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Computational Analysis of Street Vendor and Pedestrian Interactions in Lagankhel, Nepal

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Abstract

Street vendors play an important role in urban economy of developing countries, including Nepal. Regardless their contribution to accessibility, affordability, and social vibrancy, they are often excluded from the spatial planning. Many researchers fail to catch the adaptive, informal and interactive nature of street vending, notably in relation to pedestrian movement and behavior. This study investigates the spatial and social dynamics between street vendors and pedestrian in dense urban setting of Lagankhel, Nepal, through computational tools.

This study investigates the spatial arrangement and social interaction between street vendor and pedestrian through using computational tool. This research was conducted in the Lagankhel area of Lalitpur, a busy marketplace where both vendor activity and pedestrian flow intensify during the evening peak hours.

Field observations were combined with parametric simulations: Isovist analysis was used to examine spatial visibility, while PedSim was simulated the pedestrian movement flow and stopping behavior. Data were collected across four urban zones to assess vendors positioning, visibility and interaction duration.

Findings show that street vendors tend to occupy spaces with greater visual openness and spatial permeability, particularly near nodes of natural pedestrian slowdown or congregation. Pedestrians were observed to pause more frequently in areas with higher visibility catchment. These spatial behaviors highlight the adaptive strategies of vendors and the informal logic underlying their placement. Computational outputs showed that dense clustering of vendors reduced pedestrian flow efficiency, while clearer sightlines improved spatial legibility.

These results support the development of inclusive planning frameworks that account for the dynamics of street vending without undermining pedestrian accessibility

Keywords: *Computational tool, Streets vendors, Pedestrian behavior, Spatial visibility, Lagankhel*

1. Introduction

Street vending forms a vital part of the informal economy in many developing countries, including Nepal. Vendors offer affordable goods and services, promote cultural exchange, and enhance the vibrancy of public spaces. In Nepal's urban centers like lagankhel, Lalitpur, street vendors are deeply embedded in daily life, providing economic sustenance for both themselves and the local population.

However, rapid urbanization has intensified the conflict between informal vending and formal urban planning. Unregulated street vending often leads to congestion, safety concerns and disputes over public space. Relocation polices though well-intentioned have frequently failed, reducing vendor income and detaching them from key foot traffic zones. This misalignment revels a need for more responsive spatial strategies that integrate the adaptive behaviors of vendors and pedestrians.

Emerging computational tools such as parametric design, Isovist analysis and pedestrian simulation models offer new ways to analyze these complex interactions. These tools can bridge the gap between informal urban activity and data-driven planning, offering insight into movement patterns, visual accessibility and the spatial performance of vendors locations.

This research focuses on lagankhel, a densely populated transit and market hub in Lagankhel, a densely populated transit and market hub in Lalitpur, to explore how computational analysis can better inform spatial planning for street vendors without compromising pedestrian mobility.

1.1 Objectives

Street vendors play an essential role in the urban economy, mainly in developing countries like Nepal, current urban planners and architects' strategies often fail to adequately integrate them. Traditional relocation efforts have been unsuccessful due to decreased income for context and accessibility, and the loss of the vendors; informal identities. While computing analysis offer potential solutions for creating dynamic and engagement between street vendors and pedestrian. This research aim:

- To analyze the spatial planning arrangement and social dynamic between street vendors and pedestrian relative to pedestrian flow by using computational tool.

1.2 Literature Review

Street vending has gained scholarly attention for its economic, cultural and spatial significance in rapidly urbanizing cities. In developing countries, street vendors sere as essential service providers and income generators, particularly for low-income populations.(Torky & Heath, 2021) noted that vendors foster community cohesion while stimulating local economies. Similarly, (Sandhika et al., 2024) emphasized that vendors in Indonesia and Bangladesh adapt spatial strategies based on surrounding pedestrian flow, vehicular access and socio-political regulations.

A theoretical framework grounded in space syntax theory, introduced by Hillier (Van Nes, 2014), underpins much of the analysis of pedestrian behavior and spatial accessibility. The theory posits that spatial configurations inherently influence human movement patterns. In particular, the Natural Movement Theory(Van Nes, 2014) explains how pedestrian flows emerge from the street network's geometry, thereby affecting informal commercial activity. Areas with higher connectivity and integration are often more attractive to vendors due to the promise of consistent foot traffic. However, excessive clustering may lead to pedestrian obstruction, reducing flow efficiency.

(Lovanka et al., 2023) proposed that the concept of adaptability vendors' ability to adjust to spatial and temporal constraints and permeability, or ease of pedestrian access through vending zones. Their work highlights the importance of spatial legibility, particularly in hierarchical street layouts. However, this study, while detailed, is context- specific and would benefit from comparison with other case studies in South Asia, where legal and political challenges such as snit-vending drives (as seen in the Jakarta (Lovanka et al., 2023)) create friction between informal economies and urban authorities.

Moreover, traditional urban markets often lack the flexibility needed for evolving vendor pedestrian interactions. (Mohd et al., 2014) argue for spatial strategies that prioritize openness, visibility and interaction. (Mesher, 2009) supports these claims by advocating for designs that accommodate spontaneous social behavior within urban spaces.

Recently, computational approaches have enabled more nuanced analyses of informal urban dynamics. Tools such as Rhino and Grasshopper, with plugins like Pedsim and Isovist, offer parametric environments for simulating pedestrian flows and visibility catchment areas. Benedikt's (1979) concept of isovists, the visual field from a given point has become crucial in evaluating how vendors position themselves for optimal exposure (Hasgül, n.d.).

These tools, as (Dai & Wang, 2023) explain, translate qualitive urban conditions into measurable variables, enabling designers to test spatial interventions in virtual settings. However, scholar (Zhang et al., 2021) caution that such models must be contextualized through field data and human behavior studies, as computational predictions may not always capture socio-economic nuance.

This research, therefore integrates traditional spatial theory with parametric simulation, providing a holistic framework to examine how informal vendors respond to and shape urban pedestrian patterns.

2. Research Methodology

This research paper employs a mixed-method approach that integrates computational simulations with direct observations to analyze the spatial and social dynamics between street vendors and pedestrians in Lagankhel, Nepal. The research paradigm is primarily positivist, assuming that observable patterns and relationships exist within the urban market environment, supported by computational data.

Positivism adopts an objectivist ontology, asserting that a single, objective reality exists independently of human perception. This reality is governed by universal laws that can be empirically observed and measured (Junjie & Yingxin, 2022). Positivist epistemology emphasizes empirical verification through scientific methods (e.g., statistical analysis, computational simulations, experiments). Knowledge is derived from observable cause-effect relationships, aiming for generalizable conclusions. Researchers maintain emotional neutrality to avoid bias (Junjie & Yingxin, 2022). In this paper, social dynamics i.e. positivism would prioritize computational simulations to quantify pedestrian-vendor interactions.

However, elements of constructivist and interpretivist perspectives are acknowledged when interpreting the social interactions observed on-site. This integrated approach combines quantitative analysis (through computational simulation) with qualitative insights (via direct observation) to form a holistic understanding of the urban context.

Methods

The research design is structured around three interlinked phases: site-based observation, computational simulation, and synthesis. First, the research was conducted on-site documentation of vendor types, their spatial positioning, stall sizes, and interaction with pedestrians.

