Research Article

Evaluating the parameter of visibility adopted for CPTED for user safety in public open space of Haat Bazar: Isovist and VGA

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Public open spaces (POS) are an indispensable part of a well-functioning city that humanize urban areas. However, whether an individual will utilize the space, or shy away from it, depends on the individual's perception of an area in terms of safety. The driving force that governs the safety of users in urban POS is the parameter of visibility. Enhanced visibility reduces the fear of crime through natural surveillance, which is one of seven first-generation CPTED Concepts. This study aimed to explore the effectiveness of Isovist and Visibility Graph Analysis (VGA) in evaluating the parameter of visibility for user safety in the public open space of Haat bazaar. For this purpose, Dilli Haat INA and Dilli Haat Janakpuri were identified as the most suitable study areas. These case study sites were analyzed under three main heads-1. Archival review of crime records and architectural case studies to help identify the area of interest, 2. Layout study using Isovist and VGA tools for analysis, and 3. Surveys conducted in regular summer, regular winter, and in the festive season for each of the sites. The comparative analysis of the outputs from these three heads showed that Isovist and VGA can be used as a way of evaluating the visibility based on real-time vision and human-based vision respectively. Although this paper is limited to only one typology of POS, this exploratory research has achieved new insights into visibility as a parameter of user safety for CPTED.

Highlights/ Relevance: The role of security in Maslow's hierarchy of needs and SDG targets 11.7, 16.1, 16.5 underline exigency of CPTED in POS.

The use of Isovist and VGA for evaluating visibility based on real-time and human-based vision respectively may motivate formation of a toolkit for urban designers to design defensible spaces.

Keywords: CPTED, Haat bazar, User safety, Isovist, Visibility graph analysis (VGA).

1. Introduction

Public open spaces (POS) are an indispensable part of a well-functioning city that humanize the urban areas. However, whether an individual will utilize the space, or shy away from it, depends on the individual's perception of an area in terms of safety. Every 51 minutes, there is a case of female harassment in a POS of India (Bhattacharyya, 2016). As per the National Crime Records Bureau, there was a stark 19.7% increase in cases of crime against females, reaching 0.406 million as of 2019 within 3 years (NCRB, 2016; NCRB, 2019). Cases of crime and the fright of harassment hinder a female's access to the POS and subsequently, their right to the city, setting about an emotion of detachment (Beebeejaun, 2017; Bhattacharyya, 2016; Harvey, 2012; Koskela, 1997; Mahadevia, Mishra, et al., 2016; Mehta, 2014). As per India's National Crime Records Bureau (NCRB), the national capital Delhi has a rate of 1,306 IPC crimes every 1 lakh population in 2017. The national capital stands on top of the crime rate chart for abductions and kidnappings with a crime rate of 32. This study primarily explored the POS of Haat bazaar in Delhi, though the crimes can occur at any location - be it a built or an open space.

Aim, objectives and scope

The aim of the study was to explore the effectiveness of Isovist and Visibility Graph Analysis (VGA) in evaluating the parameter of visibility of CPTED for user safety in the public open space of Haat bazaar.

The specific objectives of the study include:

- 1. To study the public spaces of urban Haat bazaars of Delhi.
- 2. To analyze the data on the safety of users in Haat Bazaars of Delhi.
- 3. To explore the parameter of visibility to promote safety of users in Haat bazaars.
- 4. To explore the effectiveness of Isovist and VGA as a way of evaluating the visibility.

The scope of the study is limited to the Public Open Spaces of urban Haat bazaars of Delhi. As this study was part of academic dissertation with time schedule, the survey sample size was confined to only 5% of the total footfall.

