



## Optimizing Traditional Public Space Through Agent-Based Simulation: "A Case of Lagan Chowk"

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### Abstract

Rapid urbanization in the Kathmandu Valley has reshaped the functioning of public spaces within dense historic settlements. Increasing population pressure, land encroachment, and infrastructure-oriented development have reduced their spatial quality and social relevance. Although many traditional courtyards and squares still remain, their capacity to support daily movement, informal gathering, and community activities has gradually declined. Public space is often treated as a fixed physical form, and conventional planning tools largely limited to static, two-dimensional drawings fail to reflect the dynamic and lived nature of these environments. This study conceptualizes public space as a dynamic system shaped by movement, behavior, and temporal variation. It adopts a data-informed design framework integrating field observation, space-syntax analysis, and agent-based simulation to examine movement patterns and spatial performance in Lagan Chowk, of Kathmandu Metropolitan City. The findings show that spatial vitality varies across time periods and that movement is structured not only by configurational accessibility but by programmatic anchors such as markets, temples, and social nodes. A persistent conflict between pedestrian movement and vehicular access is also identified, particularly in areas modified for ritual use.

The study demonstrates that accessibility alone does not ensure activity and proposes incremental, context-sensitive interventions to improve usability while preserving cultural structure.

**Keywords:** *Public Space, Movement, Agent-Based Simulation, Space Syntax*

### 1 Introduction

Public spaces in South Asian cities have historically functioned as “stages” for rituals, festivals, and the rhythms of daily social life (Madanipour, 2003). Within the historic core of the Kathmandu Valley, courtyards such as *bahals*, *chowks*, and *nanis* provided essential shared venues for walking, resting, and neighborhood gatherings (Tiwari, 1989). These spaces formed an interconnected network of open areas that mediated between the privacy of the home and the broader urban fabric, including larger civic landscapes such as Tundikhel and Durbar Square (Chitrakar et al., 2014). As Madanipour (2003) observes, well-designed public spaces facilitate a gradual transition from the intimate private sphere to the civic realm, structuring social

relationships through visibility and use. These spaces developed gradually through use and cultural practice, making them flexible and socially responsive (Lefebvre, H, 1991). This aligns with Tschumi's (1994) argument that architectural meaning emerges from the interaction of space, event, and movement a perspective especially relevant to traditional courtyards where human activity brings the environment to life. .

In recent decades, however, these vibrant spaces have faced significant pressure. Rapid population growth, informal development, and the encroachment of vehicles and private stalls have diminished the spatial quality, accessibility, and social value of many Kathmandu courtyards (Chitrakar et al., 2014). Areas once dedicated to pedestrian movement and market life are now frequently used as parking lots or mere pass-through corridors (Gutschow, 2011). At the same time, planning remains largely dependent on static, two-dimensional representation overlooks the dynamic, lived nature of public space. Although concerns regarding congestion and a lack of seating are common, quantitative evidence on user behavior remains limited. Computational approaches, including agent-based simulation, provide opportunities to address this gap (Liu & Kaneda, 2020). In Kathmandu, this analytical gap means that interventions often rely on intuition rather than empirical evidence, risking designs that fail to reflect how people actually occupy the space (Niels Gutschow and Suman Pandey, 1985).

This study applies Agent-Based Simulation (ABS) as an analytical and design-support tool to evaluate and improve the socio-spatial performance of Lagan Chowk, a dense historic courtyard in central Kathmandu. The study asks how spatial configuration and programmatic activity interact to shape movement patterns, and how incremental spatial adjustments can improve performance without altering cultural structure. Within this framework, pedestrians are represented as autonomous agents governed by simplified behavioral rules, including maintaining personal space, avoiding collisions, and moving toward points of attraction (Yang et al., 2025). As these agents interact within a defined layout, collective patterns such as flows, clustering, and bottlenecks emerge, allowing a predictive assessment of how spatial conditions shape movement and use. Unlike post-occupancy observations alone, simulation enables hypothetical adjustments to be tested before physical changes are made.

Following a pragmatist paradigm, the study integrates field surveys and mapping with spatial analysis and simulation. Interviews and direct observations document existing usage patterns, space syntax analysis evaluates connectivity and accessibility, and the agent-based model simulates pedestrian movement under existing and modified conditions. The objective is not total transformation, but the identification of sensitive spatial adjustments, including changes in circulation, seating, and activity layout, that can improve accessibility, comfort, and social interaction without undermining cultural heritage. Grounded in Lefebvre's spatial triad of perceived, conceived, and lived space and Tschumi's space-event-movement framework (Lefebvre, H, 1991), the study bridges the gap between qualitative meaning and quantitative analysis. This research contributes by demonstrating the combined use of space syntax and agent-based simulation for heritage public space, and by establishing a data-informed framework that links spatial configuration, temporal activity, and behavioral patterns to guide incremental design interventions.

## **2 Materials and Methods**

### **2.1 Methodological framework**

This study uses a mixed-methods framework to evaluate both the social significance and spatial performance of the courtyard. By blending qualitative insights with quantitative data, the research identifies how residents and visitors inhabit the space while measuring movement patterns and spatial configurations. Fieldwork, spatial analysis, and simulation are integrated to establish a direct relationship between user behavior and

physical layout, consistent with the study's focus on bridging lived space and spatial configuration.

Qualitative data were gathered through semi-structured interviews with long-term residents, vendors, shopkeepers, and local leaders. These interviews documented ritual practices, daily routines, and the informal management of the space. Additionally, participant observation was conducted during peak market hours, morning religious activities, and festival events. Field notes and photographic documentation were used to record and interpret spatial practices, temporal usage patterns, and informal activities within the site.

The quantitative phase focused on measuring movement and accessibility. Behavioral mapping and timed counts were conducted across three distinct periods morning, midday, and evening to record pedestrian and vehicle flow, density, and dwell times. Pedestrian movement data were collected through direct on-site observation and counting. The area was observed to be busiest in the morning, largely due to the vegetable market and nearby wholesale clothing shops. Additional footfall is generated by visits to Namo Buddha and Karunamaya Mandir for morning prayers. Activity declines during midday but increases again in the evening as market activity resumes. Counts were conducted at 15-minute intervals, distinguishing between movement and stationary behavior, and these data were used to inform the simulation model. Vehicular traffic was recorded using ten-minute interval counts at key junctions. These observations informed both the calibration of the simulation model and the identification of conflict zones between pedestrian and vehicular movement. Pedestrian counts were undertaken at 15-minute intervals, distinguishing between movement and stationary activity, while vehicular traffic was recorded using ten-minute interval counts at key junctions. These observations informed the calibration of the simulation model and the identification of conflict zones between pedestrian and vehicular movement.