The Market Hub area of Lagankhel was chosen as the central focus due to its high concentration of fixed vendors, intense pedestrian traffic, and spatial constraints. Field observation was conducted during evening peak hours (after 5:00 PM), which align with the highest levels of vendor activity and footfall. A series of 1-minute video recordings were used to capture pedestrian movement, vendor interaction, and stall layout. Although brief, these recordings were taken repeatedly from different points within the Market Hub, offering a representative snapshot of movement patterns and behavioral responses. The 1-minute duration was chosen based on existing literature, which suggests that critical pedestrian behaviors such as pausing, deviating paths, or engaging with vendors, can be effectively captured within 30 to 60 seconds in high-density settings.

Following fieldwork, computational analysis was carried out using Rhino + Grasshopper, integrating two plugins: Isovist for visibility analysis and PedSim for pedestrian flow simulation. Both tools were applied exclusively within the Market Hub area. For the Isovist analysis, multiple vantage points were selected based on visual corridors, obstructions, and key pedestrian intersections. These points were used to generate visibility catchment data, including visible area, and longest sightline, providing insight into spatial openness and vendor exposure. The PedSim plugin was used to simulate pedestrian flow across the same area, taking into account factors like obstacle placement (vendor stalls, building edges), attraction points, and route deviation.

Together, these methods enabled a layered understanding of how spatial arrangement affects pedestrian behavior and how vendors position themselves to maximize visibility and interaction. The findings from simulation and observation were then correlated to identify patterns of clustering, bottlenecks, and spatial inefficiencies. While computational tools provided quantifiable insight, the study also remained attentive to the social dimensions of informality, adaptability, and user agency within public space.

Conceptual Framework

Below flow chart illustrate the three-phase research methodology adopted in this study. The first phase involves direct site observations to document vendor typologies, time-based activity, and spatial distribution across four urban zones in Lagankhel. The second phase consists of computational analysis using Rhino-Grasshopper with Isovist and PedSim plugins. These tools were applied to simulate pedestrian movement patterns and evaluate spatial visibility from multiple vantage points. In the third phase, findings from field observations and simulations were overlaid and synthesized to identify high-interaction zones and critical spatial challenges. This mixed-method approach allows for a more holistic understanding of how spatial configuration affects vendor-pedestrian dynamics, supporting evidence-based urban design recommendations.

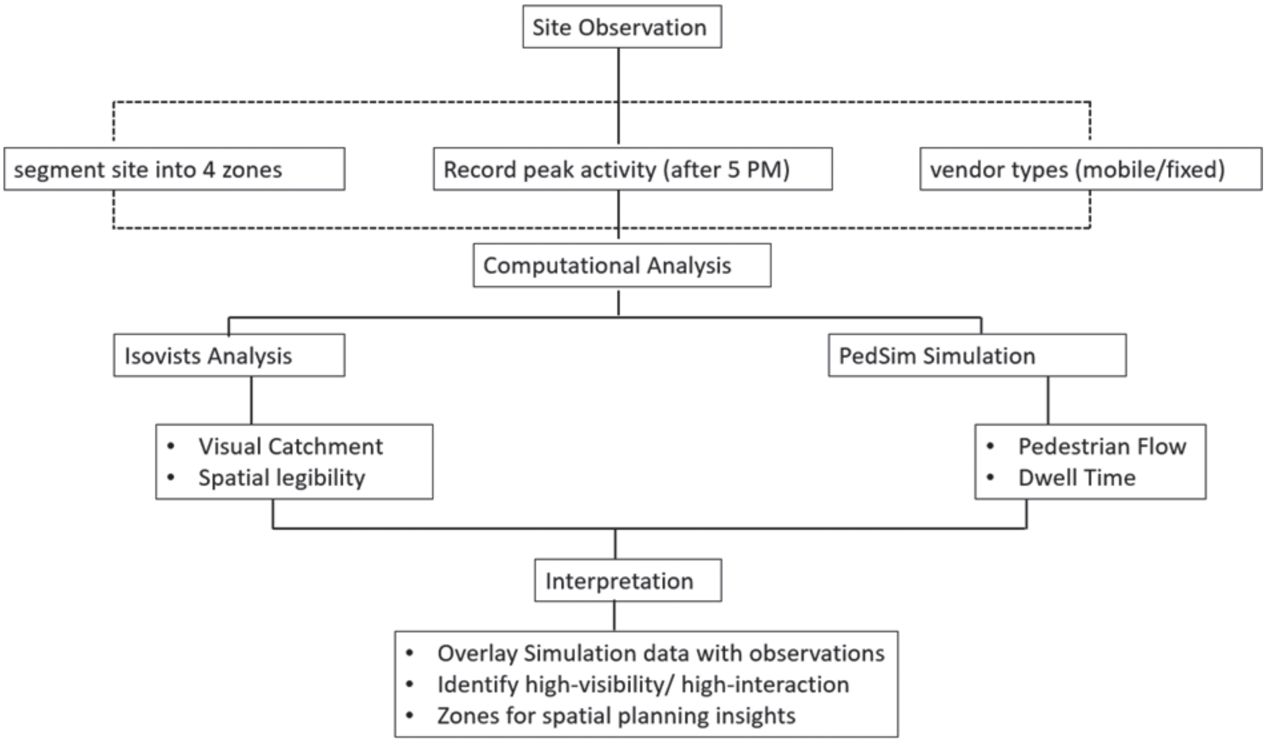

Figure 1: Conceptual Framework

3. Site

Lagankhel is deeply rooted in the cultural and historical fabric of Lalitpur, one of the most historically rich cities in Nepal. Pedestrian movement along Lagankhel Road involves a combination of sidewalk usage and shared spaces with vehicular traffic. Sidewalks may experience varying levels of foot traffic, potentially leading to congestion in busy areas. Challenges include inadequate pedestrian infrastructure, insufficient crosswalks, and potential safety concerns, particularly at intersections. The observation involves systematically watching the actions of street vendors, including the types of structures they use, the goods they sell and the spaces they occupy.

