Deconstruction of Gender Dynamics and Its Implications for Gendered Inclusive Design: Application of Urban Big Data and Interpretable Machine Learning Method in India

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Abstract

The vectors of inequality and difference are multiple - class, gender, race, culture, age, and sexuality - intersecting in a complex matrix (Dutta Gupta, 2015). Robust studies reinforce that gender inequalities in space occupation are not necessarily the consequence of normative desires, such as "equal" or "just separate" (Fuller, 2009), but can also be the result of the way urban environments are structured and culturally created, implying unequal access to space (Jacob, 2020). Although intentional gender segregation in public spaces is no longer practiced, many scholars claim that power imbalances are sustained and reproduced in spaces, resulting in "gendered" and "sexualized" city urban spaces (Klockner, 2013).

The relationship between fear experienced by women for their safety, a sense of victimization, and women's movement patterns in urban places are three phenomena that are rarely dealt with in combination. For many years, crime prevention through environmental design has been proposed as a principle for enhancing safety in urban environments and understanding the relationship between fear and safety associated with the built environment. Yet, little is known about the application of these policies to gendered urban spaces. This study proposes qualitative surveys to depict the

number of women who experience fear and the characteristics of the most frightening places. Qualitative studies, however, are said to be of limited use in understanding how fear affects social and mental processes, as well as how space is produced as a result of fear. The matter is explained with profound depth using quantitative research techniques that analyze the relationship between crime incidence and the urban environment using urban big data, such as points-of-interest (POI), crime data, and street image data from Delhi, India. The results highlight the promising approach of using multi-methods to analyze the adequacy of urban principles and policies in encouraging greater inclusion within the context of this new paradigm by examining and compiling the available data, developing gender-sensitive frameworks, conducting case studies, and critically evaluating the study area to formulate hypotheses and apply assumptions. The proposed evaluation model serves as a useful tool for policymakers and urban planners to understand gender-related crime dynamics, leading to informed decisions and improvements in the quality of urban environments.

Relevance of the research

The research's relevance lies in its exploration of the relationship between gender, safety, and urban spaces, using both qualitative and quantitative methods. By assessing the application of urban design and a planning approach in gendered urban spaces, the study aims to enhance safety and inclusion. Policymakers and urban planners can use the research findings to make informed decisions and improve the quality of urban environments, addressing power imbalances and creating safer spaces for everyone.

Keywords: Fear of violence, gender-sensitive design, urban environment, inclusive cities, crime, spatial exclusion.

1. Introduction

1.1. Gender-Related Urbanism

Given the evolving discussions within theoretical, historical, and critical spheres, especially in the realm of feminism, it is imperative to promptly situate the comprehension of urban environments concerning gender. 'Feeling unsafe' is portrayed within the political and public domain as a phenomenon that influences everyone in a similar manner, irrespective of gender or social differences (Gardner, 1990). The reality is that the indicated emotion has two components, which have been gradually revealed by sociological studies (Duncan, 1996): on one side, how individuals describe lack of safety in public areas, and on the other side, experiencing fear for oneself (Smith, 1986) It is impossible to discuss reactions to the fear of violence (Canter, 1977) in urban environments without taking into account the social and political relations that structure both the physical spaces and the everyday routines of the individuals involved (Pain, 2001). Women's fears are

substantially different from men's fears in terms of their extent, nature, and effects on women's lives (Pain, 2001). Feminist researchers have argued for nearly 30 years that societal structures of gender inequality need to change in order to eradicate women's personal experiences of violence (Koskela, 1997).

At a time when demographic and societal developments allow women greater autonomy in the different domains of life, including the public sphere, it is crucial to analyze the persistence of these fears and their impact on daily experience, particularly regarding women's use of public space. This research sought to investigate these issues from a spatial perspective and recognize the wider social role of CPTED in shaping crime and prevention. The spatiality of fear refers to a more sophisticated analysis of gendered spatiality rather than a straightforward description and recognition of the most unsafe and frightening areas in the urban environment (Colomina, 1992). The intention of the study is to investigate the relationship between spatial limitations and gender-driven power relations. The production of urban space through intersubjectivity and gender relations is the focus rather than just an individual's use of space. By using an approach in relation to the gendered social relations perspective to examine the mechanisms that engender fear, this study is an attempt to be able to negate the myth that women are naturally fearful without turning them into 'victims'.

2. Research Methodology

To form the research methodology, keywords including gender inequality, urban environment, violence, and fear of crime were surveyed across journal articles, books, and various resources. The texts were analyzed to establish a theoretical framework, guide subjective analysis, and identify the research problem. The approach appears data-driven and technology-oriented, focusing on cities in general; however, there is a disconnect between this approach and understanding human needs and concerns.

2.1. Study Area

This study investigates Delhi, India as a research area and collects demographic data and urban analytics. The study is further narrowed down to Central Delhi to explore the built environment from a 'macro' to a 'micro' scale.

2.2. Research Process

The process is broken down into sections: all of which can adjust to changing data patterns and hence urban demands.

2.2.1. Data Extraction

This study utilized available data to select variables encompassing natural, socioeconomic, spatial policies, and neighborhood factors. Data from Open Street Map (OSM) and Space Syntax were employed to analyze urban patterns tied to demographics, economy, population, transportation, and intensification points in Delhi. The geolocated datasets formed a spatial computation model. Google Street View images were collected from all directions to build a comprehensive image segmentation model, employing deep convolutional neural networks for semantic segmentation.

2.2.2. Data Analytics and Machine Learning

Linear dimensionality reduction is used to decipher correlations and the extracted prominent datasets spread over Delhi.

2.2.3. Data-Driven Site Simulations

In order to further study the spatial-temporal dynamics of spatial patterns, data-driven methods are used to run site simulations to explore the relationship between urban development and relevant driving factors like space syntax methodology for the identification of centrally located and well-integrated areas by spatial modelling. The underlying cause-effect relationships in the urban growth process were analyzed using these simulations.

3. Theoretical Framework

3.1. Social and Spatial Status of Women

3.1.1. The Historical Context of Women

The position of women in the society is a complicated, multidimensional concept. The access and positions available to women within social institutions are examples of structural patriarchy, which also encompasses ideologies (beliefs, norms, and ideals concerning the stature and duties of women in a society) (Barrett, 1988). In addition to the pre-existing notions, ideologies and structural inequality occur within various dimensions.