2. Literature review

Othman, F. et al. (2019) investigated how visual analysis techniques of Isovists can be employed to promote safe spaces using several strategies to evaluate visibility along movement patterns, including GIS, Isovist analysis, DEM, Point cloud from LiDAR, View dome tool, and statistical data comparison. The suggested methods demonstrated the capability to extract significant spatial and topological information in both 2D and 3D environments, offering valuable insights into enhancing safe spaces. Hillier B., et al. identified three ways in which space syntax methods can be applied to the study of natural landscapes: attributing attributes to spatial units (nodes in the graph representation), attributing attributes to relationships between spatial units (edges in the graph), and the use of multi-layered graphs. Knöll, M., et al. investigated how selected properties commonly used in space syntax research relate to users' ratings of stress and spatial qualities in open public spaces. The study involved extracting syntactical properties from previous literature and combining this data with city dwellers' ratings of open public spaces concerning stress perception and urban design qualities. The findings indicated a weak relation between vertices' density in an open public space's Isovist and participants' safety ratings. Line-based measures, such as global and city-wide integration, were identified as potentially valid measures for analyzing stress perception in outdoor spaces. Turner A. et al. explored how syntactic analysis of Isovists complements existing space syntax methodology, particularly in automatically generating integration values from 3D CAD models. Gupta, R in his study aimed to determine whether the spatial distribution of crime could be employed to identify areas at a higher risk of criminal activity. It utilized crime data from the Delhi Police and analyzed it using space syntax integration, GIS, and GPS techniques to identify spatial crime patterns. The findings revealed that crime hotspots tend to concentrate in areas characterized by low integration, suggesting the potential for using spatial analysis to identify and mitigate crime risk in urban environments.

3. Methodology

An evaluative research approach was adopted for conducting the study. Dilli Haat INA and Dilli Haat Janakpuri were identified as most suitable sites for conducting this study. Conducting a CPTED study on Dilli Haats is justified for several compelling reasons. These open-air markets in Delhi, known for their unique architectural and cultural features, attract a diverse array of visitors, making public safety a top priority. Assessing how the design elements impact safety can reveal opportunities to enhance security without compromising cultural significance. Moreover, Dilli Haats are vital to tourism and the local economy, so improving safety can attract more visitors, boosting economic growth. Additionally, creating a safer environment contributes to the well-being of the community by enhancing the quality of life for residents and visitors. These case study sites were analyzed under three main heads-1. Archival review of crime records and architectural case studies to help to identify the area of interest, 2. Surveys conducted in regular summer, regular winter, and in the festive season for each of these sites and 3. Layout study using Isovist and VGA tools for analysis. The outputs from these three heads were compared to test the reliability of the methods used and the results obtained. Further critical evaluation and analysis was done to draw conclusions and suggest future scope of the research.

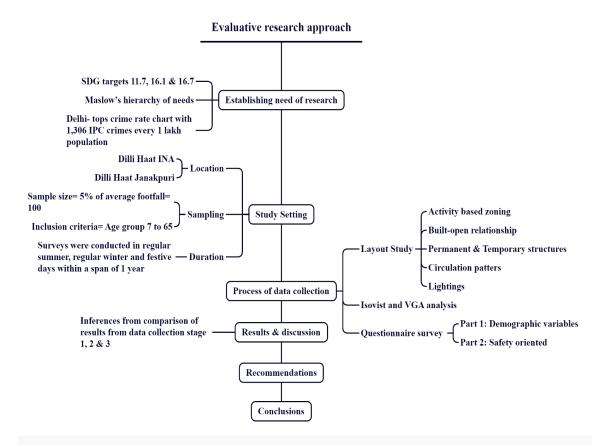


Figure 1. Schematic representation

3.1. Technologies used

3.1.1. Crime prevention through environmental design (CPTED)

CPTED, which stands for Crime Prevention Through Environmental Design, is a way of using the design and layout of our surroundings to stop criminal behavior. Seven key CPTED concepts include: territoriality, surveillance (informal and formal), access control, image/maintenance, activity programme support, target hardening and geographical juxtaposition. Some researchers, like Fisher and Nasar (1992), talk about three types of things in CPTED: places where you can see everything, places where people can hide, and ways for people to get away. Taylor and Harrell (1996) say that people are more afraid of crime in places where criminals can hide easily but it's hard for others to see or escape from. Through optimizing the visibility of spaces, it becomes possible to deter criminal activities.