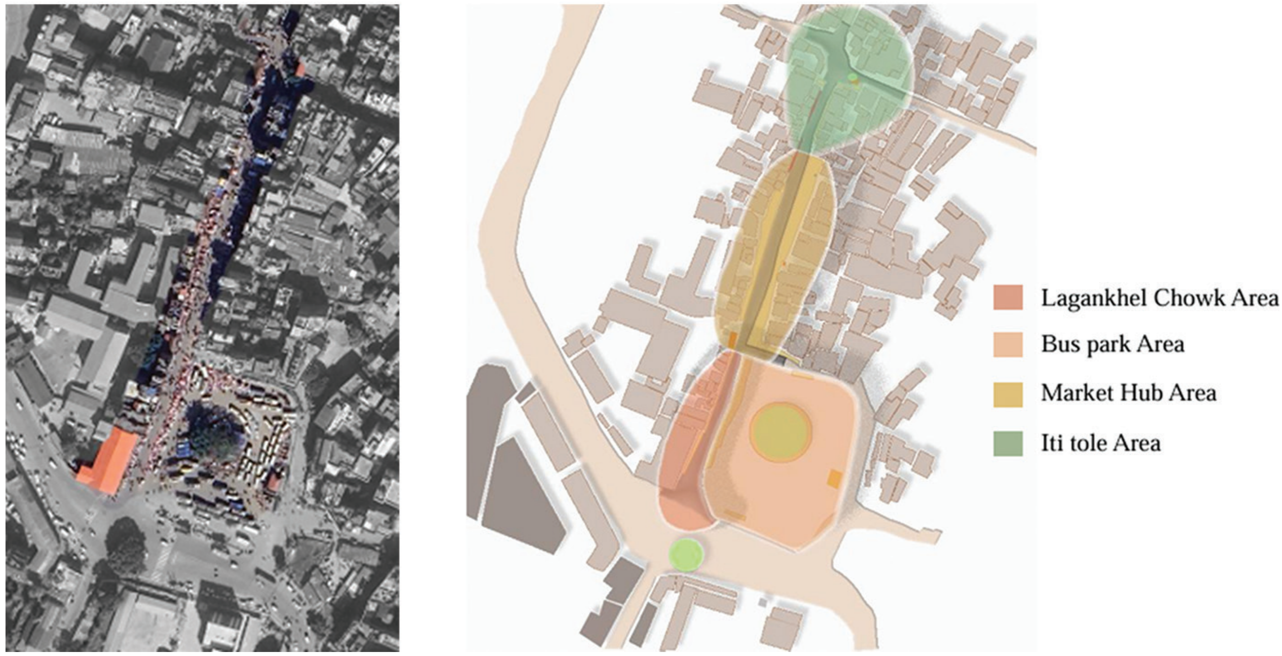

Figure 2: Site, Lagankhel Chowk Area

3.1 Site Observation

From the site visits, we have found various types of street vendors in the various types of street vendors in the Lagankhel Area. In general, we have categorized street vendors into two types i.e. Mobile Vendors and Fixed Vendors.

Mobile Vendors: They occupy spaces in the lagankhel area's roads, pathways, public spaces for a certain period of time, either morning, afternoon or evening, these vendors are characterized by their adaptability, utilizing various methods to display and carry goods.

Fixed vendors: Unlike mobile vendors, fixed vendors occupy more permanent spaces such as shop frontages, pathways, or designated market stalls. These vendors have often been operating in the same spot for decades, creating a sense of permanence and reliability. They mainly sell items like clothes and shoes, paying a nominal fee (Rs 20) for garbage disposal but not for the occupancy of public space.

Display Types of Fixed Street Vendors: Fixed Street vendors set up their stalls using different display types, including: Kiosk, Wall, Ground, Plastic Box, Platform

By understanding the diverse types and display methods of street vendors, the proposed streetscape aims to create a more inclusive and organized environment that caters to the needs of both vendors and pedestrians. The integration of street vendors and pedestrian movement is crucial for maintaining the vibrant commercial character of Lagankhel Road while addressing challenges such as congestion and safety concerns.

3.1.1 Space Management and strategies

According to the vendors, they are allowed to operate only after 5:00 PM to manage and reduce chaos related to street vending. Due to which competition for space is fierce, especially during peak hours when pedestrian and vehicular traffic peaks. Vendors often encroach on sidewalks and pathways, leading to congestion and conflicts with pedestrians. The average space occupied by a fixed vendor is approximately 1.5m x 1.2m, which is often insufficient, forcing them to extend their displays into walking areas.

To manage space more effectively, vendors employ various display methods, such as using plastic stools, crates, and makeshift platforms. These strategies are a response to the need for visibility and accessibility in a crowded marketplace.

Type of Material used by Fixed Vendors: Street Vendors utilize a variety of materials to optimize their display and operational efficiency. Material and their uses are: Plastic stool/ chair and steel stand for vertical support while plywood as a horizontal or base platform for stalls which serves as stable and flat surface for placing or displaying goods. Plastic Fruit Basket / crate containers were used primarily for displaying products, especially shoes, fruits, vegetables.

3.2 Data Collection

3.2.1 Site segmentation and observation zones

To ensure a comprehensive spatial analysis, the study area was divided into four key zones as shown in fig3, based on the activity patterns and urban typology:

1. **Lagankhel Chowk Area**: Dense intersection with heavy foot traffic
2. **Bus Park Area**: Transition zone with regulated vending and vehicular access
3. **Market Hub Area:** Core commercial street with high vendor clustering
4. **Iti Tole Area:** Peripheral yet active zone with mixed vendor types

Observations were conducted after 5:00 PM to capture peak vendor and pedestrian activity. Data were recorded using manual mapping, field notes, and 1-minute video captures at high-density points. Vendors were classified as either mobile or fixed, and their display types (e.g., platform, crate, wall) were documented. The spatial footprint of each stall was also measured.

Figure 3: Site Division

Lagankhel Chowk Area:

The vendors set up their stalls in pedestrian pathways, which are public spaces typically designated for foot traffic. Their presence in these areas causes congestion and conflicts with pedestrians. The observation was noted on types of goods being sold by the vendors in peak hour 5:00pm. During peak hour, as shoppers tend to prioritize groceries and clothing afterwork as shown in fig:4

Figure 4: Data collection of Lagankhel Chowk Area

Bus Park Area:

Figure 5: Bus park area

Vendors operate within designated areas with planning and size were assigned by the government as shown in figure 5, with vending permitted from 5:00 PM onwards were they primarily sold clothing as figure 6. Prior to this time, space is used as the (tampo) vehicle parking. From the observations a variety of goods sold in this location, primarily featuring vegetable vendors. Some vendors also mention that the government has specifically directed vegetable selling to occur around the temple tree area (open space) as in figure 7,8,9 limiting their ability to set up elsewhere except in Lagankhel Chowk and around the temple tree. Additionally, there are also a significant number of clothing vendors present in the vicinity.