Figure 1. The feminist movements during the 1960s – 70s. *Source: Femcrunch*

Women in India went through a cultural revolution in the 2000s that placed a strong emphasis on women's rights to freedom, choice, and independence under the influence of economic liberalization and the development of modern technology (Misra, 1997). Due to the widespread use of social media, the term "fourth-wave feminism," which originated in the West, appeared almost simultaneously in India as well.

Figure 2. The Gujarat Stepwells provide a pleasant counterpoint to this paradigm by conveying stories about women, and life. *Source: Gujaratexpert*

Despite the revolutionary campaigns and noteworthy advancements, it must be underlined that the path leading toward a universal acceptance of feminist ideas and their implications for future research remains patchy. The diverse theoretical approaches for the study of gender relations put forward by feminist and non-feminist scholars are often challenging to reconcile and remain ignored in the field of architecture and design.

3.1.2. Theoretical Link Between the Status of Women and Violence

There are several theoretically viable mechanisms that connect these aspects of women's status to violence against women (Bryson, 2016). First, when men are dominant both in number and power in the family, political, economic, and other social institutions, their policies and practices are more likely to express, reinforce, and justify male dominance over women (Massey, 1994). Second, violence is a tool that males can use in institutions where men assert power and control to keep women out or under their control.

Fear among women is a key factor in this process. Criminologists have been intrigued by the "fear-victimization paradox," which holds that although men are more likely to be victims of violent crime than women, women are more fearful than men (Pain, 2014). Assumptions are made that women's fears are illogical and irrational, yet others have discovered explanations for the emotions encountered by them. According to feminist theory, men are able to control women's behavior, restrict or limit their involvement, and so maintain control over social institutions because of their ability to instill fear in them (Harvey, 2009. Men's dominance over women is secured by the instillation of a culture of fear.

3.2. Social and Spatial Domains Intertwined

3.2.1. Intersection of Gender and Built Environment

The study of space and gender must be interdisciplinary; in addition to sociology, it also considers geography, history, urban planning, and geography (Bondi & Rose 2003). Some of the strongest criticisms of conventional fear of crime theory have been made by feminist criminologists, particularly Stanko (1987, 1990a, 1997), who has highlighted the socio-political production of fear of crime, essentially its gendered form.

According to Rachel Pain, "a common assumption in a typical traditional geographical approach is that women's physical fears are more significant than the metaphorical connotations of place" (Pain, 2014). One treats space as a surface when they are only focused solely on the spatial variations in their levels of fear (Bondi, 1991). Critical social and cultural geography discourses have long argued that space is more than merely a surface on which social behaviors take place (Harvey, 2009). Instead, space is a social category in and of itself, formed by social behaviors. Space functions as both a social practice's medium and its product (Smith, 1987).
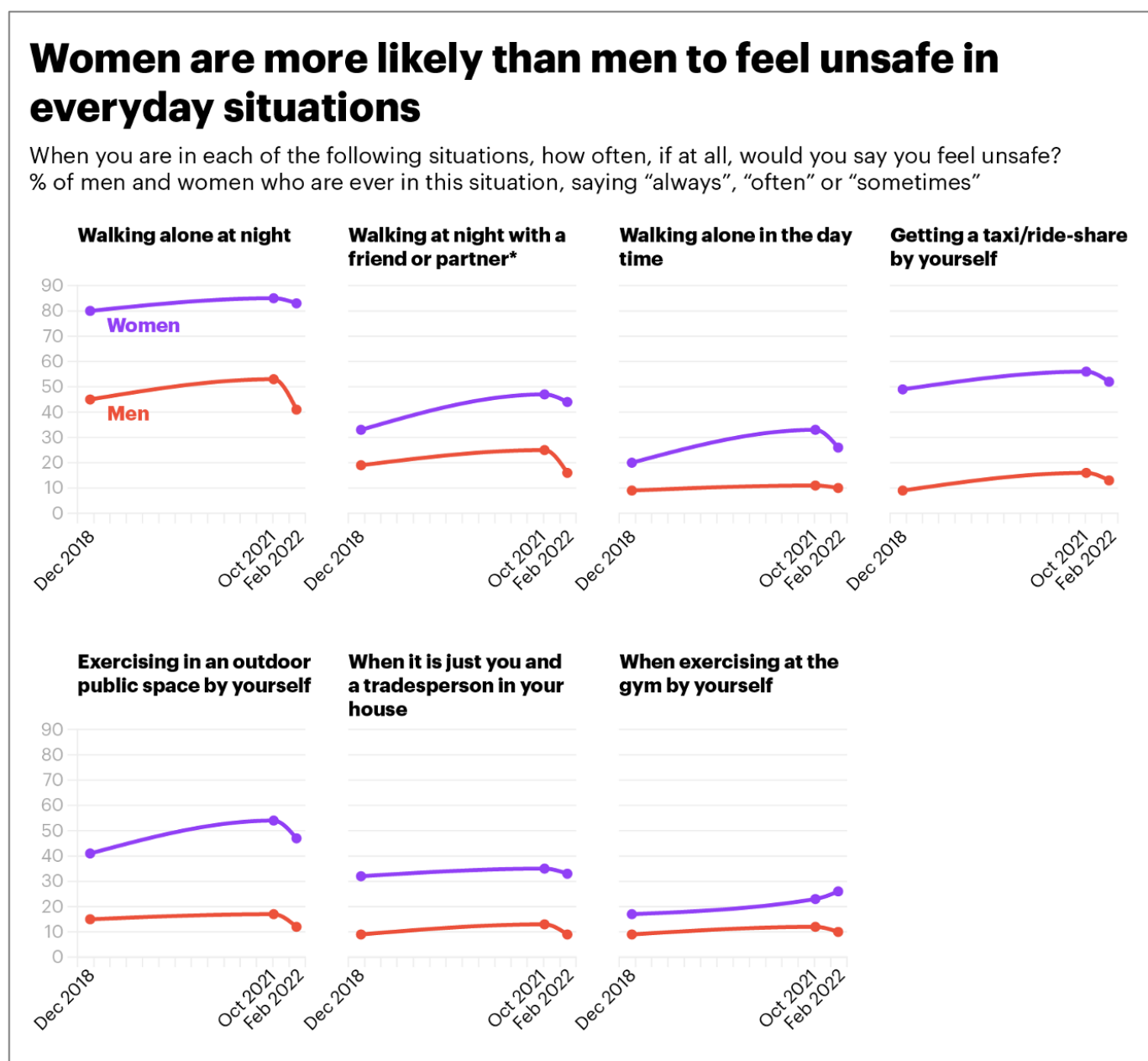

Figure 3. Statistics depicting the unsafe experience faced by women in their daily activities. *Source: YouGov, Twitter*

3.3. Linking Fear to the Built Environment

3.3.1. Fear and Emotion from a Gender-Sensitive Perspective

Feminist geographers emphasize fear as a key factor shaping the gendered experience of urban spaces. Geographies of fear research extensively explores the link between women's fear and their urban interactions. However, despite its significance, fear of crime research often overlooks the gender dimension, using gender merely as a control variable rather than exploring its impact (Kusum, 1996). Notably, the urban environment, particularly well-designed public spaces, affects women's well-being and fear reduction (Booth, 1996). Yet, research connecting various urban aspects and people's subjective well-being with gender remains scarce. This study aims to investigate how women's emotional states are influenced by their momentary satisfaction with urban public spaces, while considering personal and experiential variables.