To analyze how the physical layout influences movement, Space Syntax analysis was applied using axial and segment mapping within DepthmapX (Hillier et al., 1993). This process calculates key spatial indicators: Integration measures how easily a specific area is reached from all others within the system, while connectivity evaluates the immediate visual and physical links of a space. In addition, entropy was considered to understand the distribution of spatial depth and to identify clustered zones and potential bottlenecks.

Primary data were gathered through site surveys, behavioral observations, gate-counts, and photographic documentation. Physical dimensions and entry points were measured for accurate modeling, while gate-count surveys recorded user numbers, movement directions, and demographic categories. Secondary sources, including historical maps and existing literature, provided additional context. The minimum sample size for interviews and surveys was determined using the standard formula for an unknown population:

where  $Z = 1.96$  (95% confidence level),  $p = 0.5$ , and  $e = 0.10$  (10% margin of error). Substituting these values gives:

$$n = \frac{1.96^2 \cdot 0.5(1 - 0.5)}{0.10^2} = 96.04$$

The value was rounded up to ensure adequate representation, resulting in a minimum sample size of 97 respondents. The courtyard was digitally modeled using precise site measurements of entrances, pathways, and open areas. Different user groups such as residents, visitors, and elderly individuals were represented as autonomous agents. Each agent follows specific behavioral logic, including maintaining personal space, moving toward specific destinations, responding to the immediate environment, and avoiding collisions. As these agents interact within the modeled spatial layout, collective patterns such as flow concentration, clustering, and bottlenecks emerge, allowing a predictive assessment of spatial performance (Cheliotis, 2020). Data collection and analysis

### 3 Data collection and analysis

#### 3.1 Pedestrian And Vehicular Movement

The data of pedestrian movement was collected by watching and counting people on-site. The numbers show that the area is busiest in the morning, mostly because of the vegetable market and the nearby wholesale clothing shops. Many people also visit Namu Buddha and Karunamaya Mandir for morning prayers, which adds to the crowd. While it gets much quieter during the middle of the day, the streets get busy again in the evening when the market starts back up. We counted people every 15 minutes and noted whether they were walking through or standing in one spot. This information was used to build our simulation model.

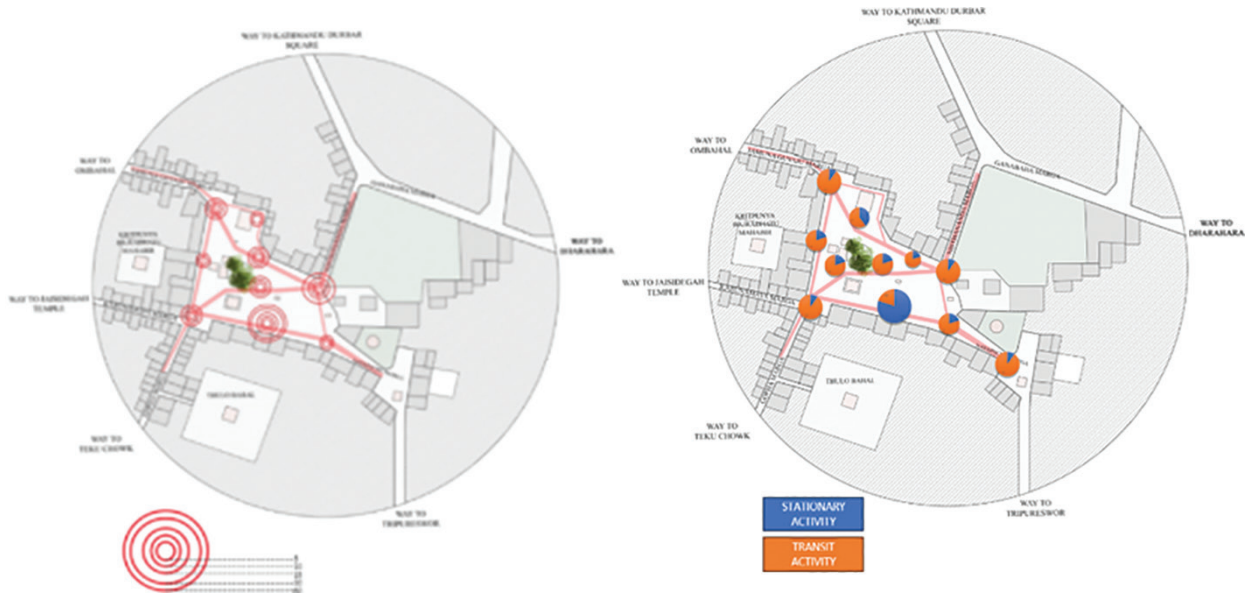
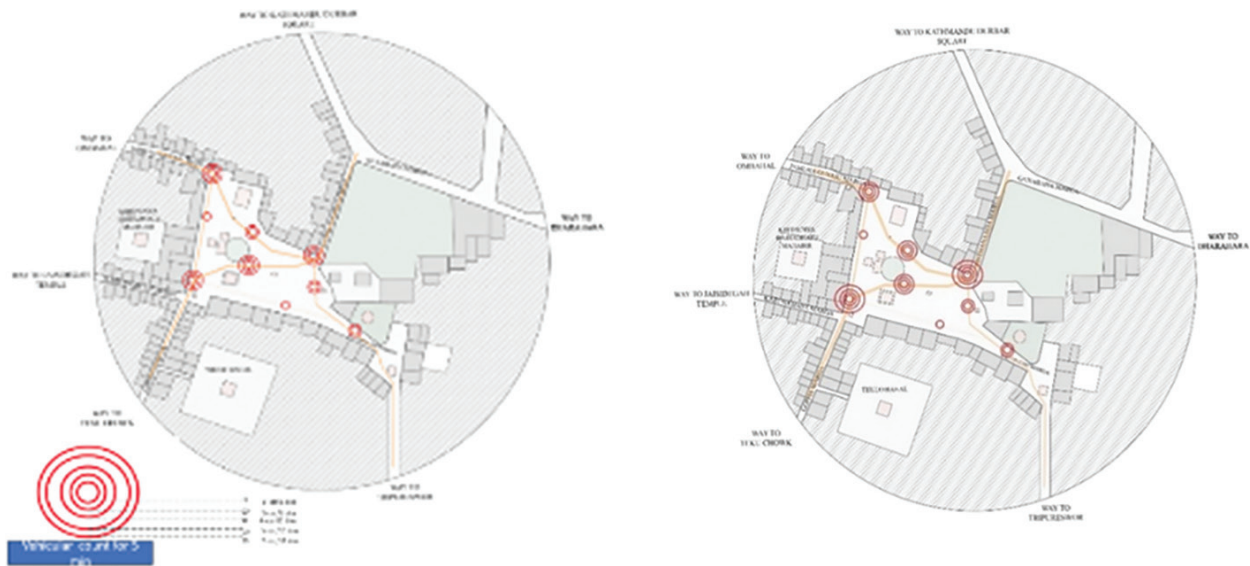


Figure 1: Morning Pedestrian count

The vehicle traffic was tracked at major junctions and inside the plaza using ten-minute counts at different times of the day. Traffic is usually light in the morning but grows steadily as the day goes on. The busiest time is between 2:00 PM and 3:00 PM. After that, the number of cars drops slightly, but the area stays fairly busy through the early evening (5:00 PM to 6:00 PM).



