	M2	M	Street Width
city centre	C1	C	Urban / City
empty	K5	K	Open Spaces /parks
city	C1	C	Urban / City
Med	D2	D	Moderate Density
close but not crowded	A2	A	Compact urban form
quieter part of city	G2	G	Less to Non-Active
central but low	B1	B	Height of the Buildings
Civic centre	C1	C	Urban / City
High Street	C1	C	Urban / City
3/4 storeys of flats	B1	B	Height of the Buildings
no natural environment, urban spaces and taller buildings	B1	B	Height of the Buildings
silence	G2	G	Less to Non-Active

connecting street for residential to city	H1	H	Residential
Pedestrian friendly	O2	O	Pedestrian Friendly
Human	L2	L	Density of people in the street
Medium-rise buildings with more space for vegetation and pedestrians.	B2	B	Length of the Buildings (Façade)

Low Density -Image Descriptions-Glasgow (GLA)-MST-Step 4

Low-Density	**Construct Code**	**Category Code**	**Construct Name**
Small flat buildings	A1	A	Loose / Scattered urban form
low rise on left , large hall on right is rarely used	A1	A	Loose / Scattered urban form
height	A1	A	Loose / Scattered urban form
1-3 Stories	A1	A	Loose / Scattered urban form
Low	A1	A	Loose / Scattered urban form
sparse buildings	A1	A	Loose / Scattered urban form
low and far apart buildings	A1	A	Loose / Scattered urban form
spacious	A1	A	Loose / Scattered urban form
unblocked skyline	A1	A	Loose / Scattered urban form
There does not appear to be any larger scale buildings in this image and the buildings pictured are quite spread out	A1	A	Loose / Scattered urban form
Lack of buildings makes the area seem less dense	A1	A	Loose / Scattered urban form
low and far apart buildings	A1	A	Loose / Scattered urban form
more spacious	A1	A	Loose / Scattered urban form
Sparsity of buildings	A1	A	Loose / Scattered urban form
open, looks quiet	A1	A	Loose / Scattered urban form
very open	A1	A	Loose / Scattered urban form
large spacious	A1	A	Loose / Scattered urban form
Open structure	A1	A	Loose / Scattered urban form
large spacious	A1	A	Loose / Scattered urban form
large spacious	A1	A	Loose / Scattered

			urban form
Open skyline	A1	A	Loose / Scattered urban form
open aspect	A1	A	Loose / Scattered urban form
spacious space	A1	A	Loose / Scattered urban form
open area	A1	A	Loose / Scattered urban form
large spacious	A1	A	Loose / Scattered urban form
Spacious street. Only a few parked cars.	A1	A	Loose / Scattered urban form
low buildings and open	A1	A	Loose / Scattered urban form
No people, no traffic, wide skyline	A1	A	Loose / Scattered urban form
not busy roads but compact buildings on the side	A2	A	Compact urban form
Large open spaces between buildings	A3	A	Space between the buildings
Large open spaces between buildings	A3	A	Space between the buildings
Buildings are not close and there is enough space	A3	A	Space between the buildings
Large open spaces between buildings	A3	A	Space between the buildings
Distance between two structures across road.	A3	A	Space between the buildings
wide open spaces between buildings	A3	A	Space between the buildings
3 Stories	B1	B	Height of the Buildings
low rises	B1	B	Height of the Buildings
Small buildings	B1	B	Height of the Buildings
Small building height	B1	B	Height of the Buildings
no high buildings	B1	B	Height of the Buildings
3 Stories	B1	B	Height of the Buildings
Low	B1	B	Height of the Buildings
1-2 Stories	B1	B	Height of the Buildings
low building height	B1	B	Height of the Buildings
A few smaller buildings with plenty of green space.	B1	B	Height of the Buildings
no big buildings	B1	B	Height of the Buildings
1-3 Stories	B1	B	Height of the Buildings
Low	B1	B	Height of the Buildings
no flats just single/double storey	B1	B	Height of the Buildings
low number of buildings	B1	B	Height of the Buildings
1-3 Stories	B1	B	Height of the Buildings
Short buildings	B1	B	Height of the Buildings
Storeys	B1	B	Height of the Buildings

low-level housing and school possibly	B1	B	Height of the Buildings
Low rise	B1	B	Height of the Buildings
Small flat buildings	B1	B	Height of the Buildings
Smaller council buildings	B1	B	Height of the Buildings
height	B1	B	Height of the Buildings
Medium-low height buildings with a lot of open space	B1	B	Height of the Buildings
Smaller buildings suggest fewer residents	B1	B	Height of the Buildings
Low	B1	B	Height of the Buildings
Low rise buildings	B1	B	Height of the Buildings
Height	B1	B	Height of the Buildings
Low rise buildings	B1	B	Height of the Buildings
space and low buildings	B1	B	Height of the Buildings
Low height	B1	B	Height of the Buildings
Low height	B1	B	Height of the Buildings
Height	B1	B	Height of the Buildings
Low rise homes, wide roads.	B1	B	Height of the Buildings
Low-rise, wide street	B1	B	Height of the Buildings
Low-rise, large open space	B1	B	Height of the Buildings
Low-rise, wide street	B1	B	Height of the Buildings
Building height & emptiness's.	B1	B	Height of the Buildings
Low rise buildings, wide road	B1	B	Height of the Buildings
building height & street width	B1	B	Height of the Buildings
Low rise shops lots	B1	B	Height of the Buildings
mid to low buildings, very wide street	B1	B	Height of the Buildings
building height & street width	B1	B	Height of the Buildings
Low-rise, wide street, set-back industrial building	B1	B	Height of the Buildings
2-way traffic lane and 3-storey high blocks	B1	B	Height of the Buildings
Width of road, storey height gap sites	B1	B	Height of the Buildings
2-way traffic lane and 3-storey high blocks	B1	B	Height of the Buildings
2-way traffic lane and 3-storey high blocks	B1	B	Height of the Buildings
open space/building height	B1	B	Height of the Buildings
Greenery / park, low rise, the density increases further up the road	B1	B	Height of the Buildings
local	C1	C	Urban / City
Wealthy suburbs (Less people with lots of space)	C2	C	Sprawl / Outskirts/ Suburbs
Wealthy suburbs (Less people with lots of space)	C2	C	Sprawl / Outskirts/ Suburbs
Wealthy suburbs (Less people with lots of space)	C2	C	Sprawl / Outskirts/ Suburbs
Wealthy suburbs (Less people with lots of space)	C2	C	Sprawl / Outskirts/ Suburbs

nothing in this picture attracts people to visit this place.	F1	F	Sad / Uninspiring
quite dull. A passing through place	F1	F	Sad / Uninspiring
Open area but dull	F1	F	Sad / Uninspiring
appears run down/quite bleak	F1	F	Sad / Uninspiring
nothing going on	G2	G	Less to Non-Active
No human	G2	G	Less to Non-Active
quite street	G2	G	Less to Non-Active
not busy	G2	G	Less to Non-Active
Not much going on	G2	G	Less to Non-Active
No pedestrian life	G2	G	Less to Non-Active

Universal Illustrations (©2023 Google)


01- Super Quadra
Brasilia
Density- 76 pph


12- Unidad Independencia
Mexico
Density- 301 pph


26- North End
Boston
Density- 605 dph


07-Champs Elyees
Paris
Density- 151 -160 dph


16- Ang Mo Kio
Singapore
Density- 126 pph


18- Mi Casa
Singapore
Density- 962 pph


09-Tama
Tokyo, Japan
Density- 159 dph


13- Sporenburg
Amsterdam
Density- 200 pph


24- Coney Island
Brooklyn, New York
Density- 348 pph


05-Salamanca
Madrid
Density- 195 pph


06- Plaine Monceau
Paris
Density- 1124 pph


24- Brooklyn
New York
Density- 912 pph


02-Saconia
Spain
Density- 370 pph


17- Ang Mo Kio
Singapore
Density- 126 pph


21- Broadway
New York
Density- 1428 pph

10- Tama
Tokyo, Japan
Density- 159 pph

15- Amsterdam

Density- 151 -160 dph

27- North End
Boston
Density- 215 dph

22-Brooklyn
NewYork
Density- 912 pph

29- Manhattan,
New York
Density- 912 pph

33- Hong Kong
Singapore
Density- 2489 pph

03- Barcelona

Density- 359 dph

08- The Plan Voisin
Paris
Density- 1198 pph

28- Manhattan
New York
Density- 541 dph

25- Costa Verde Village,
San Diego, USA
Density- 146 dph

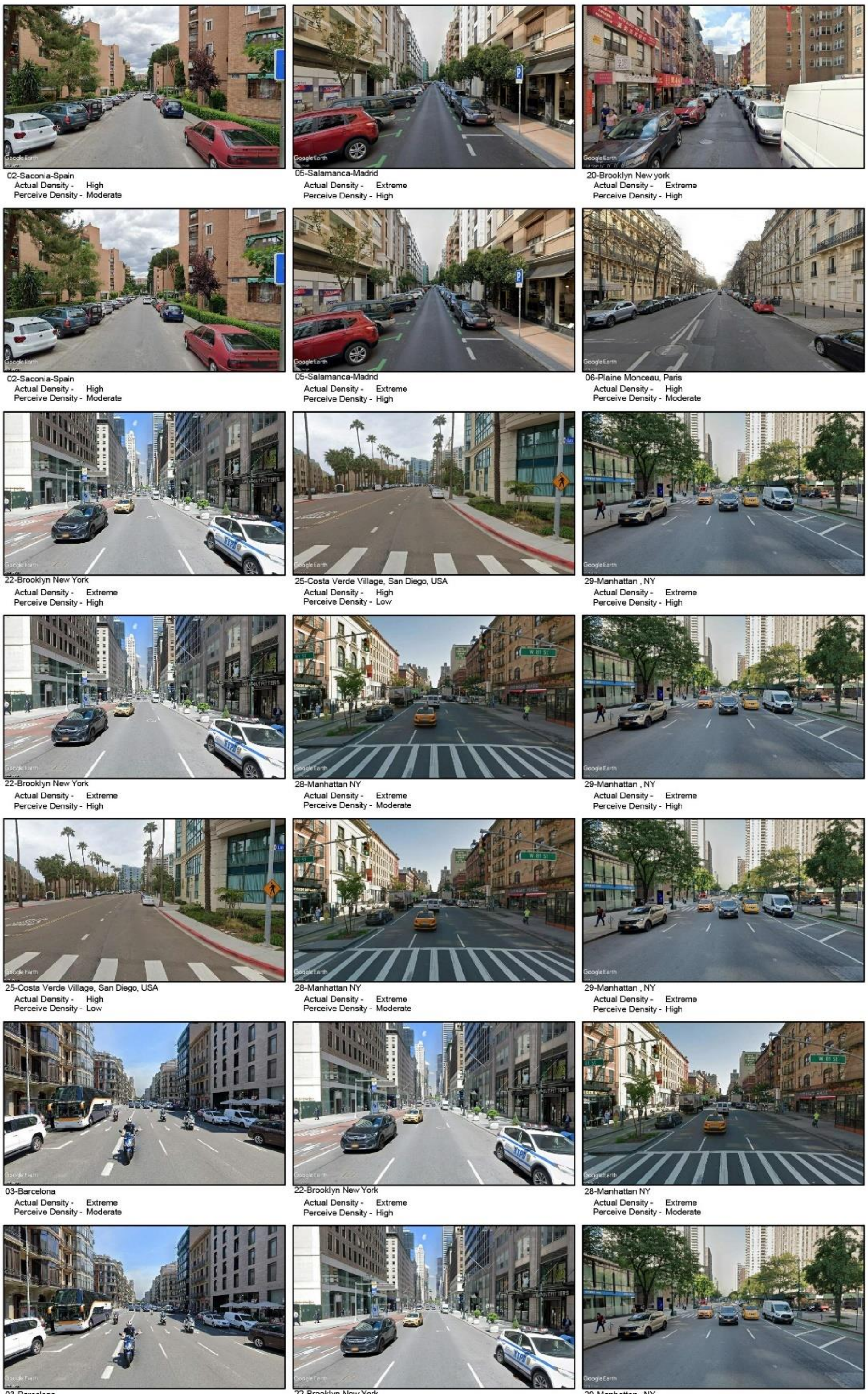
30- Wangfujing
Beijing
Density- 264 dph

34- High Street, Hongkong
China
Density- 2486 pph

Note- Images are presented in a sequence that is used for the first survey (MST)

Triads-Unique labels **(Images ©2023 Google)**

Triads - Universal Illustration (UL) - 1



Triads - Universal Illustration (UL) - 2

Frequncy Count


03-Barcelona
Actual Density - Extreme
Perceive Density - Moderate


08-The Plan Voisin, PAris
Actual Density - Extreme
Perceive Density - Moderate


22-Brooklyn New York
Actual Density - Extreme
Perceive Density - High

21


03-Barcelona
Actual Density - Extreme
Perceive Density - Moderate


08-The Plan Voisin, PAris
Actual Density - Extreme
Perceive Density - Moderate


25-Costa Verde Village, San Diego, USA
Actual Density - High
Perceive Density - Low

12


03-Barcelona
Actual Density - Extreme
Perceive Density - Moderate


08-The Plan Voisin, PAris
Actual Density - Extreme
Perceive Density - Moderate


28-Manhattan NY
Actual Density - Extreme
Perceive Density - Moderate

8


30-Wangfujing_street_Beijing
Actual Density - Extreme
Perceive Density - High


33-hong-kong-tram
Actual Density - Extreme
Perceive Density - High


34-busy-street-scene-hong-kong-china-ISF00822
Actual Density - Extreme
Perceive Density - High

88


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


20-Brooklyn New york
Actual Density - Extreme
Perceive Density - High


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

6


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


20-Brooklyn New york
Actual Density - Extreme
Perceive Density - High


27-North End Boston
Actual Density - High
Perceive Density - High

33


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

6

Triads - Universal Illustration (UL) - 3

Frequncy Count


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

11


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


27-North End Boston
Actual Density - High
Perceive Density - High

8


08-The Plan Voisin, PAris
Actual Density - Extreme
Perceive Density - Moderate


25-Costa Verde Village, San Diego, USA
Actual Density - High
Perceive Density - Low


28-Manhattan NY
Actual Density - Extreme
Perceive Density - Moderate

21


08-The Plan Voisin, PAris
Actual Density - Extreme
Perceive Density - Moderate


25-Costa Verde Village, San Diego, USA
Actual Density - High
Perceive Density - Low


29-Manhattan , NY
Actual Density - Extreme
Perceive Density - High

7


01-Brasilia-SuperQuadra-LD
Actual Density - Low
Perceive Density - Moderate


16-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate


18-Mi Casa, Singapore
Actual Density - High
Perceive Density - Moderate

10


10-Tama, Tokyo , Japan
Actual Density - Moderate
Perceive Density - Moderate


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

17


15-Amsterdam
Actual Density - Moderate
Perceive Density - Moderate


20-Brooklyn New york
Actual Density - Extreme
Perceive Density - High


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

9

Triads - Universal Illustration (UL) - 4

Frequncy Count


16-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate


18-Mi Casa, Singapore
Actual Density - High
Perceive Density - Moderate


24-Coney Island,Brooklyn, New York
Actual Density - Moderate
Perceive Density - Moderate

9


02-Saconia-Spain
Actual Density - High
Perceive Density - Moderate


10-Tama, Tokyo , Japan
Actual Density - Moderate
Perceive Density - Moderate


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

32


02-Saconia-Spain
Actual Density - High
Perceive Density - Moderate


10-Tama, Tokyo , Japan
Actual Density - Moderate
Perceive Density - Moderate


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

6


02-Saconia-Spain
Actual Density - High
Perceive Density - Moderate


05-Salamanca-Madrid
Actual Density - Extreme
Perceive Density - High


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

7


20-Brooklyn New york
Actual Density - Extreme
Perceive Density - High


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High


27-North End Boston
Actual Density - High
Perceive Density - High

7


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


10-Tama, Tokyo , Japan
Actual Density - Moderate
Perceive Density - Moderate


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

10


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


15-Amsterdam
Actual Density - Moderate
Perceive Density - Moderate


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

15

Triads - Universal Illustration (UL) - 5

Frequncy Count


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


17-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate


21-Broadway NewYork
Actual Density - Extreme
Perceive Density - High

7


07-Champs ELysees-Paris
Actual Density - Moderate
Perceive Density - Moderate


12- Unidad Independencia, Mexico
Actual Density - Low
Perceive Density - Moderate


16-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

16


07-Champs ELysees-Paris
Actual Density - Moderate
Perceive Density - Moderate


16-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate


18-Mi Casa, Singapore
Actual Density - High
Perceive Density - Moderate

22


07-Champs ELysees-Paris
Actual Density - Moderate
Perceive Density - Moderate


09-Tama,Tokyo, Japan
Actual Density - Low
Perceive Density - Low


16-Ang Mo Kio, Singapore
Actual Density - High
Perceive Density - Moderate

9


01-Brasilia-SuperQuadra-LD
Actual Density - Low
Perceive Density - Moderate


13-Sporenburg, Amsterdam
Actual Density - Low
Perceive Density - Low


24-Coney Island,Brooklyn, New York
Actual Density - Moderate
Perceive Density - Moderate

9


13-Sporenburg, Amsterdam
Actual Density - Low
Perceive Density - Low


24-Coney Island,Brooklyn, New York
Actual Density - Moderate
Perceive Density - Moderate


26-North End Boston
Actual Density - Moderate
Perceive Density - High

14


15-Amsterdam
Actual Density - Moderate
Perceive Density - Moderate


20-Brooklyn New york
Actual Density - Extreme
Perceive Density - High


27-North End Boston
Actual Density - High
Perceive Density - High

20

Triads - Universal Illustration (UL) - 6

Frequncy Count


02-Saconia-Spain
Actual Density - High
Perceive Density - Moderate


10-Tama, Tokyo , Japan
Actual Density - Moderate
Perceive Density - Moderate


15-Amsterdam
Actual Density - Moderate
Perceive Density - Moderate

6


06-Plaine Monceau, Paris
Actual Density - High
Perceive Density - Moderate


15-Amsterdam
Actual Density - Moderate
Perceive Density - Moderate


27-North End Boston
Actual Density - High
Perceive Density - High

7


09-Tama,Tokyo, Japan
Actual Density - Low
Perceive Density - Low


12- Unidad Independencia, Mexico
Actual Density - Low
Perceive Density - Moderate


13-Sporenburg, Amsterdam
Actual Density - Low
Perceive Density - Low

8


09-Tama,Tokyo, Japan
Actual Density - Low
Perceive Density - Low


13-Sporenburg, Amsterdam
Actual Density - Low
Perceive Density - Low


26-North End Boston
Actual Density - Moderate
Perceive Density - High

15


09-Tama,Tokyo, Japan
Actual Density - Low
Perceive Density - Low


24-Coney Island,Brooklyn, New York
Actual Density - Moderate
Perceive Density - Moderate


26-North End Boston
Actual Density - Moderate
Perceive Density - High

7


01-Brasilia-SuperQuadra-LD
Actual Density - Low
Perceive Density - Moderate


12- Unidad Independencia, Mexico
Actual Density - Low
Perceive Density - Moderate


13-Sporenburg, Amsterdam
Actual Density - Low
Perceive Density - Low

8


01-Brasilia-SuperQuadra-LD
Actual Density - Low
Perceive Density - Moderate


12- Unidad Independencia, Mexico
Actual Density - Low
Perceive Density - Moderate


24-Coney Island,Brooklyn, New York
Actual Density - Moderate
Perceive Density - Moderate

6

Triads - Universal Illustration (UL) - 7

Universal Illustrations – Unique labels for Triads – MST-Step 2

High Density -Triads

Triads	Perceived Density	Unique Labels	Construct Code
27-North End Boston, 20-Brooklyn New york, 05-Salamanca-Madrid	ED	narrow street -high rise	M2,B1
27-North End Boston, 05-Salamanca-Madrid, 06-Plaine Monceau Paris	ED	Good environment for pedestrians provided cars are keept abey (esp 1)	O2
05-Salamanca-Madrid, 27-North End Boston, 20-Brooklyn New york	ED	Urban	C1
21-Broadway NewYork, 20-Brooklyn New york, 05-Salamanca-Madrid	ED	look busy with pedestrians	L2
27-North End Boston, 05-Salamanca-Madrid, 20-Brooklyn New york	ED	narrow	M2,B1

27-North End Boston, 06-Plaine Monceau Paris, 05-Salamanca-Madrid	ED	unknown	-
05-Salamanca-Madrid, 06-Plaine Monceau Paris, 21-Broadway NewYork	ED	Business Districts	H2
02-Saconia-Spain, 05-Salamanca-Madrid, 20-Brooklyn New york	ED	narrow	M2
27-North End Boston, 05-Salamanca-Madrid, 20-Brooklyn New york	ED	Dense	D1
20-Brooklyn New york, 05-Salamanca-Madrid, 27-North End Boston	ED	City centre residential	C1,H1
20-Brooklyn New york, 27-North End Boston, 05-Salamanca-Madrid	ED	Car Dominated	L1
05-Salamanca-Madrid, 27-North End Boston, 20-Brooklyn New york	ED	Dense lane	D1
05-Salamanca-Madrid, 20-Brooklyn New york, 02-Saconia-Spain	ED	Dense and Narrow	D1,M2
20-Brooklyn New york, 27-North End Boston, 05-Salamanca-Madrid	ED	Narrow	M2
20-Brooklyn New york, 27-North End Boston, 05-Salamanca-Madrid	ED	Narrow Streets	M2
21-Broadway NewYork, 20-Brooklyn New york, 06-Plaine Monceau Paris	ED	non residential area	H3
05-Salamanca-Madrid, 20-Brooklyn New york, 02-Saconia-Spain	ED	NARROW SPACES-PARKING	M2,K4
17-Ang Mo Kio Singapore, 06-Plaine Monceau Paris, 05-Salamanca-Madrid	ED	parking slor	K4
06-Plaine Monceau Paris, 05-Salamanca-Madrid, 02-Saconia-Spain	ED	Parked cars	K4
06-Plaine Monceau Paris, 20-Brooklyn New york, 15-Amsterdam	ED	no greenary	K1
20-Brooklyn New york, 27-North End Boston, 05-Salamanca-Madrid	ED	Narrow Streets	M2

05-Salamanca-Madrid, 27-North End Boston, 20-Brooklyn New york	ED	Tall compact buildings	A2,B1
06-Plaine Monceau Paris, 05-Salamanca-Madrid, 27-North End Boston	ED	Enclosed	E1
05-Salamanca-Madrid, 20-Brooklyn New york, 02-Saconia-Spain	ED	residential area	H1
20-Brooklyn New york, 05-Salamanca-Madrid, 27-North End Boston	ED	Narrow Alleyways	M2

Moderate Density -Triads

Triads	**Perceived Density**	**Unique Labels**	**Construct Code**
26-North End Boston, 13-Sporenburg Amsterdam, 24-Coney Island Brooklyn New York	MD	narrow street	M2
26-North End Boston, 13-Sporenburg Amsterdam, 09-TamaTokyo Japan	MD	Relatively intimate	A2
18-Mi Casa Singapore, 13-Sporenburg Amsterdam, 24-Coney Island Brooklyn New York	MD	unique road markings	M3
09-TamaTokyo Japan, 24-Coney Island Brooklyn New York, 01-Brasilia-SuperQuadra-LD	MD	look empty	K9
09-TamaTokyo Japan, 13-Sporenburg Amsterdam, 26-North End Boston	MD	narrow	M2
09-TamaTokyo Japan, 24-Coney Island Brooklyn New York, 18-Mi Casa Singapore	MD	Signs	K2
09-TamaTokyo Japan, 07-Champs Elysée’s-Paris, 13-Sporenburg Amsterdam	MD	car facing me	L1
13-Sporenburg Amsterdam, 01-Brasilia-SuperQuadra-LD, 24-Coney Island Brooklyn New York	MD	Housing Estate	H1

24-Coney Island Brooklyn New York, 13-Sporenburg Amsterdam, 01-Brasilia-SuperQuadra-LD	MD	Similar architecture -post war flats	P1
26-North End Boston, 13-Sporenburg Amsterdam, 09-TamaTokyo Japan	MD	Threshold on to street	O1
24-Coney Island Brooklyn New York, 13-Sporenburg Amsterdam, 01-Brasilia-SuperQuadra-LD	MD	Car focused, very few people, commercial surroundings	L1,L2,H2
13-Sporenburg Amsterdam, 24-Coney Island, Brooklyn New York, 26-North End Boston	MD	Plain facades made of brick and glass with direct link to street	P2
24-Coney Island Brooklyn New York, 01-Brasilia-SuperQuadra-LD, 13-Sporenburg Amsterdam	MD	Residents road	H1
26-North End Boston, 13-Sporenburg Amsterdam, 24-Coney Island Brooklyn New York	MD	-	-
24-Coney Island Brooklyn New York, 09-TamaTokyo Japan, 16-Ang Mo Kio Singapore	MD	line on the road	M3
13-Sporenburg Amsterdam, 26-North End Boston, 24-Coney Island Brooklyn New York	MD	Building with vehicles	L1
26-North End Boston, 13-Sporenburg Amsterdam, 09-TamaTokyo Japan	MD	Condensed	A2
13-Sporenburg Amsterdam, 01-Brasilia-SuperQuadra-LD, 24-Coney Island Brooklyn New York	MD	road quality	M3
13-Sporenburg Amsterdam, 26-North End Boston, 24-Coney Island Brooklyn New York	MD	Residential	H1
16-Ang Mo Kio Singapore, 09-TamaTokyo Japan, 24-Coney Island Brooklyn New York	MD	road signs/works	M3
13-Sporenburg Amsterdam, 18-Mi Casa Singapore, 09-	MD	city suburb	C2

TamaTokyo Japan			
24-Coney Island Brooklyn New York, 09-TamaTokyo Japan, 18-Mi Casa Singapore	MD	roads	M2
12-Unidad Independencia Mexico, 13-Sporenburg Amsterdam, 09-TamaTokyo Japan	MD	building heights	B1
13-Sporenburg Amsterdam, 24-Coney Island Brooklyn New York, 16-Ang Mo Kio Singapore	MD	-	-
26-North End Boston, 13-Sporenburg Amsterdam, 24-Coney Island Brooklyn New York	MD	Parking	K3
13-Sporenburg Amsterdam, 09-TamaTokyo Japan, 26-North End Boston	MD	Narrow, Residential	M2,H1
12-Unidad Independencia Mexico, 09-TamaTokyo Japan, 13-Sporenburg Amsterdam	MD	low rise/residential	B1,H1
09-TamaTokyo Japan, 26-North End Boston, 13-Sporenburg Amsterdam	MD	Secondary Route	M2
13-Sporenburg Amsterdam, 09-TamaTokyo Japan, 18-Mi Casa Singapore	MD	enclosure safety	E1
13-Sporenburg Amsterdam, 09-TamaTokyo Japan, 16-Ang Mo Kio Singapore	MD	Ghost Town	F4

Low Density – Triads

Triads	**Perceived Density**	**Unique Labels**	**Construct Code**
07-Champs ELysees-Paris, 12-Unidad Independencia Mexico, 01-Brasilia-SuperQuadra-LD	LD	parking	K3
13-Sporenburg Amsterdam, 01-Brasilia-SuperQuadra-LD, 12-Unidad Independencia Mexico	LD	parking	K3

26-North End Boston, 12-Unidad Independencia Mexico, 13-Sporenburg Amsterdam	LD	Small Streets	M2
26-North End Boston, 12-Unidad Independencia Mexico, 13-Sporenburg Amsterdam	LD	Small Streets	M2
26-North End Boston, 01-Brasilia-SuperQuadra-LD, 09-TamaTokyo Japan	LD	Small street	M2
12-Unidad Independencia Mexico, 01-Brasilia-SuperQuadra-LD, 13-Sporenburg Amsterdam	LD	"Off Street" Parking	K3
09-TamaTokyo Japan, 26-North End Boston, 12-Unidad Independencia Mexico	LD	Back Streets	N1
13-Sporenburg Amsterdam, 26-North End Boston, 12-Unidad Independencia Mexico	LD	Sidestreet	O1
26-North End Boston, 12-Unidad Independencia Mexico, 13-Sporenburg Amsterdam	LD	Narrow Streets	M2
07-Champs ELysees-Paris, 12-Unidad Independencia Mexico, 01-Brasilia-SuperQuadra-LD	LD	Lots of Cars	L1
12-Unidad Independencia Mexico, 26-North End Boston, 01-Brasilia-SuperQuadra-LD	LD	Parking congested streets	K4
01-Brasilia-SuperQuadra-LD, 13-Sporenburg Amsterdam, 12-Unidad Independencia Mexico	LD	Grittiness	F1
26-North End Boston, 12-Unidad Independencia Mexico, 07-Champs ELysees-Paris	LD	Similar Vibe	F1
01-Brasilia-SuperQuadra-LD, 13-Sporenburg Amsterdam, 12-Unidad Independencia Mexico	LD	residential area	H1
26-North End Boston, 09-TamaTokyo Japan, 12-Unidad Independencia Mexico	LD	BUILDINGS BOTH SIDES	P8
01-Brasilia-SuperQuadra-LD, 26-North End Boston, 18-Mi Casa Singapore	LD	close space vs open	K5

26-North End Boston, 01-Brasilia-SuperQuadra-LD, 24-Coney IslandBrooklyn New York	LD	tight roads	M2
26-North End Boston, 24-Coney IslandBrooklyn New York, 01-Brasilia-SuperQuadra-LD	LD	Narrow Streets	M2
26-North End Boston, 01-Brasilia-SuperQuadra-LD, 13-Sporenburg Amsterdam	LD	Residence	H1
09-TamaTokyo Japan, 12-Unidad Independencia Mexico, 26-North End Boston	LD	out of town	C2
01-Brasilia-SuperQuadra-LD, 07-Champs ELysees-Paris, 12-Unidad Independencia Mexico	LD	The density of cars	L1
26-North End Boston, 13-Sporenburg Amsterdam, 12-Unidad Independencia Mexico	LD	Very high density with narrow streets	M2
26-North End Boston, 01-Brasilia-SuperQuadra-LD, 24-Coney IslandBrooklyn New York	LD	Building height	B1
13-Sporenburg Amsterdam, 26-North End Boston, 01-Brasilia-SuperQuadra-LD	LD	Parking	K3
12-Unidad Independencia Mexico, 26-North End Boston, 24-Coney IslandBrooklyn New York	LD	cars faced away	L1
26-North End Boston, 18-Mi Casa Singapore, 01-Brasilia-SuperQuadra-LD	LD	dense	LD
01-Brasilia-SuperQuadra-LD, 12-Unidad Independencia Mexico, 24-Coney IslandBrooklyn New York	LD	greenery	K1
26-North End Boston, 09-TamaTokyo Japan, 01-Brasilia-SuperQuadra-LD	LD	Secondary Roads, Quieter	M2,G2
01-Brasilia-SuperQuadra-LD, 12-Unidad Independencia Mexico, 13-Sporenburg Amsterdam	LD	Residential Parking -non-organised	K3

