Temporal Dynamics and Activity Patterns of Pilgrims in the Tirumala Temple Complex: An Urban Analysis

S. Iswarya Lakshmi[1*] [ID] **, D. Prathyusha Reddy[2]** [ID] **and Karteek Guturu[3]** [ID]

[1*&2]Student, Master of Urban design, School of Planning and Architecture, Vijayawada, Andhra Pradesh, India
[3]Assistant Professor, Department of Architecture, School of Planning and Architecture, Vijayawada, Andhra Pradesh, India
E-mail: prathyushareddydara00@gmail.com, karteekg@gmail.com
*Corresponding Author: iswaryalakshmisiva@gmail.com

Abstract - Tirumala, a sacred hill town in Andhra Pradesh, India, is renowned for the Sri Venkateswara Temple-one of the most visited Hindu pilgrimage destinations in the world. The temple complex exhibits pronounced spatial and temporal variations arising from pilgrim behavior, ritual schedules, and movement patterns. These continual shifts affect the functionality and accessibility of public spaces, influencing congregation densities, circulation efficiency, and spatial adaptability across different times of the day. The study aims to analyze the temporal dynamics of pilgrim activity, focusing on how ritual-based transitions influence spatial congestion and the adaptive use of spaces within the sacred precinct. A fifteen-day on-site investigation was conducted during the off-season month of February, concentrating on the 0.4 km² core area surrounding the main shrine, which accommodates an average daily flow of 7,500–8,000 pilgrims. The methodology combined direct observation, spatial mapping, and 24-hour time-lapse documentation to record variations in movement flows, congregation intensity, and accessibility at different temporal phases. The results reveal distinct cyclical patterns of activity, with predictable peaks during ritual hours and dynamic transformations of space during low-density periods, demonstrating how pilgrims and temple management adapt to temporal shifts. The study concludes that adaptive spatial planning strategies are essential to enhance the pilgrim experience, ensure efficient circulation, and preserve the ritualistic and cultural sanctity of Tirumala's sacred environment.

Keywords: Temporal Activity, Tirumala, Pilgrim Behavior, Congregational Spaces, Spatial Mapping

I. INTRODUCTION

Sacred spaces such as the Tirumala temple complex are characterized by highly dynamic spatial and temporal transformations influenced by religious rituals, pilgrim activities, and movement patterns. Tirumala, a major global pilgrimage destination, experiences notable fluctuations in crowd density throughout the day, affecting the functionality, accessibility, and adaptability of its public spaces. The site operates within a structured yet ever-changing environment, with rituals guiding patterns of congregation, queue management, and movement through spaces. The interaction between pilgrims, temple authorities, and the built environment creates a constantly evolving spatial system that requires careful analysis to enhance efficiency, manage congestion, and preserve the sacred essence of the space. Understanding the temporal

dynamics of public spaces in Tirumala is crucial for improving the overall pilgrimage experience while maintaining cultural and religious traditions. Spaces within the temple precinct, including courtyards, queue areas, congregation zones, and informal gathering spaces, serve multiple purposes depending on the time of day, the nature of the ritual, and the density of devotees. Some areas experience periodic congestion during specific ceremonies, while others adapt dynamically to accommodate changing functions. This cyclical transformation highlights the need for an urban design approach that integrates flexibility and adaptability into the spatial framework of sacred environments.

Fig.1 Temple and Temple Precincts (Source: Author)

II. RESEARCH AIM AND OBJECTIVE

The study aims to analyze the temporal dynamics and activity patterns of pilgrims in the Tirumala temple complex, focusing on how movement, congregation, and spatial usage change throughout a typical day. It seeks to understand the relationship between ritual schedules, crowd surges, and public space adaptability within the temple precinct. This study also aims to examine the daily variations in pilgrim activities and movement patterns within the Tirumala temple complex, focusing on how these dynamic flows shape the overall spatial experience. It seeks to analyze the influence of rituals and queue systems on congregation densities, highlighting how specific times of day and ritual schedules lead to varying levels of crowd concentration and spatial transitions. Additionally, the research assesses how time-dependent fluctuations in crowd

density impact the accessibility and functionality of public spaces, revealing critical insights into the design and management of sacred environments that accommodate large, time-sensitive pilgrim populations.