**Figure 2:** Vehicular count in day and evening

### 3.2 Temporal Dynamics of Space, user Profile and Behavior

The use of the space shifts throughout the day in response to changing routines and needs. In the morning, it functions as a neighborhood space, with the vegetable market (38.10%), ritual activities (15.50%), and local shopping (21.60%) shaping a calm, community-oriented environment. By midday, the character of the space becomes more work-focused, with work-related activity dominating (41.20%) and the presence of the vegetable market declining. Shopping remains significant (24.70%) but takes on a more formal and task-oriented nature, while movement becomes more direct and purposeful. In the evening, the space transitions into a transit and social corridor, where passing-through activity (22.60%) and shopping (21.60%) become dominant, alongside a partial return of the vegetable market (17.60%). As work-related activity decreases (11.30%), the space becomes more fluid, characterized by increased movement, interaction, and commuting flows.

The age composition of users changes noticeably over the course of the day. In the morning, the space is used more by older groups, with the 35–44 category being the most active (26.8%) and a visible share of users aged 65+ (10.3%). This aligns with routine activities such as shopping for daily needs and participating in rituals. By midday, the age profile shifts toward a younger population. The 15–24 group rises to 15.5%, along with the 25–34 group at 21.6%, suggesting a stronger presence of students and working individuals. At the same time, the proportion of elderly users becomes comparatively lower. In the evening, the distribution evens out. Working-age groups dominate, particularly those aged 35–44 (23.7%) and 45–54 (21.6%). This reflects a mix of people returning from work and others passing through, giving the space a more shared and collective character.

**Table 1:** Temporal Variation in User Demographics

		Morning		Day		Evening	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Valid	15–24	9	9.3	15	15.5	11	11.3
	25–34	20	20.6	21	21.6	20	20.6
	35–44	26	26.8	21	21.6	23	23.7
	45–54	20	20.6	13	13.4	21	21.6
	55–64	8	8.2	10	10.3	11	11.3
	65 and above	10	10.3	8	8.2	5	5.2
	Below 15	4	4.1	9	9.3	6	6.2
Total		97	100.0	97	100.0	97	100.0

The user base shows a distinct geographic shift, moving from a neighborhood hub in the morning to a city-wide destination by midday. Early on, the area feels most like a neighborhood. Local residents make up 42.3% of the crowd, their highest presence of the entire day. While people from other parts of the city still account for 54.6%, the morning is the only time where the local community has a dominant stake in the space. By the afternoon, the local character of the space is pushed to the background. People traveling from other parts of the city surge to 66.0%, while local residents drop to just 27.8%. Evening: As the workday ends, the balance resets. Local residents reappear in much higher numbers (43.3%), while the influx of outsiders drops back down to 53.6%

**Table 2:** Residency Pattern Across Time Periods

		Morning		Day		Evening	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Valid	From another part of the city	53	54.6	64	66.0	52	53.6
	Local resident	41	42.3	27	27.8	42	43.3
	Visiting / first time here	3	3.1	6	6.2	3	3.1
	Total	97	100.0	97	100.0	97	100.0

The time people spend in the space changes through the day and reflects how the space is being used at each period. In the morning, people generally stay longer. A majority (55.7%) remain for more than 30 minutes, which suggests involvement in activities like shopping in the vegetable market or attending rituals that take more time. By midday, the pattern becomes more mixed. Although many still stay for longer durations (47.4%), there is a visible increase in shorter visits. This points to a combination of people working in the area and others passing through for specific tasks. In the evening, shorter stays become more common. The share of people staying 5–15 minutes (24.7%) and less than 5 minutes (13.4%) rises, while longer stays drop to 32.0%. This indicates that the space is used more for movement and brief stops rather than extended activities.

**Table 3:** Duration of Stay Across Time Periods

		Day		Morning		Evening	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Valid	15–30 minutes	30	30.9	21	21.6	29	29.9
	5–15 minutes	17	17.5	13	13.4	24	24.7
	Less than 5 minutes	4	4.1	9	9.3	13	13.4
	More than 30 minutes	46	47.4	54	55.7	31	32.0
	Total	97	100.0	97	100.0	97	100.0

### 3.3 Agent-Based Simulation Methodology

The simulation stage of this research was carried out using Rhinoceros 3D for spatial modeling, while pedestrian movement analysis was performed through the Kova PedSim plugin in Grasshopper. The plugin operates as a physics-based simulation environment that enables the study of how individual agents move through and interact with a built spatial setting. The model integrates several key elements, including pedestrian characteristics, spatial geometry, activity locations, and the operational parameters required to run the simulation.

Pedestrian agents were defined using the Agent Type components of the plugin. Their characteristics were informed by field survey data collected at Lagan Chowk so that the simulated population would correspond to the actual demographic composition observed on site. Pedestrian counts recorded in 15-minute intervals were scaled to represent hourly inflows for three representative periods of the day. Based on this projection, the simulation used 620 agents per hour during the morning peak, 480 agents during the mid-day period, and 720 agents during the evening peak, reflecting the variation in pedestrian pressure across time.

**Table 4:** Projection of agent at Different Time Period

Age Group	Morning		Day		Evening	
	Percent (%)	Projected Agents ( $\approx 620$ )	Percent (%)	Projected Agents ( $\approx 480$ )	Percent (%)	Projected Agents ( $\approx 720$ )
15–24	9.30%	58	15.50%	74	11.3	81
25–34	20.60%	128	21.60%	104	20.6	149
35–44	26.80%	166	21.60%	104	23.7	171
45–54	20.60%	128	13.40%	64	21.6	156
55–64	8.20%	51	10.30%	49	11.3	81
65 and above	10.30%	64	8.20%	39	5.2	37
Below 15	4.10%	25	9.30%	46	6.2	45
Total	100%	620	100%	480	100	720

Standardized values for agent height and walking velocity were adopted from established pedestrian movement literature to maintain a baseline of reliability. However, it is important to note certain methodological constraints imposed by the Kova PedSim plugin. Parameters such as agent mass and physical fitness were kept at default levels. Consequently, the simulation results do not factor in variables like physical exhaustion,

weight-based movement shifts, or individual differences in spatial “bubble” tolerance.