3.3.2. Designing Out Crime: CPTED Principles

The foundation of CPTED, which stands for Crime Prevention Through Environmental Design, is rooted in the pioneering work of C. Ray Jeffrey (1971) and Oscar Newman (1973). During the 1970s, they explored the intricate relationship between crime and urban design, aiming to decipher the upsurge in crime in urban America. They coined the terms 'defensible space' (Newman) and CPTED (Jeffrey), profoundly impacting research and policy (Cozens,2001). Despite their influence, criticisms have emerged, particularly regarding the oversight of social factors in shaping crime. This has fueled a growing CPTED discourse (Cozens,2001).

Social processes significantly shape crime and its prevention in the urban environment, as seen in works by (Monday J, 2013), (De Souza& Miller, 2012), and (Meth, 2009), which highlight the impacts of health disparities, historical racial inequality, unemployment, political influences, and more on crime and its management. These factors align with the study's objective to recognize gender dynamics' role in shaping criminology research.

3.3.3. Intersectional Studies – Gender, Emotions and Urban Environment

The discussion on intersectionality underscores the dangers of treating categories as distinct oppressions, because doing so suggests a distinction of oppressions that could lead to an essentialist understanding of them (Lefebvre, 1974). In order to comprehend women's experience of fear in public space (Pain, 2001) and their "spatial knowledge," this study analyses how women experience fear in the urban environment. This analysis builds on studies focused on the intersections of many dimensions of power (Koskela, 1997). The study aims to make progress toward a comprehensive understanding of fear from an intersectional and urban environment perspective and to contribute to research on the relationship between women's fears for their safety, the emotional experience of a space, and women's mobility in the urban environment three phenomena that are rarely dealt with together.

Based on the findings of the literature review, the study proposes the following research hypothesis:

1. The spatial limitations that women face in daily life are a manifestation of the gendered power relations that are assumed.
2. Women's inferior status and their personal contributions to the upkeep of gendered power in connection to space are a direct result of their experiences with fear.
3. The urban environment can convey meaning, eradicate 'fear' and elicit urban emotions to implicate a gendered spatial context.