Universal Illustrations-Classification of Images into High, Moderate or Low density – MST-Step 3

Sr. No	Images (Thumbnails of Images) ©2023 Google		LOW DENSITY			MEDIUM DENSITY			HIGH DENSITY		
		IMG NO.	MALE	FEMALE	DO NOT	MALE	FEMALE	DO NOT	MALE	FEMALE	DO NOT
1		06-Plaine Monceau, Paris	2	2	0	9	8	0	2	2	0
2		15-Amsterdam	1	2	0	8	6	0	4	4	0
3		33-hong-kong-tram	0	0	0	0	1	0	13	11	0
4		29-Manhattan , NY	2	6	0	9	16	0	11	19	1
5		18-Mi Casa, Singapore	0	1	0	8	5	0	5	6	0
6		25-Costa Verde Village, San Diego, USA	5	7	0	7	4	0	1	1	0

7		01-Brasilia-SuperQuadra-LD	1	9	0	19	29	1	2	3	0
8		13-Sporenburg, Amsterdam	11	28	1	5	12	0	4	1	0
9		09-Tama, Tokyo, Japan	9	8	0	5	1	0	0	3	0
10		12-Unidad Independencia, Mexico	6	3	0	5	7	0	2	2	0
11		16-Ang Mo Kio, Singapore	1	9	1	17	19	0	4	13	0
12		27-North End Boston	0	1	0	6	16	1	16	14	0
13		05-Salamanca-Madrid	0	0	0	5	12	0	17	29	1
14		10-Tama, Tokyo, Japan	8	19	0	14	18	0	0	4	1
15		26-North End Boston	0	2	0	8	15	1	14	25	0
16		07-Champs Elysée's-Paris	4	5	0	7	6	0	2	1	0
17		08-The Plan Voisin, Paris	0	0	0	7	6	0	7	5	0
18		02-Saconia-Spain	2	0	0	8	9	0	3	3	0
19		03-Barcelona	0	4	0	13	24	0	9	13	1

20		22-Brooklyn New York	1	0	0	1	5	0	11	7	0
21		34-busy-street-scene-hong-kong-china-ISF00822	0	0	0	0	0	0	13	12	0
22		30-Wangfujing_street_Beijing	1	3	1	6	12	0	15	26	0
23		21-Broadway New York	0	0	0	1	2	0	12	10	0
24		28-Manhattan NY	1	6	0	17	26	1	4	9	0
25		20-Brooklyn New York	0	2	0	0	2	0	22	37	1
26		17-Ang Mo Kio, Singapore	2	6	0	11	19	0	9	6	1
27		24-Coney Island, Brooklyn, New York	6	5	0	5	7	0	2	0	0

High Density-Image Descriptions-Universal Illustrations (UI) -MST-Step 4

High-Density	**Construct Code**	**Category Code**	**Construct Name**
busy	G1	G	Highly Active
tight	A2	A	Compact urban form
apartment blocks	P5	P	Building Typology
Very traffic heavy and tall buildings relatively close together	A2	A	Compact urban form
Very traffic heavy and tall buildings relatively close together	A2	A	Compact urban form

Cramped	A2	A	Compact urban form
Signage and proximity	K2	K	Streetscape Elements
cars on both sides	K3	K	Parking Lots
too many vehicles	L1	L	Density of cars in the street
high rise building	P5	P	Building Typology
above 5 stories	B1	B	Height of the Buildings
city	C1	C	Urban / City
Tightly compacted high buildings	A2	A	Compact urban form
multi-storey buildings on either side	P8	P	Urban Canyon
Vista shows large volume of tall blocks	I1	I	Volume of buildings
escape route scheme lack of space	K7	K	Lack of Space
no colour	P3	P	Colours
public place	K6	K	Public Space Qualities
commercial	H2	H	Commercial
Houses that face one another	H1	H	Residential
not much space for pedestrian and cars	K7	K	Lack of Space
many different buildings	P6	P	Varied Built Form
one way street	M2	M	Street Width
NARROW	M2	M	Street Width
Narrow	M2	M	Street Width
parked cars	K4	K	On Street Parking
So much going on	G1	G	Highly Active
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
businesses and apartments	H3	H	Mixed
small street	M2	M	Street Width
tightly packed street	A2	A	Compact urban form
Offices	H2	H	Commercial
apartment blocks	P5	P	Building Typology
Tall buildings, not a lot of space left over	B1	B	Height of the Buildings

Main road	M2	M	Street Width
above 5 stories	B1	B	Height of the Buildings
Wide street	M2	M	Street Width
10 storey blocks of buildings on either side	P8	P	Urban Canyon
Very high storeys with many blocks	B1	B	Height of the Buildings
business district	H2	H	Commercial
huge greenery amount	K1	K	Vegetation
BIG ROAD	M2	M	Street Width
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
apartment blocks	P5	P	Building Typology
high amount of navigable space	K6	K	Public Space Qualities
Housing block	H1	H	Residential
Tower Blocks	P5	P	Building Typology
narrow street	M2	M	Street Width
Narrow street and walkable	M2	M	Street Width
narrow street	M2	M	Street Width
looks old residential	H1	H	Residential
busy narrow street	M2	M	Street Width
tight	A2	A	Compact urban form
apartment blocks	P5	P	Building Typology
Proximity	A3	A	Space between the buildings
no parking left	K3	K	Parking Lots
parking	K3	K	Parking Lots
city centre	C1	C	Urban / City
Narrow street compared to buildings	M2	M	Street Width
busy	G1	G	Highly Active
narrow road	M2	M	Street Width
not much space for pedestrian and cars	O2	O	Pedestrian Friendly
old architecture	P1	P	Style of the buildings

tight street	A2	A	Compact urban form
narrow street surrounded by buildings	M2	M	Street Width
Narrow	M2	M	Street Width
narrow street	M2	M	Street Width
mid buildings tightly packed	A2	A	Compact urban form
enclosed	E1	E	Sense of Enclosure
Wide avenue	M2	M	Street Width
very tall	B1	B	Height of the Buildings
city street view	C1	C	Urban / City
narrow/ mess	M2	M	Street Width
High rise commercial area	H2	H	Commercial
Car centric	L1	L	Density of cars in the street
skyscrapers	P5	P	Building Typology
inner city new York so very dense	D1	D	High Density
Tall Buildings makes area look dense	B1	B	Height of the Buildings
a large city road	M2	M	Street Width
business and lots of buildings	I1	I	Volume of buildings
Large, packed office buildings and storefronts	H2	H	Commercial
enclosed	E1	E	Sense of Enclosure
Towering	B1	B	Height of the Buildings
tall	B1	B	Height of the Buildings
view in the distance makes it feel less dense, although it is!	D1	D	High Density
Busy	G1	G	Highly Active
narrow/ mess	M2	M	Street Width
Local shops by the streets with high rise buildings and public transport	B1	B	Height of the Buildings
Hong Kong, very dense and busy	G1	G	Highly Active
lots of activity	G1	G	Highly Active
making as much space as possible used for housing	H1	H	Residential
Huge buildings with different purposes	I1	I	Volume of buildings

next to each other			
a big city road	M2	M	Street Width
Very dense high-rise buildings	B1	B	Height of the Buildings
narrow street -heights	E1	E	Sense of Enclosure
better	F3	F	Happy / Appreciative
narrow street	M2	M	Street Width
narrow roads	M2	M	Street Width

Moderate Density-Image Descriptions-Universal Illustrations (UI) -MST-Step 4

Medium-Density	**Construct Code**	**Category Code**	**Construct Name**
looks old residential	H1	H	Residential
,uniform elevators, large buildings	I1	I	Volume of buildings
Run down	F4	F	Dated/Run Down
busy on one side	Q4	Q	Trees on one side
mix of building heights	B1	B	Height of the Buildings
built up one side, open space the other	Q5	Q	Unbalanced -Buildings on One side
tall buildings	B1	B	Height of the Buildings
Boring plain building on the left with car park on the right	Q4	Q	Trees on one side
a small residential road	H1	H	Residential
wide street	M2	M	Street Width
green spaces	K5	K	Open Spaces /parks
wide	M2	M	Street Width
large space between buildings, but tall adding space	A3	A	Space between the buildings
large space between buildings, but tall adding space	A3	A	Space between the buildings
medium -not crammed in but still tall buildings	B1	B	Height of the Buildings
more car traffic than built environment	L1	L	Density of cars in the street

Wide streets	M2	M	Street Width
normal amount of cars	L1	L	Density of cars in the street
outside of the city	C2	C	Sprawl / Outskirts/ Suburbs
Large open road feels less dense	M2	M	Street Width
Balance between greens and greys	Q1	Q	Balanced (built / open)development
Very open road.	M2	M	Street Width
tall buildings but with vast road between	E1	E	Sense of Enclosure
character	P1	P	Style of the buildings
Heavy Architecture but not many cars	P1	P	Style of the buildings
large roads compared to building blocks	M2	M	Street Width
Adequate space for cars/traffic.	K6	K	Public Space Qualities
Two large multi-storey buildings on either side of a large divide and so this isn't too imposing	A3	A	Space between the buildings
low traffic	L1	L	Density of cars in the street
Motorway with two way traffic. No public spaces	M2	M	Street Width
wide road	M2	M	Street Width
buildings on both sides of the street but a pretty wide road	P8	P	Urban Canyon
construction	I2	I	Built up Area
Two lane roads	M2	M	Street Width
Different colours make it look busier than it is	P3	P	Colours
slighlty built up	I2	I	Built up Area
large buildings	I1	I	Volume of buildings
large buildings spread out	I1	I	Volume of buildings
green spaces	K5	K	Open Spaces /parks
Boring	F1	F	Sad / Uninspiring
green	K5	K	Open Spaces /parks

green spaces	K5	K	Open Spaces /parks
wide	M2	M	Street Width
medium -not crammed in but still tall buildings	B1	B	Height of the Buildings
Green spaces	K5	K	Open Spaces /parks
busy development	G1	G	Highly Active
5 stories	B1	B	Height of the Buildings
Landscape	K1	K	Vegetation
streets and green space make up for building blocks	K5	K	Open Spaces /parks
Clearly indicated boundaries and softer edges (landscaping) create the impression of a more open space although this has a barrier along the edge (preventing public/access)	K6	K	Public Space Qualities
community	C3	C	Neighbourhood
Spaced Buildings	A3	A	Space between the buildings
deprived suburbs	C3	C	Neighbourhood
deprived suburbs	C3	C	Neighbourhood
block of flats	P5	P	Building Typology
medium -not crammed in but still tall buildings	B1	B	Height of the Buildings
Slightly more compact	A2	A	Compact urban form
Claustrophobic street	F6	F	Overwhelming
3 to 4 stories	B1	B	Height of the Buildings
Tightly compacted medium height buildings	A2	A	Compact urban form
Cars, building height	B1	B	Height of the Buildings
a secondary route and 4-storey blocks	B1	B	Height of the Buildings
infrastructure scale	E4	E	Scale and Proportion
The narrow street adds a feeling of high density however the buildings do not appear as tall as those in other images	M2	M	Street Width
Street that only has houses on it	H1	H	Residential
tight space	A2	A	Compact urban form

Small lanea	M2	M	Street Width
Closed space makes it feel busier	E1	E	Sense of Enclosure
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
quiet area	G2	G	Less to Non-Active
busy city tall buildings a lot of elements interacting	B1	B	Height of the Buildings
open streets but tall buildings	B1	B	Height of the Buildings
tight, small road making it busier	A2	A	Compact urban form
narrow street making it feel much more dense	M2	M	Street Width
city side street	C1	C	Urban / City
Tightly compacted medium height buildings	A2	A	Compact urban form
one-way traffic route and 4-storey blocks	B1	B	Height of the Buildings
Ground floor level looks like commerical units reduced the number of storeys used for housing	B1	B	Height of the Buildings
street scale	E4	E	Scale and Proportion
a certain amount of color	P3	P	Colours
Houses that face one another	A3	A	Space between the buildings
low rise structures	B1	B	Height of the Buildings
Very narrow street with busy trafic	M2	M	Street Width
WALKABLE	O1	O	Pavement Width
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
wealthy suburbs	C2	C	Sprawl / Outskirts/ Suburbs
side street	O1	O	Pavement Width
wide street (Medium-Density)	M2	M	Street Width
wide (Medium-Density)	M2	M	Street Width
Ample space between constructions (Medium-Density)	A3	A	Space between the buildings

Ample space between constructions (Medium-Density)	A3	A	Space between the buildings
Slightly more compact (Medium-Density)	A2	A	Compact urban form
Building size (Medium-Density)	I1	I	Volume of buildings
high blocks but room for nature (Medium-Density)	B1	B	Height of the Buildings
distance between buildings (Medium-Density)	A3	A	Space between the buildings
quite a lot of space left (Medium-Density)	K5	K	Open Spaces /parks
medium dense built and vehicle (Medium-Density)	I2	I	Built up Area
wider streets feels less dense (Medium-Density)	M2	M	Street Width
Balance between greens and greys (Medium-Density)	Q1	Q	Balanced (built / open)development

Low Density-Image Descriptions-Universal Illustrations (UI)--MST-Step 4

Low-Density	**Construct Code**	**Category Code**	**Construct Name**
Close buildings	A2	A	Compact urban form
semi enclosed	E3	E	Semi Enclosed (Buildings +Vacant Land)
Cold	F1	F	Sad / Uninspiring
Derilict	K9	K	Vacant /Empty Spaces
empty space, with lots of open areas	K9	K	Vacant /Empty Spaces
seems like school or some industry place	H2	H	Commercial
wide paths	O1	O	Pavement Width
Only use appears to be cars -no life apparent	L1	L	Density of cars in the street
wide road	M2	M	Street Width
looks like garages	K3	K	Parking Lots
Spacious feeling	A1	A	Loose / Scattered

			urban form
low traffic	L1	L	Density of cars in the street
empty roads	G2	G	Less to Non-Active
a lot of free spaces	K9	K	Vacant /Empty Spaces
Looks like multi storey carp parks and not like houses	K3	K	Parking Lots
things are apart	A1	A	Loose / Scattered urban form
Wide road	M2	M	Street Width
Only use appears to be cars -no life apparent	L1	L	Density of cars in the street
wide road	M2	M	Street Width
looks like garages	K3	K	Parking Lots
Spacious feeling	A1	A	Loose / Scattered urban form
low traffic	K3	K	Parking Lots
empty roads	K9	K	Vacant /Empty Spaces
a lot of free spaces	K9	K	Vacant /Empty Spaces
Looks like multi storey carp parks and not like houses	K3	K	Parking Lots
things are apart	A1	A	Loose / Scattered urban form
Wide road	M2	M	Street Width
limited navigable space	K6	K	Public Space Qualities
WALK WAY	O1	O	Pavement Width
Car Dominated	L1	L	Density of cars in the street
less color	P3	P	Colours
lots of car spaces	K4	K	On Street Parking
Well planned housing blocks and clearly marked spaces for parking, manoeuvrability of vehicles and people	H1	H	Residential
no people	L2	L	Density of people in the street
open	A1	A	Loose / Scattered

			urban form
Car Dominated	L1	L	Density of cars in the street
wide road	M2	M	Street Width
tree/ wider view	K1	K	Vegetation
large roads wide streets	M2	M	Street Width
the road seems quite wide, compare to the number of cars.	M2	M	Street Width
wide roads	M2	M	Street Width
Car Dominated	L1	L	Density of cars in the street
wide road looks sleepy	M2	M	Street Width
like a car parking area	K3	K	Parking Lots
,Fragmented, scattered	A1	A	Loose / Scattered urban form
Neighourhood	C3	C	Neighbourhood
single storey buildings	B1	B	Height of the Buildings
tree/ wider view	K1	K	Vegetation
Low rise housing	B1	B	Height of the Buildings
low level houses	B1	B	Height of the Buildings
low buildings -only 2/3 floors	B1	B	Height of the Buildings
no real traffic wide pavements	O1	O	Pavement Width
only one lane on each side of the road makes it seem quieter	G2	G	Less to Non-Active
the number of cars are few	L1	L	Density of cars in the street
Environment appears quiet	G2	G	Less to Non-Active
parking	K3	K	Parking Lots
short buildings	B1	B	Height of the Buildings
short buildings	B1	B	Height of the Buildings
low buildings	I1	I	Volume of buildings
Spacious feeling	A1	A	Loose / Scattered urban form
Building size	I1	I	Volume of buildings
minimal traffic, 2 storey building	B1	B	Height of the Buildings

Height	B1	B	Height of the Buildings
little cars	L1	L	Density of cars in the street
quieter back alley	G2	G	Less to Non-Active
parking	K3	K	Parking Lots
low rise buildings	B1	B	Height of the Buildings
2 stories	B1	B	Height of the Buildings
sidestreet	O1	O	Pavement Width
Low building heights	B1	B	Height of the Buildings
a lot of free spaces	K9	K	Vacant /Empty Spaces
only 3 storey blocks on both side	Q2	Q	Uniform built form along the street
shorter buildings implies a less dense neighbourhood	B1	B	Height of the Buildings
least greenery	K1	K	Vegetation
No people, free car spaces	L1	L	Density of cars in the street
Smaller storey building, doesn't appear to be condensed	B1	B	Height of the Buildings
Minimal traffic density but the urban context is tall and follows a slender pinhole like perspective	B1	B	Height of the Buildings
Houses look small	P5	P	Building Typology
building hight	B1	B	Height of the Buildings
building height	B1	B	Height of the Buildings
HOUSING	H1	H	Residential
empty parks	K9	K	Vacant /Empty Spaces
no people	L2	L	Density of people in the street
Old buildings closed off	P1	P	Style of the buildings
Lack of colour	P3	P	Colours
not in main city	C2	C	Sprawl / Outskirts/ Suburbs
Quiet street-not a lot of cars	G2	G	Less to Non-Active
Community	C3	C	Neighbourhood
busy road but low buildings	B1	B	Height of the Buildings

Car Dominated	L1	L	Density of cars in the street
tree/ wider view	K1	K	Vegetation
low residential buildings	H1	H	Residential
on the road parking, not much other than housing	H1	H	Residential
the building, not that huge to accommodate more people, so its low density	E4	E	Scale and Proportion
No cars	L1	L	Density of cars in the street
Car Dominated	L1	L	Density of cars in the street
Wide road	M2	M	Street Width
People friendly spaces	O2	O	Pedestrian Friendly
Large open pedestrian spaces	O2	O	Pedestrian Friendly
everything is advertising and looks unhospitable	K2	K	Streetscape Elements

IMAGE-WISE analysis-Sample

01-ANA_GLA_Images_Analytics					
1					
EE-MD-10					
27		43		1	
Low-Density	**Construct Code**	**Medium-Density**	**Construct Code**	**High-Density**	**Construct Code**
open space	K5	tall buildings but not so dense	A1	Looks dense but more open	K5,D1
empty space	K5	mostly housing , not too tall	H1, A1		
vacant land makes the place look empty	K5	..			
low buildings but also empty spaces so feels less dense	I1	open area	K5		
more residential, less vehicle movement	H1,L1	Medium sized builngs and medium sized paths	A1,M2		
Large open spaces between buildings	A3	open pedestrian space	K5		
looks empty	K5	Housing	H1		
No people few cars	L1,L2	medium-height buildings	A1		
lonley	K5	Multiple storeys and access to commercial services	A1,H2		
empty	K5	mixed use -commercial and residential	H3		
parkings on one side, no pedestrian	K4,L1	Flats and empty space gives impression of mixed density	K5,H3		
some residential buildings next to a public building with open space	H1,K5	More Residential	H1		
quiet street	G2	Inner urban mixed	H3		
Buildins on one side	Q1	tenemantal, poor open space	P5		

no people	L2	sizeable buildings and open space	I1,K5		
Small flat buildings	A1	many buildings and cars	I1,L1		
Area looks to be only residential	H1	open square, mid rise residential tenements	K5,A1,H1		
Nothing in the car park	L1	Tenements and low-level housing	P5,H1		
open	K5	windows	P4		
large unocquipied area	K5	Taller blocks and repetitive	A1,P4		
large open space thats empty	K5	Medium height buildings with open space	A1,K5		
courtyard	K5	Tall residential with public space	A1,K5		
open space for people to move around without having to bump into each other	K5	very small road	M2		
appears quite a lonely place	L2	3 storey but also has shops underneath	A1,H3		
open spaces and smaller roads	K5,M2	open	K5		
Open and empty area on the right	K5	More open	K5		
nothing going on	G2	Housing and shops next to car park	H3,K3		
		remembering old times	FS		
		.			
		big buildings big open space	I1,K5		
		Deprived suburbs (Less people with less space)	C2		
		Med			
		open but busier	K5,G1		
		tall buildings but open space	A1,K5		
		Narrow Pavements,	O1,P5		

		Tenements			
		It is a place where people live so there will be people but there not all travelling so it is not as dense as a city	H1		
		tenement buildings.	P5		
		Has both commercial and residential space	H3		
		Mixed used space w/ tenements, storefronts and open area	H3,P5		
		residential	H1		
		semi high apartment/offices with an adjacent square	A1,H2		
		plenty open space but otherwise fairly developed with little greenery	K5		
		A lot of space to walk but tall things sticking out of the road add density	O1		
2					
EE-LD-05					
18		46		7	
Low-Density	**Construct Code**	**Medium-Density**	**Construct Code**	**High-Density**	**Construct Code**
low rise on left , large hall on right is rarely used	A1	Wide open street	M2	Event space	K5
low buildings, sky is more visible more open space -maybe also because image is taken on a sunny day it feels less dense	I1,K8,Q3	big pathway	O1	Roads with cars is not good	L1

mixed	H3	mixture of heights make the place look less dense	A1	Cars and people everywhere	L1,L2
sprawled area -low building heights	A1,C2	only one residential side	Q5,H1	wide quite streets	M2
Large open spaces between buildings	A3	Different heights on different sides	Q5	Its a city where lots of people travel to for work	L2
residential	H1	Medium sized builngs and medium sized paths	I1,O1	lots of large buildings.	I1
open air	Q3	pedestrian space	O2	city	C1
		mixed tall and low buildings	A1		
low buildings	I1	Access to public ammenities and entertainment	K6		
height	A1	More open space mix of buildings	K5,P6		
Building on right more like commercial building and small building on left looks more like retail so less housing	Q5	Empty space in image makes the place feel less dense even though the area could be quite busy	K5		
low rise, wide street	A1,M2	more of a commercial district	C2		
Wide view	Q3	Less Residential houses and wide roads	H3,M2		
Wealthy suburbs (Less people with lots of space)	C2	Inner urban mixed	C1,H3		
shorter bldgs and space for people to walk around	A1,O2	tenemantal buildings	P5		
low roofed buildings open sky seen	A1,Q3	people and cars	L1,L2		
go down shopping centre	H3	very wide pavements with low rise office buildings/residence	O1,A1,C2		
Lots of space and short buildings	A1,K5	residential	H1		
		High-to-low	P6		
		busy roads but a lot of empty	G1,K5		

		spaces still			
		Medium height buildings with open space	A1,K5		
		larger number of residential, public, cultural buildings but space for development	H1, K6		
		fairly tall but not many shops seems purely for housing	A1,H3		
		Open, quiet space	K5		
		Lower buildings but still feels busy	I1		
		Older buildings on the right and newer smaller shops on the left	P9		
		sky	Q3		
		.			
		Local shops	H2		
		busy road	G1		
		tall buildings one side	A1,Q5		
		Med	D2		
		Modern flats	P5		
		Possible places of work as well as residential	H1		
		open	K5		
		closed in	A2		
		busy but lower buildings on one side	Q5		
		Wide pavement, tenements	O1,P5		
		single story buildings	A1		

		big pavements	O1		
		building are high on one side.	Q5		

Situation Judgement Task-Appendix

Default Question Block

About the Survey

This survey intends to determine **your perception** of the urban environments represented by the images, based on the similar environments you experience in your day-to-day life. The task is a simple one. You are required to **describe** the urban environment represented in the image **using 3 choices**; next, **choose the features** of the urban environment to support your choice and last, choose how often would you **visit** a similar environment.

Age

- ○ Under 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older

Education

- ○ Student
- ○ High school graduate
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ Professional Degree
- ○ Doctorate

Gender

- ○ Male
- ○ Female
- ○ Prefer not to say

City

[ ]

Block 1

How would you describe **"Your Experience"** of being in the urban environment represented by the image?

	Comfortable	Neutral	Overwhelming
1st Choice	○	○	○

.

	Cheerful	Neutral	Depressing
2nd Choice	○	○	○

.

	Vibrant	Neutral	Dull
3rd Choice	○	○	○

Please select the features of the urban environment described below to support your choice 1 **"Comfortable"** as against Overwhelming.

(Please choose 3)

- ☐ Enclosures created by Buildings
- ☐ Number of Buildings
- ☐ Street Width
- ☐ Amount of Vegetation
- ☐ Building Use (Resi, Comm, Mixed)
- ☐ Variety of Built Form
- ☐ Activities along the Street
- ☐ Similarity of the Built Form
- ☐ Number of Cars
- ☐ Building Heights
- ☐ Building to Sky Ratio
- ☐ Number of People
- ☐ Pavement Width
- ☐ Other

Please describe your choice 1 **"Neutral"** for the urban environment represented by the image in a few words as against Comfortable or Overwhelming.

Please select the features of the urban environment described below to support your choice 1 **"Overwhelming"** as against Comfortable

(Please choose 3)

- [ ] Enclosures created by Buildings
- [ ] Number of Buildings
- [ ] Street Width
- [ ] Amount of Vegetation
- [ ] Building Use (Resi, Comm, Mixed)
- [ ] Variety of Built Form
- [ ] Activities along the Street
- [ ] Similarity of the Built Form
- [ ] Number of Cars
- [ ] Building Heights
- [ ] Building to Sky Ratio
- [ ] Number of People
- [ ] Pavement Width
- [ ] Other

Please select the features of the urban environment described below to support your choice 2 **"Cheerful"** as against Depressing

(Please choose 3)

- [ ] Enclosures created by Buildings
- [ ] Number of Buildings
- [ ] Street Width
- [ ] Amount of Vegetation
- [ ] Building Use (Resi, Comm, Mixed)
- [ ] Variety of Built Form
- [ ] Activities along the Street
- [ ] Similarity of the Built Form
- [ ] Number of Cars
- [ ] Building Heights
- [ ] Building to Sky Ratio
- [ ] Number of People
- [ ] Pavement Width
- [ ] Other

Please describe your choice 2 **"Neutral"** for the urban environment represented by the image **in a few words** as against Cheerful or Depressing

Please select the features of the urban environment described below to support your choice 2 **"Depressing"** as against Cheerful

(Please choose 3)

- [ ] Enclosures created by Buildings
- [ ] Number of Buildings
- [ ] Street Width
- [ ] Amount of Vegetation
- [ ] Building Use (Resi, Comm, Mixed)
- [ ] Variety of Built Form
- [ ] Activities along the Street
- [ ] Similarity of the Built Form
- [ ] Number of Cars
- [ ] Building Heights
- [ ] Building to Sky Ratio
- [ ] Number of People
- [ ] Pavement Width
- [ ] Other

Please select the features of the urban environment described below to support your choice 3 **"Vibrant"** as against Dull

(Please choose 3)

- ☐ Enclosures created by Buildings
- ☐ Number of Buildings
- ☐ Street Width
- ☐ Amount of Vegetation
- ☐ Building Use (Resi, Comm, Mixed)
- ☐ Variety of Built Form
- ☐ Activities along the Street
- ☐ Similarity of the Built Form
- ☐ Number of Cars
- ☐ Building Heights
- ☐ Building to Sky Ratio
- ☐ Number of People
- ☐ Pavement Width
- ☐ Other

Please describe your choice 3 **"Neutral"** for the urban environment represented by the image **in a few words** as against Vibrant or Dull

Please select the features of the urban environment described below to support your choice 3 **"Dull"** as against Vibrant

(Please choose 3)

- ☐ Enclosures created by Buildings
- ☐ Number of Buildings
- ☐ Street Width
- ☐ Amount of Vegetation
- ☐ Building Use (Resi, Comm, Mixed)
- ☐ Variety of Built Form
- ☐ Activities along the Street
- ☐ Similarity of the Built Form
- ☐ Number of Cars
- ☐ Building Heights
- ☐ Building to Sky Ratio
- ☐ Number of People
- ☐ Pavement Width
- ☐ Other

How often would you like to **visit** a similar urban environment represented by the image?