Space Syntax

Space syntax is an analytical framework rooted in architectural and urban studies that aims to comprehend the relationships between spatial configurations and human behavior within the built environment. It is based on how the layout and connectivity of spaces (visibility patterns, circulation, and spatial organization) quantitatively influence people's interaction & perception of their surroundings.

The selection of the Isovist/VGA tool was done based on the following comparative analysis.

ANALYSING THE PUBLIC OPEN SPACE FOR SAFETY					
TOOLS ► FACTORS ▼	Convex Space	Axial Space	View Dome Tool	Point cloud from LiDAR	Isovist/ VGA
3 Dimentional Space Analysis	8	•	•	•	8
Can Be used at Designing Phase for exploration of various options	0	•	•	8	•
Autocad files can be imported	•	•	•	8	•
Appropriate for exterior spaces	8	•	•	•	•
360 degree field of view	•	8	•	•	•
Type of analysis	Link analysis	Linear Visibility	⊘ Visibility	Model Generation	
Open Source Software	•	•	8	•	•

Table 1. Selection of tool

Isovists, a tool of space syntax represents a specific point's location within an enclosed polygonal space and the three-dimensional volume of space visible from that point (Benedikt, 1979; Weitkamp, 2011). Isovist/VGA can be used at designing phase for exploration of various options and finding out the option with highest values of natural surveillance. It also offers other benefits such as 360 degree field of view, appropriate for exterior spaces and an open source software where AutoCAD files can also be imported.

The integration of Isovist analysis into Geographic Information Systems (GIS) having abundant availability of geo-referenced data and visualization tools enhances visibility analysis from a human perspective. This integration involves utilizing undirected graphs to connect all visible points within a human-scale grid creating a robust framework to tackle crucial challenges concerning the interplay between the built environment and human behavior, particularly in terms of safety considerations. Hence, Isovist/VGA has been selected as the most appropriate tool for the purpose of the study.

3.2. Process of data collection

The survey was conducted at 2 locations - 1. Delhi haat INA - located in Kidwai nagar, opposite INA market, New Delhi with a site area of 6 acres and 2. Delhi haat Janakpuri located in Lal Sai Mandir Marg, Virender Nagar, Janakpuri, New Delhi with a site area of 8 acres. Average daily footfall in Dilli Haat INA and Janakpuri is 3000 and 1000 respectively as per Delhi tourism records for the year 2021. 5% of the average footfall of the two Haats i.e., 100 was taken as the sample size. Only visitors within the age group of 7 to 65 years were surveyed as per the inclusion criteria. Duration of the data collection was for one year. The surveys were conducted in summer, winter and in festive days.

Questionnaire and Space syntax were used for data collection.

The questionnaire consisted of 14 questions. Part 1 dealt with demographic variables such as gender, age, education etc. and Part 2 dealt with safety of the people using the POS of Haats. Likert Scale was used to measure the survey responses in the form of a number of ratings, which was further analyzed as bar & pie charts. Likert scale helped to measure the safety of the people in the haat. A score of 5 if given for highest safety and a score of 1 is given for lowest safety.

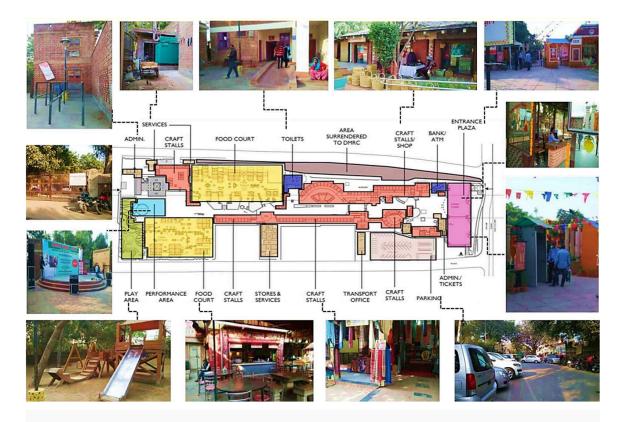
Isovist- a type of space syntax and VGA- a GIS based tool, were used as tools to analyze why people perceive places differently, why certain places are more meaningful, and some can easily be forgotten i.e. human perception in built environment. It is one of the most popular way analyzing the field of view from a particular point in a built environment.