A. Research Hypothesis

The spatial dynamics of the Tirumala temple complex are influenced by the cyclical nature of pilgrim activities, which vary throughout the day in response to ritual schedules and crowd movement patterns. This necessitates a flexible spatial framework that can adapt to changing densities and functional requirements while maintaining seamless circulation and accessibility.

B. Research Question

In what ways do temporal variations in pilgrim activities and rituals influence the spatial usage and movement patterns within the Tirumala temple complex? Secondly, how do they affect the adaptability and efficiency of the temple complex throughout a typical day?

III. SCOPE AND LIMITATIONS OF STUDY

The study's spatial focus centers on key areas within the Tirumala temple precinct, including transition zones, temple courtyards, queue systems, waiting areas, and congregation spaces, where pilgrim activity is most concentrated and dynamic. It incorporates a temporal dimension by analyzing hourly variations in movement patterns and spatial usage throughout a typical day, capturing the ebb and flow of pilgrims in relation to ritual timings and administrative operations. A behavioral perspective is also integral, observing how pilgrims adapt to varying spatial conditions such as crowd density, waiting times, and restricted movement, highlighting the interplay between sacred routines and human behavior in a highly ritualized and time-sensitive environment.

This study focuses solely on the Tirumala temple complex and its immediate precincts, without extending to the broader urban context of Tirumala. It examines a typical day under normal conditions, excluding peak seasons, festivals, and special events such as Brahmotsavam and Vaikunta Ekadasi, which cause exponential crowd surges and temporary spatial changes. By analyzing daily pilgrim activities and movement patterns, the research aims to understand routine spatial dynamics within key areas such as queue lines, courtyards, congregation zones, and waiting areas, ensuring that the findings remain relevant to the temple's everyday operations.

IV. METHODOLOGY

1. *Literature Review:* Studying existing research on spatial dynamics in temple complexes and sacred towns.
2. *Site Observations:* Documenting spatial usage, pilgrim movement patterns, and changing crowd densities at different times of the day.
3. *Data Collection:* Recording variations in public space utilization across different ritual timings and peak hours.

Fig.2 Research Methodology Used for the Study Purpose (Source: Author)

A. Tools and Techniques

A combination of on-site observations, mapping techniques, and analytical tools is employed to capture and assess the changing spatial patterns within the temple complex. The primary data collection methods include:

1. Spatial Mapping: Spatial mapping is conducted to document key congregation zones, movement corridors, and transition spaces within the temple precinct. It records pilgrim density variations, waiting areas, and the impact of ritual schedules on spatial usage. This method helps visualize how different spaces are utilized throughout the day and identifies areas of congestion, smooth flow, and adaptive transformations.

B. Time-Lapse Study

A 24-hour time-lapse study is conducted to capture the evolving spatial patterns and changing densities in key temple spaces. By recording hourly fluctuations in pilgrim movement, congregation, and waiting times, the study provides insights into how different areas of the temple complex transform in response to temporal shifts. This helps in understanding peak hours, lull periods, and the spatial adaptability of various zones in managing crowd flow efficiently.

C. Observation Study

A 24-hour observation study documents pilgrim movement, congregation patterns, and activity intensity across different time periods. By analyzing peak hours, transition phases, and lull periods, the study captures how pilgrim activities vary throughout the day, influenced by rituals, queue systems, and crowd dynamics.