- ○ Every Day
- ○ Once a Week
- ○ Once a Month
- ○ A few times in a Month
- ○ Never

Situation Judgement Task - Results
(Images 28, 03, 12, 25, 02, 33, 06 ©2023 Google)

CC-HD-24
Objective Density High
Perceived Density High

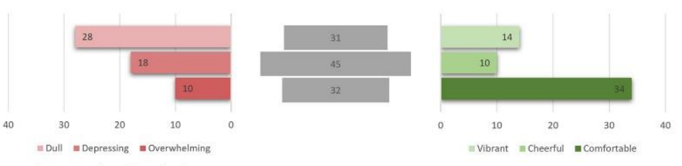


Image 1 - Neutral

IMAGE 1_FREQUENCY COUNT

	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-3	-1	-4	-2	-2	-2	-12	-12	-2	-2	0	-6	-8
Depressing	-5	-2	-5	-1	-2	-2	-3	-3	-2	-1	0	-2	-2
Overwhelming	-5	-4	-6	-1	-1	-1	-1	0	0	-1	0	-1	0
Vibrant	2	1	2	2	1	3	0	1	0	5	1	3	3
Cheerful	1	1	0	2	2	5	0	2	1	3	1	0	3
Comfortable	2	10	10	3	7	5	0	5	1	6	15	2	3

IMAGE 1_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	5.00	6.00	4.00	1.75	2.00	2.17	0.00	1.00	1.78	1.70	0.45	0.75
N_WEIGHTAGE	-13.00	-3.50	-5.00	-1.00	-1.00	-0.83	-2.29	-1.88	-0.89	0.00	-0.82	-0.83

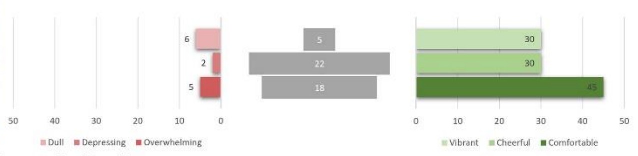
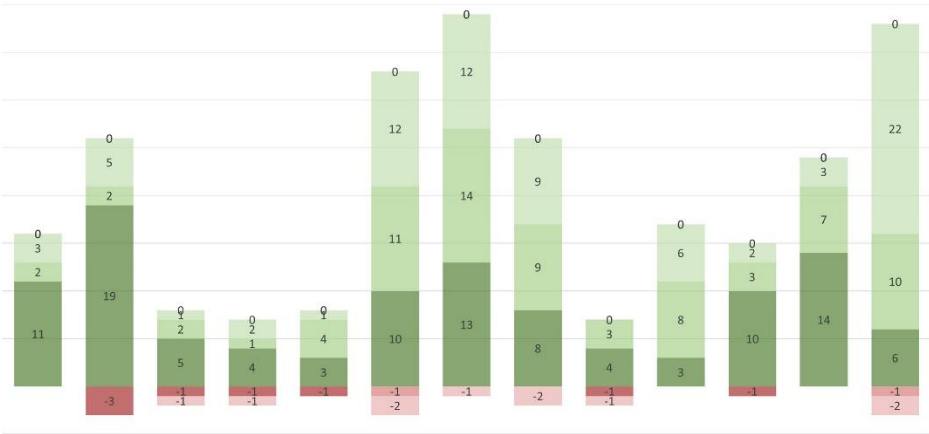


Image 2 - Positive

28- Manhattan, New York
Objective Density Extreme
Perceived Density Moderate

IMAGE 2_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	0	0	-1	-1	0	-2	-1	-2	-1	0	0	0	-2
Depressing	0	0	0	0	0	-1	0	0	0	0	0	0	-1
Overwhelming	0	-3	-1	-1	-1	0	0	0	-1	0	-1	0	0
Vibrant	3	5	1	2	1	12	12	9	0	6	2	3	22
Cheerful	2	2	2	1	4	11	14	9	3	8	3	7	10
Comfortable	11	19	5	4	3	10	13	8	4	3	10	14	6

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 2_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	16.00	13.00	2.67	1.75	1.60	5.50	5.57	3.25	2.67	1.50	2.18	3.17
N_WEIGHTAGE	0.00	-1.50	-0.67	-0.50	-0.20	-0.50	-0.14	-0.25	-0.22	-0.10	0.00	-0.25

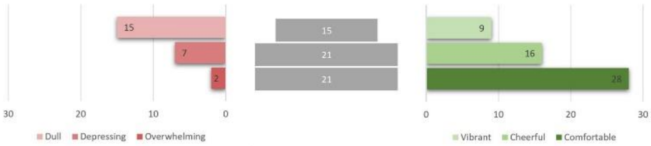
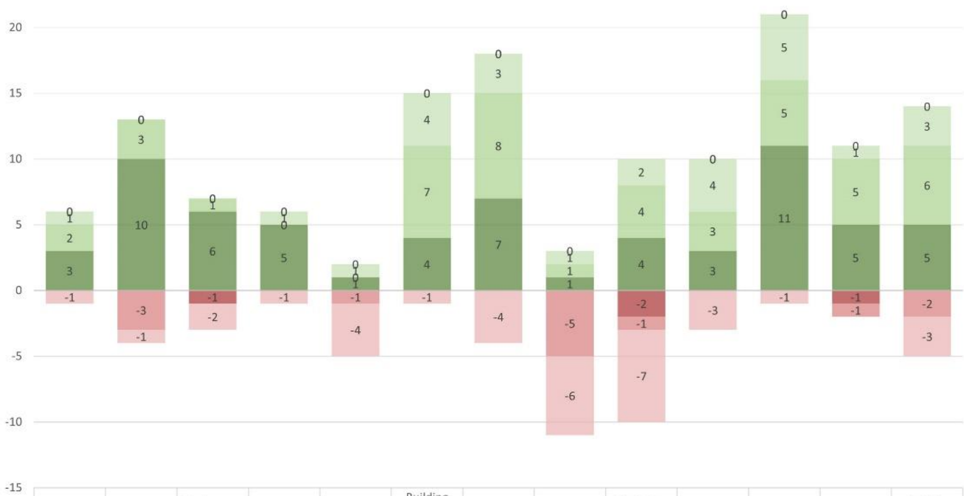


Image 3 - Neutral

EE-MD-09
Objective Density Moderate
Perceived Density Moderate

IMAGE 3_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-1	-1	-2	-1	-4	-1	-4	-6	-7	-3	-1	0	-3
Depressing	0	-3	0	0	-1	0	0	-5	-1	0	0	-1	-2
Overwhelming	0	0	-1	0	0	0	0	0	-2	0	0	-1	0
Vibrant	1	0	0	1	1	4	3	1	2	4	5	1	3
Cheerful	2	3	1	0	0	7	8	1	4	3	5	5	6
Comfortable	3	10	6	5	1	4	7	1	4	3	11	5	5

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 3_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	6.00	6.50	2.33	1.50	0.40	2.50	2.57	0.38	2.22	2.10	1.00	1.17
N_WEIGHTAGE	-1.00	-2.00	-1.00	-0.25	-1.00	-0.17	-0.57	-1.38	-1.44	-0.10	-0.18	-0.42

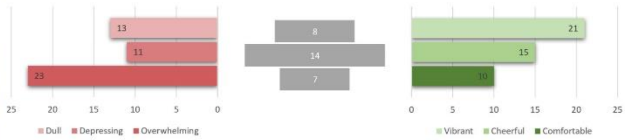


Image 4 - Negative

03-Barcelona
Objective Density Extreme
Perceived Density Moderate

IMAGE 4_FREQUENCY COUNT

	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-2	-2	0	-2	-7	-1	-1	-2	-2	-1	-4	0	-1
Depressing	-1	-3	-1	-1	-4	0	-4	-1	-1	0	-3	0	-1
Overwhelming	-7	-7	-2	-5	-18	0	0	0	-3	-1	-6	-1	-4
Vibrant	0	4	0	6	12	7	0	7	0	5	0	1	13
Cheerful	1	4	0	0	5	6	0	4	0	9	0	4	7
Comfortable	5	5	1	1	1	4	0	2	1	3	0	2	1

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 4_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	6.00	6.50	0.33	1.75	3.60	2.83	0.00	1.63	2.00	0.00	0.64	1.75
N_WEIGHTAGE	-10.00	-6.00	-1.00	-2.00	-5.80	-0.17	-0.71	-0.38	-0.89	-1.30	-0.09	-0.50

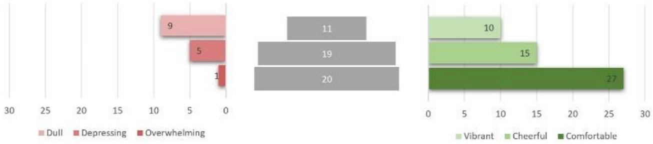
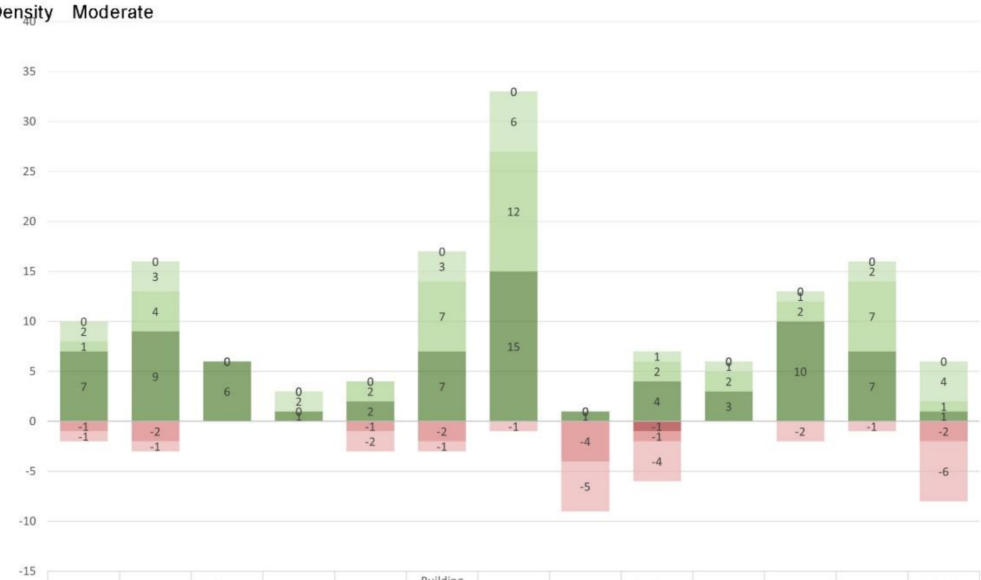


Image 5 - Positive

SE-MD-13
Objective Density Moderate
Perceived Density Moderate

IMAGE 5_FREQUENCY COUNT



	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-1	-1	0	0	-2	-1	-1	-5	-4	0	-2	-1	-6
Depressing	-1	-2	0	0	-1	-2	0	-4	-1	0	0	0	-2
Overwhelming	0	0	0	0	0	0	0	0	-1	0	0	0	0
Vibrant	2	3	0	2	0	3	6	0	1	1	1	2	4
Cheerful	1	4	0	0	2	7	12	0	2	2	2	7	1
Comfortable	7	9	6	1	2	7	15	1	4	3	10	7	1

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 5_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	10.00	8.00	2.00	0.75	0.80	2.83	4.71	0.13	1.44	1.30	1.45	0.50
N_WEIGHTAGE	-2.00	-1.50	0.00	0.00	-0.60	-0.50	-0.14	-1.13	-0.67	-0.20	-0.09	-0.67

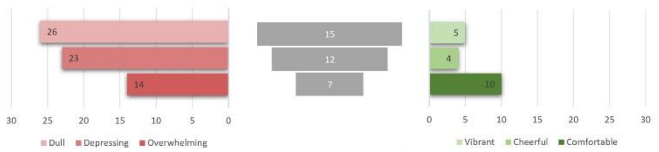
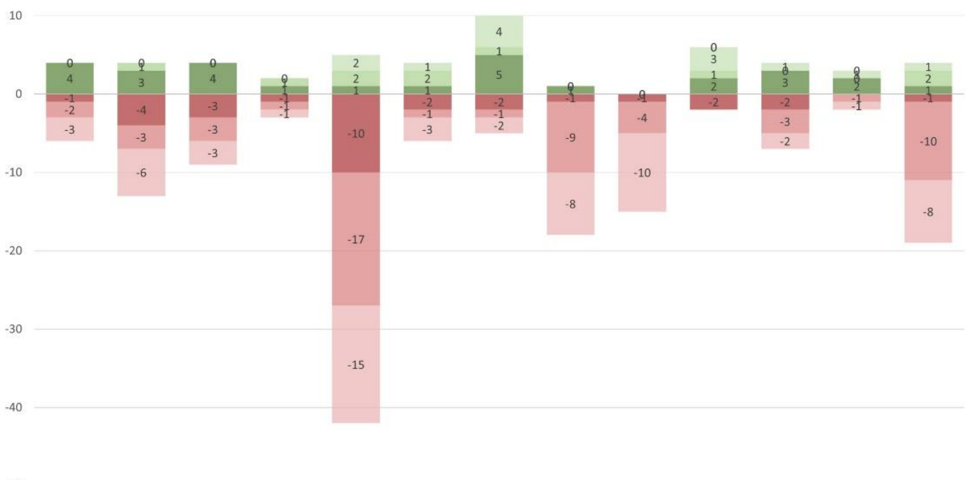


Image 6 - Negative

12-Unidad Independencia, Mexico
Objective Density Low
Perceived Density Moderate

IMAGE 6_FREQUENCY COUNT



	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-3	-6	-3	-1	-15	-3	-2	-8	-10	0	-2	-1	-8
Depressing	-2	-3	-3	-1	-17	-1	-1	-9	-4	0	-3	-1	-10
Overwhelming	-1	-4	-3	-1	-10	-2	-2	-1	-1	-2	-2	0	-1
Vibrant	0	0	0	0	2	1	4	0	0	3	1	1	1
Cheerful	0	1	0	1	2	2	1	0	0	1	0	0	2
Comfortable	4	3	4	1	1	1	5	1	0	2	3	2	1

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 6_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	4.00	2.00	1.33	0.50	1.00	0.67	1.43	0.13	0.67	0.40	0.27	0.33
N_WEIGHTAGE	-6.00	-6.50	-3.00	-0.75	-8.40	-1.00	-0.71	-2.25	-1.89	-0.70	-0.18	-1.58

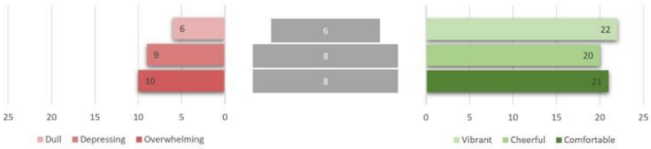
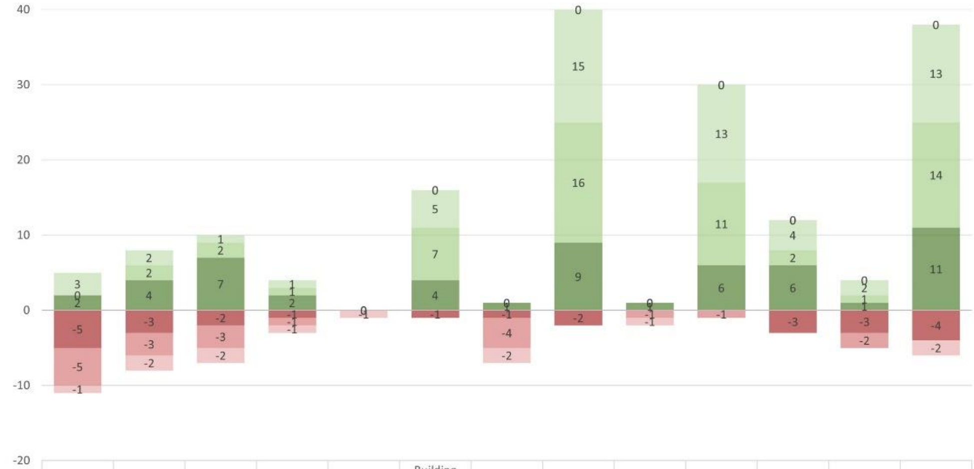


Image 7 - Positive

CC-HD-01
Objective Density High
Perceived Density High

IMAGE 7_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-1	-2	-2	-1	-1	0	-2	0	-1	0	0	0	-2
Depressing	-5	-3	-3	-1	0	0	-4	0	-1	-1	0	-2	0
Overwhelming	-5	-3	-2	-1	0	-1	-1	-2	0	0	-3	-3	-4
Vibrant	3	2	1	1	0	5	0	15	0	13	4	2	13
Cheerful	0	2	2	1	0	7	0	16	0	11	2	1	14
Comfortable	2	4	7	2	0	4	1	9	1	6	6	1	11

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 7_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	5.00	4.00	3.33	1.00	0.00	2.67	0.14	5.00	3.44	1.20	0.36	3.17
N_WEIGHTAGE	-11.00	-4.00	-2.33	-0.75	-0.20	-0.17	-1.00	-0.25	-0.33	-0.30	-0.45	-0.50

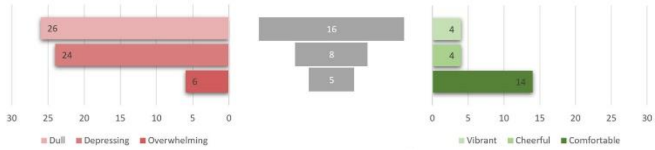


Image 8 - Negative

EE-MD-07
Objective Density Moderate
Perceived Density Moderate

IMAGE 8_FREQUENCY COUNT

	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-1	-5	-2	-3	-4	-5	-7	-9	-6	-6	-4	0	-11
Depressing	-2	-4	-5	-2	-4	-3	-11	-8	-2	-3	-7	0	-8
Overwhelming	-1	-1	-1	-3	-2	-1	-1	-1	0	0	-2	0	-1
Vibrant	0	1	1	0	1	2	0	0	1	3	0	0	2
Cheerful	0	1	0	1	0	1	0	0	0	2	0	2	1
Comfortable	5	7	2	1	0	5	0	3	1	2	3	4	3

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 8_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	5.00	4.50	1.00	0.50	0.20	1.33	0.00	0.38	1.00	0.30	0.55	0.50
N_WEIGHTAGE	-4.00	-5.00	-2.67	-2.00	-2.00	-1.50	-2.71	-2.25	-1.89	-1.30	0.00	-1.67

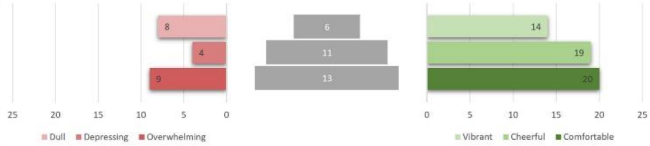
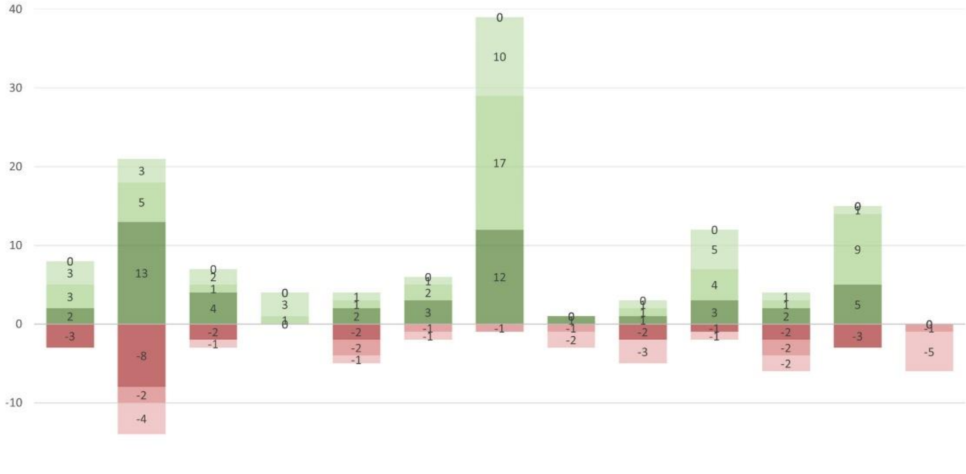


Image 9 - Positive

25-Costa Verde Village, San Diego
Objective Density High
Perceived Density Low

IMAGE 9_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	0	-4	-1	0	-1	-1	0	-2	-3	-1	-2	0	-5
Depressing	0	-2	0	0	-2	-1	-1	-1	0	0	-2	0	-1
Overwhelming	-3	-8	-2	0	-2	0	0	0	-2	-1	-2	-3	0
Vibrant	3	3	2	3	1	1	10	0	1	5	1	1	0
Cheerful	3	5	1	1	1	2	17	0	1	4	1	9	0
Comfortable	2	13	4	0	2	3	12	1	1	3	2	5	0

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 9_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	8.00	10.50	2.33	1.00	0.80	1.00	5.57	0.13	1.67	0.40	1.36	0.00
N_WEIGHTAGE	-3.00	-7.00	-1.00	0.00	-1.00	-0.33	-0.14	-0.38	-0.78	-0.60	-0.27	-0.50

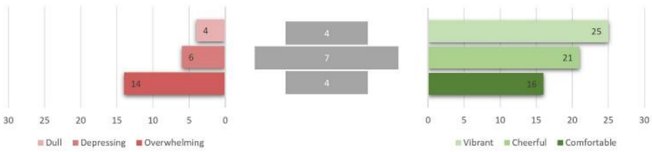
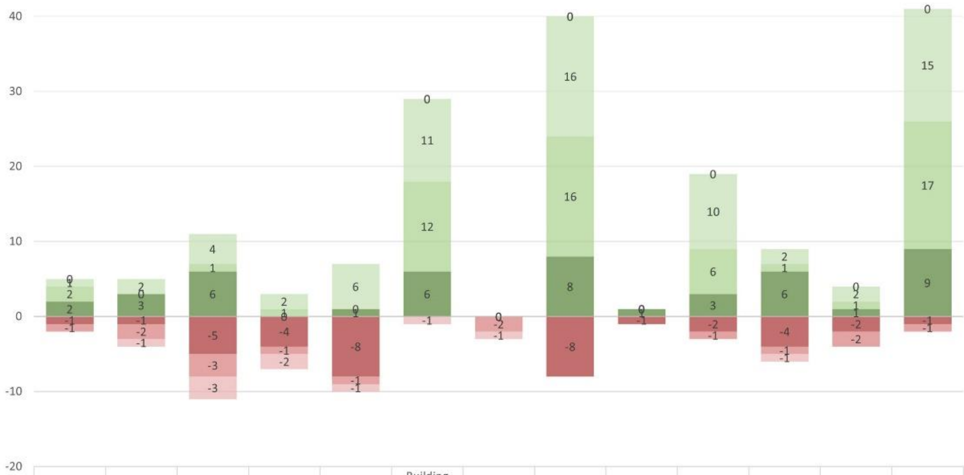


Image 10 - Positive

CC-HD-22
Objective Density High
Perceived Density High

IMAGE 10_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	0	-1	-3	-2	-1	-1	-1	0	0	0	-1	0	0
Depressing	-1	-2	-3	-1	-1	0	-2	0	0	-1	-1	-2	-1
Overwhelming	-1	-1	-5	-4	-8	0	0	-8	-1	-2	-4	-2	-1
Vibrant	1	2	4	2	6	11	0	16	0	10	2	2	15
Cheerful	2	0	1	1	0	12	0	16	0	6	1	1	17
Comfortable	2	3	6	0	1	6	0	8	1	3	6	1	9

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 10_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	5.00	2.50	3.67	0.75	1.40	4.83	0.00	5.00	2.22	0.90	0.36	3.42
N_WEIGHTAGE	-2.00	-2.00	-3.67	-1.75	-2.00	-0.17	-0.43	-1.00	-0.44	-0.60	-0.36	-0.17

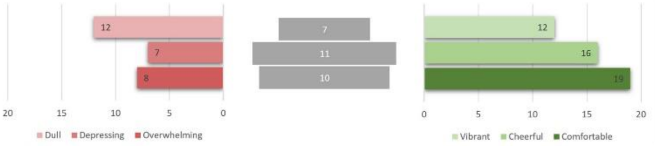
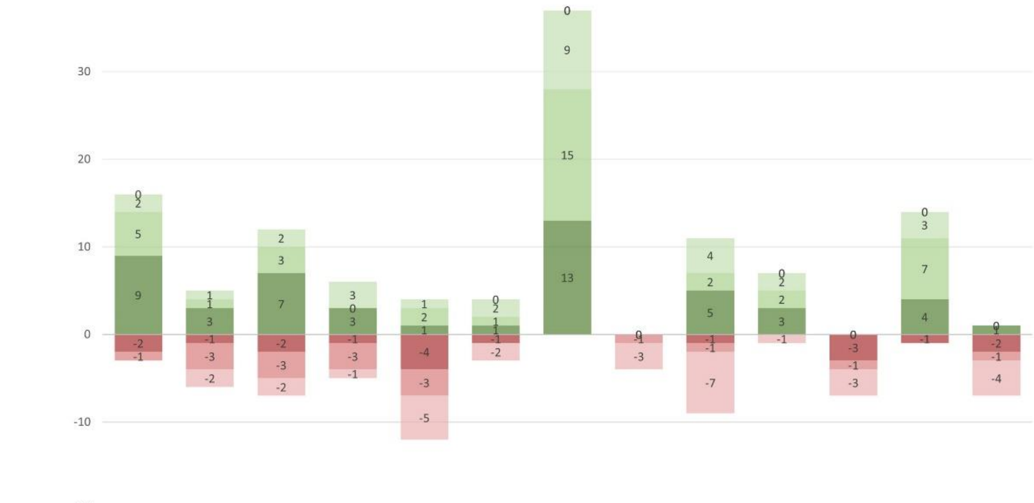


Image 11 - Positive

02- Saconia-Spain
Objective Density High
Perceived Density Moderate

IMAGE 11_FREQUENCY COUNT



	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	0	-2	-2	-1	-5	-2	0	-3	-7	-1	-3	0	-4
Depressing	-1	-3	-3	-3	-3	0	0	-1	-1	0	-1	0	-1
Overwhelming	-2	-1	-2	-1	-4	-1	0	0	-1	0	-3	-1	-2
Vibrant	2	1	2	3	1	2	9	0	4	2	0	3	0
Cheerful	5	1	3	0	2	1	15	0	2	2	0	7	0
Comfortable	9	3	7	3	1	1	13	0	5	3	0	4	1

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 11_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	16.00	2.50	4.00	1.50	0.80	0.67	5.29	0.00	2.00	0.00	1.27	0.08
N_WEIGHTAGE	-3.00	-3.00	-2.33	-1.25	-2.40	-0.50	0.00	-0.50	-1.11	-0.70	-0.09	-0.58

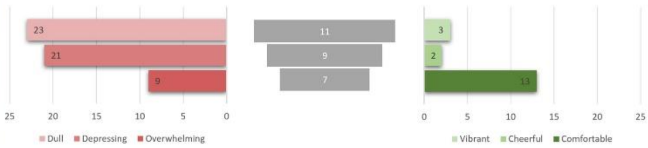


Image 12 - Negative

EE-LD-05

Objective Density Low

Perceived Density Moderate

IMAGE 12_FREQUENCY COUNT

	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-1	-2	-1	-1	-4	-4	-13	-8	-4	-4	-1	-1	-9
Depressing	-1	-3	-5	-1	-2	-6	-10	-5	-3	-2	-1	-1	-9
Overwhleming	0	-5	0	-1	-5	-2	-2	-1	-2	-1	-1	0	-1
Vibrant	0	1	1	0	1	2	0	1	0	1	0	0	2
Cheerful	0	0	0	0	1	1	0	2	0	0	1	0	1
Comfortable	4	3	1	0	1	1	0	2	1	2	10	6	1

Comfortable Cheerful Vibrant Overwhleming Depressing Dull

IMAGE 12_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	4.00	2.00	0.67	0.00	0.60	0.67	0.00	0.63	0.44	1.10	0.55	0.33
N_WEIGHTAGE	-2.00	-5.00	-2.00	-0.75	-2.20	-2.00	-3.57	-1.75	-1.78	-0.30	-0.18	-1.58

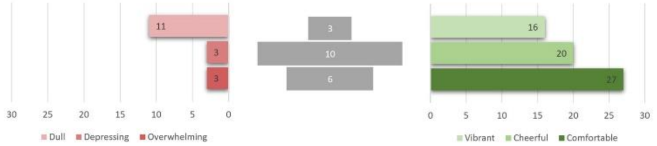


Image 13 - Positive

SE-LD-09
Objective Density Low
Perceived Density Low

IMAGE 13_FREQUENCY COUNT

	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-1	-3	0	-3	-3	-2	0	-8	0	0	0	0	-8
Depressing	0	0	0	0	0	-2	0	-2	0	0	0	0	-1
Overwhelming	0	-1	-1	0	0	0	0	-1	0	-2	0	-1	-1
Vibrant	1	5	3	1	0	1	13	2	0	3	4	3	5
Cheerful	6	5	1	2	2	2	19	1	1	1	6	7	1
Comfortable	2	10	1	3	2	3	23	2	0	4	13	9	1

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 13_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	9.00	10.00	1.67	1.50	0.80	1.00	7.86	0.63	1.00	2.30	1.73	0.58
N_WEIGHTAGE	-1.00	-2.00	-0.33	-0.75	-0.60	-0.67	0.00	-1.38	-0.22	0.00	-0.09	-0.83

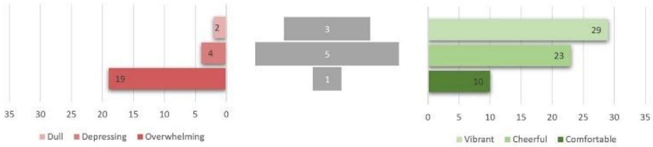
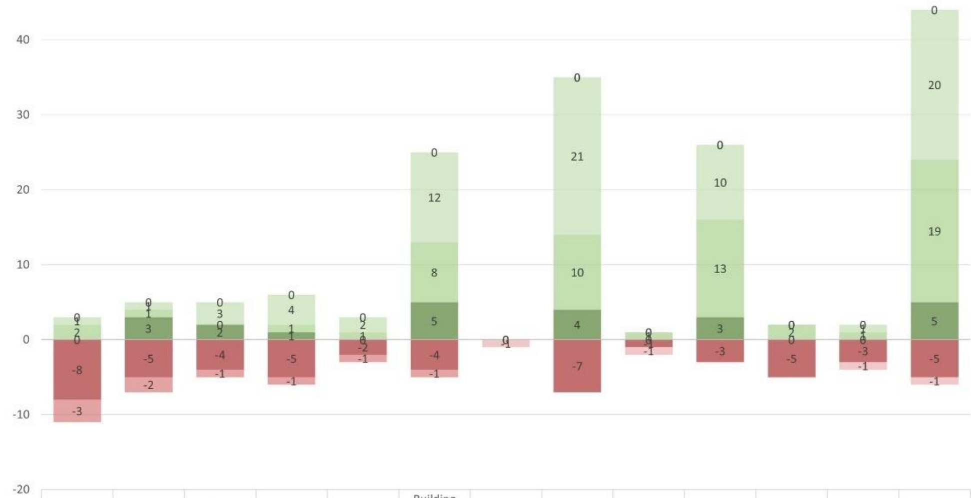