4. Analytical Results

4.1. Data compilation and Data mapping

The aim of this process is to explore the built environment from a 'macro' to a 'micro' scale. Qualitative data extracted from various online sources included datasets with significant social and spatial characteristics that define the urban environment and its use. Datasets such as road network, residential densities, pedestrianization levels, permeable neighborhood density, economic development levels, population density, transportation, and people's perception of the public areas were mapped using GIS to study the complexity of patterns formed by the data across Central Delhi. To understand the significance of social qualities of space in relation to the built environment, data from Twitter related to keywords signifying negative and positive emotions such as 'fear', 'happy', 'calm', 'sad' was extracted and mapped on QGIS.
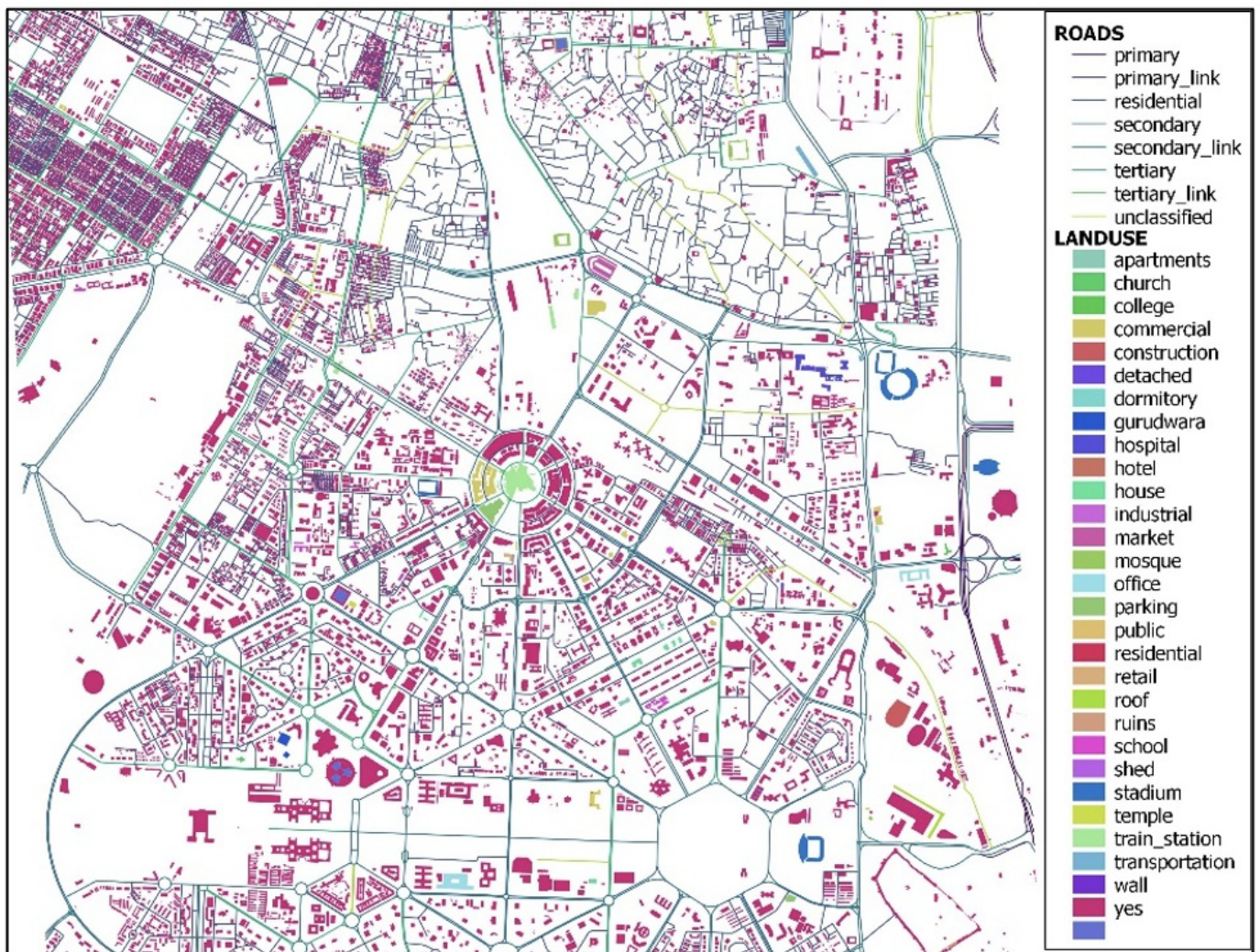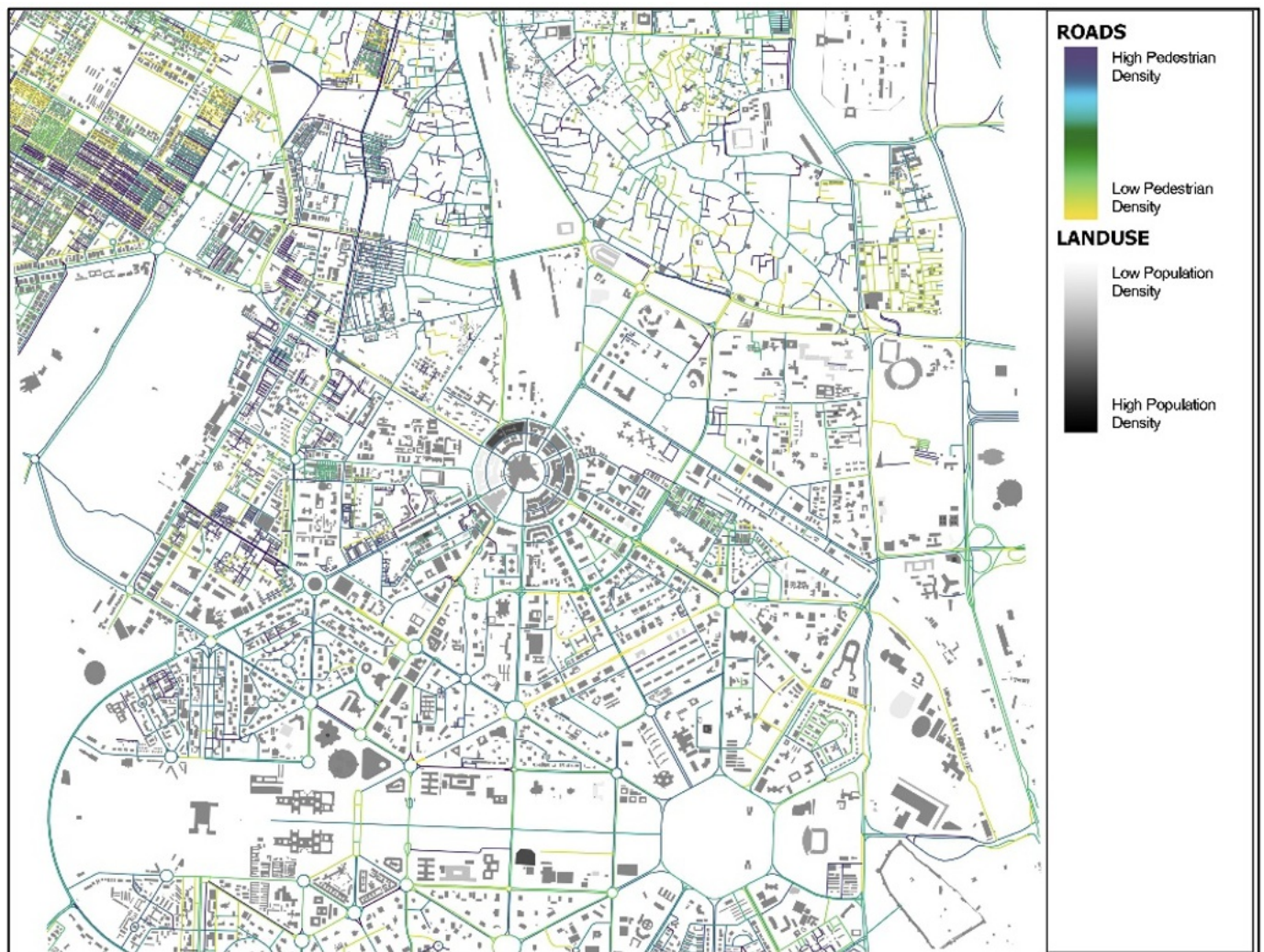
Figure 4. Land use and Mobility
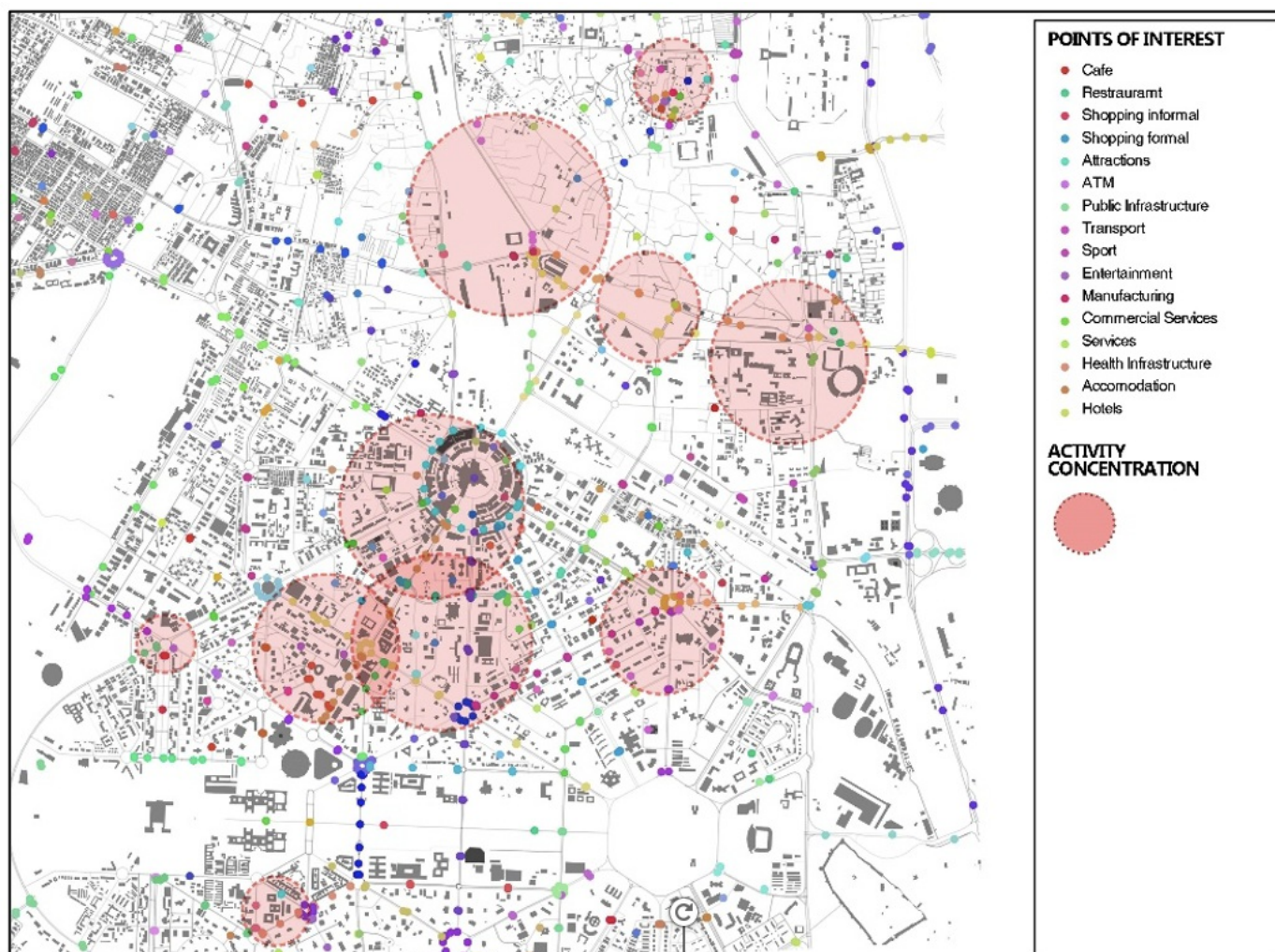
Figure 5. Pedestrian Density
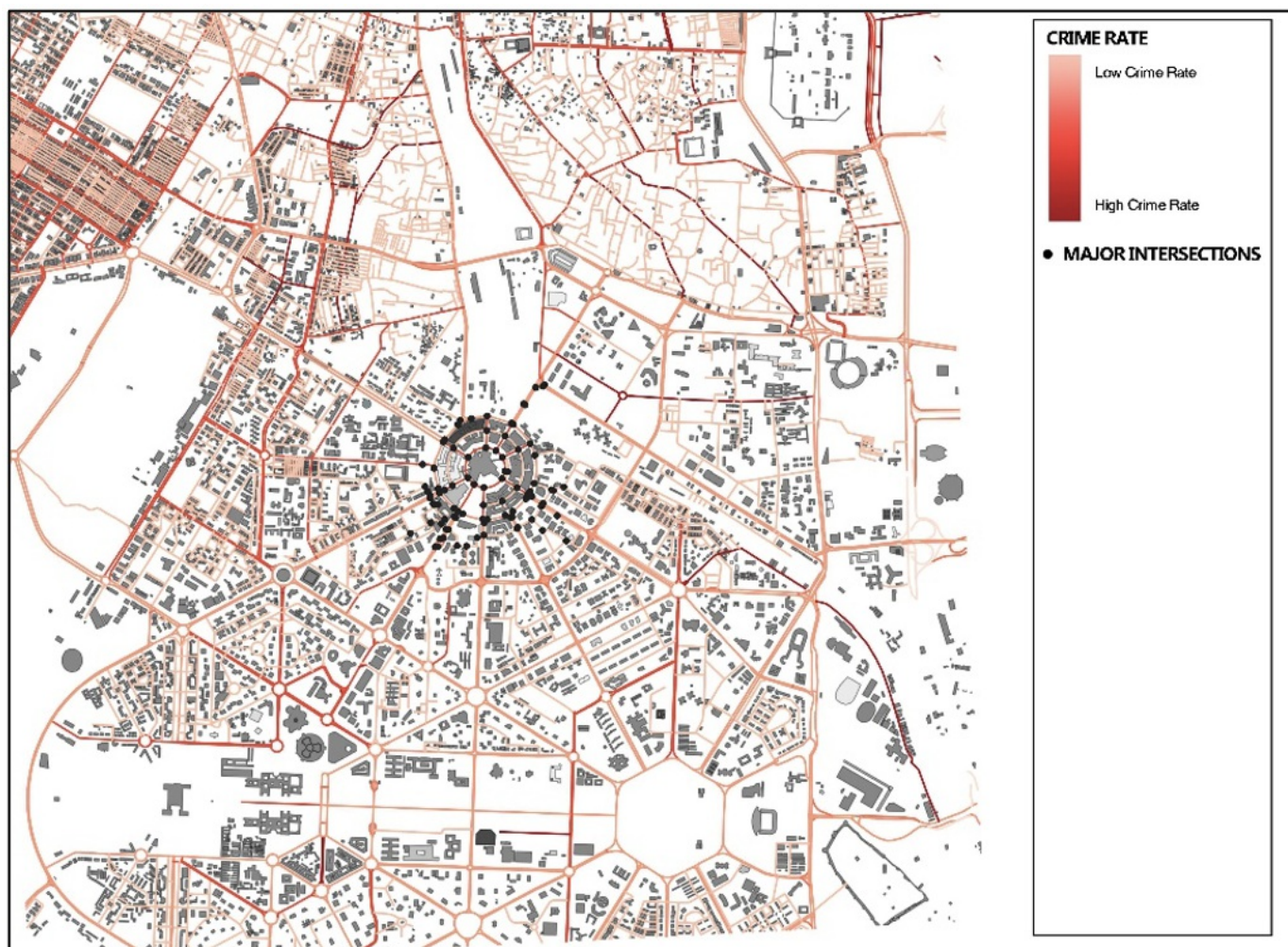
Figure 6. Economic Density
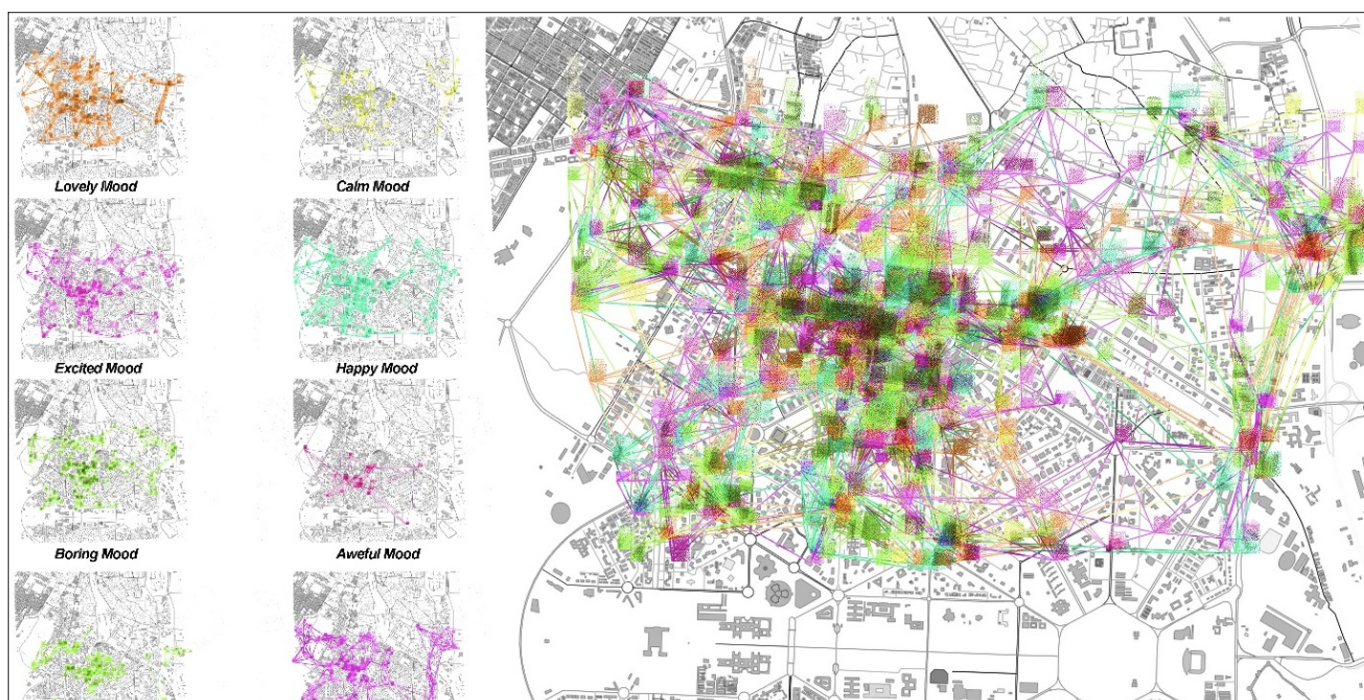
Figure 7. Crime Rate