4. Findings and Discussion

4.1. Dilli Haat INA

4.1.1. Layout study

Constructed in 1993 under Delhi Tourism and Municipal Corporation of Delhi, Dilli Haat INA situated in Kidwai Nagar, opposite INA market, New Delhi is a popular tourist destination and one of the most visited shopping complexes in South Delhi. Covering a site area of 6 acres, it has approximately 12% ground coverage and a built-up area of 3190 sq.m. The figures below represent the layout study under various heads as per figure 1.



 $\textbf{Figure 2.} \ \textbf{Activity based zoning plan}$

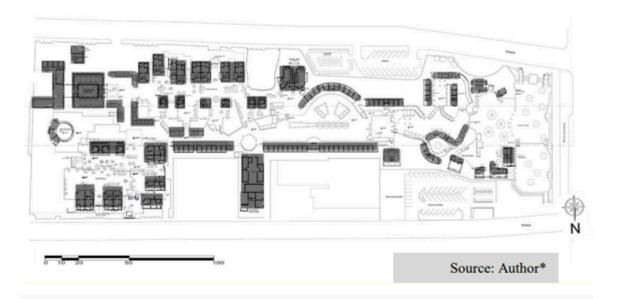


Figure 3. Built-open Relationship

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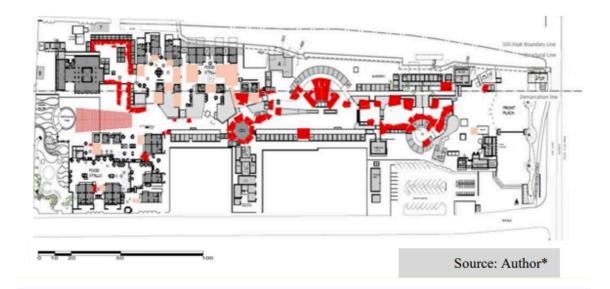