Image 14 - Positive

33- Hong Kong
Objective Density Extreme
Perceived Density High

IMAGE 14_FREQUENCY COUNT



	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	0	0	0	0	0	0	-1	0	-1	0	0	-1	-1
Depressing	-3	-2	-1	-1	-1	-1	0	0	0	0	0	0	0
Overwhelming	-8	-5	-4	-5	-2	-4	0	-7	-1	-3	-5	-3	-5
Vibrant	1	1	3	4	2	12	0	21	0	10	0	1	20
Cheerful	2	1	0	1	1	8	0	10	1	13	2	1	19
Comfortable	0	3	2	1	0	5	0	4	0	3	0	0	5

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 14_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	3.00	2.50	1.67	1.50	0.60	4.17	0.00	4.38	3.00	0.20	0.18	3.67
N_WEIGHTAGE	-11.00	-3.50	-1.67	-1.50	-0.60	-0.83	-0.14	-0.88	-0.56	-0.50	-0.36	-0.50

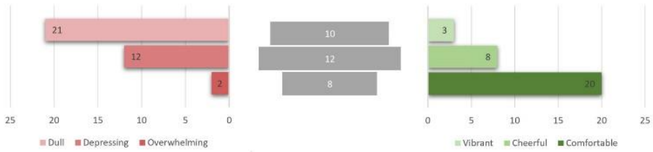


Image 15 - Negative

SE-LD-05
Objective Density Low
Perceived Density Low

IMAGE 15_FREQUENCY COUNT

	Building Heights 1	Street width 2	Enclosures created by buildings 3	Number of buildings 4	Number of Cars 5	Building Use (Resi, Comm, Mixed) 6	Amount of vegetation 7	Number of People 8	Similarity of the Built Form 9	Variety of Built Form	Pavement Width 10	Building to Sky Ratio 11	Activities along the Street 12
Dull	-1	-1	0	-1	-3	-3	-2	-7	-7	0	0	0	-9
Depressing	0	-1	0	-1	-3	-5	-3	-4	0	-3	-1	0	-6
Overwhelming	0	-1	-1	0	-1	0	0	0	0	0	0	0	0
Vibrant	2	0	0	0	0	1	2	0	0	0	0	2	0
Cheerful	2	1	0	1	0	1	7	0	0	0	2	6	0
Comfortable	7	9	3	1	2	2	7	2	1	0	12	5	2

Comfortable Cheerful Vibrant Overwhelming Depressing Dull

IMAGE 15_WEIGHTAGE

	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	11.00	5.00	1.00	0.50	0.40	0.67	2.29	0.25	0.11	1.40	1.18	0.17
N_WEIGHTAGE	-1.00	-1.50	-0.33	-0.50	-1.40	-1.33	-0.71	-1.38	-1.11	-0.10	0.00	-1.25

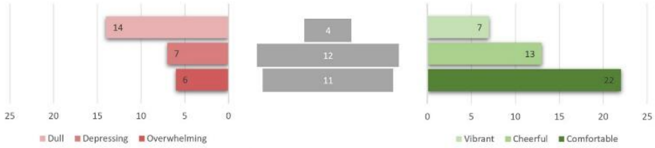


Image 16 - Positive

06- Plaine Monceau, Paris
Objective Density Low
Perceived Density Moderate

IMAGE 16_FREQUENCY COUNT

	Building Heights	Street width	Enclosures created by buildings	Number of buildings	Number of Cars	Building Use (Resi, Comm, Mixed)	Amount of vegetation	Number of People	Similarity of the Built Form	Variety of Built Form	Pavement Width	Building to Sky Ratio	Activities along the Street
	1	2	3	4	5	6	7	8	9		10	11	12
Dull	-1	-1	0	-1	-3	-3	-2	-7	-7	0	0	0	-9
Depressing	-2	-2	0	-2	-4	0	-1	-1	-4	0	0	0	0
Overwhelming	-1	-1	-1	-1	-1	0	0	-1	-3	0	-2	0	-1
Vibrant	2	2	0	1	1	2	0	0	1	1	3	2	1
Cheerful	2	3	2	0	1	1	3	0	7	1	3	6	0
Comfortable	4	13	9	2	2	0	4	0	11	0	9	4	0

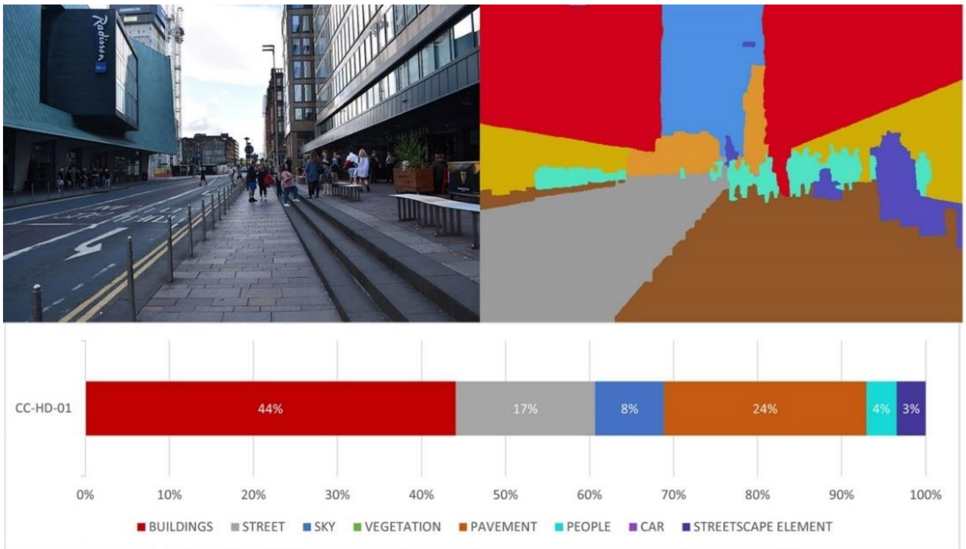
Comfortable Cheerful Vibrant Overwhelming Depressing Dull

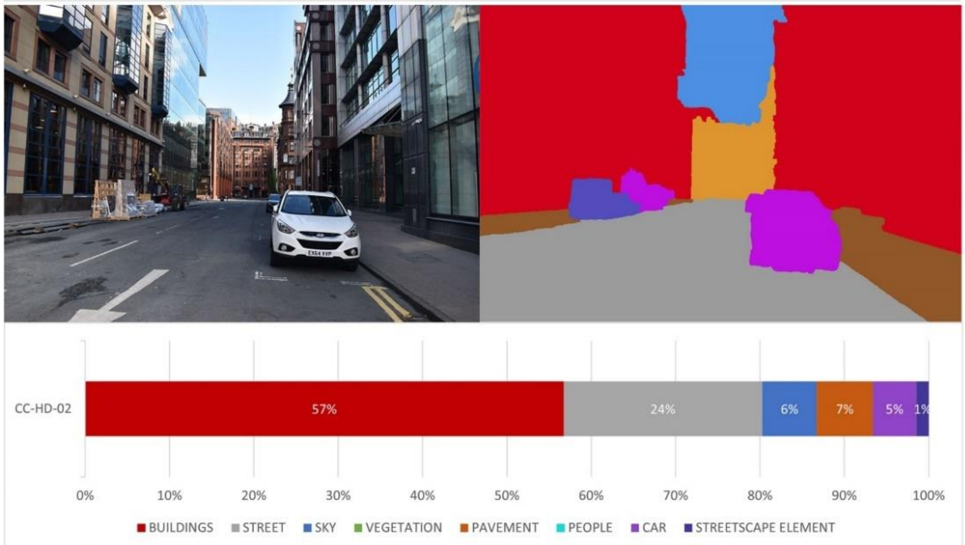
IMAGE 16_WEIGHTAGE

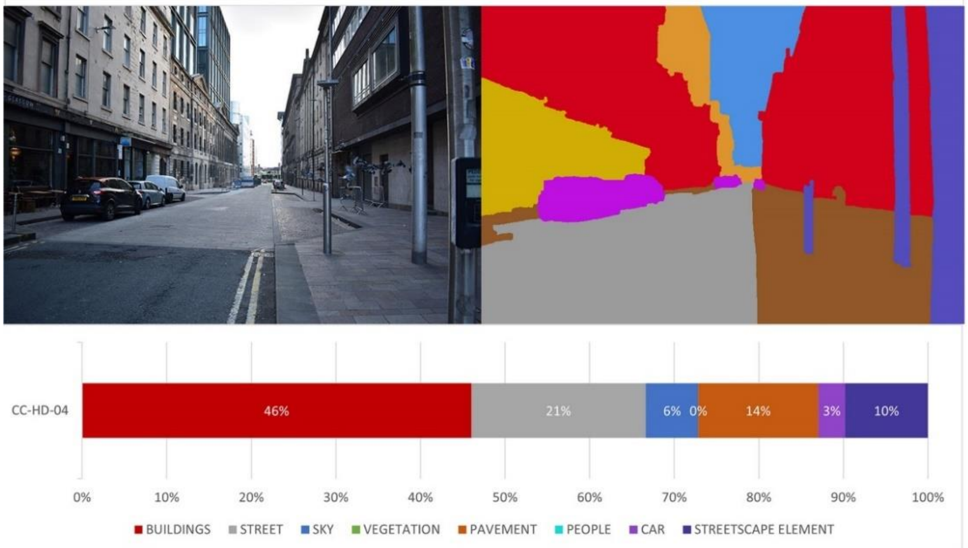
	1	2	3	4	5	6	7	8	9	10	11	12
P_WEIGHTAGE	8.00	9.00	3.67	0.75	0.80	0.50	1.00	0.00	2.33	1.50	1.09	0.08
N_WEIGHTAGE	-4.00	-2.00	-0.33	-1.00	-1.60	-0.50	-0.43	-1.13	-1.56	-0.20	0.00	-0.83

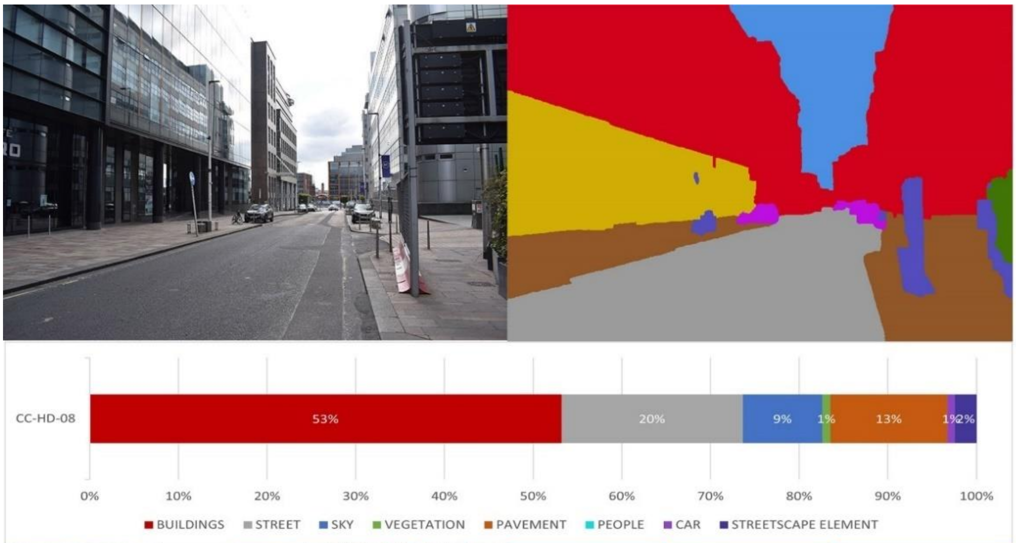
Appendix A2 – Supplementary Material to Chapter 6

Image segmentation – Glasgow

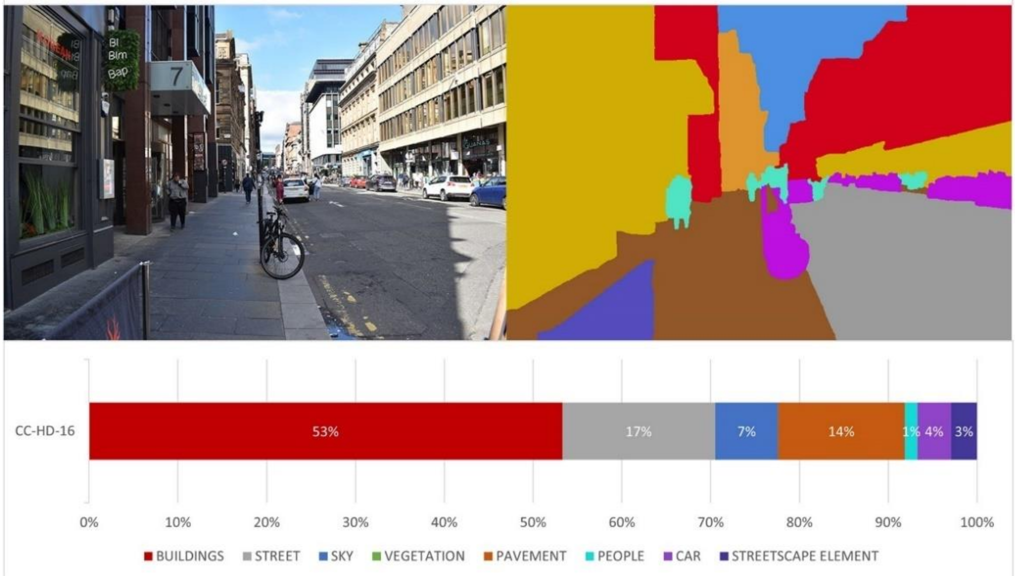




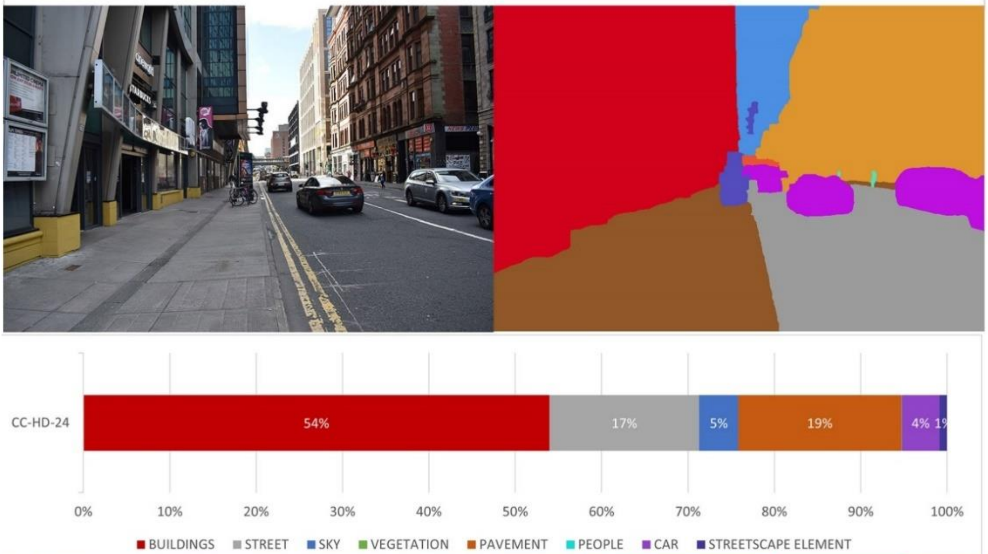


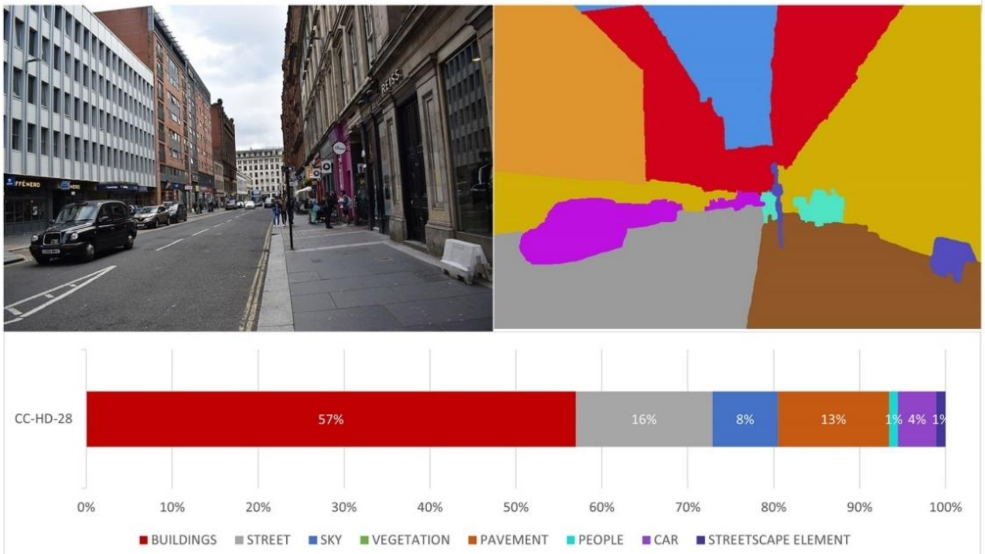

CC-HD-08
53%
20%
9%
1%
13%
1%
2%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


CC-HD-09
53%
24%
9%
14%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

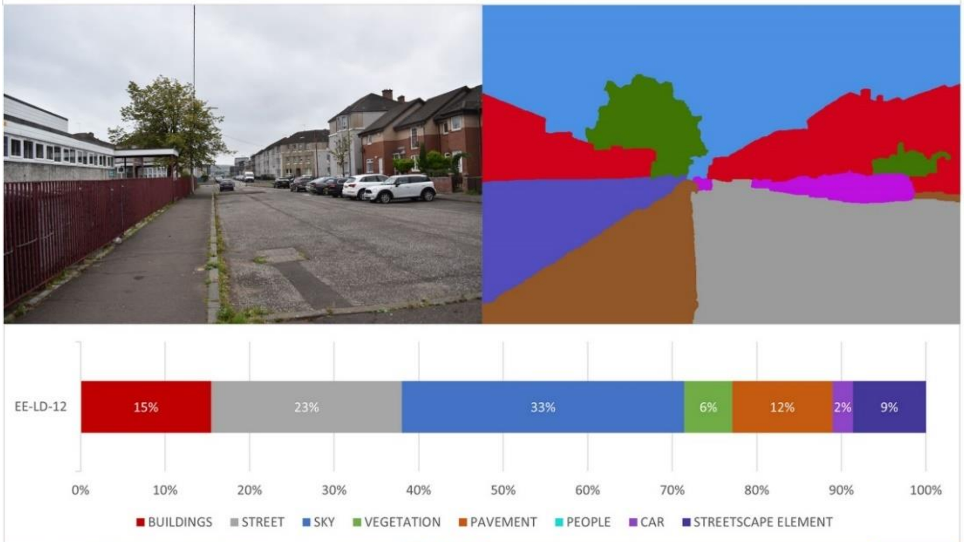

CC-HD-16
53%
17%
7%
14%
1%
4%
3%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


CC-HD-22
52%
8%
6%
0%
21%
2%
7%
4%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


CC-HD-24
54%
17%
5%
19%
4%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

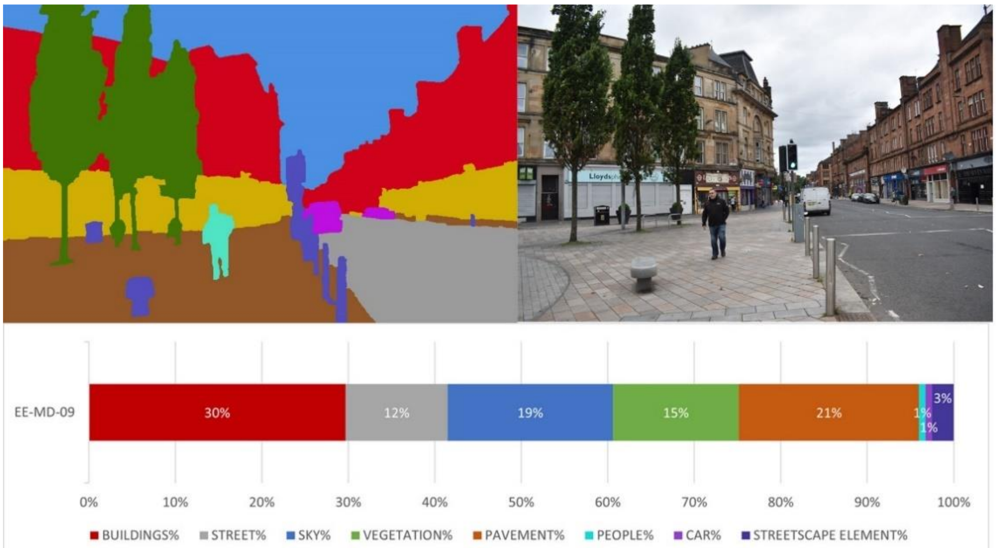

CC-HD-28
57%
16%
8%
13%
4%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

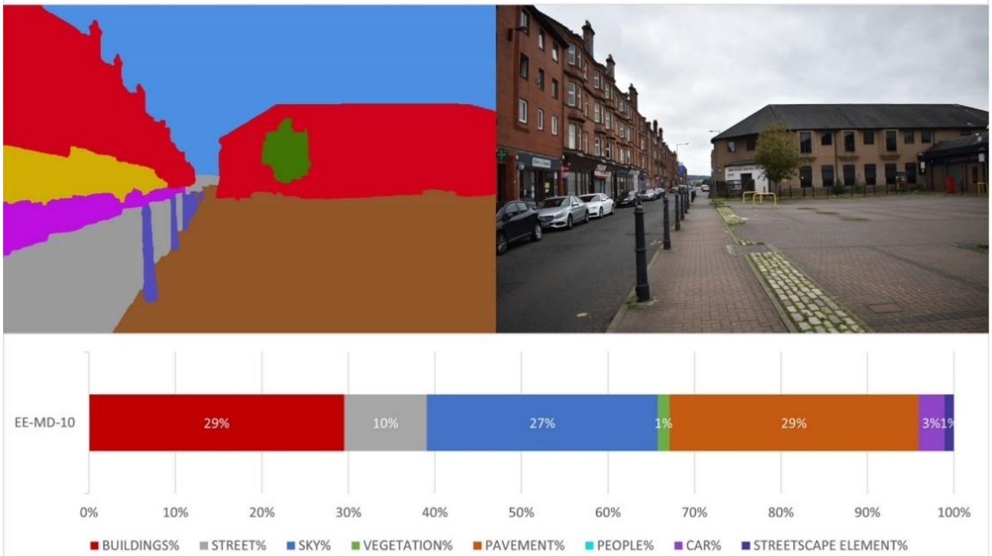

EE-LD-11
22%
19%
35%
7%
13%
2%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

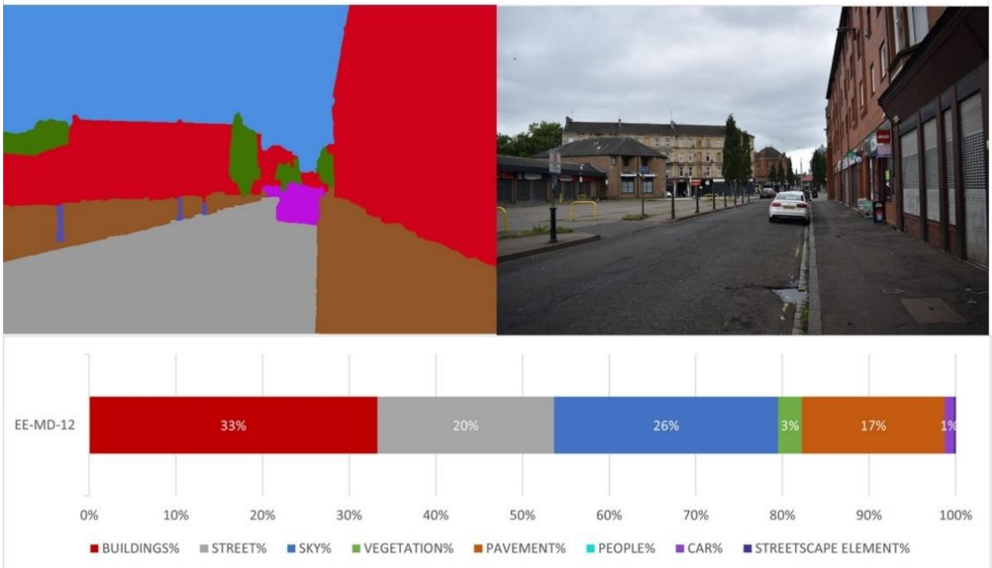

EE-LD-12
15%
23%
33%
6%
12%
2%
9%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

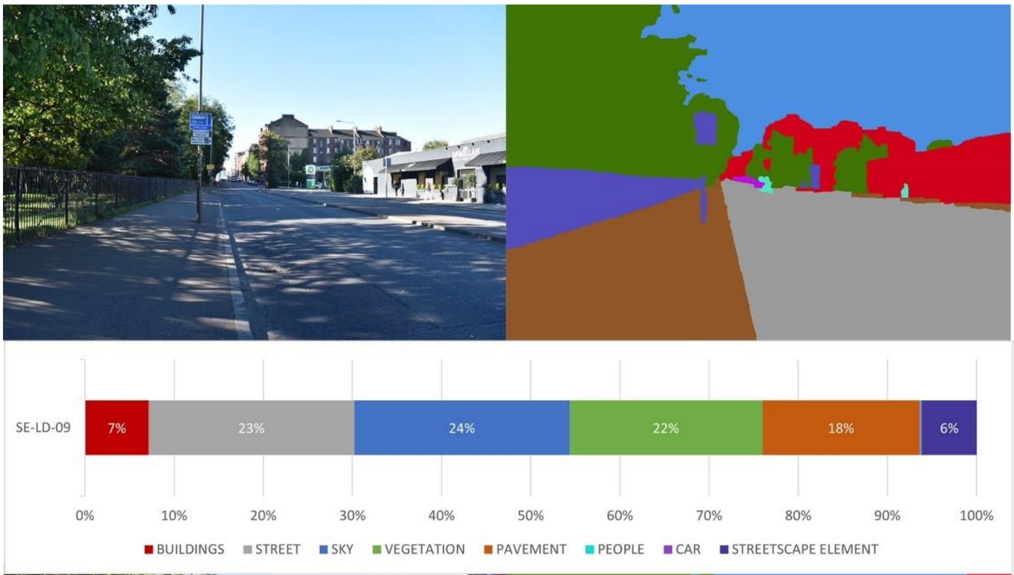

EE-MD-07
28%
21%
30%
9%
3%
9%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%

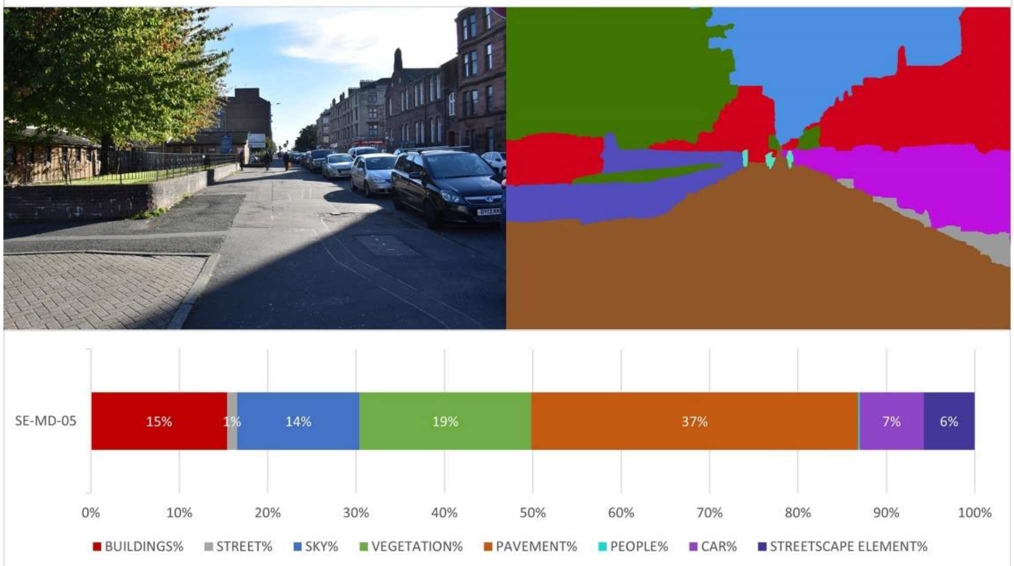
CC-LD-01
26%
7%
30%
19%
2%
17%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%
EE-LD-05
26%
11%
36%
17%
1%
8%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%
EE-LD-10
25%
17%
27%
12%
15%
1%
4%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

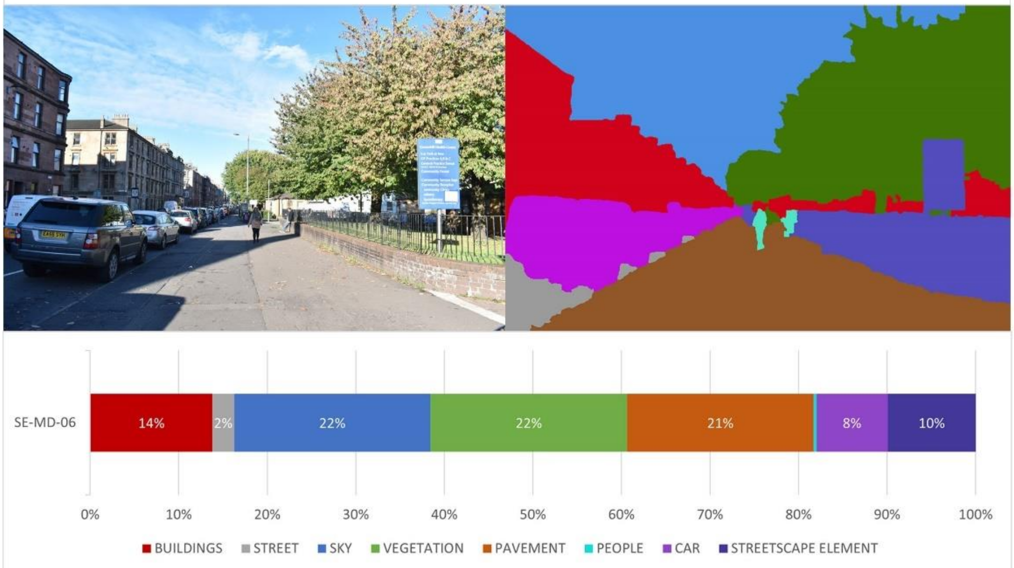

EE-MD-09
30%
12%
19%
15%
21%
1%
1%
3%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET% SKY% VEGETATION% PAVEMENT% PEOPLE% CAR% STREETSCAPE ELEMENT%