V. SPATIAL AND CULTURAL SIGNIFICANCE OF TEMPLES

The spatial and cultural significance of temples in urban contexts has long been a subject of academic inquiry. Scholars have explored how sacred architecture shapes not only spiritual practices but also the social and economic dynamics of cities. The study of sacred spaces, particularly

temples, through the lens of spatial configuration, heritage, and pilgrimage behavior has been approached using interdisciplinary tools ranging from space syntax and GIS to ethnography, survey analysis, and cultural geography. A foundational framework was established by Hillier and Hanson [10], who introduced *The Social Logic of Space*, proposing that spatial arrangements inherently structure human interaction. Hillier [9] further developed the concept of centrality as a process, using deformed grid theory to explain pedestrian movement in organically evolved urban areas.

These theoretical frameworks underpin much of the subsequent spatial analyses of temple environments. Building on this, Batty [1] proposed an integration of space syntax with spatial interaction models, highlighting that while space syntax captures local structural properties of urban form, spatial interaction models account for dynamic flows. This integration enables a more comprehensive understanding of movement patterns in religious precincts and pilgrimage centers. Dettlaff [5] elaborated on space syntax as a method for interdisciplinary spatial analysis, providing a detailed overview of axial, convex, and visibility graph analyses (VGA). He emphasized how these techniques can quantify visual accessibility, spatial integration, and depth relationships-vital for understanding the social functioning of temple layouts.

Studies such as Pramanik [17] and Eldiasty [6] applied these techniques directly to temple heritage. Pramanik [17] analyzed the Lingaraj Temple in Odisha using DepthmapX to conduct integration and visibility analysis, revealing spatial hierarchies that support both ritual sequencing and public circulation. In their study of Rosetta, Egypt, Eldiasty [6]. utilized a combination of topic modeling and space syntax to assess urban heritage for potential UNESCO nomination. Their multi-layered approach allowed the team to evaluate not only spatial configurations but also the cultural narratives embedded in the site.

Zhou [24] used space syntax metrics-intelligibility, integration, connectivity, and mean depth-to evaluate the internal spatial structure of Daming Temple. Their findings suggest a correlation between spatial visibility and historical layering, enabling quantitative tracking of heritage evolution. Sharmin and Kamruzzaman [18], through a meta-analysis of over 60 studies, validated these tools by statistically correlating space syntax measures (integration, choice, connectivity) with pedestrian flow. Their findings confirmed that spatial configuration significantly predicts pedestrian behavior, which is crucial in temple precincts.

Srirangam and Forsyth [21] explored the spatial relationship between retail and temple activity in Chennai using GIS mapping and space syntax proximity analysis. They demonstrated that temples historically functioned as anchors of economic and social life, influencing commercial patterns in their vicinity. Moving from spatial tools to socio-cultural perspectives, Bhardwaj [3] pioneered the cultural

geography of Hindu pilgrimage, outlining the sacred spatial hierarchy and cyclical movement of devotees. His work laid the groundwork for understanding pilgrimage beyond religious doctrine, focusing on spatial experience, temporality, and social cohesion.

Building on these foundations, Sougaijam [20] examined the diversification and unification of Indian social identity, highlighting the role of temple culture and pilgrimage in shaping collective traditions. His discussion emphasized how pilgrimage serves as a unifying social activity that reinforces cultural continuity across regions, thereby influencing spatial congregation patterns in sacred environments. Similarly, Murugaiyan and Jeyanthi [15] studied the attitudes of domestic tourists in the Madurai temple district, identifying behavioral variations among pilgrims and visitors within temple towns. Their analysis provided insights into visitor motivations, spatial preferences, and temporal rhythms of temple-based tourism, offering parallels to the behavioral observations made in Tirumala.

Extending this approach, Meena [13] introduced methodological advancements in forecasting tourism demand, emphasizing the integration of temporal analysis for predicting visitor inflow patterns. The study's findings reinforce the importance of incorporating time-based mapping and data interpretation frameworks in understanding fluctuating pilgrimage activities, thereby supporting the temporal dynamics methodology adopted in the present research.