Figure 4. Temporary/ permanent structures

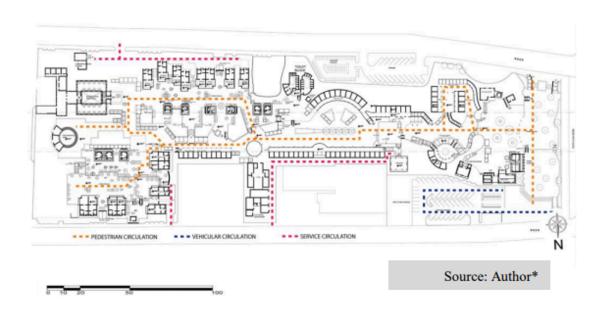


Figure 5. Circulation pattern

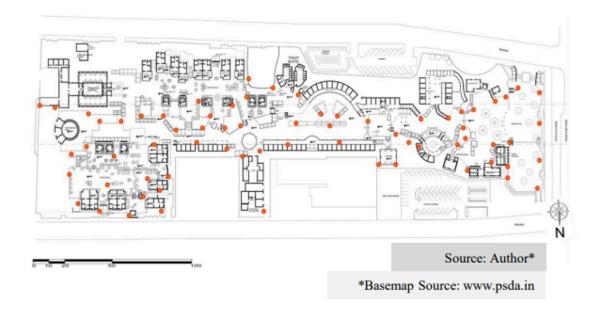


Figure 6. Lighting

4.1.2. Isovist and Visibility Graph Analysis

The Visibility Graph Analysis of the axial map of Dilli Haat INA showed that the street corresponding to the first half of the central spine from entrance had the highest values of visibility but comparatively smaller values of integration to the overall system. This is by virtue of its linear character which supports its function as a shopping street. In comparison, the latter half of the central spine with a nearer value in visibility has very high value of integration as it is well integrated into the network of food zones on both sides. The food zones that flank as networks on both sides of the spine after the roundabout has a medium level of visual connectivity and integration. The lowermost portion of the site has lesser integration levels due to its visual discontinuity. This is visible through in-situ observation. Space syntax tools further reveal the underlying properties of the spatial configuration of Dilli Haat.



4.1.3. Questionnaire survey

A survey was conducted to assess the safety perception of people at the haat. The results showed that people feel most safe in the afternoon (56%) and least safe at 10:30 PM (27%). They also feel safer during 7 PM in summer (52%) than in winter (45%). People feel safer on regular

days (70%) than on festive days (60%).

In terms of location, people feel most safe in front of the shops (70%) and least safe in voids and toilets (49%). The public visibility is insufficient for 30% of the people. The night lighting of the haat is neutrally safe and sufficient for 54% of the people, while 27% think it is unsafe. The public toilets of the haat are neutrally safe for 59% of the people, but 40% feel it unsafe. The pedestrian pathways in the haats are safe and clear for 54% of the people.

The survey also found that 81.4% of the people have no idea regarding lost/found provision in the haat. Additionally, 45.5% of the people feel that the haat is unsafe for children. 70% of people feel most safe at the entrance and least safe at the end (57%).

4.2. Dilli Haat Janakpuri

4.2.1. Layout Study

Constructed in 2014 under Delhi Tourism and Municipal Corporation of Delhi, Dilli Haat Janakpuri is situated in Lal Sai Mandir Marg, Virender Nagar, Janakpuri, New Delhi. Covering a site area of 9.6 acres, it has approximately 27.8% ground coverage and a built-up area of 9028 sq.m. The underlying layer that bonded the overall program of formal and informal shops was its "rhythmic heartbeat concept". The figures below represent the layout study under various heads as per figure 1.



Figure 8. Activity based zoning plan

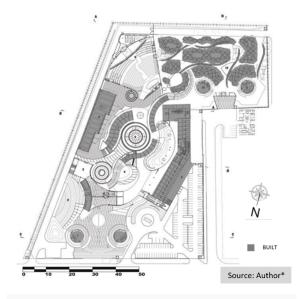


Figure 9. Built-open Relationship

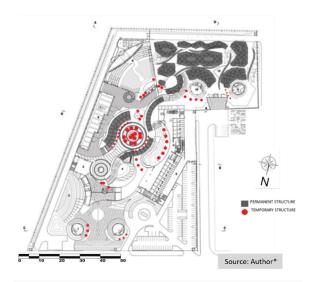
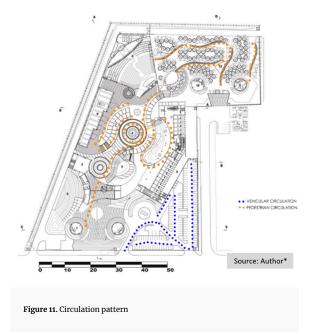


Figure 10. Temporary/ permanent structures



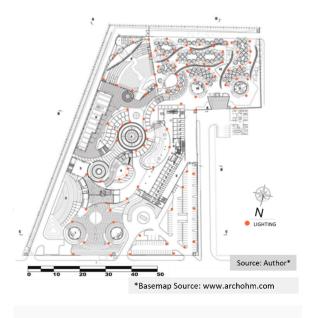


Figure 12. Lighting

4.2.2. Isovist and Visibility Graph Analysis

The visibility analysis of the Dilli Haat Janakpuri plan shows that the street corresponding to the entrance has the high values of visual connectivity and integration to the overall system. In comparison, the latter half of the central spine with lower visibility value poorly connected to the network of food zones. The rear end of the haat has the lowest values of visibility. The canopy structures further lower the visual connectivity values. The toilets have lesser integration levels due to their visual discontinuity. This is visible through insitu observation. Space syntax tools further reveals how urban spaces and their configurations can translate into positive public value.