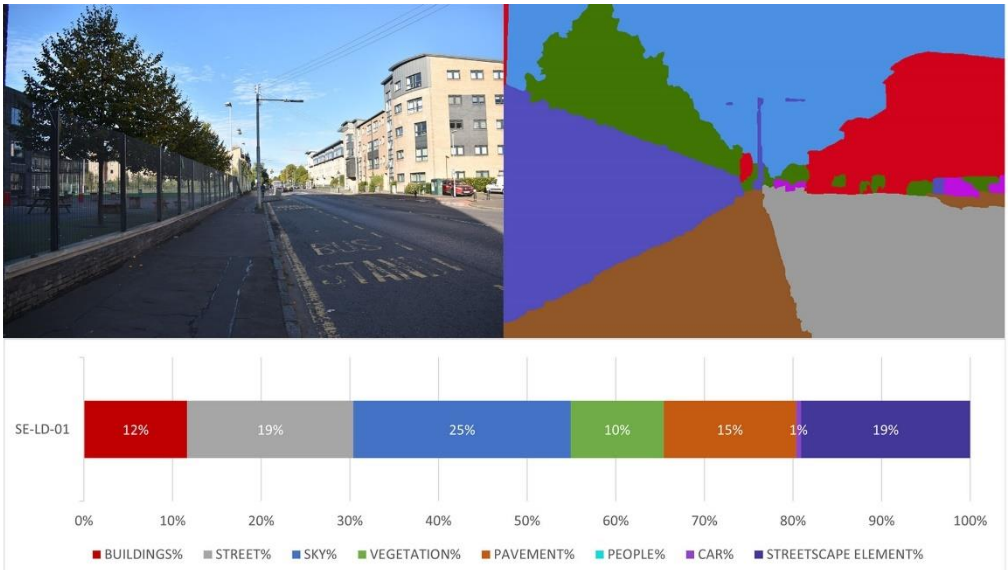

EE-MD-10
29%
10%
27%
1%
29%
3%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET% SKY% VEGETATION% PAVEMENT% PEOPLE% CAR% STREETSCAPE ELEMENT%

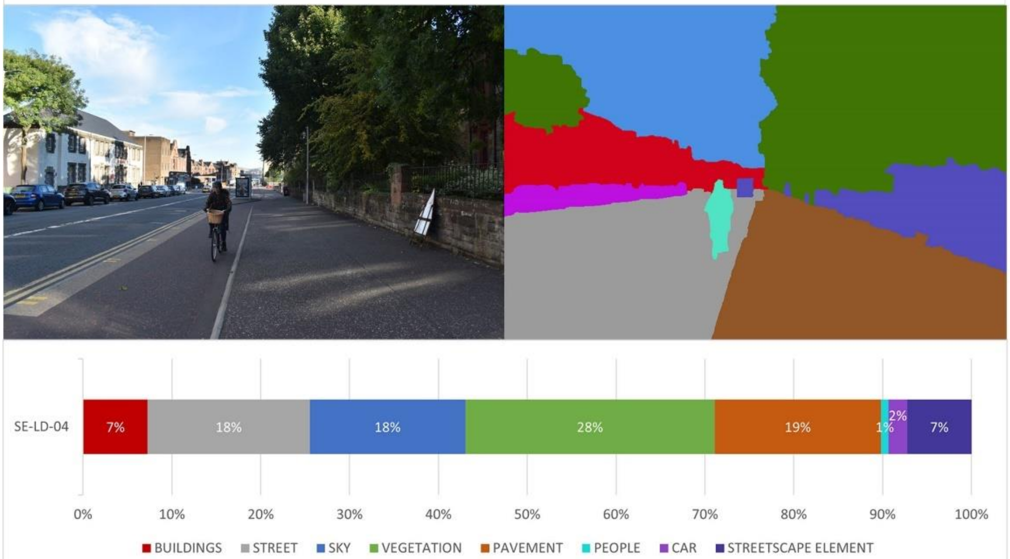

EE-MD-12
33%
20%
26%
3%
17%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET% SKY% VEGETATION% PAVEMENT% PEOPLE% CAR% STREETSCAPE ELEMENT%


SE-LD-09
7%
23%
24%
22%
18%
6%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


SE-MD-05
15%
1%
14%
19%
37%
7%
6%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%

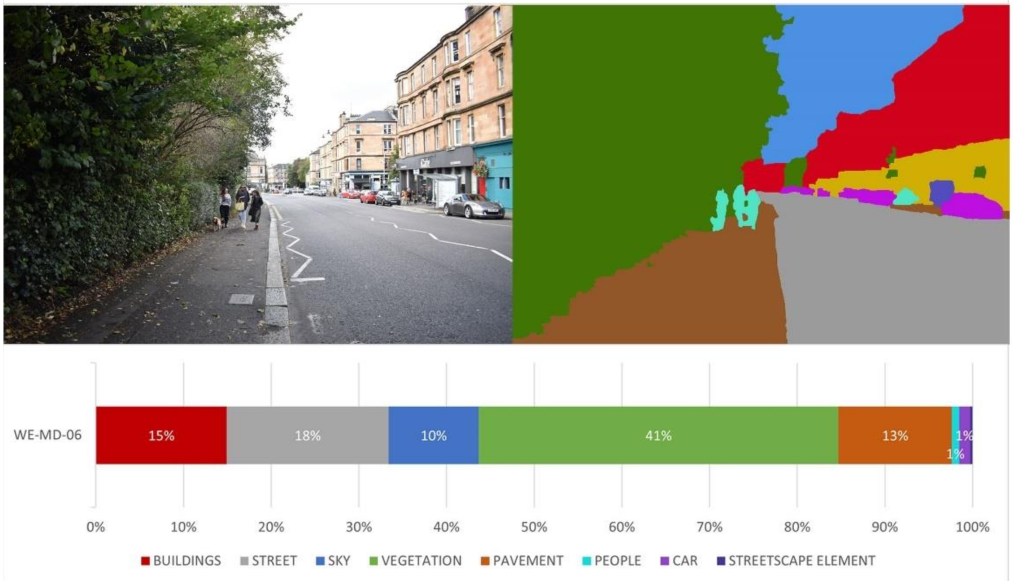

SE-MD-06
14%
2%
22%
22%
21%
8%
10%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


SE-LD-01
12%
19%
25%
10%
15%
1%
19%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%


SE-LD-04
7%
18%
18%
28%
19%
1%
2%
7%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

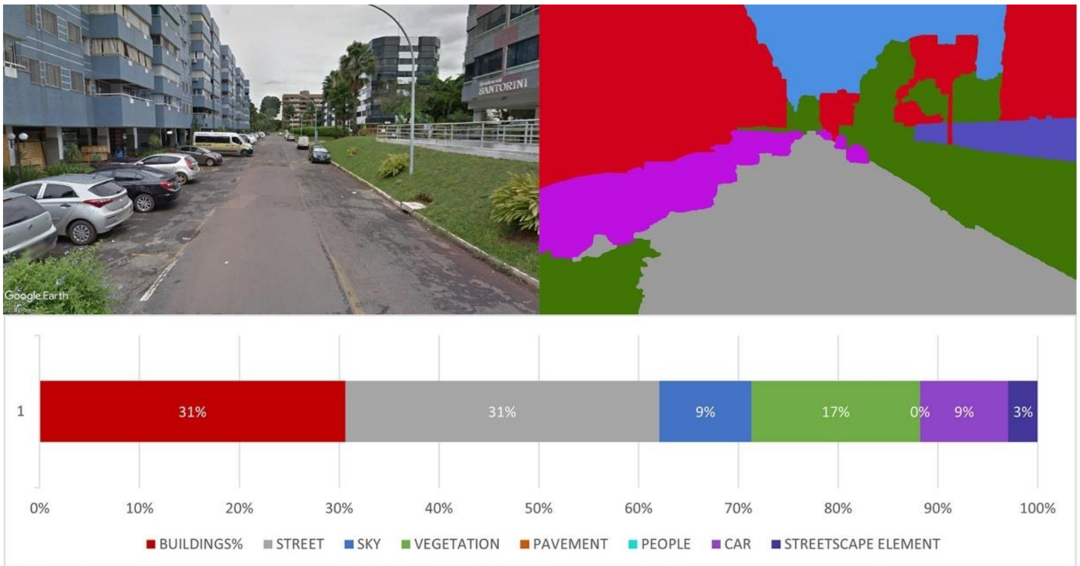

SE-LD-05
15%
10%
28%
11%
33%
2%
1%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

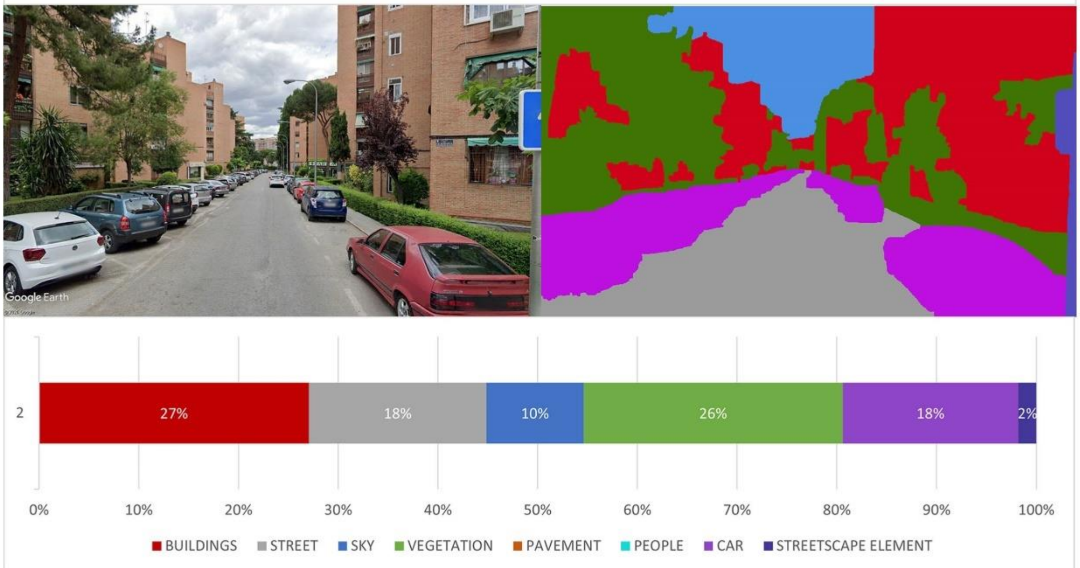

SE-MD-13
21%
21%
16%
20%
12%
2%
7%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

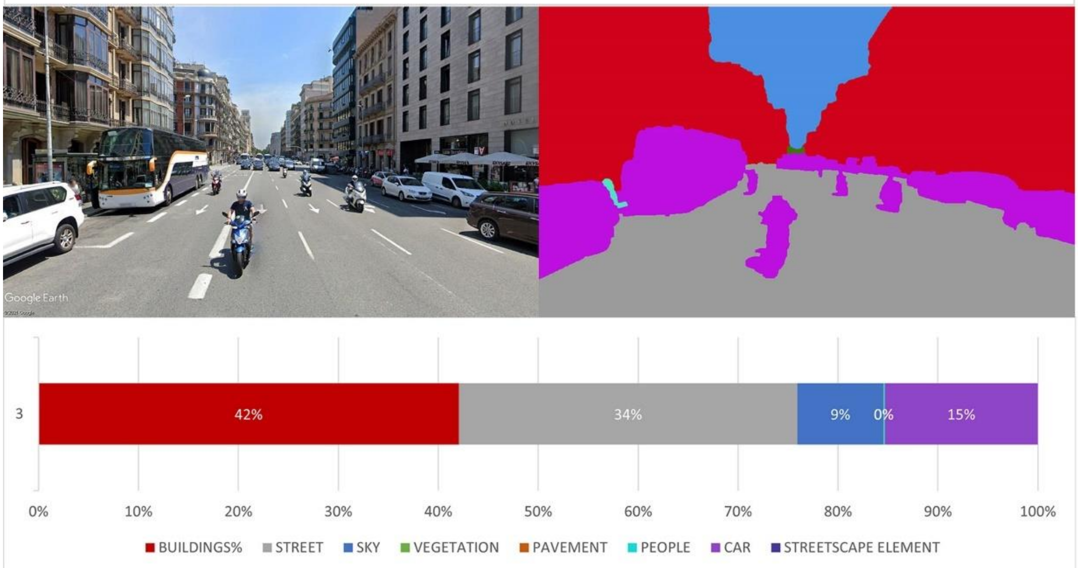

WE-MD-06
15%
18%
10%
41%
13%
1%
1%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

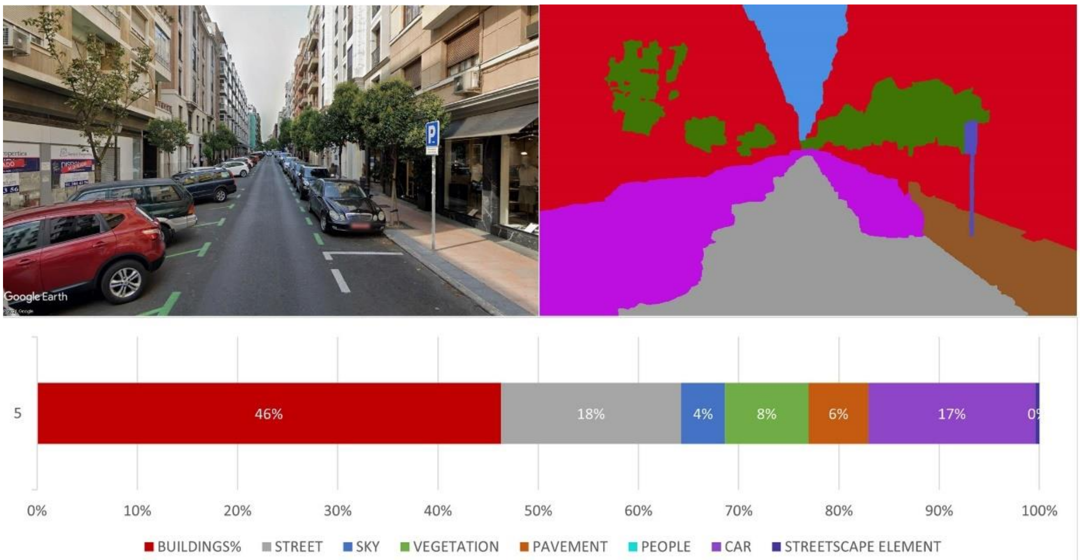

WE-MD-09
40%
9%
22%
1%
24%
1%
1%
3%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET%
SKY%
VEGETATION%
PAVEMENT%
PEOPLE%
CAR%
STREETSCAPE ELEMENT%

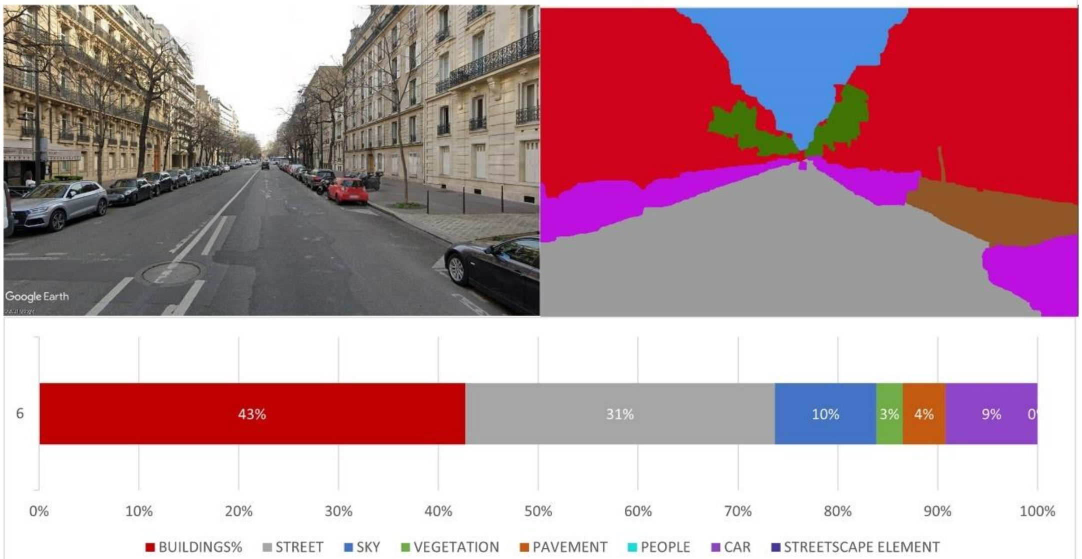
Image segmentation – Universal Illustrations
(Images ©2023 Google)

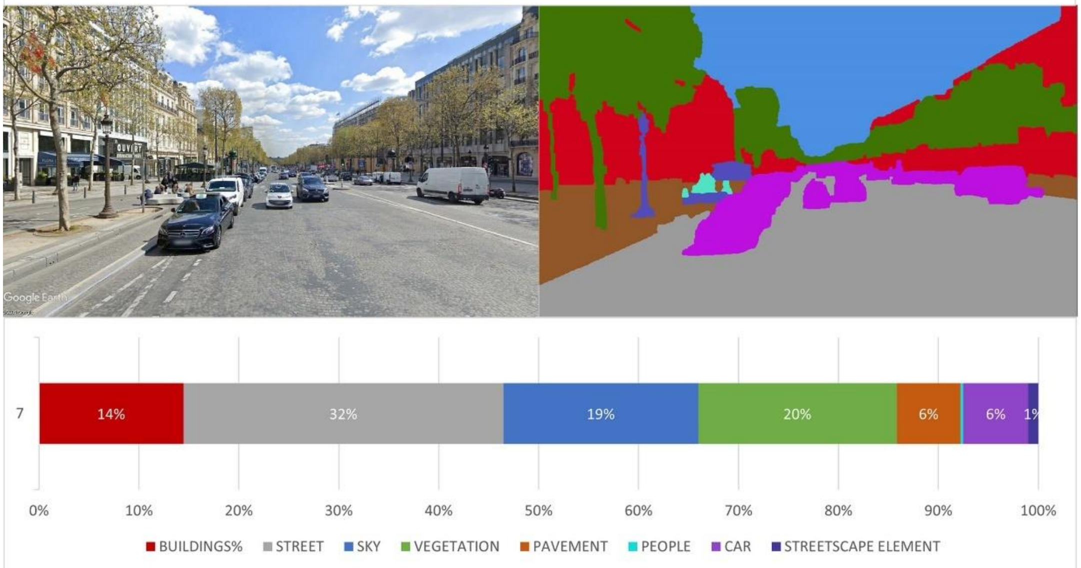




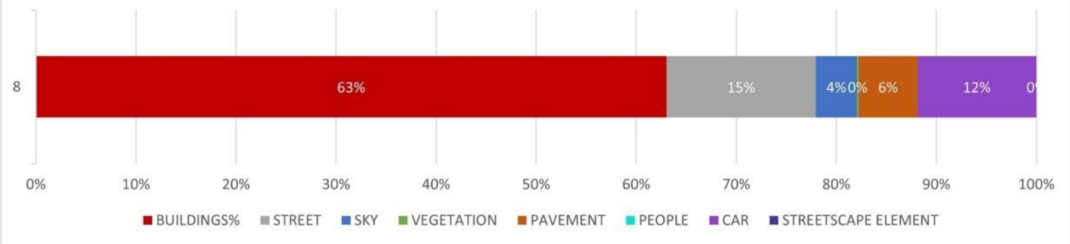


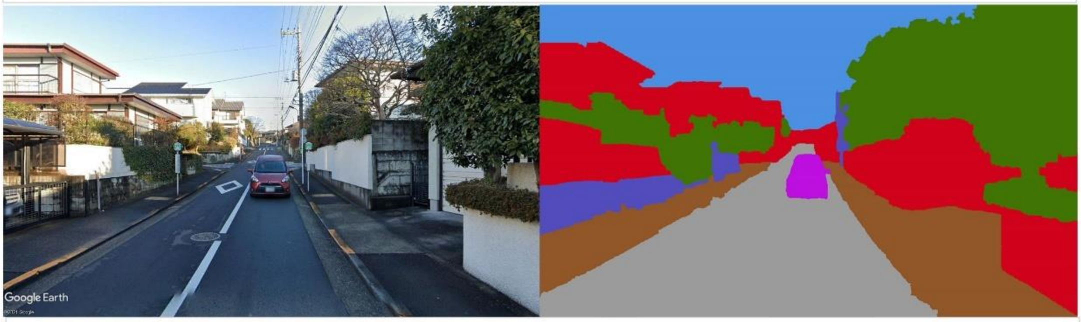

Google Earth
5
46%
18%
4%
8%
6%
17%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

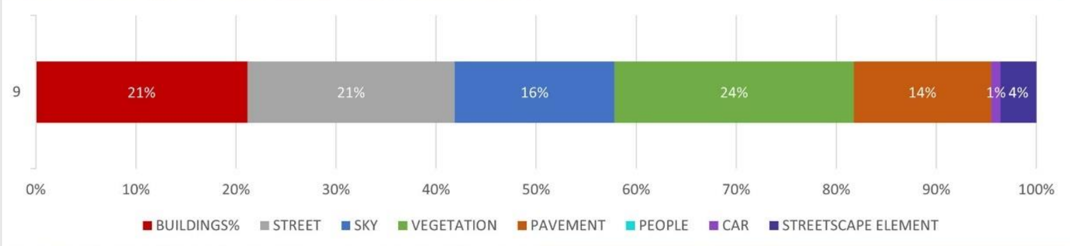

Google Earth
6
43%
31%
10%
3%
4%
9%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

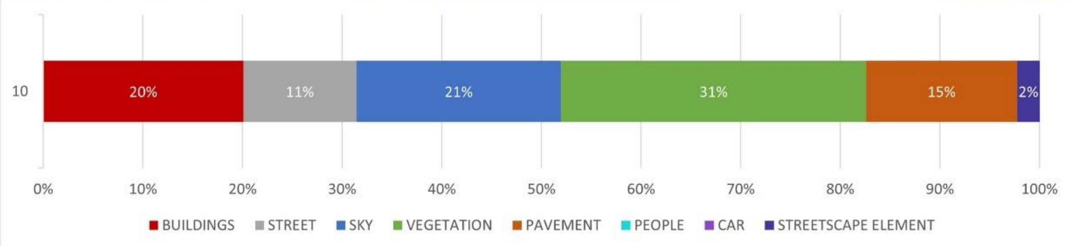

7
14%
32%
19%
20%
6%
6%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

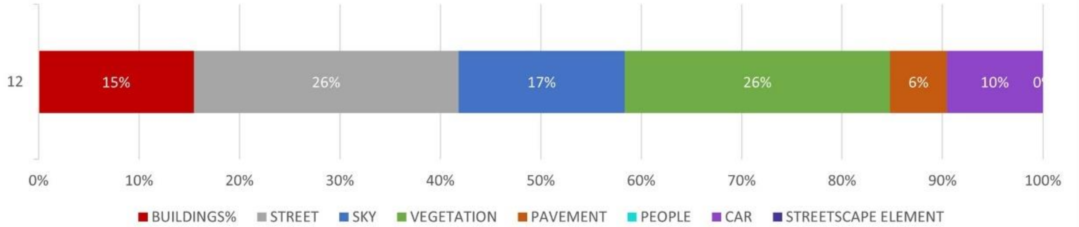

Google Earth

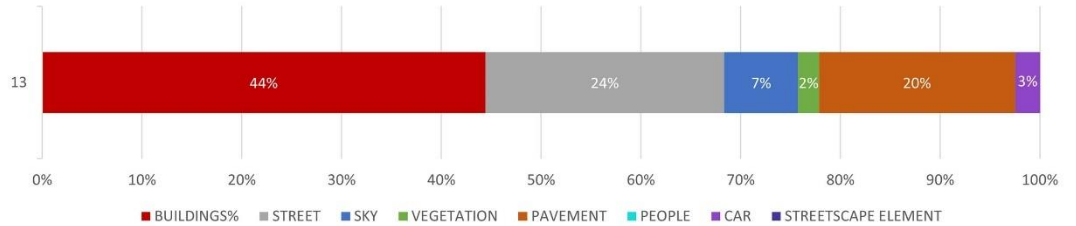

8
63%
15%
4%
0%
6%
12%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

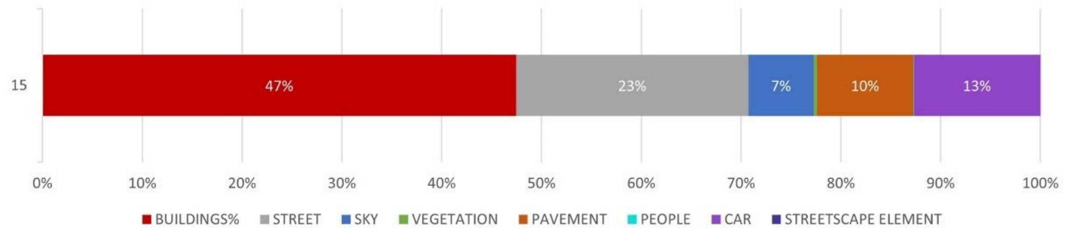

Google Earth

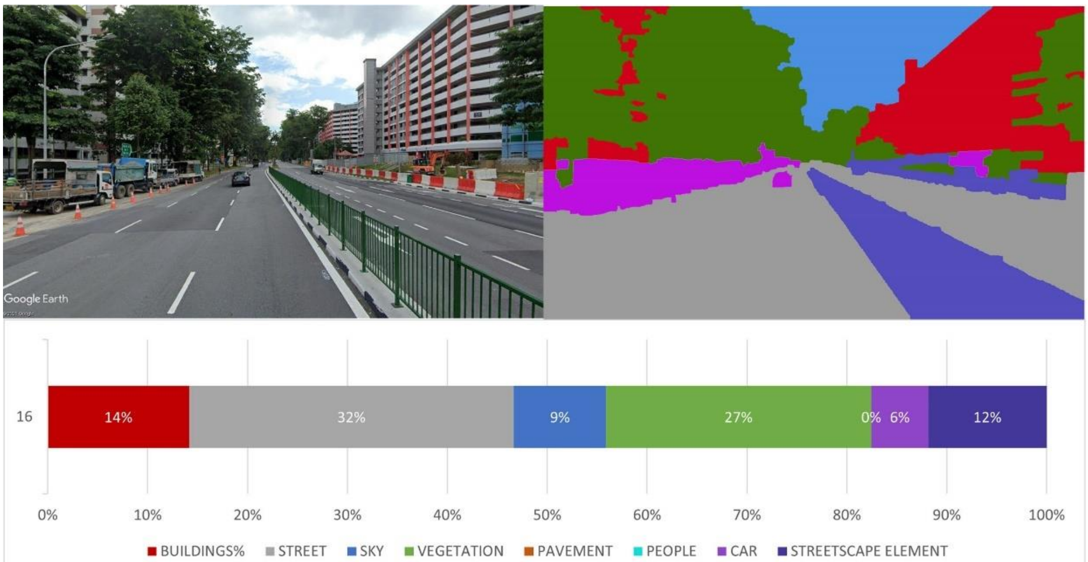

9
21%
21%
16%
24%
14%
1%
4%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS%
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