Figure 8. Emotions such as 'happy', 'sad', 'fear', 'pleasant', 'love', 'bored' extracted and mapped in Central Delhi from Twitter using machine

learning analysis.

4.2. Modelling and Analysis

After the data compilation, the analytical phase begins with the spatial analysis including the use of modelling techniques such as axial and segment-angular analysis, high-resolution spatial network modelling, visibility, and Visual Graph Analysis (VGA). The pedestrian or vehicular movement patterns are further analyzed to create an in-depth understanding of human activities and interactions in their areas. Statistical analysis is used to explore the relationship between human activity and spatial configuration.

Figure 9. Spatial Network Modelling with space syntax analysis showing Integration 1000R.
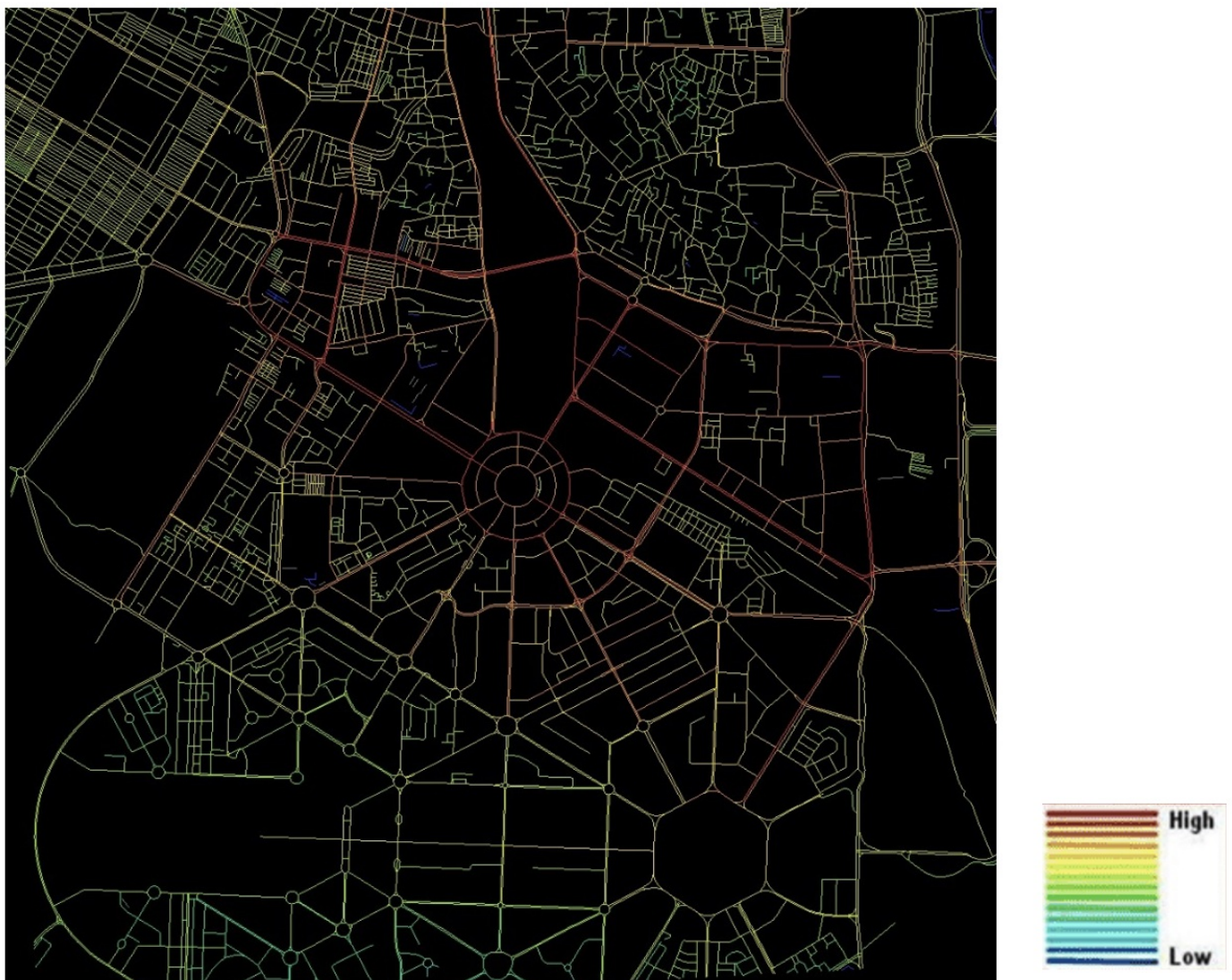
4.3. Machine Learning Dimensionality Analysis