**Table 5:** Agent Behavior Speed parameter data

Age Group	Lower Domain (m/s)	Upper Domain (m/s)
Below 15	0.90	1.40
15–24	1.30	1.55
25–34	1.34	1.48
35–44	1.34	1.48
45–54	1.31	1.45
55–64	1.20	1.38
65 and above	0.94	1.26

Beyond simple movement, this study incorporates a “Sociability Factor” to represent the social warmth and “stickiness” of the public space. This factor (ranging from 1 to 10) dictates how agents linger or interact with their surroundings. The value is a composite score derived from four survey-based indices:

1. Social Comfort: Self-reported comfort levels in the space.
2. Visitation Frequency: How often a user returns to the site (Daily to First-timer).
3. Stay Duration: A measure of temporal engagement (from  $<5$  minutes to  $>30$  minutes).
4. Activity Purpose: Points assigned based on social potential (e.g., ritual participation scores higher than transient market movement).

**Table 6:** Agent Interaction

Age Group	Comfort Index (1-5)	Frequency Index (1-5)	Duration Index (1-5)	Purpose Index (1-5)	Factor (1-10)
65 and above	3.25	4.75	4.25	4	7.75
35–44	3.25	4.75	5	2.5	7.47
55–64	3	4.25	4.75	2.5	6.86
45–54	2.88	4.38	4.62	2.12	6.55
25–34	2.67	4.67	4.17	2	6.19
Below 15	3	5	3.5	2	6.06
15–24	2	2	3.33	3.67	4.62

The “Program Components” define the logic of why agents stop or move toward specific zones. These are driven by Activity Attraction Factors, which use the relative frequency of mentioned activities from the survey to create a probability of involvement. For instance, in the morning simulation, the “Vegetable Market” acts as a primary node with a 0.38 probability of involvement, whereas work-related movement is a more secondary driver at 0.13.

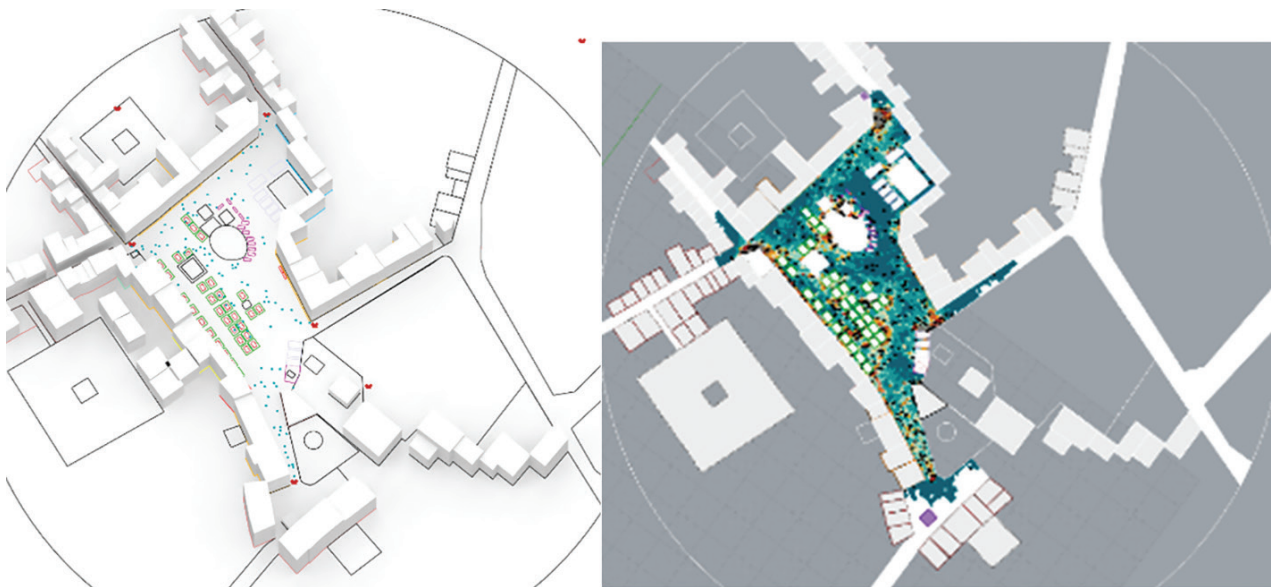
The physical environment is digitized as a series of walkable surfaces and obstacles that define the agents’ possible paths. The Compiled Simulation then bridges these three elements—the demographic agents, the programmatic goals, and the 3D environment—into a single executable model. The final Run Simulation

component initiates the physics engine, allowing for the observation of emergent movement patterns, bottlenecks, and social clustering at Lagan Chowk.

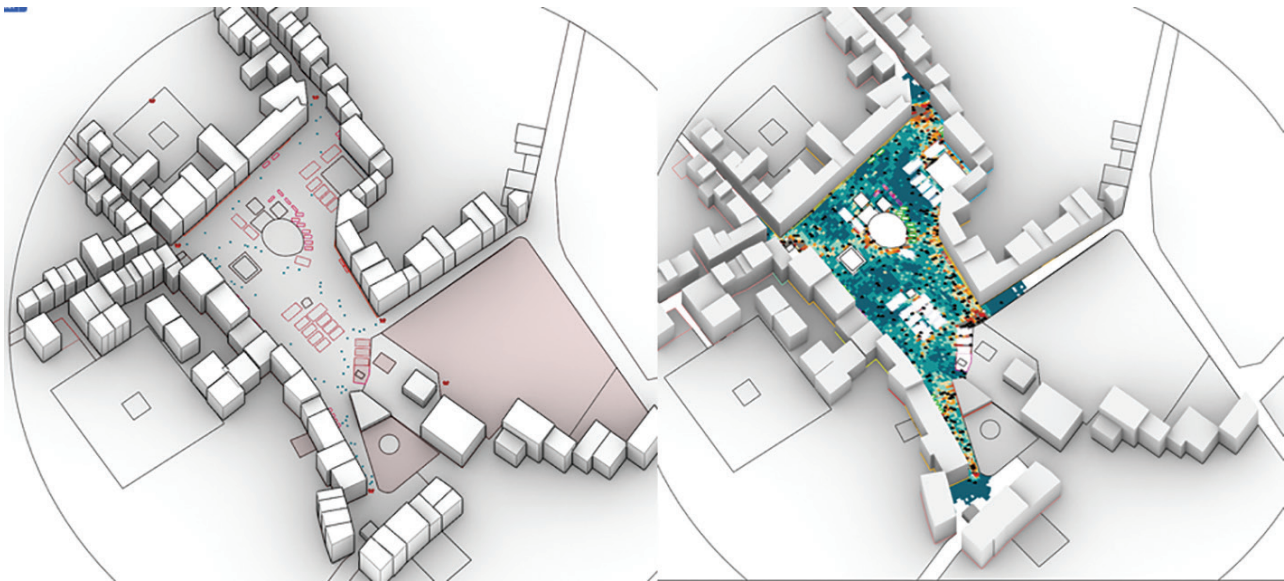
**Table 7:** Program Probability Attraction Factor

Morning			Day			Evening		
Purpose	Total Mentions	Probability of Involvement (0–1)	Purpose	Total Mentions	Probability of Involvement (0–1)	Activity Category	Frequency (n)	Probability (0–1)
Vegetable Market	37	0.38	Work-related	40	0.4	Shopping	21	0.29
Shopping	21	0.22	Shopping	24	0.24	Vegetable Market	17	0.23
Leisure	18	0.19	Leisure	16	0.16	Leisure	13	0.18
Ritual / Religious Activity	15	0.15	Resting / Waiting	12	0.12	Work-related	11	0.15
Work-related	13	0.13	Ritual / Religious Activity	5	0.05	Resting / Waiting	8	0.11
Resting / Waiting	8	0.08	Vegetable Market	3	0.03	Ritual / Religious Activity	3	0.04

By integrating agent behaviors, programmatic anchors, and environmental variables into the Kova Ped Sim plugin for Grasshopper, the simulation generates heat maps that visualize pedestrian density across three distinct temporal phases. These maps represent “actual” movement where red zones indicate high-intensity interaction and transit.