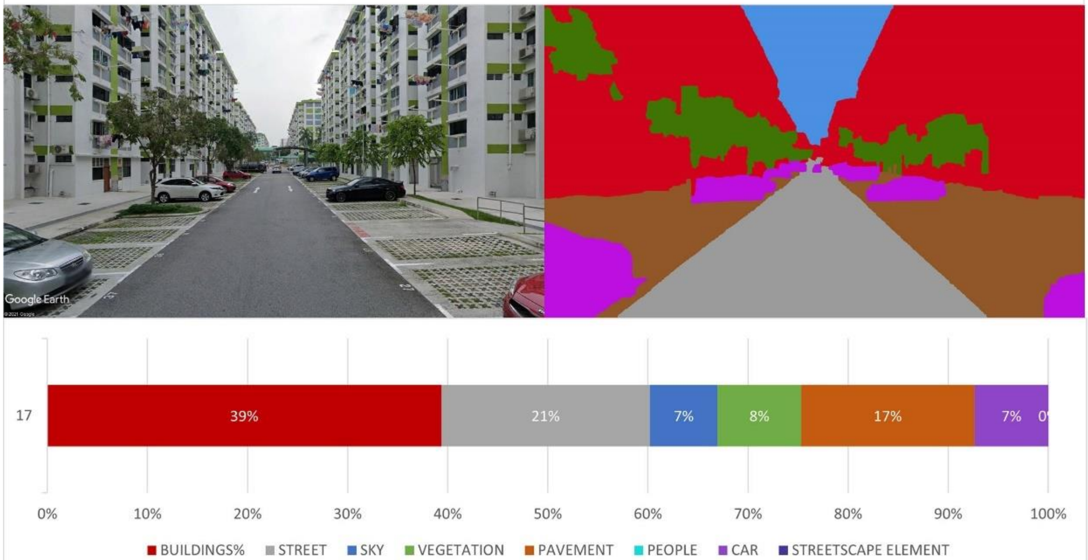

10
20%
11%
21%
31%
15%
2%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

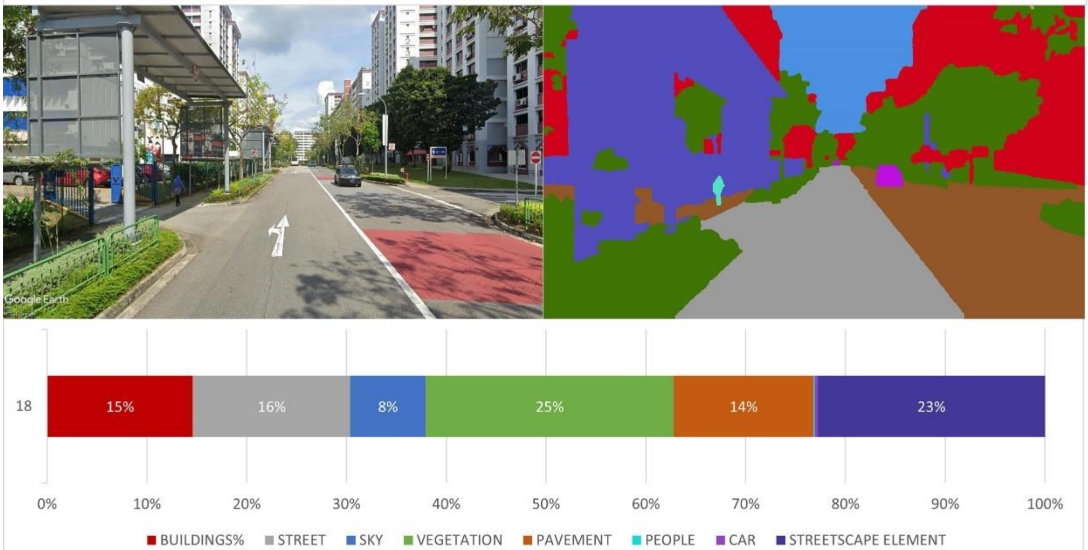

12
15%
26%
17%
26%
6%
10%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

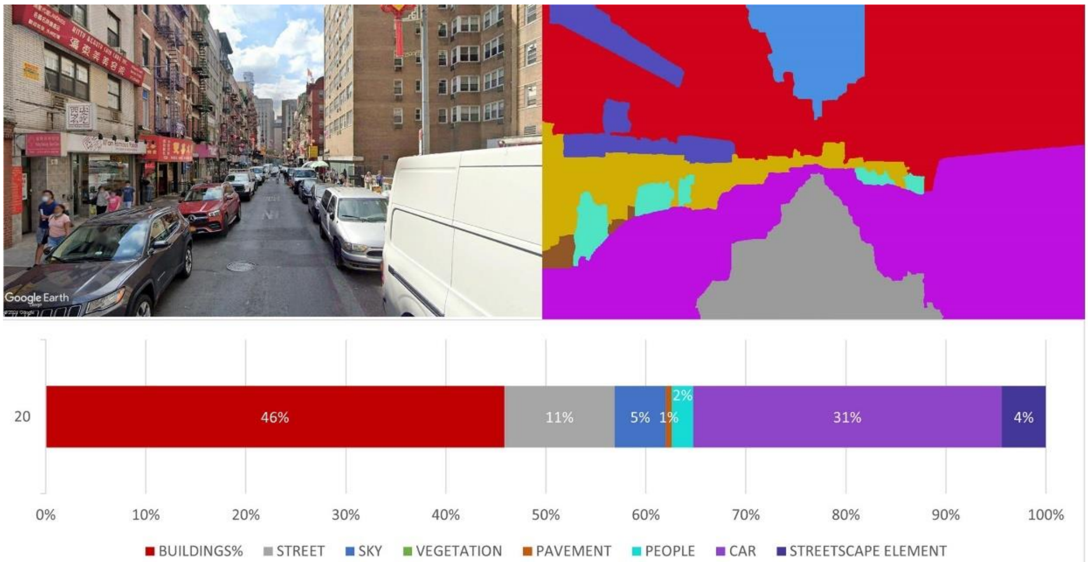

13
44%
24%
7%
2%
20%
3%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

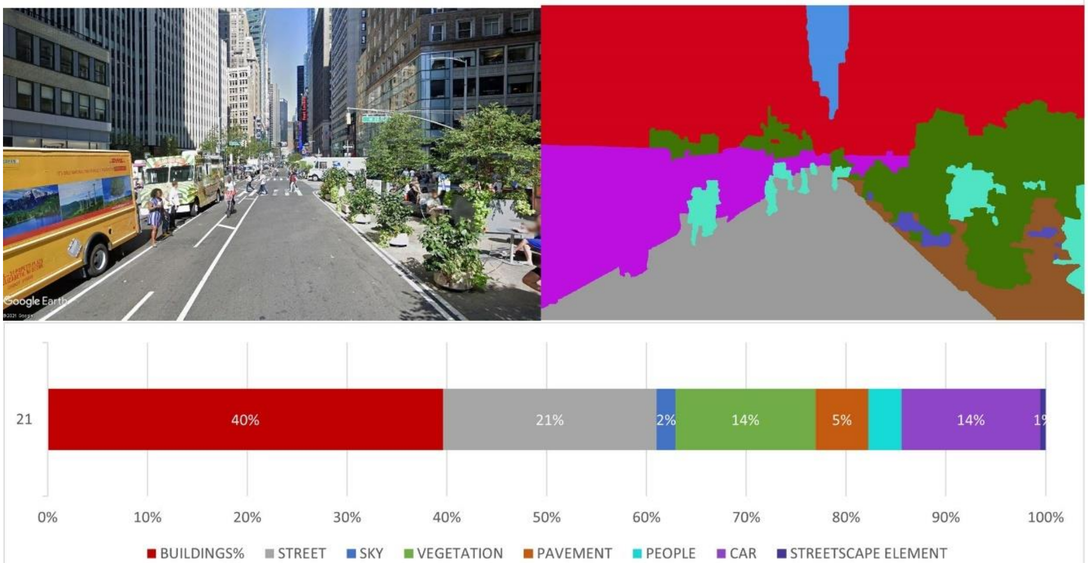

15
47%
23%
7%
10%
13%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

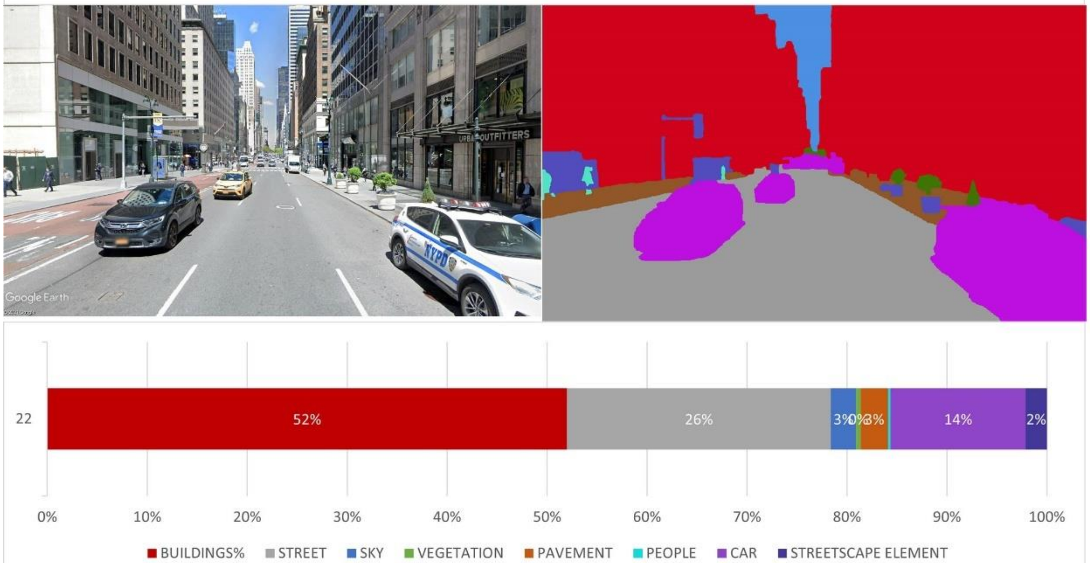

16
14%
32%
9%
27%
0%
6%
12%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

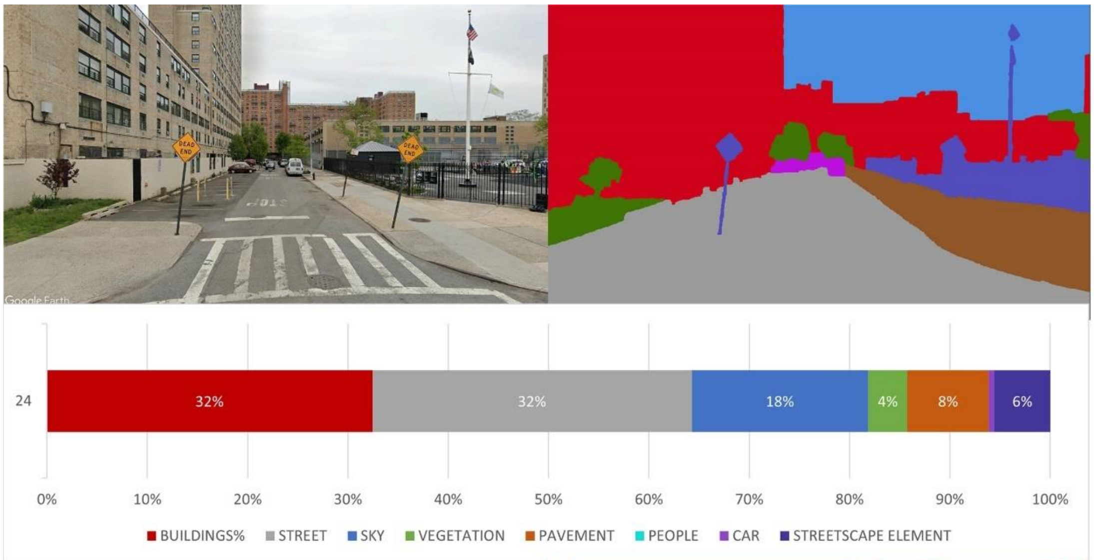

17
39%
21%
7%
8%
17%
7%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


18
15%
16%
8%
25%
14%
23%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


Google Earth
20
46%
11%
5%
1%
2%
31%
4%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

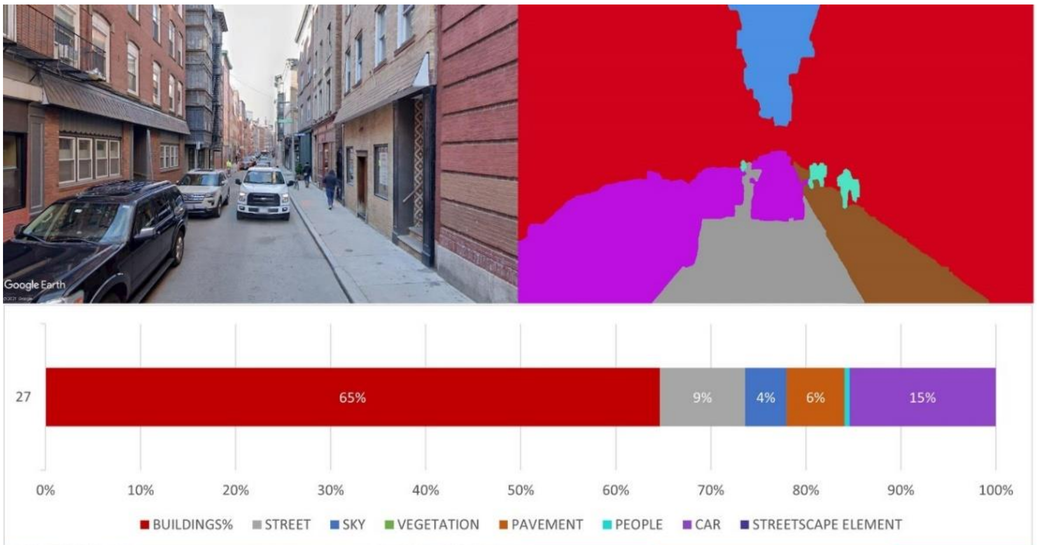

Google Earth
21
40%
21%
2%
14%
5%
14%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


Google Earth
NYPD
URBAN OUTFITTERS
22
52%
26%
3%
14%
2%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


24
32%
32%
18%
4%
8%
6%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


25
26%
39%
14%
14%
4%
1%
2%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

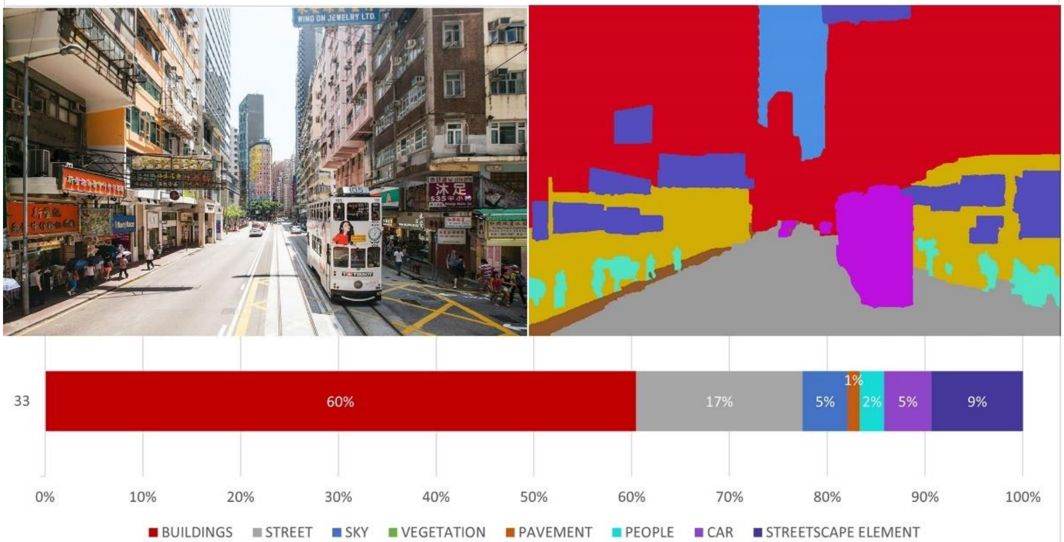

26
58%
12%
8%
0%
7%
13%
3%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

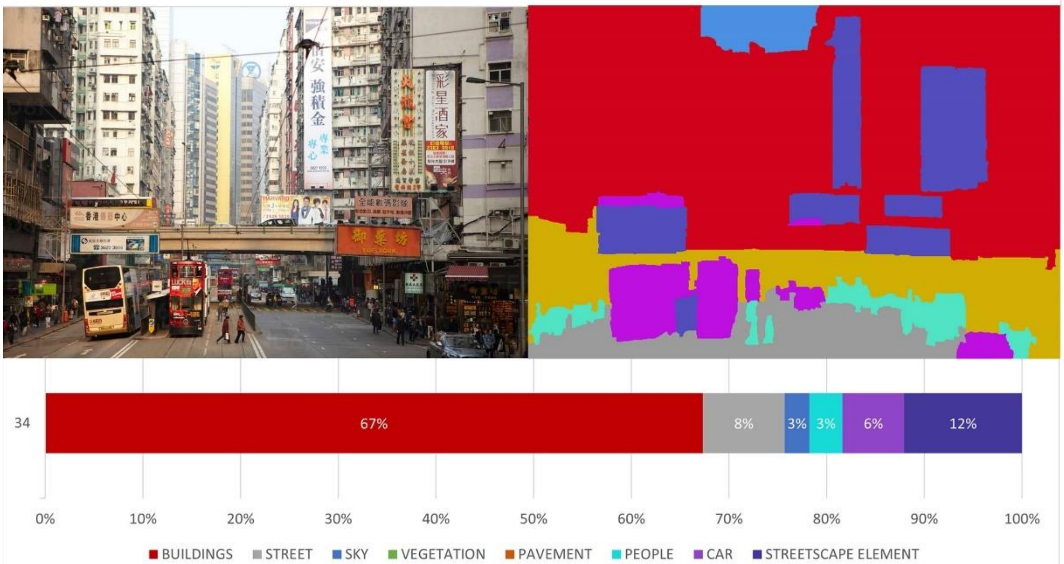

Google Earth
27
65%
9%
4%
6%
15%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


W 81 St
Google Earth
28
41%
35%
10%
4%
5%
4%
2%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT


Google Earth
29
20%
38%
4%
26%
4%
6%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
BUILDINGS% STREET SKY VEGETATION PAVEMENT PEOPLE CAR STREETSCAPE ELEMENT

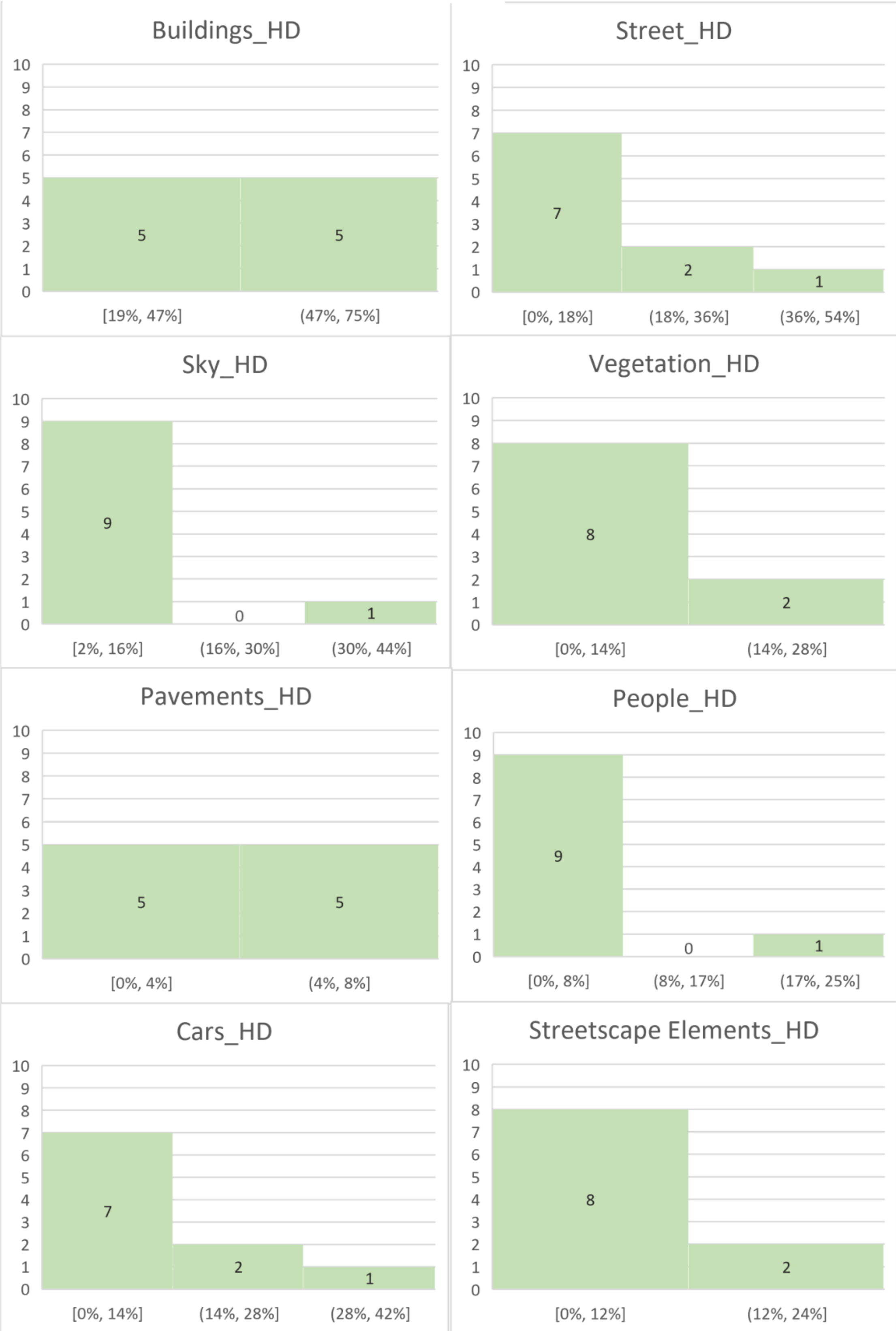

30
19%
32%
6%
3%
17%
23%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT


33
60%
17%
5%
1%
2%
5%
9%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

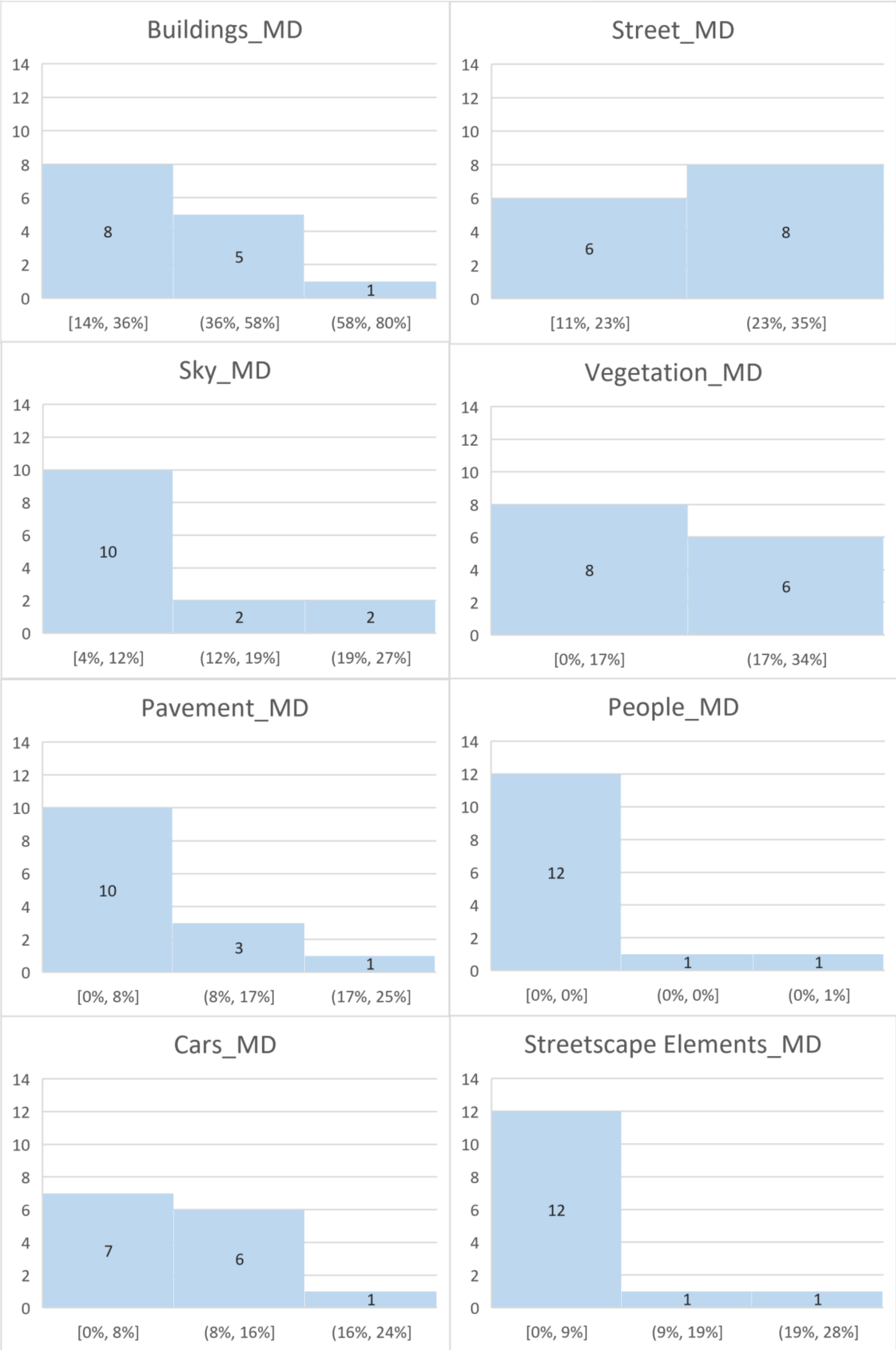

34
67%
8%
3%
3%
6%
12%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
BUILDINGS
STREET
SKY
VEGETATION
PAVEMENT
PEOPLE
CAR
STREETSCAPE ELEMENT

Histogram Analysis – Universal Illustrations

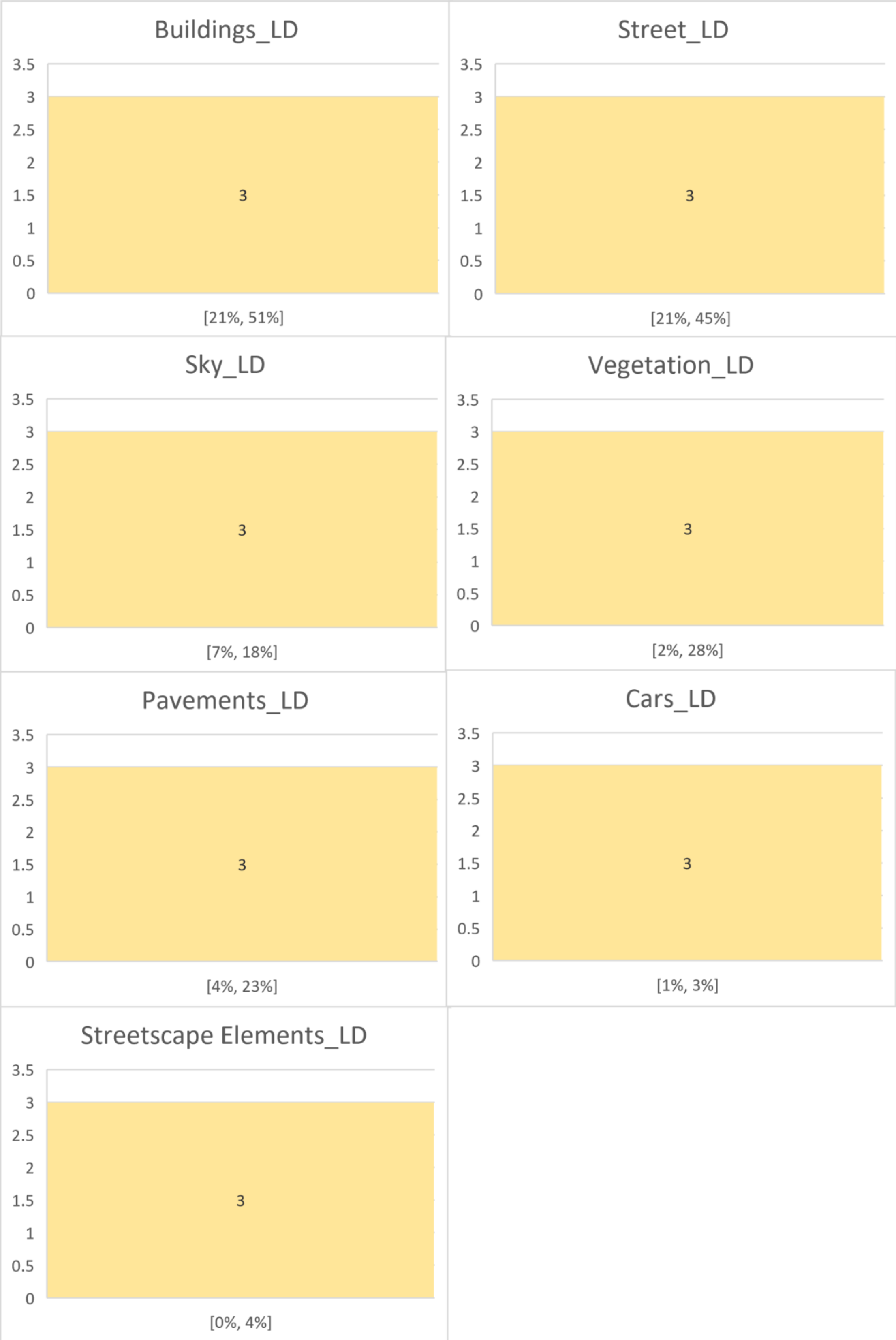
High Density - Universal Illustrations



Moderate Density - Universal Illustrations



Low Density - Universal Illustrations



Ethics Application Form
(Thumbnail images ©2023 Google)

OFFICE USE ONLY
UECREF
Date
Paper

University of Strathclyde Glasgow

Ethics Application Form

Please answer all questions

1. Title of the investigation
The Role of Urban Form in the Perception of Density
Please state the title on the PIS and Consent Form, if different: *N/A*

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)
Name: Dr. Ombretta Romice ☐ Professor ☒ Reader ☐ Senior Lecturer ☐ Lecturer ☐ Senior Teaching Fellow ☐ Teaching Fellow Department: Architecture Telephone: +44 (0)141 548 3006 E-mail: ombretta.r.romice@strath.ac.uk

3. Other Strathclyde investigator(s)
Name: Madhavi Prashant Patil Status (e.g. lecturer, post-/undergraduate): Postgraduate PhD Researcher Department: Architecture Telephone: +44 (0) 7593252546 E-mail: madhavi.patil@strath.ac.uk

4. Non-Strathclyde collaborating investigator(s) (where applicable)
Name: *N/A* Status (e.g. lecturer, post-/undergraduate): *N/A* Department/Institution: *N/A* If student(s), name of supervisor: *N/A* Telephone: *N/A* E-mail: *N/A* Please provide details for all investigators involved in the study: *N/A*

5. Overseas Supervisor(s) (where applicable)
Name(s): *N/A* Status: *N/A* Department/Institution: *N/A* Telephone: *N/A* Email: *N/A* I can confirm that the local supervisor has obtained a copy of the Code of Practice: Yes ☐ No ☐ Please provide details for all supervisors involved in the study: *N/A*

6. Location of the investigation
At what place(s) will the investigation be conducted *Glasgow – Scotland* *The fieldwork consists of self-clicked images or Google Street views, mainly two-point perspectives. The survey will be conducted online using a self-generated web application.*
If this is not on University of Strathclyde premises, how have you satisfied yourself that adequate Health and Safety arrangements are in place to prevent injury or harm? *N/A*

7. Duration of the investigation			
Duration(years/months):	3 months		
Start date (expected):	01/09/2020	Completion date (expected):	*01/12/2021*

8. Sponsor Please note that this is not the funder; refer to Section C and Annexes 1 and 3 of the Code of Practice for a definition and the key responsibilities of the sponsor.
Will the sponsor be the University of Strathclyde: Yes ☒ No ☐ If not, please specify who is the sponsor: *N/A*

9. Funding body or proposed funding body (if applicable)
Name of funding body: *N/A* Status of proposal – if seeking funding (please click appropriate box): ☐ In preparation ☐ Submitted

☐ Accepted
Date of submission of proposal: *N/A* Date of start of funding: *N/A*

10. Ethical issues

Describe the main ethical issues and how you propose to address them:

The investigation involves human participation, but no personal or sensitive information will be asked for. The identity of all participants will be kept anonymous.

11. Objectives of investigation (including the academic rationale and justification for the investigation) Please use plain English.

This research is investigating the human perception of density in Glasgow. The research on density so far focuses on the objective aspects of density. This investigation aims at understanding the subjective aspects related to density with special reference to urban form.