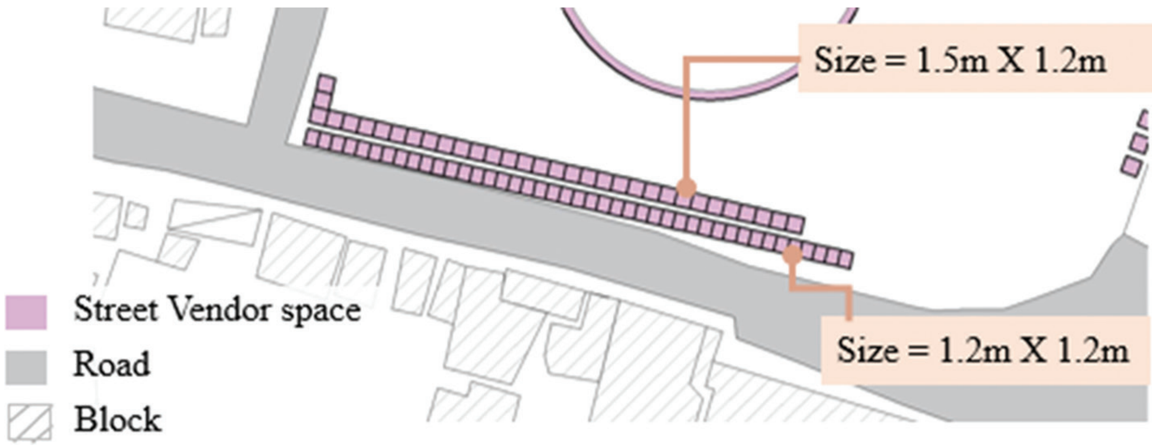

Figure 6: Existing spatial plan of street vendors

Figure 7: Data collection of Bus Park Area

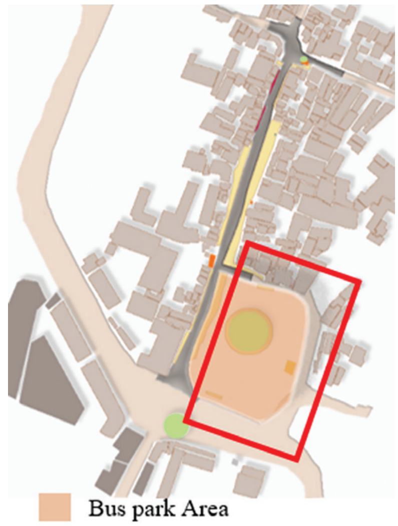

Figure 8: Around Temple tree (open space), Bus stop waiting and footpath area

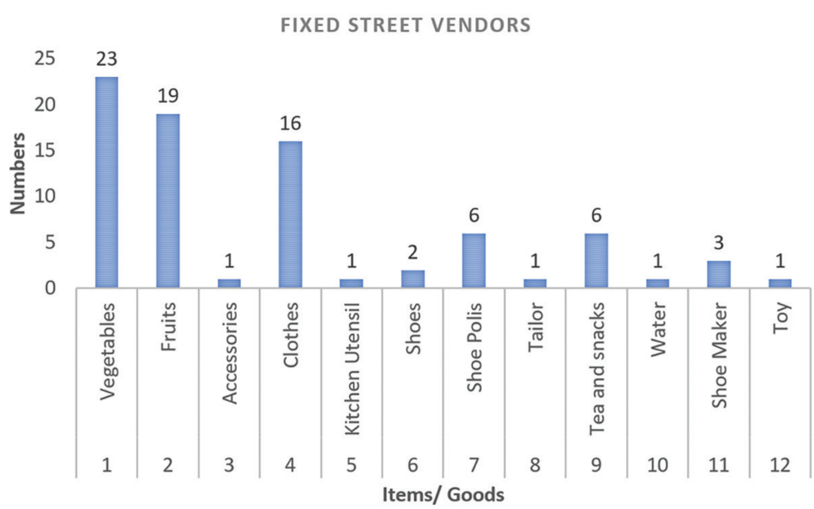

Figure 9: Data collection in open space, Bus stop waiting and footpath area

Market Hub Area:

In the bustling area of market hub, a significant number of street vendors occupy shop frontage spaces, creating a symbiotic relationship with the shop owners, where they can take advantage of the foot traffic generated by the established businesses. The vendors have organized themselves in a way that respects each other's space, with vending activities typically commencing around 5:00 pm, aligning with peak pedestrian traffic times as shown in Figure 10. Observation data reveals that there are six different types of goods being sold in this area. Notably, clothing vendors make up the majority, totaling 45, while the fewest vendors are those selling toys as shown in fig11.

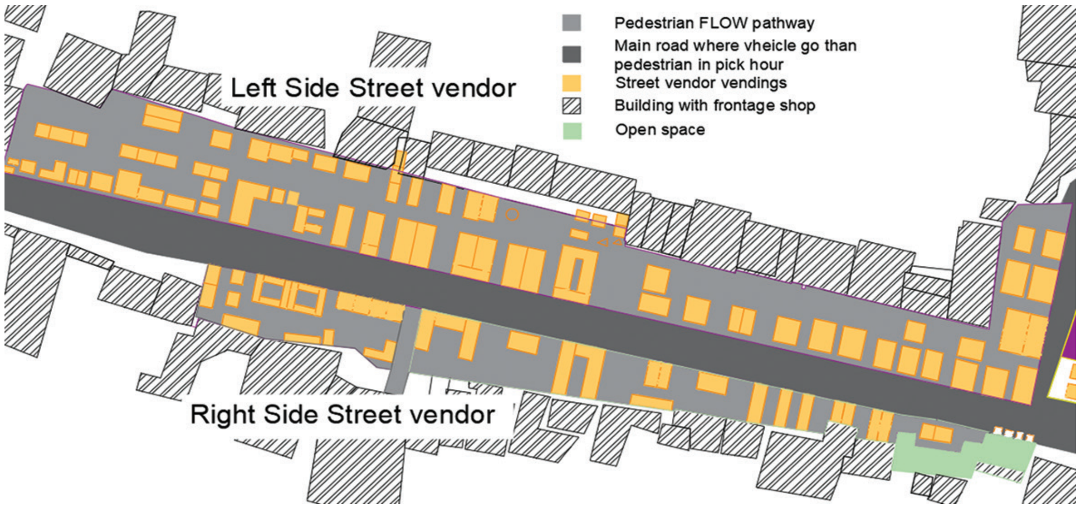

Figure 10: Current plan of street vendors in market hub area

Figure 11: Data collection form Market Hub Area

Iti Tole Area:

Observations of this area reveal a diverse range of goods being sold, with vendors offering seven different types of products. Clothing item dominates the market, with 10 vendors selling garments, likely taking advantage of the post-work shopping rush as shown in Figure 12. This variation in goods sold throughout the day reflects the vendors' adaptability and keen understanding of their customers' needs, ensuring that they can meet the demand at while maintaining a steady flow of business.

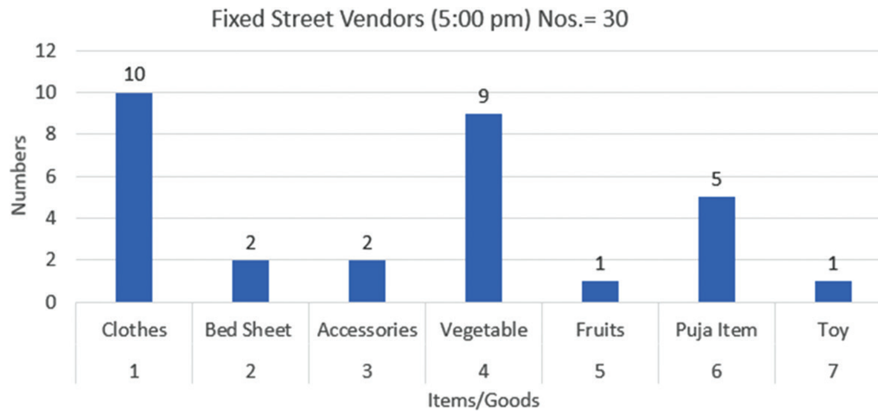

Figure 12: Data collection from Iti tole Area

3.2.2 Overall Street Vendors- Active Street Vendors During Peak Hours

Street vendors play a significant role in shaping lagankhel's urban landscape, with a total of 360 active vendors selling 16 different items contributing to the vibrancy of the area across key locations. The Market Hub Area hosts the largest concentration with 164 vendors, followed by the Bus Park Area with 151 vendors. These two areas are crucial commercial zones, drawing both vendors and customers due to their high foot traffic. The Lagankhel Chowk Area has 15 fixed vendors, while the Iti Tole Area, a smaller but still active zone, accommodates30vendors. This distribution of street vendors underscores the diverse and widespread nature of street vending in Lagankhel, with fixed vendors playing essential roles in meeting the needs of the local population.