**Figure 3:** Simulation visualization of morning



**Figure 4:** Simulation Visualization Of day

**Morning Phase:** The simulation reveals a primary concentration around the vegetable market, mirroring real-world field observations. A secondary, yet significant, cluster appears in the corridor between the Karunamaya Temple and the adjacent chautari, highlighting this as a core social node. **Daytime Phase:** Activity shifts toward the retail storefronts. However, the heat map also identifies congestion within the central parking zone, suggesting that stationary vehicles act as a physical disturbance to fluid pedestrian movement. The temple-chautari axis remains a consistent point of interest. **Evening Phase:** High-intensity “heat” is distributed between both the market and shopping areas. Across all timeframes, the simulation consistently identifies the plaza entry points as major red zones. This is largely due to the “funnel effect” created by narrow streets opening into the square, which naturally compresses pedestrian flow and creates a recurring bottleneck.

### 3.4 Space Syntax Analysis

Space syntax provides a framework for evaluating how spatial layouts interact with human behavior. Rather than viewing space as a static backdrop, this theory posits that physical configuration is intrinsic to social activity. It suggests that what occurs within a specific room, corridor, or plaza is fundamentally shaped by its relationship to the broader network of connected spaces.



**Figure 5:** Integration map syntax analysis map

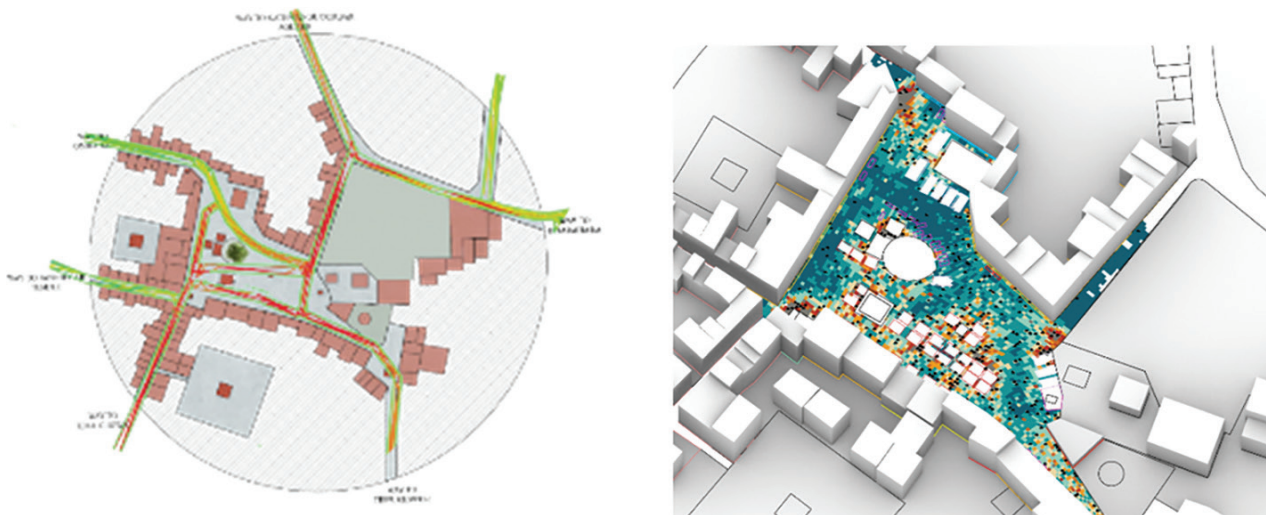
Integration measures how well-connected a specific area is to the rest of the settlement. High integration values indicate “core” zones that are easily accessible, naturally drawing higher pedestrian volumes. In Lagan Chowk, these highly integrated streets serve as the backbone for both social and economic life. The constant foot traffic in these zones supports a thriving dress market and local tea stalls. This spatial connectivity ensures that daily routines, commercial interests, and ritual processions coexist within the same high-visibility corridors.

While integration looks at connectivity, entropy measures the distribution of “depth” within a system.



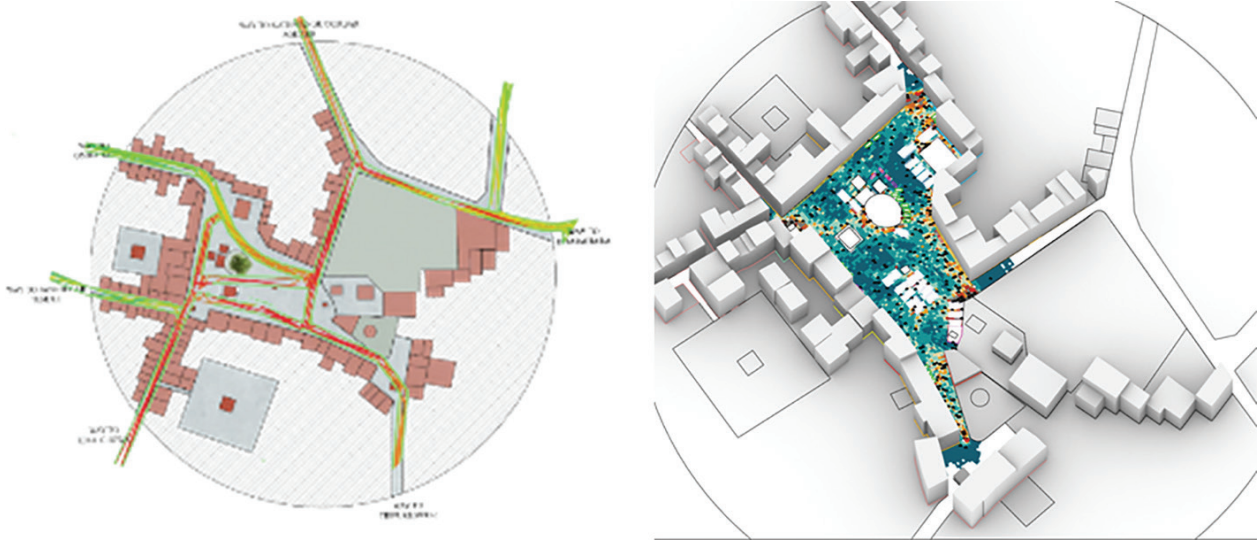
**Figure 6:** Entropy-depth map syntax analysis map

Low entropy occurs when spaces are tightly clustered around a specific point, creating uneven depth, while high entropy indicates a more dispersed, even layout. This metric is particularly effective for identifying topological landmarks that hold cultural weight. In the case of Lagan Chowk, the spatial data reveals a distinct “red zone” characterized by tight clustering. This area functions as a strategic bottleneck and gateway. Beyond its role in daily navigation, it serves as the primary entry point for the Jatra route, marking it as a critical ritual threshold where the community’s spiritual and physical paths intersect.