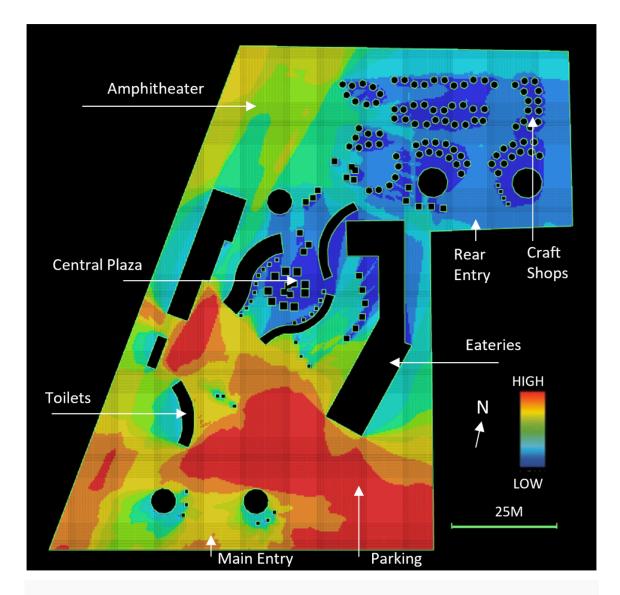


Figure 13. VGA of Dilli Haat Janakpuri

4.2.3. Survey

The results showed that people feel most safe from morning to evening (54%) and least safe during late hours after 6:30 PM (37%). They also feel safer during 7 PM in summer (59%) than in winter (41%). People feel safer on festive days (78%) than on regular days (50%).

In terms of location, 48% people feel safe in front of the shops and 37%safe in front of the voids and empty spaces and toilets. The public visibility of the entire haat is safe for 60% of the people. However, 59% of the people feel that the night lighting of the haat is not sufficient in terms of safety of women and children. The public toilets of the haat are not safe for 60% of the people. The pedestrian pathways in the haats are safe and clear for 45% of the people.

The survey also found that 86.4% of the people have no idea regarding lost/found provision in the haat. Additionally, 40% of the people feel that the haat is safe for children and 27% feels that it is not safe. 70% of people feel most safe at the entrance and least safe at the end (42%).

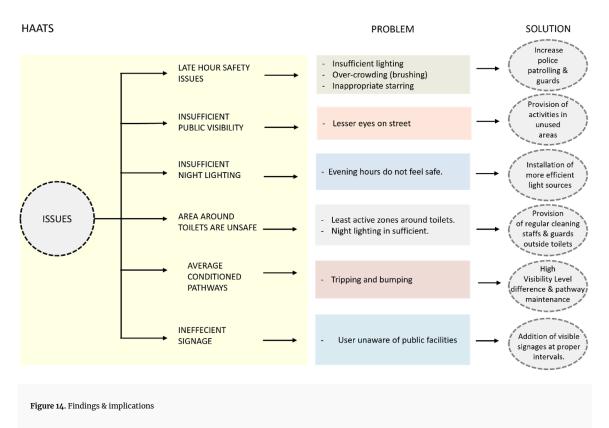
4.3. Implications

The data from the survey conducted at Dilli Haat reveals several important quantitative impact relationships related to safety, visitor perceptions, and areas for improvement. Firstly, there is a clear correlation between the time of day and people's sense of safety. The majority