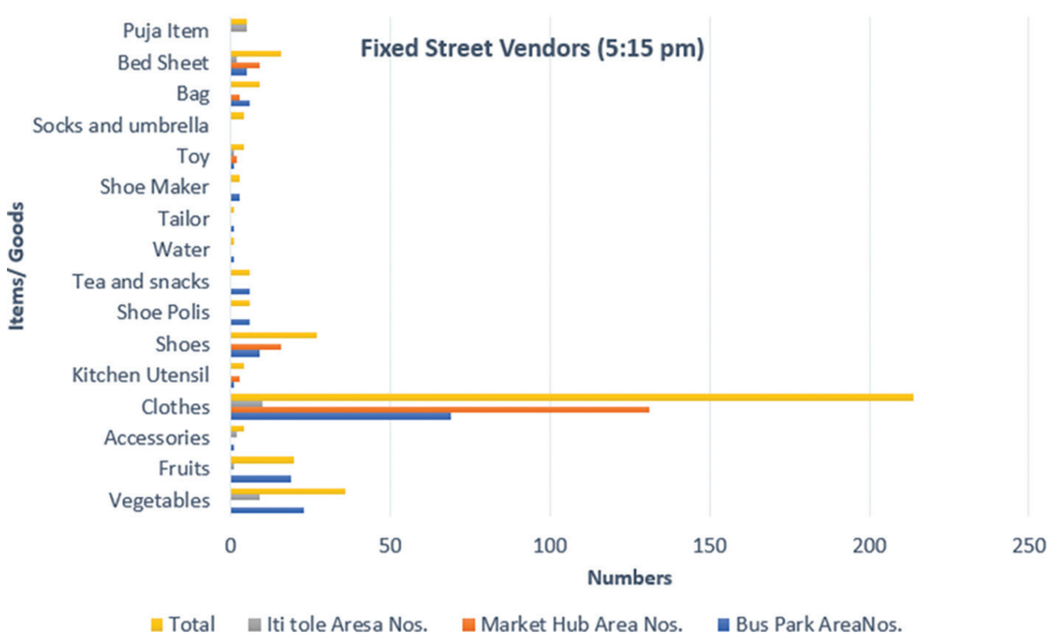

Figure 13: Overall active street vendor during peak hours

3.2.3 Flow Pedestrian Flow and Interaction with Vendors

Pedestrian flow and interaction with street vendors in Lagankhel, illustrate in figure 14, a dynamic relationship between people's movements and vendor activities throughout the day. The area has three mainnodes, withthe highest pedestrian traffic observed at node 1 and 3. The analysis indicates that pedestrian flow peaks around 5:00 pm, coinciding with the dismissal of schools and the beginning of the evening market. This period sees a significant increase in street vendor activity, with many vendors setting up their stalls along busy corridors, highlighting how they time their setup to align with pedestrian rhythms.

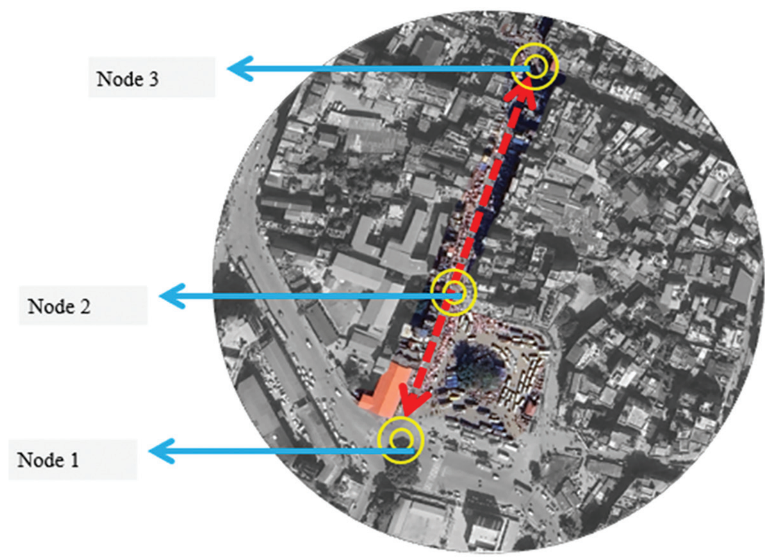

Figure 14: Street Nodes

Pedestrian-Vendor Interaction: The interaction between pedestrians and vendors is most intense during peak hours, particularly in areas with high foot traffic like Lagankhel Chowk and the Bus Park area. The design and management of these spaces must consider the need for smooth pedestrian movement while accommodating the vendors' operational needs.

Table 1: Fixed Street vendors- Time and space occupied by customers

SN	Goods	Time
1	Accessories	Max 4 minutes
2	Shoes	Max 3 minutes
3	Vegetables	Max 5 minutes
4	Bags	Max 3 minutes
5	Clothes	Max 5-7 minutes
6	Kitchen	Max 2-3 minutes

From the observation, it can be concluded that customers tend to spend the most time engaging with clothing goods as show in table 1. This trend can be attributed to several factors inherent in the shopping experience for clothing, which often involves a more deliberate decision-making process compared to other types of goods.

3.2.4 Summary of spatial metrics and simulation input data

To support the computational simulations and respond to spatial performance needs, this study extracted quantifiable data points from field observations. These metrics were later used as baseline parameters for Isovist and PedSim analyses.

A comparative summary of vendor characteristics and spatial conditions across the four study zones is presented below:

Table 2: Summary of spatial metric and simulation input data

Zone	Dominant Vendor Type	Avg. Stall Size (m^2)	Visibility	Avg. Dwell Time
Lagankhel Chowk	Fixed (accessories, clothes)	1.5	Moderate to High	3–5 minutes
Bus Park	Fixed (vegetables, clothing)	1.8	Moderate	4–6 minutes
Market Hub	Fixed (clothing)	2.3 – 3.2	High (linear layout)	5–7 minutes
Iti Tole	Mixed (mobile + fixed)	1.2	Low to Moderate	2–4 minutes

A comparative summary of vendor characteristics as table 2 across zones showed that the Market Hub had the highest concentration of vendors (164), predominantly selling clothes, while the Bus Park area followed with 151 vendors, mainly focused on vegetables and accessories. The Chowk and Iti Tole areas had fewer vendors but still contributed to spatial congestion due to their constrained layouts and poor pedestrian path management. Overall, the integration of vendor positioning, visibility metrics, interaction time, and clustering effects provides a data-rich foundation for further computational simulation, which is discussed in the following section.

4. Site Analysis

The site analysis is essential for understanding the spatial dynamics between street vendors and pedestrians, aiming to evaluate the existing spatial arrangement and its effectiveness in facilitating pedestrian movement. This research focuses on the market hub area for further analysis, as the Laghankhel and bus park areas have already been adjusted by the government into adequately sized spaces for street vendors, which the vendors found satisfactory. There is a recognized need for more attention to the spatial layout in the market hub area.

4.1 Isovist Analysis

Isovist analysis is a method utilized to quantify visibility from specific viewpoints in urban settings, specifically at the Lagankhel market hub. This research employs Rhino-Grasshopper with an Isovist plugin as Figure 15, drawing from Space Syntax and Urban Visibility Studies to understand how spatial arrangements affect pedestrian movement and interactions.