**Figure 7:** Morning integration map from space syntax and simulation result comparison

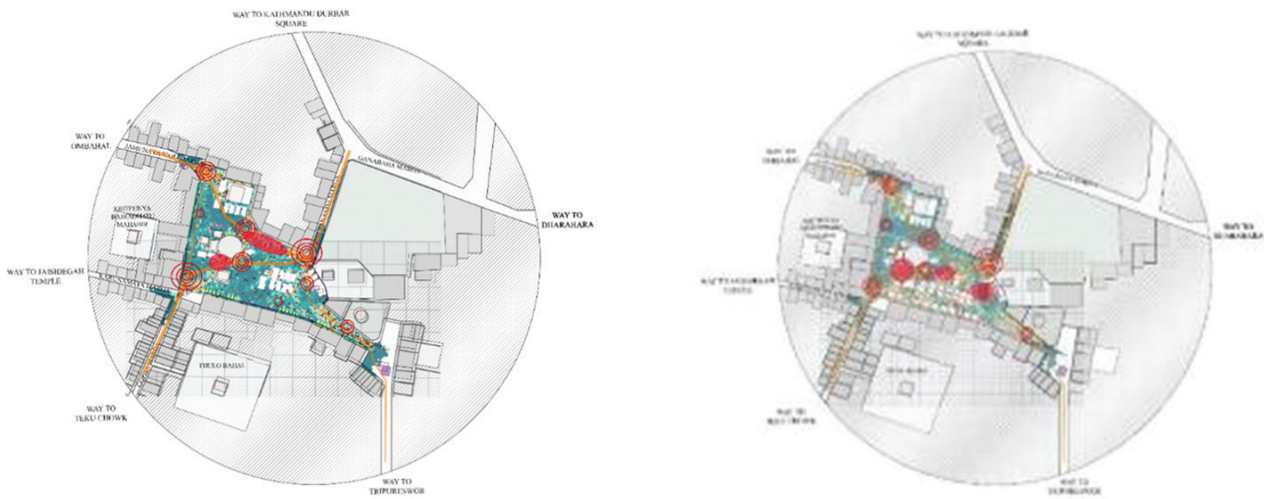
While Space Syntax integration maps highlight zones with high movement potential based on layout, Agent-Based Simulations reveal a more nuanced reality. Actual pedestrian flow fluctuates throughout the day, peaking sharply during the morning and evening market hours. For much of the day, activity remains sparse despite a “favorable” spatial configuration. This discrepancy proves that physical layout is only one piece of the puzzle; the presence of specific temporal functions like the markets what actually breathes life into the square.



**Figure 8:** Day integration map from space syntax and simulation result comparison

### 3.5 Vehicular and Pedestrian Movement Conflict

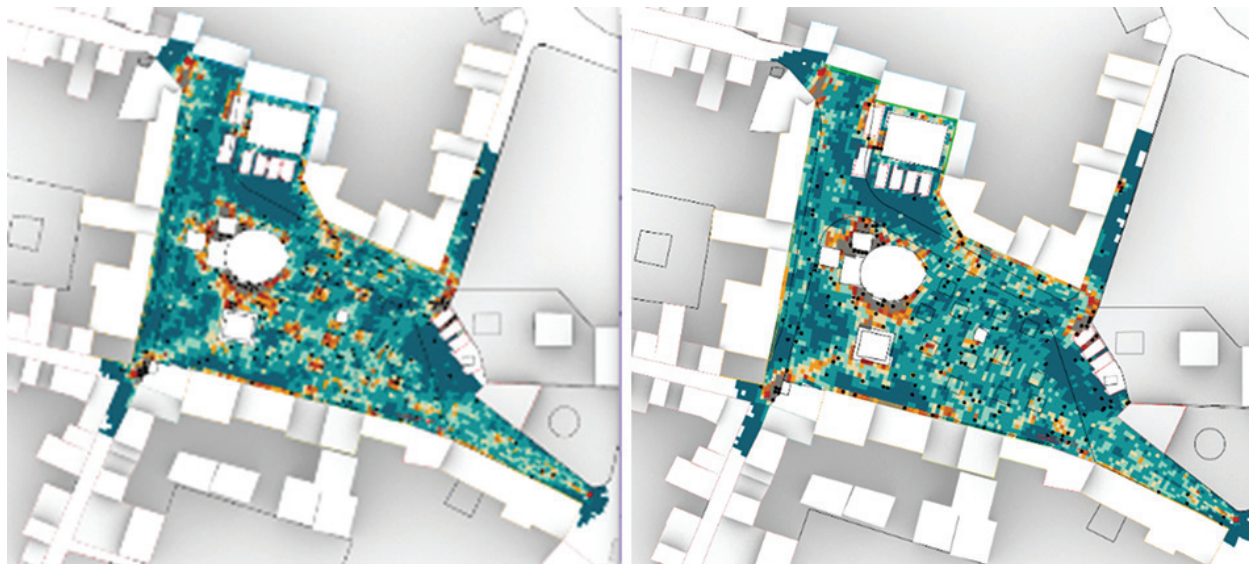
By overlaying vehicular traffic maps with pedestrian simulation heat maps, several critical intersection points become clear. The narrow corridor between the Chautari and Karunamaya Temple emerges as the most consistent conflict zone. While retail areas face disruptions during peak daylight hours, the evening vegetable market experiences its own set of minor disturbances. Field surveys validate these findings, showing that traffic significantly degrades the pedestrian experience. A substantial 75.82% of respondents expressed frustration, with 48.35% agreeing and 27.47% strongly agreeing that vehicles make the plaza uncomfortable. This suggests that the presence of cars creates a psychological barrier, effectively discouraging people from lingering or moving freely.



**Figure 9:** overlapping of day and evening vehicular and simulation result

Local interviews reveal a specific historical trade-off: the plaza was paved entirely in stone specifically to accommodate the Seto Machindranath Jatra chariot. Previously, softer ground and greenery caused the heavy chariot wheels to sink, stalling the procession.