The data required for the investigation will be collected through online surveys to understand people perception of built landscape. Online surveys included two specific techniques 1. Multiple sorting task and 2. Repertory Grid Technique which require a minimum participation of 100 people. These techniques will be developed as web applications. Spatial analysis software's namely GIS and Python will be used for the deduction of results.

12. Participants

Please detail the nature of the participants:
Participants of all age groups will be considered for the survey. Participants will be selected irrespective of their profession, occupation, or education. A minimum of 100 participants are required for the survey.

Summarise the number and age (range) of each group of participants:
Number: Total – 100
Young Adults (18-34) - 40 numbers
Adult (35-54) - 20 numbers
Senior (55 and above) – 20 numbers
Moderated Participants (mixed ages groups) - 20 numbers.

Please detail any inclusion/exclusion criteria and any further screening procedures to be used:
N/A

13. Nature of the participants
Please note that investigations governed by the Code of Practice that involve any of the types of participants

listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.

Do any of the participants fall into a category listed in Section B1(b) (participant considerations) applicable in this investigation?: Yes ☐ No ☒
If yes, please detail which category (and submit this application to the UEC):
N/A

14. Method of recruitment

Describe the method of recruitment (see section B4 of the Code of Practice), providing information on any payments, expenses or other incentives.

Online surveys will be shared sent through emails and shared in specific groups.

Online zoom sessions will be conducted to record the experience of survey for a focused group (moderated participants) only.

15. Participant consent

Please state the groups from whom consent/assent will be sought (please refer to the Guidance Document). The PIS and Consent Form(s) to be used should be attached to this application form.

Consent will be obtained from all the participants within the online survey at the beginning of the survey after reading the Participant Information Sheet.

16. Methodology
Investigations governed by the Code of Practice which involve any of the types of projects listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval.

Are any of the categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation? ☐ Yes ☒ No
If 'yes' please detail: *N/A*

Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English.
The researcher will use surveys that will be shared online to collect data from people living in Glasgow to understand their perception of the built environment. An interactive session will also be conducted and recorded for a focused group of 20 participants to understand the experience of the survey. Two surveys are designed for the purpose of this research. The first survey is based on a technique used in subjective analysis known as the Multiple Sorting Task. The Second survey is another technique for identifying personal constructs known as Repertory Grid Technique. The Second Survey will be followed by the analysis of the first survey, hence the time duration to carry out both the surveys in around 3 months.

What specific techniques will be employed and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measures charts as an Appendix to this application. Please include questionnaires, interview schedules or any other non-standardised method of data collection as appendices to this application.

The first survey is designed as an image sorting task, sample od which is attached in the appendix.
The secondary survey is also a task where participants are to rate the images using a Likert Scale. Sample of this survey is also attached in the mail.

Where an independent reviewer is not used, then the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? Yes ☐ No ☒
If yes, please provide the name and contact details of the independent reviewer:
N/A

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to carry out the proposed research in accordance with the written methodology.

The researcher conducted interviews and surveys before in Mumbai as a part of her master's degree research.

18. Data collection, storage, and security

How and where are data handled? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify.

The data collected online for the surveys will be anonymous. The survey contains fields to enter the name and email so in case they wanted to participate in further studies and know about the results. The information about the focused study group will be kept confidential and will be stored in a separate location on the university storage cloud.

Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use:

All the data collected from the surveys will be stored on the university storage cloud in Excel formats and on the link below as raw data:
https://www.mongodb.com/cloud/atlas
The back up of the same will be kept on Google Drive and Strathclyde OneDrive account. The responses will be stored for further research however the all the personal data will be destroyed after the completion of studies.

Will anyone other than the named investigators have access to the data? Yes ☐ No ☒
If 'yes' please explain:
N/A

19. Potential risks or hazards
Briefly describe the potential Occupational Health and Safety (OHS) hazards and risks associated with the investigation: *Since all the surveys are conducted online there are not any expected health and safety hazards or risks associated.*
Please attach a completed OHS Risk Assessment (S20) for the research. Further Guidance on Risk Assessment and Form can be obtained on safety: Risk Assessment Forms (strath.ac.uk) See form: https://safetysystems.strath.ac.uk/ra.php?ID=4675

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?
The raw data and the analysis will be an essential part of the PhD research and the results will be published as journal papers.

21. How will the outcomes of the study be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
The findings will be published based on the cumulative analysis of the surveys. There will be no direct or indirect reference to the persons from whom the data is collected.

Checklist	Enclosed	N/A
Participant Information Sheet(s)	☒	☐
Consent Form(s)	☒	☐
Sample questionnaire(s)	☒	☐
Sample interview format(s)	☒	☐
Sample advertisement(s)	☐	☒
OHS Risk Assessment (S20)	☐	☒
Any other documents (please specify below)	☐	☒

22. Chief Investigator and Head of Department Declaration
Please note that unsigned applications will not be accepted and both signatures are required

I have read the University's Code of Practice on Investigations involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed before all approvals required have been obtained.

Signature of Chief Investigator

Please also type name here: Dr.Ombretta Romice

I confirm I have read this application, I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department

Please also type name here Prof. Timothy Sharpe

Date: /9 /21

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship

This application requires the University to sponsor the investigation. This is done by the Head of Department for all DEC applications with exception of those that are externally funded and those which are connected to the NHS (those exceptions should be submitted to R&KES). I am aware of the implications of University sponsorship of the investigation and have assessed this investigation with respect to sponsorship and management risk. As this particular investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and there are no management risks posed by the investigation.

If not applicable, tick here ☒

Signature of Head of Department

Please also type name here

Date: / /

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance

The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: ▪ treating or preventing disease or diagnosing disease or ▪ ascertaining the existence degree of or extent of a physiological condition or ▪ assisting with or altering in any way the process of conception or ▪ investigating or participating in methods of contraception or ▪ inducing anaesthesia or ▪ otherwise preventing or interfering with the normal operation of a physiological function or ▪ altering the administration of prescribed medication.	*No*

If "**Yes**" please go to **Section A (Clinical Trials)** – all questions must be completed
If "**No**" please go to **Section B (Public Liability)** – all questions must be completed

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial; ii. known to be pregnant at the time of the trial	

*If "**Yes**" the UEC should refer to Finance*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT; iv. Venepuncture (withdrawal of blood); v. Muscle biopsy; vi. Measurements or monitoring of physiological processes including scanning; vii. Collections of body secretions by non-invasive methods; viii. Intake of foods or nutrients or variation of diet (excluding administration of drugs).	

*If "**No**" the UEC should refer to Finance*

Will the proposed research take place within the UK?	

*If "**No**" the UEC should refer to Finance*

Title of Research	*Sustainable Management of Public Parks in Cairo*
Chief Investigator	*Prof. Branka Dimitrijevic*
Sponsoring Organisation	*University of Strathclyde*
Does the proposed research involve:	
a) investigating or participating in methods of contraception?	***No***
b) assisting with or altering the process of conception?	***No***
c) the use of drugs?	***No***
d) the use of surgery (other than biopsy)?	***No***
e) genetic engineering?	***No***
f) participants under 5 years of age(other than activities i-vi above)?	***No***
g) participants known to be pregnant (other than activities i-vi above)?	***No***
h) pharmaceutical product/appliance designed or manufactured by the institution?	***No***
i) work outside the United Kingdom?	***Yes***

If **"YES"** to **any** of the questions a-i please also complete the **Employee Activity Form** (attached).
If **"YES"** to **any** of the questions a-i, <u>and this is a follow-on phase</u>, please provide details of SUSARs on a separate sheet.

*If "**Yes**" to any of the questions a-i then the UEC/DEC/SEC should refer to Finance (insurance-services@strath.ac.uk).*

Section B (Public Liability)	
Does the proposed research involve :	
a) aircraft or any aerial device	***No***
b) hovercraft or any water borne craft	***No***
c) ionising radiation	***No***
d) asbestos	***No***
e) participants under 5 years of age	***No***
f) participants known to be pregnant	***No***
g) pharmaceutical product/appliance designed or manufactured by the institution?	***No***
h) work outside the United Kingdom?	***No***

*If **"YES"** to any of the questions the UEC/DEC/SEC should refer to Finance (insurance-services@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	N/A
Are Medical Practitioners involved in the project?	N/A
If YES, will Medical Practitioners be covered by the MDU or other body?	N/A

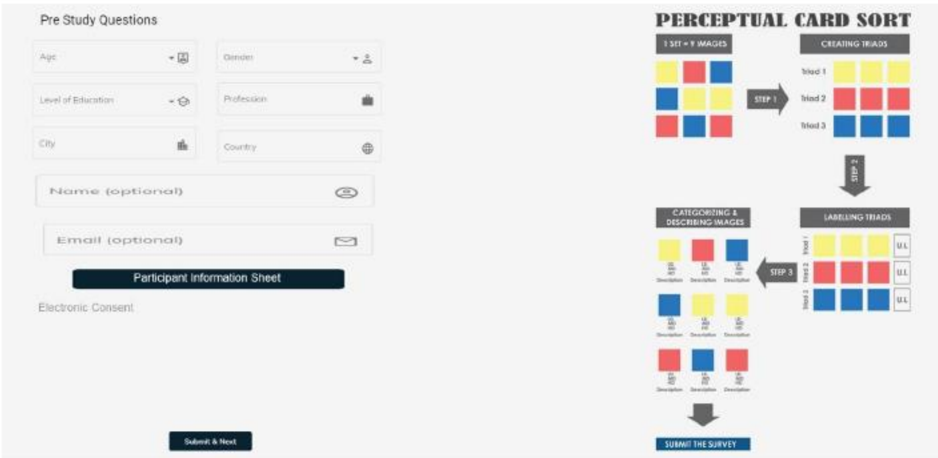
This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases it may be more appropriate to refer to a group of persons rather than individuals).

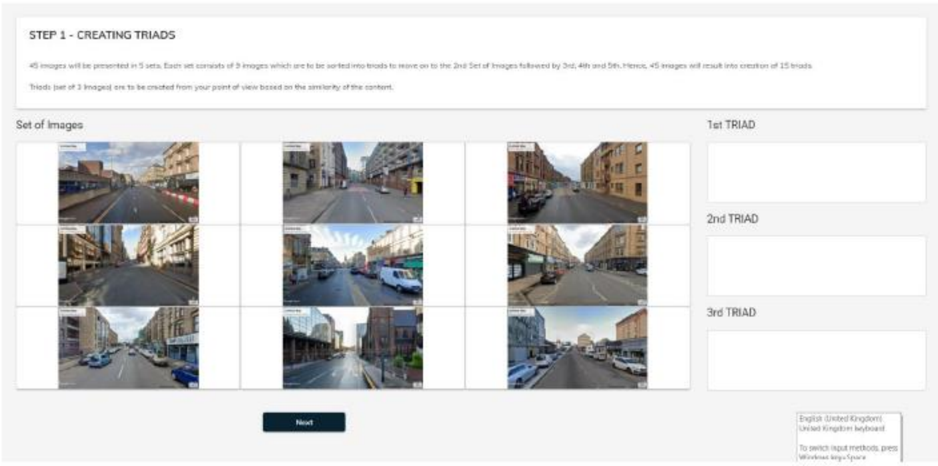
Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No

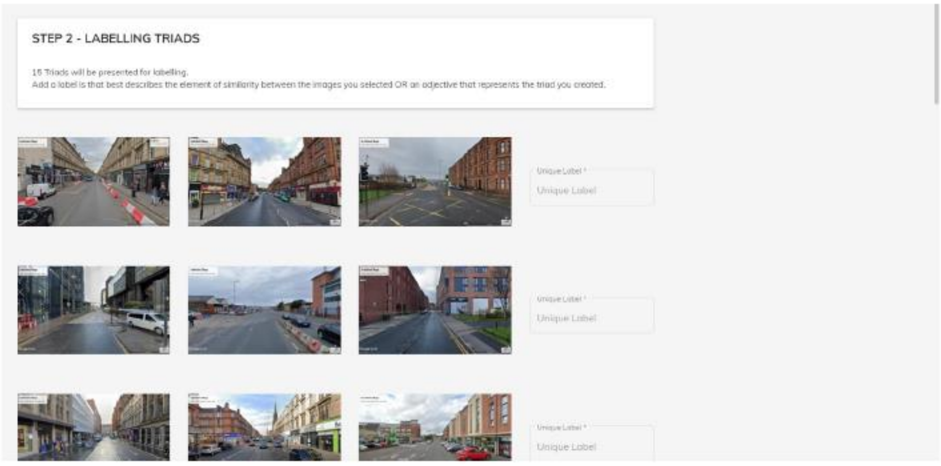
		Yes / No
		Yes / No

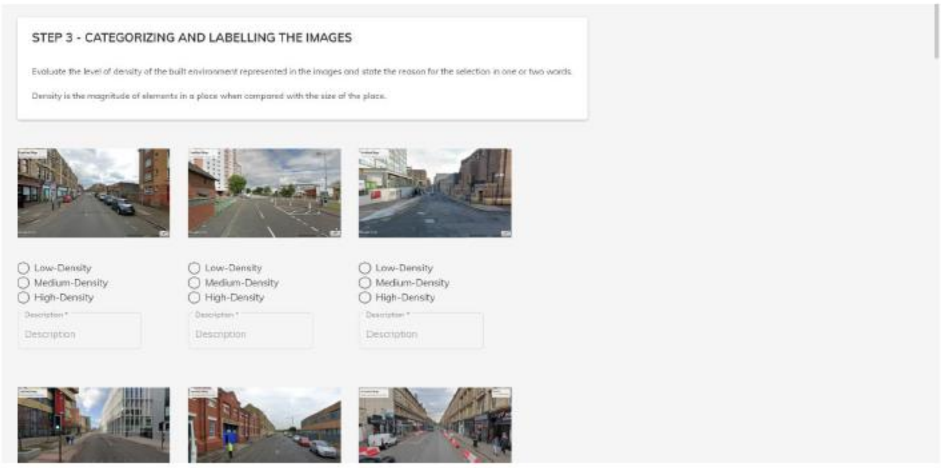
Please provide any further relevant information here:

Sample survey 1- Multiple Sorting Task

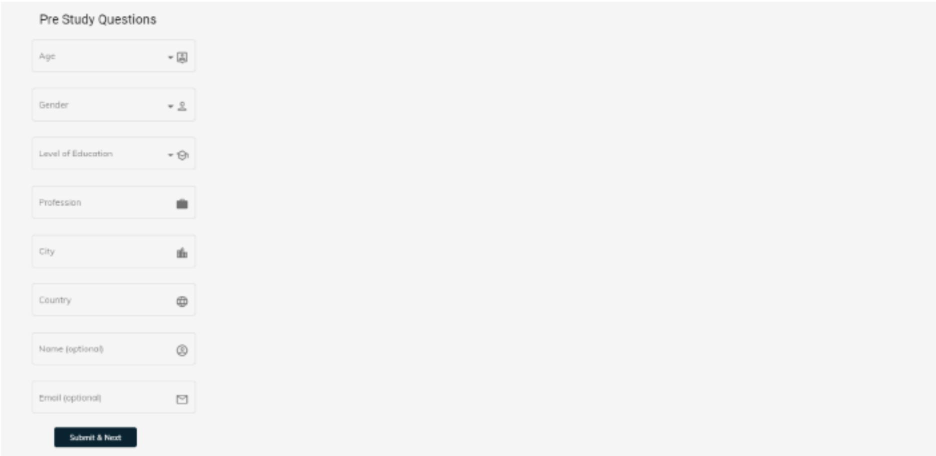





STEP 2 - LABELLING TRIADS
15 Triads will be presented for labelling.
Add a label is that best describes the element of similarity between the images you selected OR an adjective that represents the triad you created.
Unique Label *
Unique Label
Unique Label *
Unique Label
Unique Label *
Unique Label


STEP 3 - CATEGORIZING AND LABELLING THE IMAGES
Evaluate the level of density of the built environment represented in the images and state the reason for the selection in one or two words.
Density is the magnitude of elements in a place when compared with the size of the place.
Low-Density
Medium-Density
High-Density
Description *
Description
Low-Density
Medium-Density
High-Density
Description *
Description
Low-Density
Medium-Density
High-Density
Description *
Description

Sample survey 2- Repertory Grid Technique


Pre Study Questions

Age

Gender

Level of Education

Profession

City

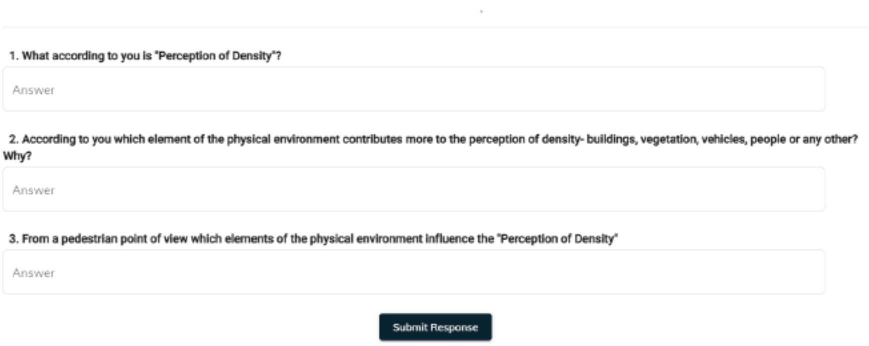
Country

Name (optional)

Email (optional)

Submit & Next

RGT - Part 1


1. What according to you is "Perception of Density"?

Answer

2. According to you which element of the physical environment contributes more to the perception of density- buildings, vegetation, vehicles, people or any other? Why?

Answer

3. From a pedestrian point of view which elements of the physical environment influence the "Perception of Density"

Answer

Submit Response

RGT – Part 2


a


b


c

Categories	Constructs	Emergent Pole				Implicit Pole
			a	b	c	
Streetscape	Street Length	Continuous				Interrupted
	Vegetation	Present				Absent

Participant Information Sheet

Name of department: Architecture
Title of the study: The Role of Urban Form in the Perception of Density

Invitation
Hello! You are being invited to take part in a research study conducted by me Madhavi Patil, a PhD Student at the University of Strathclyde, Glasgow, Scotland.
Before you decide to participate, it is important that you understand the purpose and scope of the study. Please take time to read the following information carefully and decide whether you wish to take part. Thank you for reading this.

Research Project Title
The role of Urban Form in the Perception of Density

Research Purpose
The purpose of this research is to determine the indicators of *urban form* that influence the perception of density and to be able to alter or design the *urban form* to achieve optimum density while maintaining a positive perception.

Why have I been Chosen?
You have been chosen firstly because, every individual has a unique ability of perceiving things differently and your response is the key to interpret the subjective aspects within the study. Secondly, for your experience of living in Glasgow as the areas chosen for field study are within the limits of Glasgow.

Do I have to take part?
Participation in the study is voluntary and you can withdraw at any time without giving a reason. However, you participation does not involve any risks as you are not asked for any personal information revealing your identity.

What do I have to do?
The study is designed as an online card sorting task. The step wise instructions for the task will be presented before you start every step. You will be asked to complete the task which we estimate will take you around 20 mins.

Who will have access to the information?
The information collected in the task will be accessed only by the investigators.

Will my participation in this research be confidential?
All the information collected in this study will be kept strictly confidential. Any data collected about you in the online task will be stored online in a form protected by passwords and other relevant security processes. You will not be identified in any reports or publications.

Where will the information be stored and for how long?
The information will be stored on University Cloud and will be available throughout the research period.

Will I be recorded and how will the recorded media be used? (For Moderated Participants)

You will be asked to take the task online in a zoom session and asked to think out loud so that the experience of taking the task can be recorded. These recordings will be accessed by the investigators only and your identity will be kept strictly confidential.
If you do decide to take part, you will be able to keep a copy of this information sheet and you should indicate your agreement to the online consent form.

What will happen to the results of the research project?
The results of the research will be published. You will not be identified in any report or publication. If you would like to find out about the completed research and receive the feedback, please provide your contact details to me during the interview process.

Researcher Details	**Name**	Madhavi Prashant Patil PhD Student at the Department of Architecture, Faculty of Engineering, University of Strathclyde
	Telephone	+44 7593252546
	Email	madhavi.patil@strath.ac.uk
Chief Investigator details:	**Name**	Dr.Ombretta Romice Reader, Senior Lecturer, Urban Design Studies Unit, Department of Architecture, Faculty of Engineering, University of Strathclyde

This research was granted ethical approval by the University of Strathclyde Ethics Committee.

If you have any questions/concerns, during or after the research, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow
G1 1QE
Telephone: +44 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form

Name of department : **Architecture**
Title of the study : **The Role of Urban Form in the Perception of Density**

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request. This includes the following personal data:
    - audio recordings of interviews that identify me;
    - my personal information from transcripts.
- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio recorded as part of the project
- I consent to remain anonymous at the final research papers

(PRINT NAME)	
Signature of Participant:	Date:

References

Adolph, K.E. and Kretch, K.S. (2015) 'Gibson's Theory of Perceptual Learning', in *International Encyclopedia of the Social & Behavioral Sciences*. Elsevier, pp. 127–134. Available at: https://doi.org/10.1016/B978-0-08-097086-8.23096-1.

AECOM (2016) 'Townscape and Visual Effects', *Stamford Bridge Grounds Redevelopment: Environmental Statement Part 2*, 2015.

Aiden, Boland and Evron (1988) *UC Berkley, College of Environmental Design*.

Alexander, C. (1978) *A Pattern Language: Towns, Buildings, Construction*. OUP USA (Center for Environmental Structure Series).

Alexander, E.R. (1993) 'Density Measures: A Review and Analysis', *Journal of Architectural and Planning Research*, 10(3), pp. 181–202. Available at: http://www.jstor.org/stable/43028746.

Alexander, E.R., Reed, K.D. and Murphy, P. (1988) *Density Measures and Their Relation to Urban Form*, *Center for Architecture and Urban Planning Research Books*. Publications in Architecture and Urban Planning. Available at: https://dc.uwm.edu/caupr_mono/37.

Altman, I. (1975) *The Environment and Social Behavior: Privacy, Personal Space, Territory, Crowding*. Brooks/Cole Publishing Company.

Altman, I. and Chemers, M.M. (1984) *Culture and Environment*. Cambridge University Press (Brooks/Cole basic concepts in environment and behavior series).

Alyari, M. (2018) 'Role of environmental psychology in strategic development of urban public spaces based on aesthetic needs of citizens', *Journal of Urban Design and Mental Health* [Preprint]. Available at: https://www.urbandesignmentalhealth.com/edition-5.html (Accessed: 15 July 2023).

Angel, S., Lamson-Hall, P. and Blanco, Z.G. (2021) 'Anatomy of density: measurable factors that constitute urban density', *Buildings and Cities*, 2(1), pp. 264–282. Available at: https://doi.org/10.5334/bc.91.

Appleyard, D. (1971) *The View from the Road*. Mit.

Appleyard, D., Gerson, M.S. and Lintell, M. (1981) *Livable Streets*. University of California Press (Urban studies : planning).

Appleyard, D. and Lintell, M. (1972) 'The Environmental Quality of City Streets: The Residents' Viewpoint', *Journal of the American Planning Association*, 38(2), pp. 84–101. Available at: https://doi.org/10.1080/01944367208977410.

Araldi, A. and Fusco, G. (2016) 'Urban Form from the Pedestrian Point of View : Spatial Patterns on a Street Network'.

Aung, A.M.N. (2020) 'Relationship Between Enclosure Ratio and Emotional Experience on Shwedagon Complex', *International Journal for Innovative Research in Multidisciplinary Field*, pp. 219–225.

Aurora, F.P.J.M.A.S.O.A.D. (2015) *Why Density?* a+t architect publishers.

Baum, A. and Koman, S. (1976) 'Differential response to anticipated crowding: Psychological effects of social and spatial density', *Journal of Personality and Social Psychology*, 34(3), pp. 526–536. Available at: https://doi.org/10.1037/0022-3514.34.3.526.

Beck *et al.* (1987) *UC Berkley, College of Environmental Design*.

Bergdoll, J.R. and Williams, R.W. (1990) 'Density Perception on Residential Streets', *Berkeley Planning Journal*, 5(1). Available at: https://doi.org/10.5070/bp35113131.

Berggren, C.C. (2017) *Urban Density and Sustainability*, *Smart Cities Collective*. Available at: https://www.smartcitiesdive.com/ex/sustainablecitiescollective/urban-density-and-sustainability/241696/ (Accessed: 27 June 2023).

Berghauser Pont, M. *et al.* (2021) 'Systematic review and comparison of densification effects and planning motivations', *Buildings and Cities*, 2(1), p. 378. Available at: https://doi.org/10.5334/bc.125.

Berghauser Pont, M., Haupt, P. and D'Laine, C. (2010) *Spacematrix : space, density and urban form*.

Berghauser Pont, M.Y. *et al.* (2020) 'A systematic review of the scientifically demonstrated effects of densification', *IOP Conference Series: Earth and Environmental Science*, 588(5). Available at: https://doi.org/10.1088/1755-1315/588/5/052031.

Bobkova, E., Marcus, L. and Pont, M.B. (2017) 'Multivariable measures of plot systems: Describing the potential link between urban diversity and spatial form based on the spatial capacity concept.', *Proceedings - 11th International Space Syntax Symposium, SSS 2017*, (July), pp. 47.1-47.15.

Boeing, G. (2018) 'Measuring the Complexity of Urban Form and Design', *Urban Design International*, 23, pp. 281–292. Available at: https://doi.org/10.1057/s41289-018-0072-1.

Bosselmann, P. and Gilson, K. (1977) 'Visualizing Urban Form', *New York*, pp. 9–30.

Bosselmann, P., Macdonald, E. and Kronemeyer, T. (1999) 'Livable Streets Revisited', *Journal of the American Planning Association*, 65(2), pp. 168–180. Available at: https://doi.org/10.1080/01944369908976045.

Bramley, G. and Power, S. (2009) 'Urban Form and Social Sustainability: The Role of Density and Housing Type', *Environment and Planning B: Planning and Design*, 36(1), pp. 30–48. Available at: https://doi.org/10.1068/b33129.

Brown, N. (2001) 'Edward T. Hall, Proxemic Theory, 1966. CSISS Classics', *eScholarship*, p. 5. Available at: https://escholarship.org/uc/item/90h3m29x.

Burger, J.R. *et al.* (2022) 'Global city densities: Re-examining urban scaling theory', *Frontiers in Conservation Science*, 3. Available at: https://www.frontiersin.org/articles/10.3389/fcosc.2022.879934.

Burton, E. (2000) 'The Compact City: Just or Just Compact? A Preliminary Analysis', *Urban Studies*, 37(11), pp. 1969–2006. Available at: https://doi.org/10.1080/00420980050162184.

Burton, E. (2002) 'Measuring Urban Compactness in UK Towns and Cities', *Environment and Planning B: Planning and Design*, 29(2), pp. 219–250. Available at:

https://doi.org/10.1068/b2713.

Cabe (no date) *The principles of inclusive design. (They include you.)*. Available at: www.cabe.org.uk.

Campoli, J. and Maclean, A.S. (2002) 'Visualizing Density higher Density Catalog Images, 9.1 - 134.5 units per acre', *Lincoln Institute of Land Policy Working Paper*, pp. 1–38.

Campoli, J. and MacLean, A.S. (2007) *Visualizing Density*. Lincoln Insitute of Land Policy.

Canter D, J, B. and Groat L (1985) 'A multiple sorting procedure for studying conceptual systems. In: Brenner, M., Canter, D., Brown, J. (Eds.), The Research Interview: uses and Approaches', pp. 79–114. Available at: https://www.davidcanter.com/wp-content/uploads/2012/04/A-Multiple-Sorting-Procedure.pdf.

Canter, D. V (1977) *The Psychology of Place*. Architectural Press. Available at: https://books.google.co.uk/books?id=DjolAQAAIAAJ.

Canter, D. V (1996) 'A multiple sorting procedure for studying conceptual systems', in. Dartmouth Publishing Company.

Carmona, M. *et al.* (2010) *Public Place Urban Space, The Dimension of Urban Design*. Second Edi, *Architectural Press*. Second Edi. Oxford, UK. Available at: http://jurnal.unmer.ac.id/jbm/article/download/70/11%0Ahttp://repository.unpas.ac.id/5617/6/BAB III nita - revisi.pdf%0Ahttp://repository.unpas.ac.id/id/eprint/5617%0A%0Ahttp://repository.ut.ac.id/4408/2/SKOM4101-M1.pdf.

Cervero, R. and Bosselmann, P. (1994) *An Evaluation of the Market Potential for Transit-Oriented Development Using Visual Simulation Techniques*, *Uctc no 247*. IURD Monograph Series. Available at: https://escholarship.org/uc/item/10j9z500 (Accessed: 3 June 2023).

Cheng, V (2010) *Human Perception of Urban Density*. Doctor of Philosophy.

University of Cambridge.

Cheng, Vicky (2010) ‘Understanding Density and High Density’, in E. Ng (ed.) *Designing High-Density Cities*. UK, USA: Earthscan, pp. 3–16.

Cheng, V.B. and Vicky, B.C. (2010) *HUMAN PERCEPTION OF URBAN DENSITY*. Doctor of Philosophy. University of Cambridge.

Churchman, A. (1999) ‘Disentangling the concept of density’, *Journal of Planning Literature*, 13(4), pp. 389–411. Available at: https://doi.org/10.1177/08854129922092478.

Clemente, O. *et al.* (2005) ‘Measuring Urban Design Qualities an Illustrated Field Manual of the’, *Growth Lakeland*, p. 35. Available at: http://www.activelivingresearch.org/files/FieldManual_071605.pdf.

Cohen, J. (2015) ‘Perceptual constancy.’, in *The Oxford handbook of philosophy of perception.* New York, NY, US: Oxford University Press, pp. 621–639. Available at: https://doi.org/10.1093/oxfordhb/9780199600472.001.0001.

Cullen, G. (1971a) *The Concise Townscape*. Architectural Press.

Cullen, G. (1971b) *The Concise Townscape*. Van Nostrand Reinhold Company.

Debals, O. and Brabandere, B. De (2020) *Image Segmentation*. Available at: https://segments.ai/ (Accessed: 4 June 2023).

Dember, W.N., Jolyon West, L. and Epstein, W. (2023) ‘perception’, *Encyclopedia Britannica*. Available at: https://www.britannica.com/topic/perception (Accessed: 3 July 2023).