Using linear dimensionality, the data is further reduced from the three-dimensional aspect using machine learning

techniques such as K-means clustering and Principal component analysis. The resultant clusters are mapped to understand the dominant datasets which are – population, Public Transport Access Levels, points of interest, economic activity, pedestrian footfall and its influence over Central Delhi.
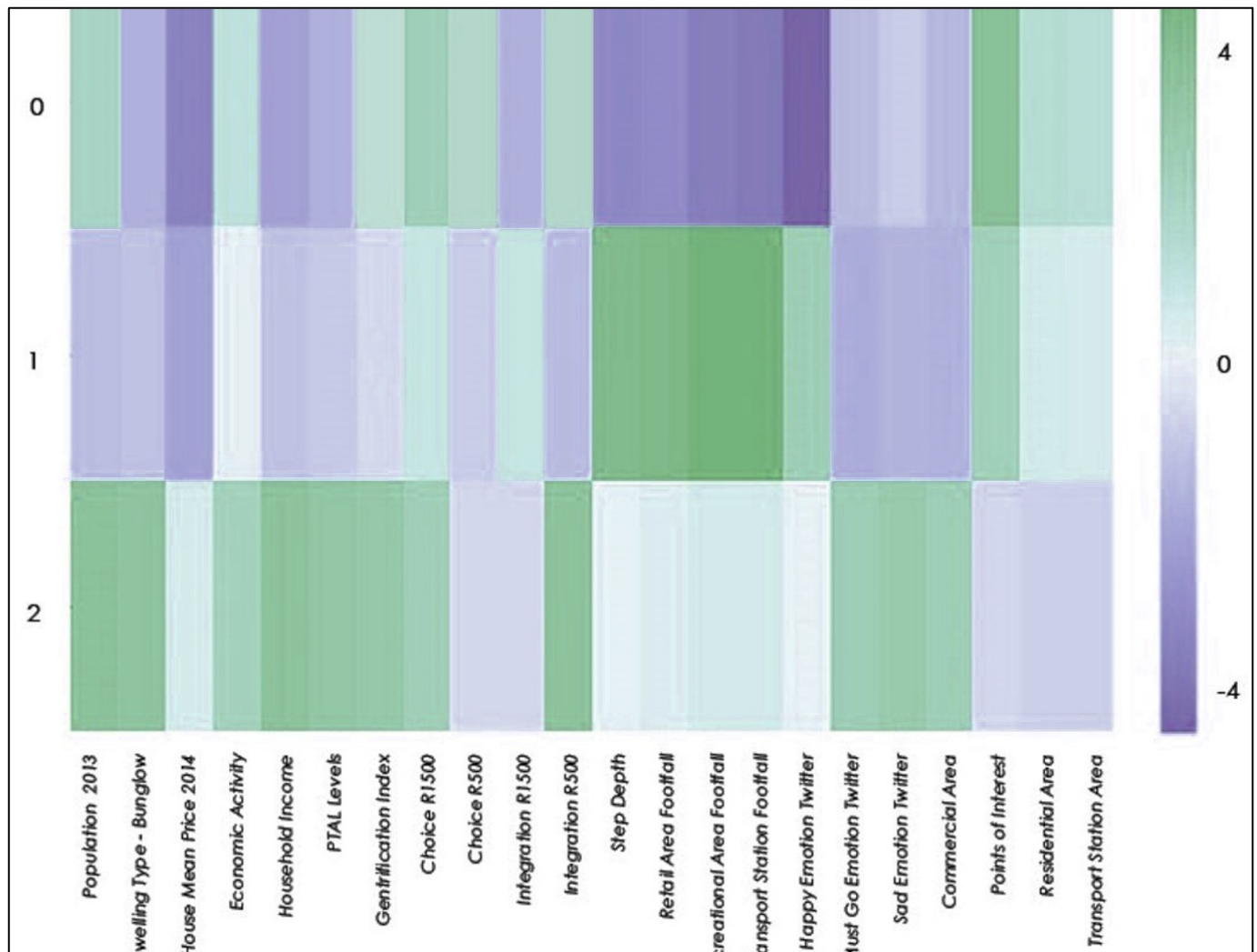

Figure 10. Principal Component Analysis used for analysing the dominant datasets prevalent in Central Delhi and understanding the contextual framework

4.4. Categorize the Urban Spaces Using Image Semantic Segmentation

Image semantic segmentation is an integral part of machine vision technology regarding image understanding. Semantic segmentation based on supervised learning can divide an image into several specific regions with unique properties and propose targets of interest, which is the process of linking each pixel in an image to a class label. These labels may include buildings, trees, roads, etc. Semantic segmentation enables the fast recognition, segmentation and processing of image data. The following simulation is performed in areas with extracted emotional data to get a building-to-image percentage. The images were analysed using semantic segmentation to segregate different elements such as sky, trees, roads and buildings.
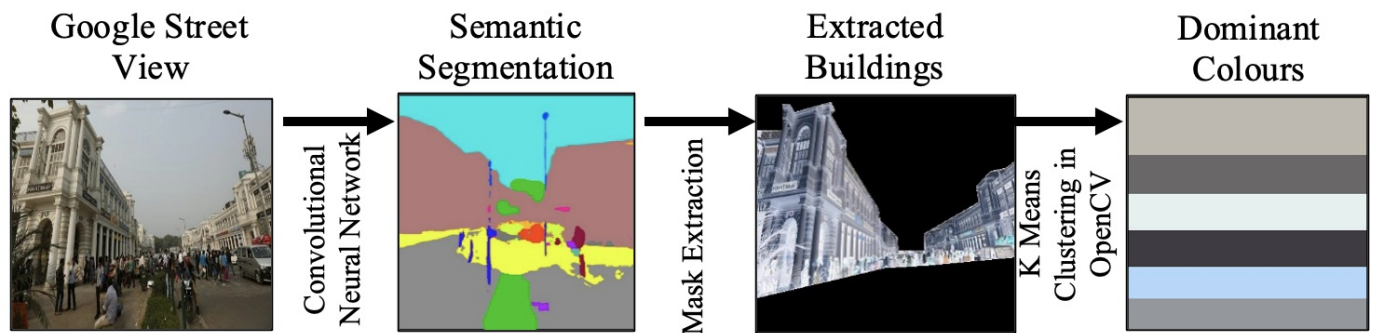
Figure 11. Image and semantic segmentation model.