Shinde [19] addressed environmental challenges in pilgrimage centers, identifying tensions between spiritual goals and ecological impacts. Through field surveys and stakeholder interviews, he found that unregulated pilgrim flows often overwhelm resources, calling for better spatial planning and ecological awareness. Verma [23] conducted an empirical survey during the Kumbh Mela in Ujjain, collecting data on activity participation and travel patterns. Their findings showed that pilgrims exhibit distinct spatial behaviors, such as clustering around ritual nodes and relying on visual cues for navigation, underlining the need for responsive spatial infrastructure. Similarly, Pawar and Patil-Gulavane [16] conducted a spatio-temporal analysis of the Mahalaxmi Temple in Kolhapur, using statistical tools and GIS mapping to identify seasonal pilgrimage trends and demographic shifts in footfall.

Hancock [8], through ethnographic fieldwork in southern India, emphasized that Hindu temples are *modernities remade*-adapting to new publics and socio-political expectations. Her study explored how spatial practices reflect evolving notions of community and identity.

In a similar cultural vein, Bharne and Krusche [2] presented a compendium of temple architecture and urbanism, analyzing sacred geometries, cardinal orientation, and symbolic zoning across various Hindu traditions. Their work underscores the urban-ordering role of temples, often designed as microcosms of the universe.

Choudhary [4] combined theatre anthropology and spatial theory to examine how temple spaces act as stages for ritual performance, negotiating continuity between past and present. His work frames temples not just as built forms but as performative spaces where time, movement, and sacred narrative coalesce. On ritual and spatial order, Huspeková [11] conducted a ritual field study of a Gaudiya Vaishnava temple, observing how daily practices, spatial divisions, and embodied movement create a rhythm of sacred occupation. This aligns with Jacobsen [12], who studied how diasporic Hindu temples reconfigure spatial arrangements in global contexts, often modifying traditional layouts to suit multicultural and zoning constraints.

In East Asian contexts, Chi-Hsiang *et al.* (2021) analyzed temple tourism in Taiwan using questionnaire surveys and structural equation modeling (SEM). They found that cultural significance, physical accessibility, and event-based activities were the most influential factors driving tourist satisfaction. Gao [7] employed GIS spatial-temporal analysis to map the distribution of Buddhist temples and pagodas across the Liaoning region, uncovering the ways in which topography and imperial support shaped temple locations and urban development.

Mukil [14] approached sacred spaces through the lens of sustainability and cultural attributes, using a grounded theory approach to study an Indian village. Their findings emphasized nature connectedness, indigenous belief systems, and vernacular temple design as key elements of sustainable spatial practice. Together, these works construct a comprehensive understanding of sacred spatialities, integrating quantitative spatial analysis, ethnographic inquiry, sustainability, cultural geography, and behavioral studies.

VI. METHODOLOGICAL APPROACHES FOR STUDYING TEMPORAL DYNAMICS IN TIRUMALA

To examine the spatial and temporal patterns of pilgrim activity within the Tirumala Temple Complex, this study employed a combination of spatial mapping and congestion analysis, time-lapse studies with temporal mapping, and structured observational surveys. Over a 15-day period during the off-season, an average daily pilgrim volume of 7,500–8,000 individuals within an area covering approximately 100 acres was documented, based on coordinated field counts, administrative data, and visual verification.

A. Spatial Mapping and Congestion Analysis

Spatial mapping and congestion analysis are methods used to understand how people and activities are distributed and move through a physical space, especially in dense or busy environments. Spatial mapping helps visualize congregation zones, movement patterns, and congestion hotspots within the temple precinct. Hillier [9] suggests that spatial accessibility and centrality influence movement patterns, which can be mapped to identify areas requiring adaptive interventions. Srirangam and Forsyth [21] used GIS and proximity analysis to map temple influence on urban commerce, indirectly identifying congregation and activity hotspots.

B. Time Lapse Studies and Temporal Mapping

Time-lapse analysis captures hourly fluctuations in pilgrim movement, congregation densities, and spatial utilization. Documenting changes in activity patterns over 24-hour cycles provides a comprehensive understanding of:

1. Peak and off-peak usage of key spaces.
2. Shifts in queue densities during ritual transitions.
3. Evolving spatial adaptability in response to crowd variations.