Methodology and Algorithm

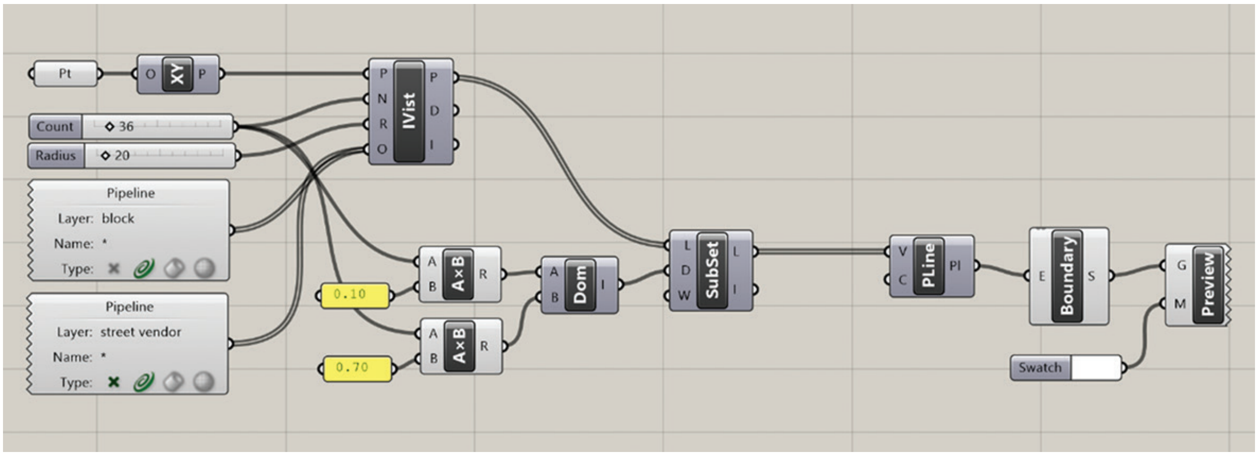

Figure 15: Isovist Analysis alogorithm

Eighteen points were selected for analysis based on visibility, axial lines, directional changes, and obstructions as shown in Figure 16. For each vantage point, the plugin creates a field-of-view measuring total visible area, perimeter, and sightlines. For the Parameter Calculation metrics include visible area (representing openness), longest sightline (minimumof1,000feet for accessibility) (Yin, 2017a), and the effects of obstructions like buildings and street elements.

Table 3: Parameters measured

Metric	Definition
Visible Area (m²)	Total unobstructed area visible from each point
Longest Sightline (m)	Maximum distance viewable before obstruction (minimum 10m considered optimal)
Perimeter and obstruction	Total length of visual boundary

Figure 16: Indicating Vantage Points

Pedestrian flow data was from 1minute video observations correlates with isovist results to estimate pedestrian exposure. The raw isovist fields and algorithm outputs identify 'hot spots' where visibility as shown in figure 17 and potential pedestrian interaction are maximized. Its findings that areas with long uninterrupted sightlines are most effective in attracting pedestrians, aligning with principles of urban design that emphasize visibility for safety and commerce. Physical obstructions reduce visibility, which may hinder vendor exposures; reconfiguration of these elements can enhance site visibility. The higher visible areas correspond to the higher density of pedestrians, indicating that optimized sightlines benefit both the visibility of the vendor and the flow of pedestrians.

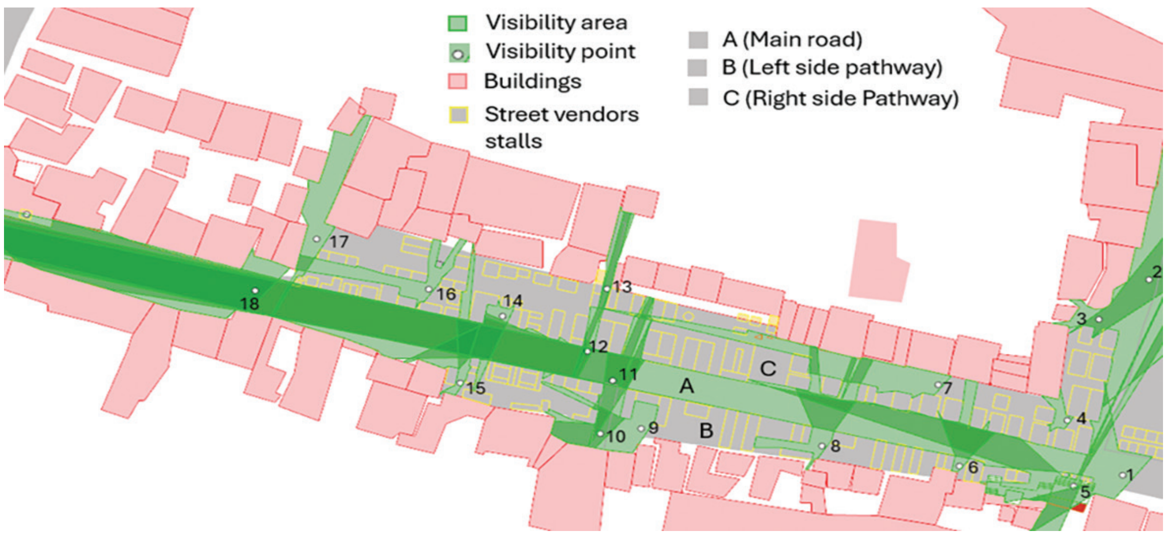

Figure 17: Visibility area from the vantage points

4.2 Pedestrian Flow Analysis

The pedestrian flow analysis was conducted using Rhino-Grasshopper with the Pedsim plugin. This simulation tool enables to quantify how the pedestrians navigate and interact within the urban space of Lagankhel, particularly in relation to Street vendors, Retail stores, and other public amenities. The study draws upon established theories in urban design and planning and space syntax, such as those discussed by (Yin, 2017b), to explore the relationship between spatial configuration and human movement.

Methodology and Simulation Parameters

The analysis was structured around several key parameters:

- **Access Radius:** A radius of 400 meters was selected based on urban design research that suggests most pedestrians are willing to walk within a 400 to 800 m range to access amenities. This distance represents a comfortable walking range and helps to model realistic pedestrian behavior.
- **Population and Time Interval:** Pedestrian flow data were collected from a one-minute video analysis, which revealed that approximately 124 pedestrians pass through the area per minute. For the simulation, a five-minute interval was considered, resulting in an estimated 620 pedestrians.
- **Stopping Probability:** The likelihood that pedestrian will stop to interact with a vendor is a core aspect of the simulation. In this analysis, a stopping probability of 0.5 (50%) was set. This means that, on average, 310 out of the 620 simulated pedestrians are expected to stop naturally, aligning

with observational data. (Note: In Pedsim, the stopping probability is expressed as a value between 0 and 1, not as a fixed number.)

- **Visiting Time:** The duration that pedestrians spend at specific nodes (e.g., in front of vendor stalls) is simulated. The data indicate that different types of goods result in varying interaction times; for example, clothing purchases typically engage customers for 5–7 minutes, while other categories like shoes and accessories attract shorter engagements.
- **Obstacles and Environmental Elements:** The simulation considers physical obstacles such as buildings, vendor stalls, poles (for street lighting and wayfinding), and ground-level temples. These elements interrupt sightlines and affect pedestrian trajectories. Parameters such as a 40° vision angle and a maximum sight distance of 300 meters (corresponding to approximately 1,000 feet or three city blocks, as per (Yin, 2017b) were used to simulate realistic visual fields.