However, this transition to hard paving was a double-edged sword. While it streamlined the festival, it also invited unrestricted vehicular traffic into the heart of the square. On a positive note, the festival’s deep cultural roots serve as a shield against permanent development, ensuring the plaza remains an open public asset. That said, residents have noted that the underlying RCC (Reinforced Cement Concrete) base may be hindering natural drainage, a point that warrants further environmental scrutiny.

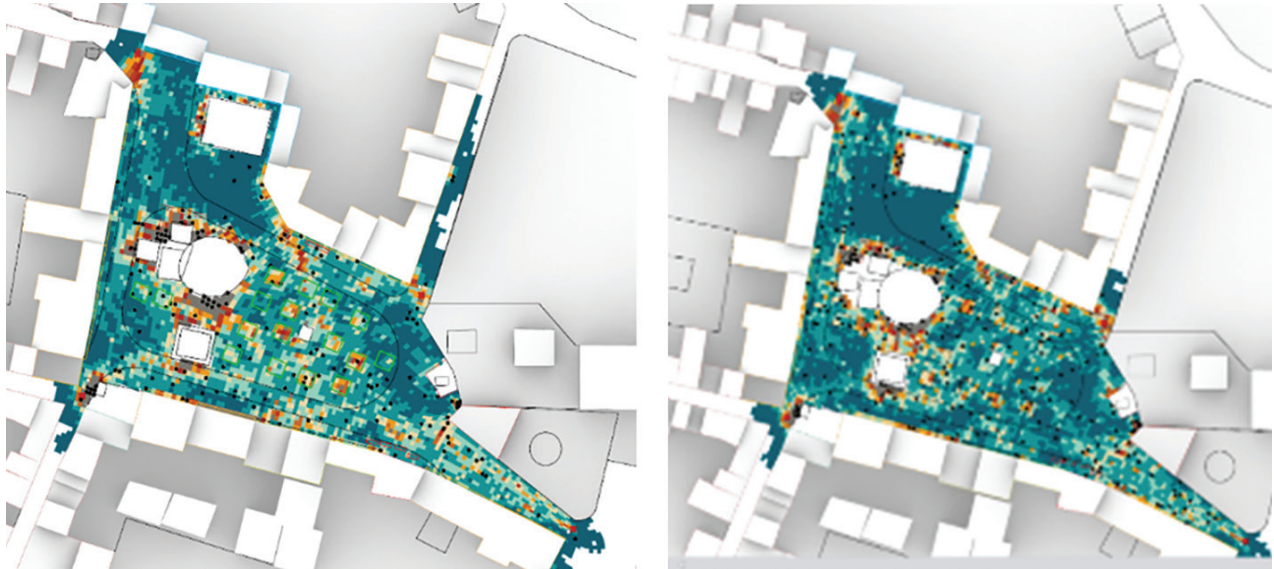


**Figure 10:** Option 1 For Simulation testing for morning and day Program

The final simulation trials demonstrate that removing parked cars from the central plaza immediately boosts pedestrian flow and overall accessibility. Previously, stationary vehicles acted as physical “clogging” points that stifled circulation. Among the Tow design configurations tested to mitigate traffic-pedestrian friction,

Option 2 proved most effective. It yielded the lowest number of conflict points, offering a clear blueprint for prioritizing human movement over vehicular convenience.

#### 4 Results and Discussion



**Figure 11:** Option 2 For Simulation testing for morning and day Program

The socio-spatial performance of Lagan Tole's courtyard is shaped by the interaction of spatial configuration, cultural practice, and temporal variation in use. By integrating observational data, space syntax analysis, and agent-based simulation, consistent behavioral patterns can be identified.

The use of the space shifts throughout the day in response to changing routines and needs. In the morning, it functions primarily as a neighborhood space, where the vegetable market (38.10%), ritual activities (15.50%), and local shopping (21.60%) shape a relatively calm and community-oriented environment. By midday, the character of the space becomes more work-focused, with work-related activity dominating (41.20%) and the presence of the vegetable market declining. Shopping remains significant (24.70%) but becomes more formal and task-oriented, while movement becomes more direct and purposeful. In the evening, the space transitions into a transit and social corridor, where passing-through activity (22.60%) and shopping (21.60%) become dominant, alongside a partial return of the vegetable market (17.60%). As work-related activity decreases (11.30%), the space becomes more fluid, characterized by increased movement, interaction, and commuting flows. This indicates that spatial vitality is not static but varies according to temporal activity patterns.

Beyond temporal variation, spatial configuration also shapes movement patterns. Space syntax analysis indicates that the courtyard possesses high theoretical movement potential. However, simulations reveal that accessibility alone does not ensure activity. Movement instead clusters around functional anchors such as temples, chautaris, and vendor hubs. Without these programmatic triggers, even highly integrated spatial zones remain underutilized, suggesting that layout provides the framework, while function activates use. This finding aligns with Madanipour (2003), who emphasizes that public space is defined through patterns of use and social interaction rather than form alone. It also extends Lefebvre's (1991) argument that space is produced through lived practice by demonstrating that configurational accessibility requires activation through temporal and programmatic conditions. While space syntax studies emphasize movement potential