The final model outputs the result of segmenting the land use into colors. The result contains 10,340,400 open spaces, 54,530,450 landscape spaces and 100,200,405 built spaces. According to the segmentation results, landscape spaces have the highest proportion, followed by open spaces and built spaces have the highest proportion.

4.5. Correlation of Emotional Data and Image Segmentation

The last part of the study intends to explore the correlation between the emotional data extracted and the image segmentation model and discover which spaces have the potential to influence gender segregation based on evoking negative and positive emotions amongst people while traversing through the built environment by computing rank cross-relation to indicate the strength of the correlations (figure 22).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\left[n\left(\sum x^2\right) - (\sum x)^2\right]\left[n\left(\sum y^2\right) - (\sum y)^2\right]}}$$
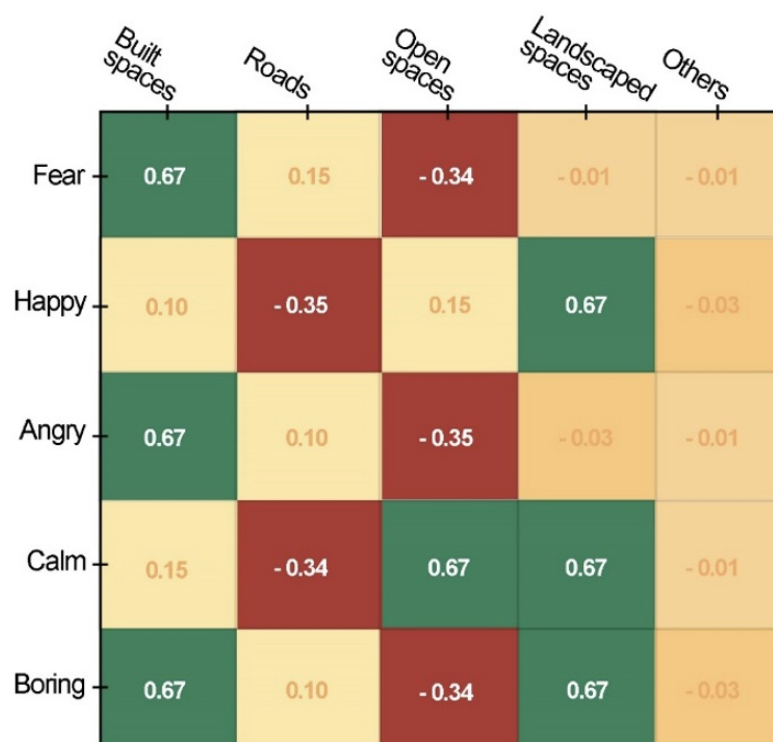
Figure 12. The study analysed correlations between social media emotional data and a segmentation model. Cross-correlation ranked perceptions experienced together. High 'fear' and 'angry' emotions were linked to 'built spaces' and 'roads' (less 'open spaces'). 'Happy' and 'calm' emotions dominated 'landscaped spaces' and open areas. 'Awful' and 'boring' emotions correlated with 'landscaped spaces' and 'built spaces'. On average, landscaped areas related to 'boring', 'happy', and 'calm' emotions; open spaces to 'calm', 'happy', and 'boring'; built spaces to 'fear' and 'angry' emotions. Despite not reflecting expected values, these strong correlations provide valuable insights into the study.

5. Discussion

This study aimed to enhance awareness of gender and sexuality aspects in design and emotional perception while assessing the inclusiveness of established urban design guidelines in these areas. Given the limited literature on this topic in architecture, the assumption was that CPTED's design guidelines lacked complete gender and emotion inclusivity. Data exposed gender inequalities and 'fear' patterns, revealing societal biases. Notably, a culture of violence against women stemmed from gender inequity, intertwined with women's fear of sexual violence due to reported incidents. This generalized fear was justified, as women shared knowledge of assaults on others, inducing fear despite personal experiences. Few studies explored emotional connections to happiness in urban spaces. The study plans to craft a design strategy from emotional data and highlight the link between urban development and emotions. A positive urban atmosphere correlated with better emotional states. Future research should delve into design elements impacting urban ambience, bridging subjective emotions and objective urban characteristics for effective urban planning.

6. Conclusion

Unnecessarily aggravated by gender-ignorant urban planning, disproportionate fear of urban crime is an oppressive, informal social control of women that frequently serves to divert attention away from the more common issue of domestic violence. The study on gender-specific usage of urban spaces offers a number of fairly broad recommendations to the existing CPTED literature from the perspective of gender-sensitive urban development to assist both sexes in finding the appropriate spaces.

1. The intersection of gender, fear and emotions would build the global relevance of the CPTED literature through the addition of diverse perspectives.
2. It raises awareness of the idea that space is not neutral; depending on how it is designed, women's and girls' use of, appropriation of, and safety in such places may be supported or undermined.
3. To lessen displacements and rivalry for use, there should be enough open space that can be appropriated nearby.
4. It recognizes that women are aware of when, why, and places in cities where they feel unsafe, and that their fears are rooted in reality (the connection between feelings of fear and violence).
5. People should be encouraged to use and appropriate a diverse range of spaces to promote multi-functional utilization.
6. Parks and sports facilities, for instance, should be used for several purposes.
7. A crucial precondition is security. This can be accomplished with the use of open structures, visual linkages with the environment, and supervision.
8. Diverse demographic groups should have access to different facilities. They should be defined in detail.
9. Atmospheric quality is extremely important, especially for women.
10. Small-scale structures are necessary because a dominant, arena-type atmosphere encourages gender-specific types of appropriation.
11. In addition, females, especially those in the early stages of puberty, require specific protected times or places in order to reach their full potential unimpeded, such as when participating in sports away from male gaze. Although gender-sensitive participation methods must be ensured, the public's effective engagement should be self-evident.
12. Interim usage projects need to be planned more flexibly and with greater care for gender-sensitive challenges.
13. In addition, more in-depth research is required to comprehend the effects of changing gender relations in relation to a variety of emotional states and encounters with the urban environment.

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Biography

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