Although not all studies explicitly used time-lapse imagery, temporal dimensions were addressed through spatio-temporal GIS analyses, as in Pawar and Patil-Gulavane [16], who charted seasonal footfall at the Mahalaxmi Temple, and Verma [23], who mapped activity patterns and travel behaviors during the Kumbh Mela to highlight crowd rhythms over time. Ethnographic works such as Huspeková [11] captured daily ritual cycles and their spatial rhythms, offering qualitative equivalents of time-lapse insights.

C. Observational Study

The Tirumala temple complex is a hub of religious, social, and commercial activities. Coconut breaking and diya lighting mark devotional offerings, while people processions and bathing rituals at Pushkarni are integral to temple traditions. Temporal activities like flower selling and pooja stalls, along with commercial shops selling prasadam and souvenirs, cater to visitors. The idol procession is a key event, drawing large crowds, while pilgrims capture moments through photography, enriching the temple's vibrant atmosphere. After long hours of rituals and movement, resting areas provide relief to devotees, offering a space to pause and rejuvenate.
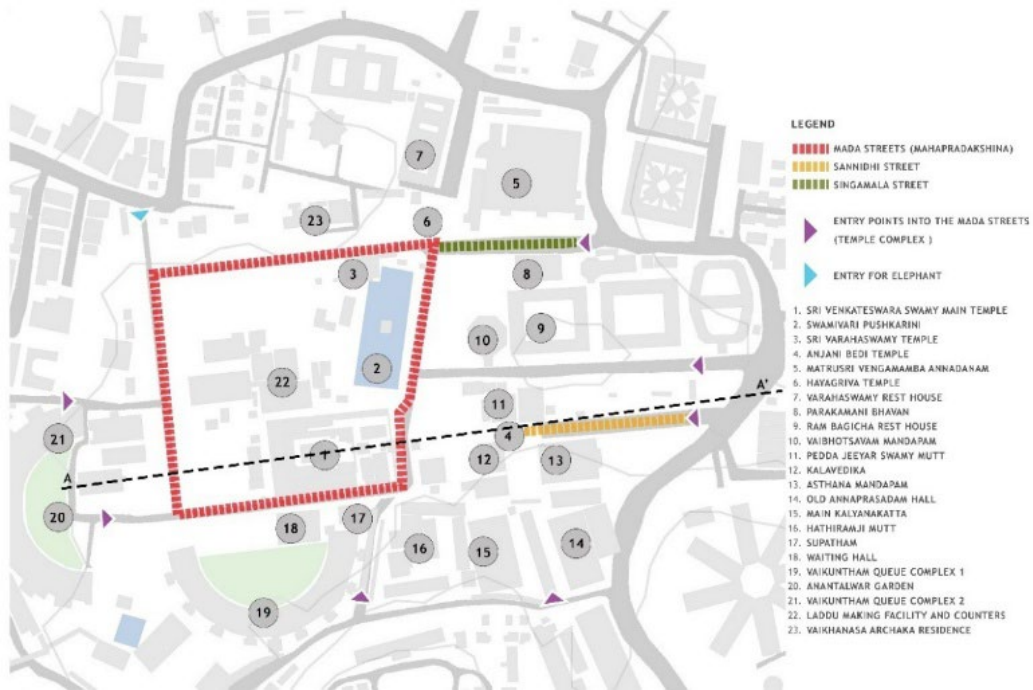
Fig.3 Temple Complex and its Surroundings (Source: Author)