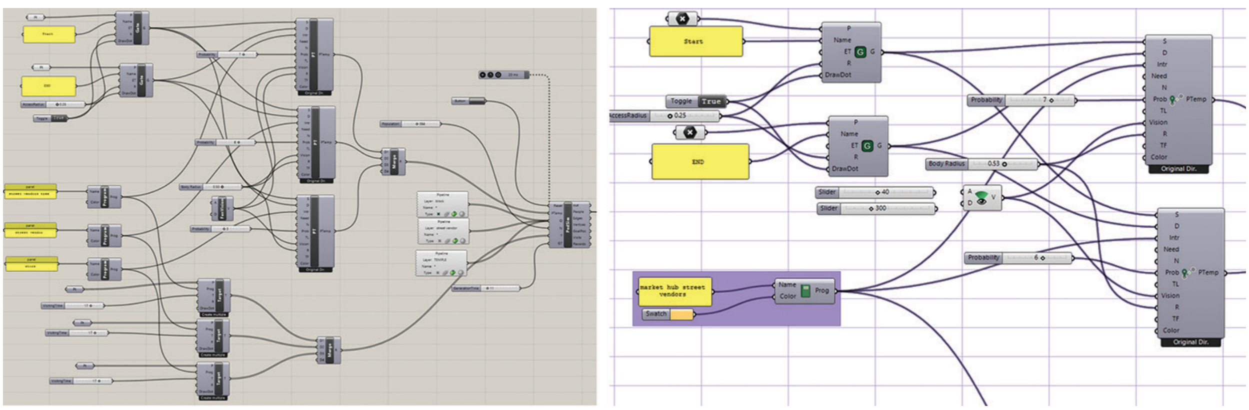

Figure 18: Pedestrian flow analysis algorithm

Figure 19: Pedestrian Interest Points

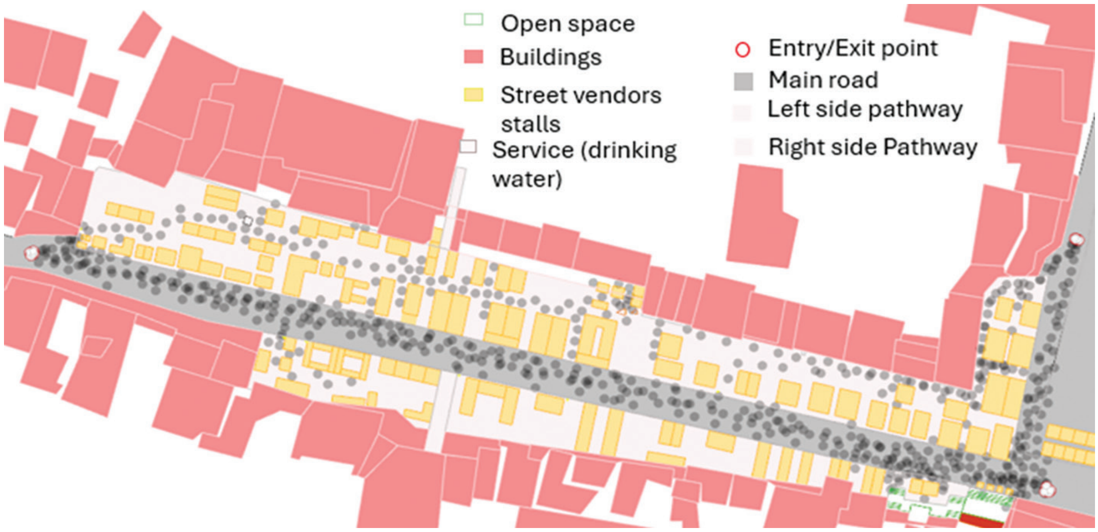

Figure 20: Pedestrian Flow Analysis

Overall Population was integrated 1-minute recorded video analysis to estimate pedestrian density i.e. 124 pedestrian pass per minutes. Simulated visiting time spent at vendor stalls, revealing that clothing attracts longer engagement compared to other goods. Obstacle factors like buildings, vendor stalls, street elements were considered, affecting sightlines and pedestrian routes. The algorithm (Figure 18) followed a systematic process that identified critical points of interest where vendors attract foot traffic as shown in Figure 19. This analysis showed that pedestrian flow peaks at 5:00 pm, corresponding to school dismissals and evening market activities, highlighting the synchronization of vendor operations with pedestrian movement as Figure 20. It identified three main nodes of high pedestrian density and suggested that reconfiguring physical barriers could improve flow and interactions with vendors. Areas with dense vendor placement showed a notable decrease in circulation efficiency. The clustering of stalls tended to create bottlenecks, forcing pedestrians to alter their natural paths, often resulting in congestion. This analysis emphasized the importance of understanding spatial dynamics to improve pedestrian movement and vendor participation in urban markets.

4.3 Limitation and Cross-validation

Despite the strengths of computational tools such as Isovist and PedSim, the analysis presented in this study is not without limitations. The Isovist plugin, while effective in measuring spatial visibility, relies solely on geometric parameters and does not account for the dynamic or behavioral factors that influence how pedestrians perceive and navigate space in real life. It assumes a static environment and does not incorporate human variability, such as attention span, social influence, or individual decision-making processes. Similarly, the PedSim plugin, though useful for modeling agent-based pedestrian flow, is based on simplified behavioral rules. It cannot fully simulate complex motivations such as price sensitivity, product appeal, or cultural behaviors that often influence how pedestrians interact with vendors. Furthermore, the accuracy of the simulation depends heavily on the quality and precision of input data particularly stall dimensions, pedestrian counts, and movement speeds. Any inaccuracies in these parameters can reduce the reliability of the output. To enhance the validity of the simulation, cross-validation was performed using field-collected video footage and manual observations. Simulated flow patterns, congestion points, and stall interaction zones were compared against real-world pedestrian behavior observed across multiple nodes during peak evening hours. Multiple iterations of the simulation were also conducted to ensure consistency and reduce anomalies caused by stochastic agent behavior. These cross-validation steps strengthen the credibility of the findings, although further real-time tracking or longitudinal studies would enhance robustness in future research.

5. Results and Discussion

5.1 Results

The computational analysis complements these observations by quantifying both pedestrian flow and visual accessibility. Pedestrian flow simulations confirm that high-density nodes typically at intersections or narrow corridors that coincide with clusters of fixed vendors, resulting in decreased movement efficiency. The isovist analysis further quantifies the visual impact of vendor placements; areas with unobstructed sightlines correlate with smoother pedestrian navigation, whereas densely clustered vendor zones show reduced visible areas and compromised wayfinding. Quantitative measures such as the size of the stalls and the distribution patterns of vendors also highlight that excessive clustering of vendors adversely affects both pedestrian flow and spatial legibility. These results underscore that open, well-connected spaces facilitate natural movement, whereas over-clustered zones congestion and hinder effective circulation.

5.2 Findings

Fixed street vendors in Lagankhel operate from semi-permanent stalls situated in high-traffic areas such as bus parks and market hubs. They provide are liable shopping presence, primarily selling clothes, shoes, vegetables, and accessories during peak hours for local residents. These vendors occupy various urban spaces, including temple areas, front doors of stores, sidewalks, and bus stop to maximize visibility. However, effective space management pose a significant challenge due to their small operational areas. The fierce competition for prime locations often results in congestion in busy pedestrian zones, disrupting foot traffic and complicating the organization of their stalls. Stall sizes typically ranging from 2.3 to 3.2 square feet, revealing the spatial constraints they endure (Figure 21). The struggle to balance accessibility with limited space highlights the necessity for strategic planning and optimized vendor placement in Lagankhel's densely populated urban environment.