(56-63%) feel most safe during the morning to evening hours, while a significant portion (27-37%) feels least safe during late hours after 6:30 PM. This indicates that the perception of safety is strongly influenced by the time of day. Secondly, seasonal variation also impacts safety perceptions. People feel safer during the summer evening hours (59%) compared to winter (41%). This suggests that not only weather conditions and seasonal changes can affect how visitors perceive safety, but their perception is also mostly linked to the daylighting. Furthermore, mostly users prefer evenings and mornings for visiting POS in summer due to the harsh sun of daytime, which means that during evening hours there is a higher footfall in Dilli Haat. Although during the winters the evenings are much colder, and people prefer to visit POS during daytime when the sun is up. This strongly implies that people's perception of safety is directly linked with the footfall and hence the natural surveillance. Thirdly, the location within Dilli Haat plays a crucial role in safety perceptions. Visitors feel most safe in front of the shops (63%) but least safe in front of voids, empty spaces, and toilets (83%). Additionally, the entrance is perceived as the safest (67%), while the end is considered the least safe (33%). This highlights the importance of well-lit and well-monitored areas within the market.

In addition, the type of day, whether it's a festive day or a regular day, also influences safety perceptions. More people (56%) feel safer on festive days compared to regular days (44%) in Dilli Haat Janakpuri where the footfall is usually very low, while more people (67%) feel safer on regular days compared to festive days (33%) in Dilli Haat INA where footfall is usually on the higher end. This demonstrates that special events and festivals attract the users into public spaces hence increasing the natural surveillance as seen in Dilli Haat Janakpuri. Interestingly, while natural surveillance essential for the perception of safety, this natural surveillance reduces when there is overcrowding as seen in the example of INA. Moreover, there is a significant concern regarding night lighting and public toilets, with 59% feeling that they are not safe. This underscores the need for improved lighting and security measures around these facilities.

The quantitative impact relationships between safety perceptions, time of day, season, type of day, location, and awareness of services at Dilli Haat suggest that there are some safety concerns at the haat, especially for women and children.



The study further highlighted several key issues identified at Dilli Haat along with their corresponding problems and potential solutions. Late-hour safety concerns are prevalent, marked by insufficient lighting, overcrowding, and inappropriate behavior. To address these issues, it is crucial to increase police patrolling and the presence of security guards to ensure the safety of visitors during extended hours of operation.

Moreover, the insufficient public visibility in certain areas of the venue poses a challenge, resulting in fewer eyes on the street. To rectify this, Dilli Haat management should consider utilizing unused areas for activities that attract visitors, thus enhancing overall public visibility.

Another significant issue revolves around the safety of areas around the restrooms, which are often perceived as least active zones due to inadequate night lighting and insufficient cleaning. To mitigate this concern, Dilli Haat should allocate regular cleaning staff and security guards to maintain a safe and hygienic environment around the toilets. Additionally, the average-conditioned pathways within the market can lead to tripping and bumping incidents. To address this, regular maintenance of the pathways and enhancing their visibility, particularly in areas with level differences, is essential.

Lastly, the issue of inefficient signage contributes to user unawareness of available public facilities within Dilli Haat. To enhance visitor convenience, visible signages should be strategically placed at proper intervals throughout the venue, providing clear guidance and information on the location of essential facilities. In summary, addressing these identified issues through the proposed solutions will help Dilli Haat maintain its status as a vibrant cultural hub while ensuring the safety, visibility, and accessibility of the space for all visitors.

5. Recommendations

- · Increase the number of guards and police patrolling in POS
- Usage of performances to engage more public
- · Provision of performance areas in front of eateries,
- · Closure of the rear entrance
- Provision of slot wise entry to limit the crowd,
- · Installation of CCTV cameras and loudspeakers,
- Installation of Fog lights, Radiating and Moving lights
- · Provision of regular cleaning staff and stationed guards around the toilets
- Well-placed Signages at appropriate intervals throughout the premises.

6. Conclusions

The comparative analysis of the outputs from these layout study, VGA analysis and questionnaire surveys showed that Isovist and VGA can be used as a way of evaluating the visibility based on real-time vision and human-based vision respectively. Although this paper is limited to only one typology of POS, this exploratory research has achieved new insights into visibility as a parameter of user safety for CPTED.

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