VII. TIME WISE DAILY ACTIVITY AND SPATIAL TRANSFORMATIONS IN THE TEMPLE COMPLEX

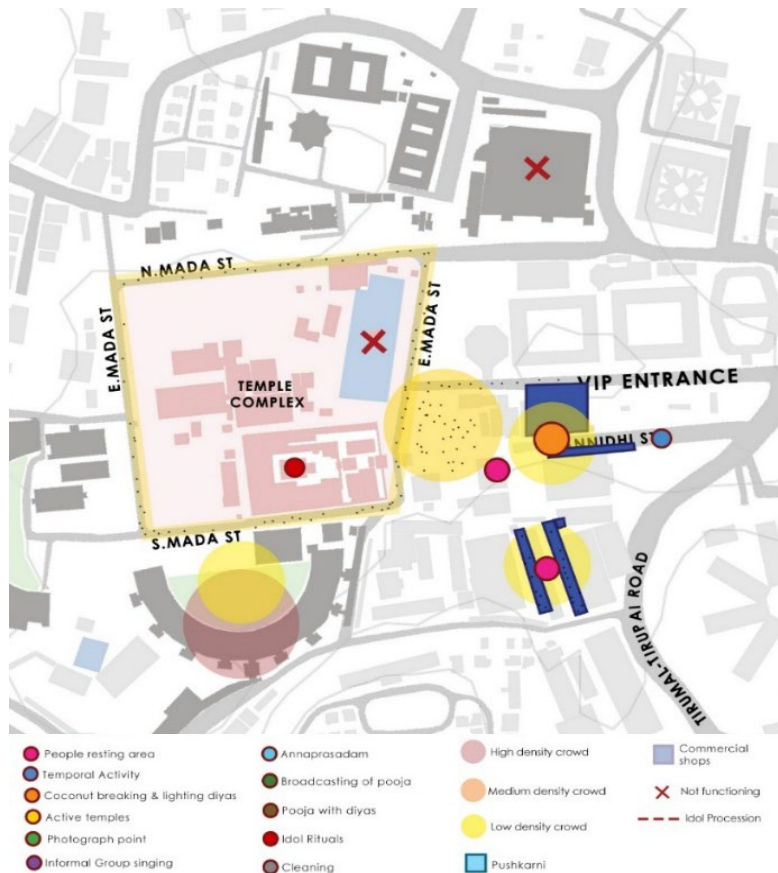*A. Time Interval: 00.00 - 03.00*

Fig.4 Temporal Activities in the Temple Complex During 00.00 to 06.00 (Source: Author)

During this early time slot, activities within the temple precinct are primarily ritualistic and ceremonial. The Ekanta Seva at 1:30 AM marks the final ritual of the day, during cleaning and resetting in preparation for the next day's rituals. The Suprabhatam Seva (2:30 AM–3:00 AM) marks the ceremonial awakening of Lord Venkateswara, attracting a limited number of dedicated devotees, which results in moderate activity around the temple entrances. Following this, the Thomala Seva (3:30 AM–4:00 AM) involves adorning the deity with garlands-a largely private ritual with minimal public engagement. Overall, pilgrim movement remains low, limited to those participating in early morning sevas, and the public spaces within the temple complex experience little crowd pressure.

B. Time Interval: 03:00–06:00

This period marks a gradual increase in activity as various reparatory rituals unfold. The Koluvu and Panchanga Sravanam (4:00 AM–4:15 AM) and the First Archana (4:15 AM–5:00 AM) are conducted privately, contributing minimally to spatial congestion. Around this time, cleaning and preparatory work also occur within the temple premises, while smaller shrines like the Varaha Swamy and Hayagriva temples see a steady influx of pilgrims. On the Mada Streets, vendors begin setting up stalls, and pilgrims engage in early morning rituals such as applying namam and tying holy threads, creating a slow but steady spatial

which the deity is ceremoniously put to rest. This event formally concludes the temple's daily spiritual cycle, and public spaces gradually empty out, allowing for transformation.