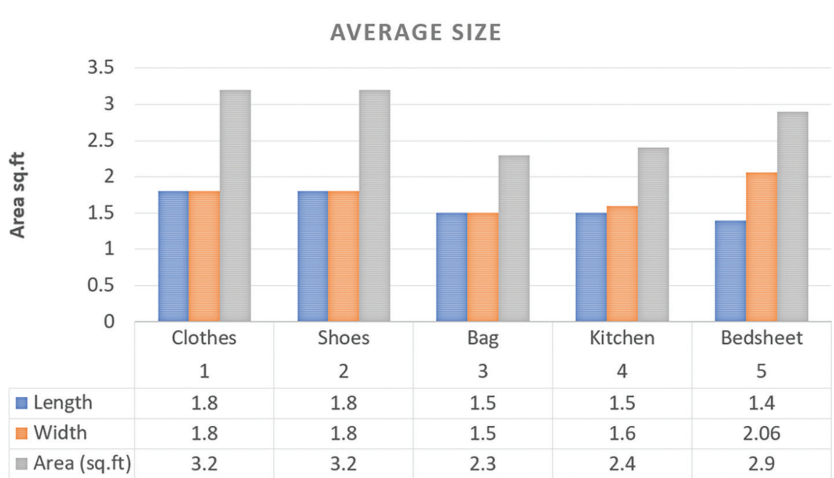

Figure 21: Average stall size of different street vendors items

Since, vendors are allowed to operate only after 5:00 PM, which intensifying competition for space during this period. The encroachment of vendors into pedestrian pathways disrupts natural walking paths, forcing pedestrians to navigate around stalls, which leads to slower movement and safety concerns, mainly at intersections. Vendors tend to cluster in areas with high foot traffic, such as near bus stops and market hubs areas. While this increases their visibility and sales opportunities, it exacerbates congestion and reduces pedestrian comfort. Moreover, spatial observations identified critical nodes where pedestrian movement is intensified, but also where the cumulative presence of vendors creates bottlenecks.

Form the isovist analysis it is found that Vendors strategically position themselves in high-visibility areas to attract customers. It reveals that spaces with greater visual access (e.g., open areas near intersections) are preferred by vendors. In some areas, such as narrow pathways or crowded zones, the placement of stalls creates visual obstructions that hinder pedestrian navigation and reduce overall spatial legibility. This analysis suggests that vendors located along clear linear pathways benefit from improved visibility without disrupting pedestrian flow. Similarly, clustering in dead-end spaces or overly narrow zones leads to reduced permeability and accessibility. The spatial layout of Lagankhel includes both open spaces and constrained pathways. Vendors adapt their setups based on these configurations, but poorly managed layouts result in underutilized or overcrowded spaces

5.3 Discussion

The findings of this study provide important insights into the spatial and social dynamics between street vendors and pedestrians, particularly in dense urban settings like Lagankhel. The spatial behaviors observed closely align with key theories of urban movement and visibility. For instance, the strong relationship between open sightlines, visibility catchment, and vendor engagement supports the principles of Space Syntax theory, which argues that spatial configuration influences movement patterns. Vendors gravitating toward visually open and spatially integrated areas confirms the logic of "natural integration" driving economic opportunity.

However, the results also highlight a limitation within traditional Space Syntax assumptions. While increased integration generally promotes movement, the introduction of excessive vendor clustering in these high-traffic areas disrupted pedestrian flow, as shown in PedSim simulations. This suggests a threshold effect, when too many obstacles occupy integrated spaces, they begin to undermine the very flow that made those spaces commercially attractive. In this way, informal spatial behavior challenges the assumption that integrated paths always maintain high performance under all conditions.

The data also strongly support the Natural Movement Theory proposed by Hillier and Van Nes (Van Nes, 2014). Pedestrians naturally slowed or stopped in areas of high visibility, particularly at intersections and wide corridors. These natural pauses created opportunities for interaction with nearby vendors. The correlation between dwell time and openness confirms that movement behavior is not only shaped by necessity but also by spatial affordances visibility, legibility, and unobstructed lines of sight.

Beyond these theoretical confirmations, the study aligns with contemporary research on responsive urban environments, particularly the work of (Lovanka et al., 2023) on adaptability and permeability. Street vendors in Lagankhel exhibited high adaptability, adjusting their stall types, materials, and exact locations daily in response to shifts in pedestrian volume. However, the spatial permeability of key paths was often reduced when vendors over-occupied narrow walkways, creating friction points and visual obstructions that reduced legibility for pedestrians.

These findings suggest that visibility and accessibility do not always work in harmony. Although high visibility is economically beneficial for vendors, excessive occupation of those spaces can reduce overall spatial performance. Urban designers and policy makers must therefore balance these forces encouraging visibility without allowing overcrowding. Computational tools such as Isovist and PedSim offer an evidence-based approach to managing this balance, identifying optimal vendor zones that enhance economic activity while maintaining walkability.

While computational analysis confirms many foundational urban theories, it also reveals tensions between informal economic activity and formal spatial performance. Integrating vendor-friendly policies with data-driven spatial planning will be essential in designing inclusive and efficient urban markets.

6. Conclusions and Recommendation

This research demonstrates that computational tools such as Isovist and PedSim can effectively reveal the spatial logic behind street vendor behavior and pedestrian movement in dense urban settings like Lagankhel, Nepal. Through a combination of field observation and simulation, the study identifies a strong link between spatial visibility, vendor placement, and pedestrian engagement. Vendors tended to occupy highly visible nodes with open sightlines and high foot traffic, while pedestrians exhibited longer dwell times in visually legible areas free from vehicular conflict. However, the benefits of vendor clustering came at a cost dense stall arrangements significantly reduced flow efficiency, causing in pedestrian movement speed, particularly in narrow corridors.

The findings highlight the dual nature of urban informality: while street vendors enhance vibrancy and economic inclusion, unregulated spatial occupation can hinder public circulation. This tension underscores the need for design strategies that balance adaptability with spatial order. Computational analysis proves especially valuable in identifying threshold points where visibility and clustering begin to reduce rather than improve spatial performance.

From this research, several key design and policy recommendations emerge. First, designated vending zones should be based not only on traditional market logic but also on spatial performance metrics such as visibility catchment and integration values. Second, stall clustering should be limited in narrow walkways, and vendor distribution should be guided using simulation outputs to preserve pedestrian permeability. Third, flexible and modular stall systems should be encouraged, enabling vendors to adapt to changing spatial conditions without encroaching on circulation paths.

For architects, urban planners and municipal authorities, this research provides a framework for integrating informal economies into formal spatial planning processes. By using parametric tools, cities can test various vendor layout scenarios before implementation, ensuring more inclusive, efficient, and socially responsive public spaces.

7. Limitation and Direction for future research

While this study offers valuable insights into the interaction between street vendors and pedestrians through computational and observational analysis, several limitations must be acknowledged. First, data collection was limited to the evening peak hour after 5:00 PM, which, although relevant for vendor activity, may not fully capture daily or seasonal variations in pedestrian behavior. The findings therefore reflect a snapshot of peak-time dynamics rather than a full temporal spectrum.

Second, the pedestrian simulations were based on simplified behavioral rules within the PedSim plugin, which does not account for complex social factors such as individual preferences, group behavior, or economic motivations. Similarly, the Isovist analysis focused solely on static visual fields, without incorporating perceptual or environmental elements such as noise, lighting, or signage that also influence pedestrian decision-making.

Another limitation is the absence of detailed socioeconomic profiling of vendors and pedestrians. While the spatial behaviors were carefully mapped, the motivations, challenges, and preferences of the actors involved were not explored in depth, which could have added a richer layer of interpretation. Additionally, the study did not engage directly with the policy and regulatory environment governing street vending in Nepal, which limits its immediate application to governance reform.

Future research could address these gaps by incorporating longitudinal data, tracking behavior over multiple times of day and across different seasons. Integrating real-time GIS data, mobile tracking, or AI-powered video analytics could enhance the precision of pedestrian modeling. Further, combining spatial data with interviews or surveys would enrich the behavioral dimension, offering a more comprehensive understanding of how social, economic, and spatial factors interact in informal markets. Exploring similar studies in other South Asian cities could also offer comparative insights and inform scalable urban strategies.

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