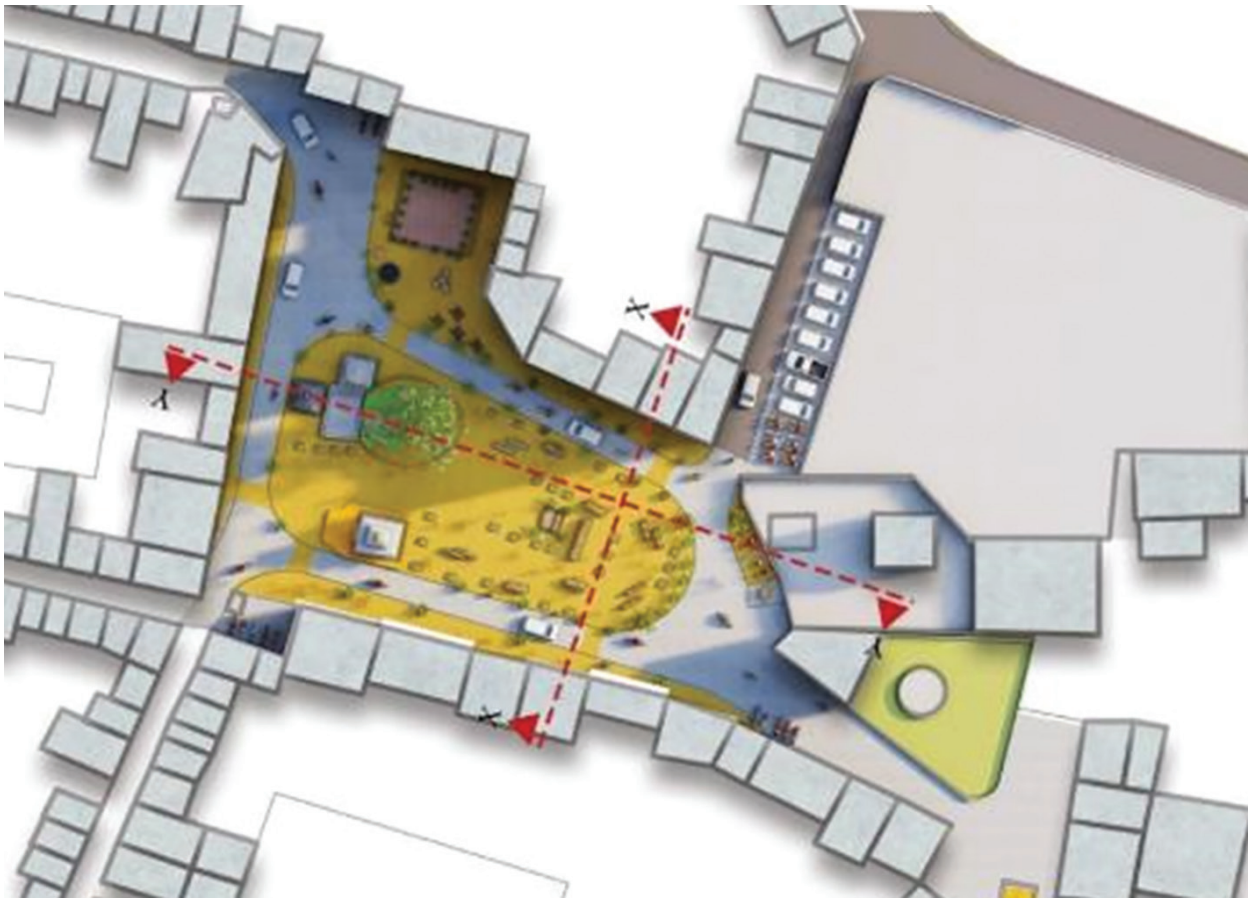
(Hillier et al., 1993), the present study shows that in historic courtyards, localized anchors play a more decisive role in structuring movement.

In addition to configurational effects, a key tension emerges between pedestrian movement and vehicular access. A critical tension exists between pedestrian comfort and vehicular permeability. Historical modifications, specifically the installation of continuous stone paving to accommodate the Seto Machindranath Jatra chariot, have unintentionally enabled unrestricted vehicular access. While this supports ritual processions, it degrades everyday safety and social comfort. Survey data confirm that users perceive vehicle intrusion as a primary barrier to walkability. This reflects observations by Gutschow (2011), where incremental physical changes in Kathmandu's historic public spaces alter everyday use, and the present study demonstrates how such modifications directly influence movement patterns and conflict zones. User behavior varies significantly by age and intent. Older residents tend to occupy shaded seating and temple precincts for long durations, fostering community bonds. In contrast, younger users and commuters primarily utilize the space for circulation. This divergence indicates the need to accommodate both prolonged occupation and efficient movement within the same spatial framework.

Cultural practices, particularly the Seto Machindranath Jatra, act as a protective mechanism for the courtyard, preventing permanent structural encroachments and preserving its status as an open public asset. However, the infrastructure developed for these rituals, including hard-surface paving and removal of physical barriers, has facilitated increased vehicular access. This dual condition highlights the need to reconcile ritual requirements with everyday pedestrian use and spatial performance. Agent-based modeling proved effective in identifying bottlenecks and crowding at narrow entry points. While the study focuses on current conditions, the results highlight specific zones such as vendor placement areas and circulation bottlenecks where spatial adjustments could improve the courtyard's flow and usability. This supports Liu and Kaneda (2020), who argue that simulation enables a more precise understanding of pedestrian behavior than conventional observation, and demonstrates its applicability within culturally embedded historic environments.

#### **4.1 Design implication**

The simulation results helped identify key conflict zones between pedestrian and vehicular movement. Based on this, the intervention focuses on reducing these conflicts while respecting existing cultural practices. Since the movement of the chariot during the Seto Machindranath Jatra requires flexible space, permanent structures are avoided. Instead, movable planting elements are introduced as a soft barrier to limit vehicular access into the central plaza without obstructing movement during the festival. To support daily activities, modular furniture is proposed. In the morning, it can be used by vegetable vendors, while at other times it functions as seating for pedestrians in this busy urban setting. The ground surface is not differentiated by height, again to allow smooth chariot movement, but different paving materials are used to subtly distinguish pedestrian and vehicular zones. The intervention also considers the cultural importance of the chautara. As it is associated with the deity Seto Machindranath, the upper platform remains relatively undisturbed, respecting local sentiments. However, the lower portion is adapted into stepped seating, allowing it to be integrated into everyday use without compromising its cultural value.



**Figure 12:** Master plan For Optimized Lagan Chowk

The design aims to balance heritage sensitivity with everyday functionality, ensuring that both festival requirements and daily urban activities are accommodated. The findings demonstrate that incremental, evidence-based adjustments can improve accessibility and social interaction without altering the cultural structure of the courtyard.



Figure 13: Section at X-X At morning Time



Figure 15: Section at X-X At Day Time



**Figure 14:** Section at Y-Y At morning Time

## 5 Conclusions

The study concludes that the performance of Lagan Chowk is shaped by the interaction between spatial configuration, cultural practice, and temporal patterns of use. While the spatial layout provides a basic framework for accessibility, the vitality of the courtyard depends on programmed activity and user behavior. Without these active layers, even well-configured heritage spaces risk functioning as transitional corridors rather than socially productive environments.

By integrating agent-based simulations with space syntax analysis, the study identifies patterns of pedestrian density, movement concentration, and spatial conflict. This combined approach demonstrates that the evaluation of heritage public space requires both configurational analysis and behavioral modeling. A key finding is that certain spatial modifications, particularly paving interventions introduced to accommodate ritual movement such as the Seto Machindranath chariot festivals unintentionally enabled vehicular intrusion, thereby reducing pedestrian comfort and social interaction.

At a theoretical level, the study advances the integration of socio-spatial theory and computational analysis by demonstrating how Lefebvre's concept of lived space can be operationalized through agent-based simulation and space syntax. It shows that spatial configuration alone does not produce social life, but requires temporal and programmatic activation to generate sustained use.

At the same time, the findings should be interpreted in light of certain limitations. The agent-based simulation relies on simplified behavioral rules and does not fully capture social negotiation, cultural preference, or adaptive decision-making under varying conditions. Parameters related to physical ability and perception were generalized, and the simulation environment does not incorporate learning or long-term behavioral adaptation. In addition, the model is calibrated using observations from selected time periods, which may not represent seasonal variation or exceptional events such as festivals at full scale. These limitations indicate the need for future research incorporating longitudinal data and more complex behavioral modeling to enhance accuracy and applicability.

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