Dempsey, N. *et al.* (2010) ‘Elements of Urban Form’, in M. Jenks and C Jones (eds) *Dimensions of the Sustainable City*, pp. 21–52. Available at: https://doi.org/10.1007/978-1-4020-8647-2.

Dempsey, N., Brown, C. and Bramley, G. (2012) ‘The key to sustainable urban development in UK cities? The influence of density on social sustainability’, *Progress in Planning*, 77(3), pp. 89–141. Available at:

https://doi.org/10.1016/j.progress.2012.01.001.

Démuth, A. (2012) *Perception Theories*, *Applications of Case Study Research*. Available at: http://issafrica.org/crimehub/uploads/3f62b072bd80ab835470742e71a0fcb5.pdf%5Cnhttp://www.cdc.gov/ViolencePrevention/pdf/SchoolViolence_FactSheet-a.pdf%5Cnwww.sace.org.za.

Department for Environment Food and Rural Affairs (2013) *Sustainable Development Indicators*, *Crown Copyright*. Available at: https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/series/sustainable-development-indicatorsv (Accessed: 27 June 2023).

DETR (1998a) 'Chapter 2 - The History of Density as a Planning Tool', in *Planning Research Programme- The Use of Density in Urban Planning*, pp. 8–19.

DETR (1998b) 'Chapter 5 - Density and Other Policy Objectives', in *Planning Research Programme -The Use of Density in Urban Planning*. Goldthorpe, Rotherham: Department of the Environment, Transport and the Regions Publications Sale Center, pp. 43–52.

Doherty, S. and Nelson, R. (2010) 'Using projective techniques to tap into consumers' feelings, perceptions and attitudes ... getting an honest opinion', *International Journal of Consumer Studies - Int J Consum Stud*, 34, pp. 400–404. Available at: https://doi.org/10.1111/j.1470-6431.2010.00880.x.

Downs, R.M. and Stea, D. (2017) *Image and Environment: Cognitive Mapping and Spatial Behavior*. New York: Routledge. Available at: https://doi.org/https://doi.org/10.4324/9780203789155.

Duarte, F. (2017) *Space, Place, and Territory: A Critical Review on Spatialities*. Routledge.

Dudovskiy, J. (2018) 'The Ultimate Guide to Writing a Dissertation in Business Studies: A Step-by-Step Assistance.'

Edney, J.J. (1977a) 'Theories of Human Crowding: A Review', *Environment and*

Planning A: Economy and Space, 9(11), pp. 1211–1232. Available at: https://doi.org/10.1068/a091211.

Edney, J.J. (1977b) 'Theories of Human Crowding: A Review', *Environment and Planning A: Economy and Space*, 9(11), pp. 1211–1232. Available at: https://doi.org/10.1068/a091211.

Emo, B. *et al.* (2017) 'Towards defining perceived urban density', *Proceedings of the International Conference on Education and Research in Computer Aided Architectural Design in Europe*, 2, pp. 637–646. Available at: https://doi.org/10.52842/conf.ecaade.2017.2.637.

Etymology Dictionary (no date) *Perception- Meaning*.

European Commission DG Environment (2018) *Science for Environment Policy(2018) Indicators for Sustainable Cities*, *European Union*. UWE, Bristol. Available at: https://doi.org/10.2779/121865.

Evans, G.W. (2003) 'The Built Environment and Mental Health', *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 80(4).

Evans, G.W., Lepore, S.J. and Allen, K.M. (2000) 'Cross-cultural differences in tolerance for crowding: Fact or fiction?', *Journal of Personality and Social Psychology*, 79(2), pp. 204–210. Available at: https://doi.org/10.1037/0022-3514.79.2.204.

Ewing, R. *et al.* (2016) 'Identifying and Measuring Urban Design Qualities Related to Walkability', *Journal of Physical Activity and Health*, 3(s1), pp. S223–S240. Available at: https://doi.org/10.1123/jpah.3.s1.s223.

Ewing, R. *et al.* (2018) 'Testing Newman and Kenworthy's Theory of Density and Automobile Dependence', *Journal of Planning Education and Research*, 38(2), pp. 167–182. Available at: https://doi.org/10.1177/0739456X16688767.

Feibleman, J.K. (1970) 'Cultural Conditioning', in J.K. Feibleman (ed.) *The New Materialism*. Dordrecht: Springer Netherlands, pp. 134–146. Available at: https://doi.org/10.1007/978-94-010-3165-3_10.

Filipowicz, J. (2018) *Urban Density doesn't necessarily determine living standards*, *The Fraser Institute Blog*.

Fisher-Gewirtzman, D. (2003) 'Using the spatial openness metric for comparative evaluation of urban environments', *Design* [Preprint].

Fisher-Gewirtzman, D. (2018) 'Perception of density by pedestrians on urban paths: an experiment in virtual reality', *Journal of Urban Design*, 23(5), pp. 674–692. Available at: https://doi.org/10.1080/13574809.2018.1444471.

Fisher-Gewirtzman, D. and Wagner, I.A. (2003) 'Spatial openness as a practical metric for evaluating built-up environments', *Environment and Planning B: Planning and Design*, 30(1), pp. 37–49. Available at: https://doi.org/10.1068/b12861.

Flachsbart, P.G. (1979) 'Residential Site Planning and Perceived Densities', *Journal of the Urban Planning and Development Division*, 105(November 1979), pp. 103–117.

Freedman, J.L. (1975) *Crowding and behavior.*, *Crowding and behavior.* Oxford, England: W. H. Freedman.

Gehl, J. (2010) *Cities for People*. Island Press; 1st edition.

Gehl, J. (2011) *Life Between Buildings: Using Public Space*. Island Press.

Gehl, J. and Gemzøe, L. (1996) *Public Spaces, Public Life*. Danish Architectural Press and the Royal Danish Academy of Fine Arts, School of Architecture.

Gehl, J. and Gemzøe, L. (2003) *New City Spaces*. Danish Architectural Press.

Gehl, J., Kaefer Johansen, L. and Solvekg, R. (2016) 'Close Encounters with Buildings', in *The City at Eye Level*, pp. 29–35.

Gehl, J. and Koch, J. (2001) *Life Between Buildings: Using Public Space*. Danish Architectural Press.

Gehl, J. and Svarre, B. (2013) *How to Study Public Life*. Island Press.

Gerber, P.J. and Murphy, H. (no date) *The Perception Process*.

Gibson, James J (1966) *Gibson's "Senses Considered as Perceptual Systems"*, *The*

Reciprocity of Perceiver and Environment. George Allen and Unwin LTD, London. Available at: https://doi.org/10.4324/9781315514413-15.

Gibson, J J (1966) *The senses considered as perceptual systems.*, *The senses considered as perceptual systems.* Oxford, England: Houghton Mifflin.

Gibson, J.J. (1977) 'Gibson_James_J_1977_The_Theory_of_Affordances.pdf', *Perceiving, acting, and knowing. Toward an ecological psychology*, pp. 67–82. Available at: http://www.pnas.org/lookup/doi/10.1073/pnas.1618228114.

Gibson, J.J. (2015) *The Ecological Approach to Visual Percpetion*. Psychology. New York NY: Taylor adn Francis Group, LLC.

Gifford, R. and Ng, C.F. (1982) 'The relative contribution of visual and auditory cues to environmental perception', *Journal of Environmental Psychology*, 2(4), pp. 275–284. Available at: https://doi.org/https://doi.org/10.1016/S0272-4944(82)80027-3.

Gifford, R., Steg, L. and Reser, J.P. (2011) *Environmental Psychology*, *IAAP Handbook of Applied Psychology*. Available at: https://doi.org/10.1002/9781444395150.ch18.

Gjerde, M. (2010) 'Visual Aesthetic Perception and Judgement Of Urban Streetscapes', *W101-Special Track 18th CIB World Building Congress*, p. 11. Available at: http://cibworld.xs4all.nl/dl/publications/w101_pub338.pdf#page=16.

Godoy-Shimizu, D., Steadman, P. and Evans, S. (2021) 'Density and morphology: from the building scale to the city scale', *Buildings and Cities*, 2(1), pp. 92–113. Available at: https://doi.org/10.5334/bc.83.

Goffin, K. (2014) 'Repertory Grid Technique', *Essential Skills for Management Research*, pp. 199–225. Available at: https://doi.org/10.4135/9781848605305.n11.

Goldstein, E.B. (2009) *Encyclopedia of Perception*. SAGE Publications (A Sage reference publication).

Green, E.J. (2023) 'Perceptual constancy and perceptual representation', *Analytic Philosophy* [Preprint]. Available at: https://doi.org/10.1111/phib.12293.

Green, K. *et al.* (2018) *The Perception Process*, *Minnesota State Colleges and*

Universities, Creative Commons Attribution-NonCommercial 4.0 International License. Available at: http://introtocommopensource.ridgewater.edu/ModuleII/ModIISect2.html (Accessed: 3 July 2023).

Gregory, R.L. (1974) *Concepts and Mechanisms of Perception*. 2009/07/09, *Psychological Medicine*. 2009/07/09. London: Gerald Duckworth & Co Ltd. Available at: https://doi.org/DOI: 10.1017/S0033291700057056.

Groat, L.N. (1985) 'PSYCHOLOGICAL ASPECTS OF CONTEXTUAL COMPATIBILITY IN ARCHITECTURE: A Study of Environmental Meaning', *Submitted in Fulfillment of the Degree of Doctor of Philosophy*, 1. Available at: http://epubs.surrey.ac.uk/847475/1/10798496.pdf.

Guberman, S. (2017) 'Gestalt theory rearranged: Back to wertheimer', *Frontiers in Psychology*, 8(OCT). Available at: https://doi.org/10.3389/fpsyg.2017.01782.

Hall, E.T. (1966) *The Hidden Dimension*. Knopf Doubleday Publishing Group.

Haney, W.G. and Knowles, E.S. (1978) 'Perception of neighborhoods by city and suburban residents', *Human Ecology*, 6(2), pp. 201–214. Available at: https://doi.org/10.1007/BF00889095.

Harper, C. (2013) 'housing Compaction , Scale and Proximity An investigation into the spatial implications of density for the design of new urban housing'.

Harvey, C. (2009a) 'A simplified measure of streetscape enclosure for examining built environment influences on walking', pp. 1–14.

Harvey, C. (2009b) 'A simplified measure of streetscape enclosure for examining built environment influences on walking', pp. 1–14.

Harvey, C. and Aultman-Hall, L. (2016) 'Measuring Urban Streetscapes for Livability: A Review of Approaches', *Professional Geographer*, 68(1), pp. 149–158. Available at: https://doi.org/10.1080/00330124.2015.1065546.

Herzog, T.R. (2006) 'Perception and Evaluation of Urban Spaces', in *Environmental*

Aesthetics: Theory, Research and Applications. Cambridge University Press, pp. 251–269.

Hess, P. (2014) 'Density, Urban', in A.C. Michalos (ed.) *Encyclopedia of Quality of Life and Well-Being Research*. Dordrecht: Springer Netherlands, pp. 1554–1557. Available at: https://doi.org/10.1007/978-94-007-0753-5_698.

Hook, D. and Glaveanu, V.P. (2013) 'Image Analysis: An Interactive Approach to Compositional Elements', *Qualitative Research in Psychology*, 10(4), pp. 355–368. Available at: https://doi.org/10.1080/14780887.2012.674175.

Howard R. Moskowitz (1978) 'Magnitude Estimation : Notes on What , How , When , and Why To Use It', *Journal of Food Quality*, 3(1977), pp. 195–227.

Hren, D. (2022) *How to Deal with the Confirmation Bias: The eCommerce Advantage*, *Conversion Designer*. Available at: https://hren.io/blog/cognitive-biases/confirmation-bias (Accessed: 25 July 2023).

Hsieh, H.F. and Shannon, S.E. (2005) 'Three approaches to qualitative content analysis', *Qualitative Health Research*, 15(9), pp. 1277–1288. Available at: https://doi.org/10.1177/1049732305276687.

Hulshof, C.D. (2005) 'Log File Analysis', *Encyclopedia of Social Measurement*. Edited by Kimberly Kempf-Leonard. Texas,USA: Elsevier Inc. Available at: https://www.sciencedirect.com/referencework/9780123693983/encyclopedia-of-social-measurement (Accessed: 16 July 2023).

Intaitė, M. *et al.* (2013) 'Interaction of bottom-up and top-down processes in the perception of ambiguous figures', *Vision Research*, 89, pp. 24–31. Available at: https://doi.org/https://doi.org/10.1016/j.visres.2013.06.011.

Jacobs, J. (1961) *The Death and Life of Great American Cities*. Random House (Vintage books).

Jenks, M., Burton, E. and Williams, K. (1996) *The Compact City: A Sustainable Urban Form?* E & FN Spoon.

Kaplan, R. and Kaplan, S. (1989) *The Experience of Nature: A Psychological Perspective*. Cambridge University Press.

Kaplan, S. (1987) 'Aesthetics, Affect, and Cognition: Environmental Preference from an Evolutionary Perspective', *Environment and Behavior*, 19(1), pp. 3–32. Available at: https://doi.org/10.1177/0013916587191001.

Kaplan, S. and Kaplan, R. (1982) *Cognition and Environment: Functioning in an Uncertain World*. Praeger (Praeger scientific).

Kelly, G.A. and Kelly, G.A. (2017) 'A brief introduction to personal construct theory', *Construttivismi*, pp. 3–25. Available at: https://doi.org/10.23826/2017.01.003.025.

Kent, F. and Madden, K. (2016) 'Streets as Places', in *The City at Eye Level*, pp. 68–71.

Kleinheksel, A.J. *et al.* (2020) 'Qualitative Research in Pharmacy Education: Demystifying Content Analysis', *American Journal of Pharmaceutical Education*, 84(1), pp. 127–137. Available at: https://doi.org/10.5688/ajpe8417113.

Koffka, K. (1935) *Principles of Gestalt psychology.*, *Principles of Gestalt psychology.* Oxford, England: Harcourt, Brace.

Kumar, A. (2022) 'OBSERVATION METHOD', *International Journal of Scientific Research*, 13, pp. 1–14.

Laerd Statistics (2018) *Spearman's Rank-Order Correlation*, *2018 Lund Research Lt*. Available at: https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php (Accessed: 4 April 2023).

Lehmann, S. (2019) 'Understanding and Quantifying Urban Density Toward more Sustainable City Form', in L. D'Acci (ed.) *The mathematics of urban morphology. Modeling and simulation in science, engineering and technology.* Cham, Switzerland: Springer Nature Switzerland AG 2019, pp. 547–556. Available at: https://doi.org/10.1007/978-3-030-12381-9 Library.

Lilli, E.E. (2013) 'Spaciousness & preference: a study in the perception of density in the suburban residential built environment', (June).

Loo, C. (1990) 'The Psychological Consequences of Crowding.', *Contemporary Sociology*, 19(4), p. 582. Available at: https://doi.org/10.2307/2072829.

Loo, C.M. (1972) 'The Effects of Spatial Density on the Social Behavior of Children', *Journal of Applied Social Psychology*, 2(4), pp. 372–381. Available at: https://doi.org/10.1111/j.1559-1816.1972.tb01288.x.

Lozano, E.E. (1974) 'Visual Needs in the Urban Environment', *The Town Planning Review*, 45(4), pp. 351–374. Available at: http://www.jstor.org/stable/40103026.

Lynch, K. (1964) *The Image of the City*. MIT Press (Harvard-MIT Joint Center for Urban Studies Series).

Lynch, K. (1984) *Good City Form*. MIT Press (Architecture, urban studies).

MacLean, L. and Salama, A.M. (2019) 'Towards a context specific and multidimensional Quality of Urban life model', *Open House International*, 44(1), pp. 25–33. Available at: https://doi.org/10.1108/ohi-01-2019-b0004.

Madani-Pour, A. (1996) *Design of Urban Space: An Inquiry into a Socio-Spatial Process*. Wiley.

Marks, L. (1988) 'Magnitude estimation and sensory matching', *Attention Perception & Psychophysics*, 43, pp. 511–525. Available at: https://doi.org/10.3758/BF03207739.

Mcleod, S. (2023) *Visual Perception Theory In Psychology*. Available at: https://www.simplypsychology.org/perception-theories.html (Accessed: 3 June 2023).

Metropolitian Council (no date) *DENSITY, DIVERSITY, & DESIGN*, *Metropolitian Council*. Available at: https://metrocouncil.org/Communities/Planning/TOD/Planning-Fundamentals/Density-Diversity-Design.aspx (Accessed: 17 July 2023).

Miguel, F.K. and Pessotto, F. (2016) 'Projective aspects on cognitive performance: distortions in emotional perception correlate with personality', *Psicologia: Reflexão e*

Crítica, 29(1), p. 17. Available at: https://doi.org/10.1186/s41155-016-0036-6.

Moye, J.N. (2021) 'The Psychophysics of Perception', in *The Psychophysics of Learning*. Emerald Publishing Limited, pp. 31–49. Available at: https://doi.org/10.1108/978-1-80117-113-720211004.

Mueller, C.W. (1981) 'The Perception of crowding', *Retrospective Theses and Dissertations*, p. Paper 6836.

Namazian, A. and Mehdipour, A. (2013a) 'Psychological Demands of the Built Environment , Privacy , Personal Space and Territory in Architecture', *International Journal of Psychology and Behavioral Sciences*, 3(4), pp. 109–113. Available at: https://doi.org/10.5923/j.ijpbs.20130304.04.

Namazian, A. and Mehdipour, A. (2013b) 'Psychological Demands of the Built Environment, Privacy, Personal Space and Territory in Architecture', *International Journal of Psychology and Behavioral Sciences*, 2013, pp. 109–113.

Nasar, J.L. (1988) 'Perception and evaluation of residential street scenes', in J.L. Nasar (ed.) *Environmental Aesthetics: Theory, Research, and Application*. Cambridge: Cambridge University Press, pp. 275–289. Available at: https://doi.org/DOI: 10.1017/CBO9780511571213.026.

Nasar, J.L. (1989a) 'Perception, Cognition, and Evaluation of Urban Places', in I. Altman and E.H. Zube (eds) *Public Places and Spaces*. Boston, MA: Springer US, pp. 31–56. Available at: https://doi.org/10.1007/978-1-4684-5601-1_3.

Nasar, J.L. (1989b) 'Perception, Cognition, and Evaluation of Urban Places', in I. Altman and E.H. Zube (eds) *Public Places and Spaces*. Boston, MA: Springer US, pp. 31–56. Available at: https://doi.org/10.1007/978-1-4684-5601-1_3.

Nasar, J.L. (1989c) 'Perception, Cognition, and Evaluation of Urban Places', in I. Altman and E.H. Zube (eds) *Public Places and Spaces - Human Behaviour and Environment, Advances in Theory and Research Volume 10 B*. New York: Plenum Publishing Corporation, pp. 31–56.

Nasar, J.L. (1998) *The Evaluative Image of the City*. SAGE Publications (The Evaluative

Image of the City).

Newman, O. (1972) *Defensible Space; Crime Prevention Through Urban Design*. Macmillan (Architecture/Urban affairs).

Newman, P. and Hogan, T. (1981) 'A Review of urban density models: Toward a resolution of the conflict between populace and planner', *Human Ecology*, 9(3), pp. 269–303. Available at: https://doi.org/10.1007/BF00890739.

Norberg Schultz, C. (1980) *Genius Loci: Towards a Phenomenology of Architecture*. Rizzoli.

Norcross, C. (1973) *Townhouses & Condominiums: Residents' Likes and Dislikes: A Special Report*. Urban Land Institute (ULI special report).

Novelli, D.L. (2010) *The Social Psychology of Spatiality and Crowding*. Doctor of Philosophy.

Oliveira, V. (2021) 'Urban form and the socioeconomic and environmental dimensions of cities', *Journal of Urbanism*, 00(00), pp. 1–23. Available at: https://doi.org/10.1080/17549175.2021.2011378.

Patterson, F., Zibarras, L. and Ashworth, V. (2016) 'Situational judgement tests in medical education and training: Research, theory and practice: AMEE Guide No. 100', *Medical teacher*, 38(1), pp. 3–17. Available at: https://doi.org/10.3109/0142159X.2015.1072619.

Project Everyone (2021) *The 17 Goals*, *The Global Goals - For Sustainable Development*. Available at: https://www.globalgoals.org/goals/ (Accessed: 27 June 2023).

Proshansky, H.M. (1976) *Environmental Psychology: People and Their Physical Settings 2nd Ed. Edited by Horold M. Proshansky [et Al.].* Holt, Rinehart and Winston.

Qiong, O.U. (2017) 'A Brief Introduction to Perception', *Studies in Literature and Language*, 15(4), pp. 18–28. Available at: https://doi.org/10.3968/10055.

Randall, R.B. (1987) *Frequency Analysis*. Third Edition. Denmark: K. Larsen & Sen A/S.

DK- 2600 Glostrup.

Rapoport, A. (1975a) 'Toward a Redefinition', *Environment and Behaviour*, 7(2), pp. 133–158.

Rapoport, A. (1975b) 'Toward a Redefinition', *Environment and Behaviour*, 7(2), pp. 133–158.

Rapoport, A. (1975c) 'Toward a Redefinition of Density', *Environment and Behavior*, 7(2), pp. 133–158. Available at: https://doi.org/10.1177/001391657500700202.

Rapoport, A. (1982) *The Meaning of the Built Environment: A Nonverbal Communication Approach*. SAGE Publications.

Rapoport, A. (1990) *The Meaning of the Built Environment - A Nonverbal Communication Approach*. University of Arizona Press.

Relph, E.C. (1976) *Place and Placelessness*. Pion (Research in planning and design). Available at: https://books.google.co.uk/books?id=ml0FAQAAIAAJ.

RICS (2021) *Urban density: Promoting sustainable development – Part 1*, *Royal Institution of Chartered Surveyors*. Available at: https://www.rics.org/news-insights/wbef/urban-density-promoting-sustainable-development-part-1 (Accessed: 27 June 2023).

Rock, I. (1985) 'Perception and knowledge', *Acta Psychologica*, 59(1), pp. 3–22. Available at: https://doi.org/https://doi.org/10.1016/0001-6918(85)90039-3.

Rubin, H.J. and Rubin, I.S. (2005) *Qualitative Interviewing (2nd ed.): The Art of Hearing Data*. SAGE Publication,Inc. Available at: https://doi.org/https://doi.org/10.4135/9781452226651.

Ryan, T.W. (1985) 'Image Segmentation Algorithms', *Architectures and Algorithms for Digital Image Processing II*, 0534, p. 172. Available at: https://doi.org/10.1117/12.946577.

Saegert, S. (1973) 'Crowding: Cognitive overload and behavioral constraint', *Environmental Design Research*, 2.

Salingaros, N. and van Bilsen, A. (2005) *Principles of Urban Structure*.

Sanoff, H. (2016) *Visual research methods in design*, *Visual Research Methods in Design*. Available at: https://doi.org/10.4324/9781315541822.

Simkus, J. (2023) *Confirmation Bias In Psychology: Definition & Examples*, *Simply Psychology*. Available at: https://www.simplypsychology.org/confirmation-bias.html (Accessed: 3 July 2023).

Snow, J.C. *et al.* (2014) 'Real-world objects are more memorable than photographs of objects', *Frontiers in Human Neuroscience*, 8(OCT), pp. 1–11. Available at: https://doi.org/10.3389/fnhum.2014.00837.

Sommer, R. (1969) *Personal Space: The Behavioral Basis of Design*. Prentice-Hall (A Spectrum book).

Sommer, R. (2007) *Personal Space: The Behavioral Basis of Design*. Bosko Books (Spectrum book).

Sonne, W. (2017) *Urbanity and Density: In 20th Century Urban Design*.

Spreiregen, P.D. (1981) *Urban Design, the Architecture of Towns and Cities*. R.E. Krieger Publishing Company.

Steemers, K., Ramos, M. and Sinou, M. (2004) 'Urban Diversity', in *Environmental Diversity in Architecture*. Taylor & Francis.

Stewart, T.R. *et al.* (1984) 'Judgments of photographs vs. field observations in studies of perception and judgment of the visual environment', *Journal of Environmental Psychology*, 4(4), pp. 283–302. Available at: https://doi.org/10.1016/S0272-4944(84)80001-8.

Stilwell, M. (2017) *Housing the returning soldiers "Homes Fit for Heroes"*. Available at: http://www.socialhousinghistory.uk/wp/wp-content/uploads/2017/04/Homes_Fit_For_Heroes.pdf (Accessed: 5 July 2023).

Stokols, D. (1972) 'On the distinction between density and crowding: Some implications for future research', *Psychological Review*, 79(3), pp. 275–277. Available at: https://doi.org/10.1037/h0032706.

Stokols, D. (1976) ‘The Experience of Crowding in Primary and Secondary Environments’, *Environment and Behavior*, 8(1), pp. 49–86. Available at: https://doi.org/10.1177/001391657600800104.

Swansburg, J.E. and Neyedli, H.F. (2019) ‘Symbolic, non-directional predictive cues affect action execution’, *Attention, Perception, and Psychophysics*, 81(7), pp. 2391–2399. Available at: https://doi.org/10.3758/s13414-019-01794-5.

Takahashi, H., Ban, M. and Asada, M. (2016) ‘Semantic Differential Scale Method Can Reveal Multi-Dimensional Aspects of Mind Perception’, *Frontiers in Psychology*, 7. Available at: https://www.frontiersin.org/articles/10.3389/fpsyg.2016.01717.

Taylor, R.B. (1981a) ‘Perception of Density: Individual Differences?’, *Environment and Behavior*, 13(1), pp. 3–21. Available at: https://doi.org/10.1177/0013916581131001.

Taylor, R.B. (1981b) ‘Perception of Density-Individual Differences.pdf’.

Taylor, R.B. and Stough, R.R. (1978) ‘Territorial cognition: Assessing Altman’s typology’, *Journal of Personality and Social Psychology*, 36(4), pp. 418–423. Available at: https://doi.org/10.1037/0022-3514.36.4.418.

Thwaites, K., Simpson, J. and Simkins, I. (2020) ‘Transitional edges: a conceptual framework for socio-spatial understanding of urban street edges’, *Urban Design International*, 25(4), pp. 295–309. Available at: https://doi.org/10.1057/s41289-020-00115-9.

Tuan, Y.F. (1977) *Space and Place: The Perspective of Experience*. University of Minnesota Press (Tales and Travels of a School Inspector Series).

Urban Task Force (2005) *Towards an Urban Renaissance*.

Velarde, M.D., Fry, G. and Tveit, M. (2007) ‘Health effects of viewing landscapes – Landscape types in environmental psychology’, *Urban Forestry & Urban Greening*, 6(4), pp. 199–212. Available at:

https://doi.org/https://doi.org/10.1016/j.ufug.2007.07.001.

Vormann, B. (2015) ‘Urban Diversity: Disentangling the Cultural from the Economic Case’, *New Diversities*, 17(2).

Wagemans, J., Elder, J.H., Kubovy, M., Palmer, S.E., Peterson, M.A., Singh, M., von der Heydt, R., *et al.* (2012) ‘A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization’, *Psychological Bulletin*, 138(6), pp. 1172–1217. Available at: https://doi.org/10.1037/a0029333.

Wagemans, J., Elder, J.H., Kubovy, M., Palmer, S.E., Peterson, M.A., Singh, M. and Heydt, R. von der (2012) ‘A Century of Gestalt Psychology in Visual Perception I. Perceptual Grouping and Figure-Ground Organization’, *NIH Public Access* [Preprint]. Available at: https://doi.org/10.1037/a0029333.A.

Walton, D., Murray, S.J. and Thomas, J.A. (2008) ‘Relationships Between Population Density and the Perceived Quality of Neighbourhood’, *Social Indicators Research*, 89(3), pp. 405–420. Available at: https://doi.org/10.1007/s11205-008-9240-9.

Wei, B. *et al.* (2021) *Visual Sensation and Perception Computational Models for Deep Learning: State of the art, Challenges and Prospects*.

Wertheimer, M. (1938) ‘Gestalt theory.’, in *A source book of Gestalt psychology.* London, England: Kegan Paul, Trench, Trubner & Company, pp. 1–11. Available at: https://doi.org/10.1037/11496-001.

Wertheimer, M. and Riezler, K. (1944) ‘GESTALT THEORY’, *Social Research*, 11(1), pp. 78–99. Available at: http://www.jstor.org/stable/40982002.

Whyte, A.V.T. (1985) *Guidelines for field studies in environmental perception*, *MAB Technical Notes 5*.

Whyte, W.H. (1980) *The Social Life of Small Urban Spaces*. Conservation Foundation.

Winter, G. (2016) *Comparison of the planning systems in the four UK countries*.

Wohlwill, J.F. (1982) ‘The visual impact of development in coastal zone areas’, *Coastal Zone Management Journal*, 9(3–4), pp. 225–248. Available at:

https://doi.org/10.1080/08920758209361902.

Xue, H. and Desmet, P.M.A. (2019) ‘Researcher introspection for experience-driven design research’, *Design Studies*, 63, pp. 37–64. Available at: https://doi.org/10.1016/j.destud.2019.03.001.

Yang, J. and Yuan, C. (2022) ‘Application of Cognitive System Model and Gestalt Psychology in Residential Healthy Environment Design’, *Computational Intelligence and Neuroscience*, 2022. Available at: https://doi.org/10.1155/2022/5661221.

Zacharias, J. and Stamps, A. (2004) ‘Perceived Building Density as a Function of Layout’, *Perceptual and Motor Skills*, 98(3), pp. 777–784. Available at: https://doi.org/10.2466/pms.98.3.777-784.

Zehner, R.B. and Marans, R.W. (1973) ‘Residential Density, Planning Objectives and Life in Planned Communities’, *Journal of the American Institute of Planners*, 39(5), pp. 337–345. Available at: https://doi.org/10.1080/01944367308977421.

Zhang, F. *et al.* (2018) ‘Measuring human perceptions of a large-scale urban region using machine learning’, *Landscape and Urban Planning*, 180, pp. 148–160. Available at: https://doi.org/10.1016/j.landurbplan.2018.08.020.

Zhang, Y. and Wildemuth, B.M. (2009) ‘Qualitative Analysis of Content’, *Applications of Social Research Methods to Questions in Information and Library Science*, p. 421. Available at: https://doi.org/10.1002/hbm.20661.