C. Time Interval: 06.00 - 09.00

With the first bell and Sattumura (6:30 AM–7:00 AM), public *darshan* officially begins, leading to the formation of long queues and increased movement in transitional areas such as corridors and mandapams. Sarvadarshanam, the general *darshan*, commences at 7:30 AM, significantly raising crowd density. This period is characterized by a visible peak in pilgrim activity. Coconut breaking becomes a central ritual, especially on Saturdays, drawing significant crowds. Religious vendors thrive during this time, selling garlands, *prasadam* (such as *sundal*), and framed deity images. Pilgrims engage in practices such as applying *namam* and taking paid photographs. Public spaces see both formal and informal ritual use, with devotees resting and conducting personal offerings. The temple tank remains closed, but the crowd begins to increase as more devotees gather nearby. On the Mada Streets, especially on Saturdays, crowd density surges, with people applying *namam*, and footfall at the Varaha Swamy Temple increases noticeably. The Hayagriva Temple continues to experience a consistent stream of visitors.
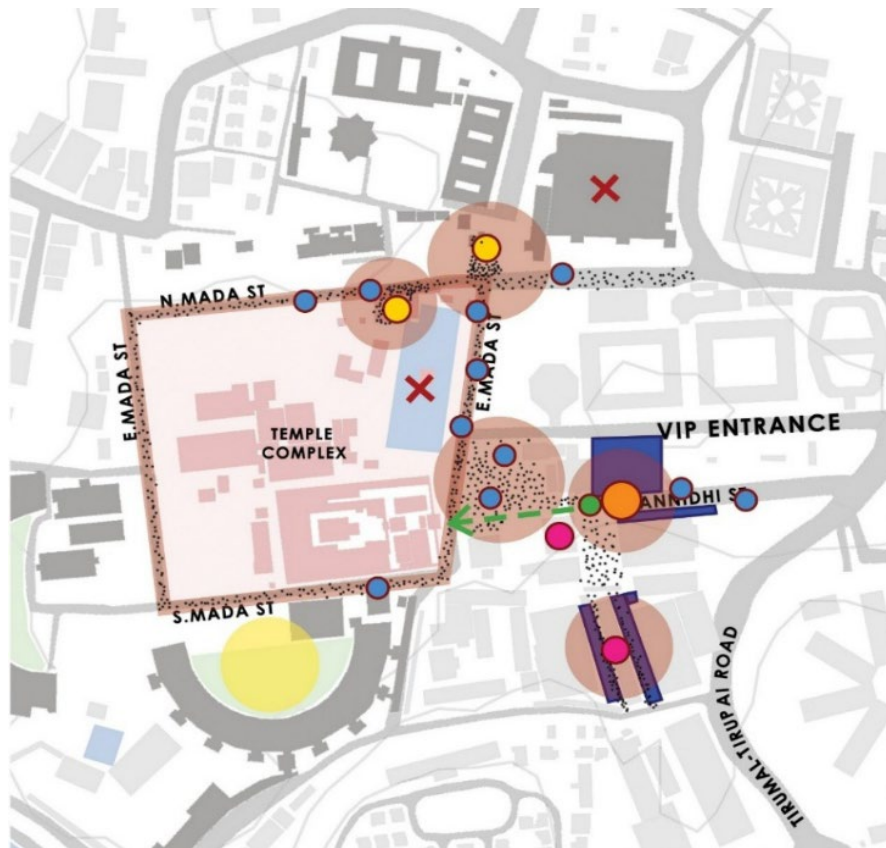

Fig.5 Temporal Activities in the Temple Complex During 06.00 to 09.00 (Source: Author)

D. Time Interval: 09.00 - 12.00

This period is one of the busiest times of the day. Pilgrims arrive in large numbers for darshan, with most of the queue lines filled. The main sanctum sees a continuous flow of visitors. Outside the temple, the Mada Streets are filled with activity, with pilgrims who have finished darshan sitting under trees to rest. Others visit shops and small temples nearby. Temple staff remain busy managing the crowd and rituals. Some special sevas may also take place during this time. The sounds of devotional songs, temple bells, and announcements fill the air. Vendors sell water, snacks, and religious items. Devotees gather in small groups for prayer or rest, while the temple kitchen prepares prasadam for distribution. The streets and spaces are fully alive.
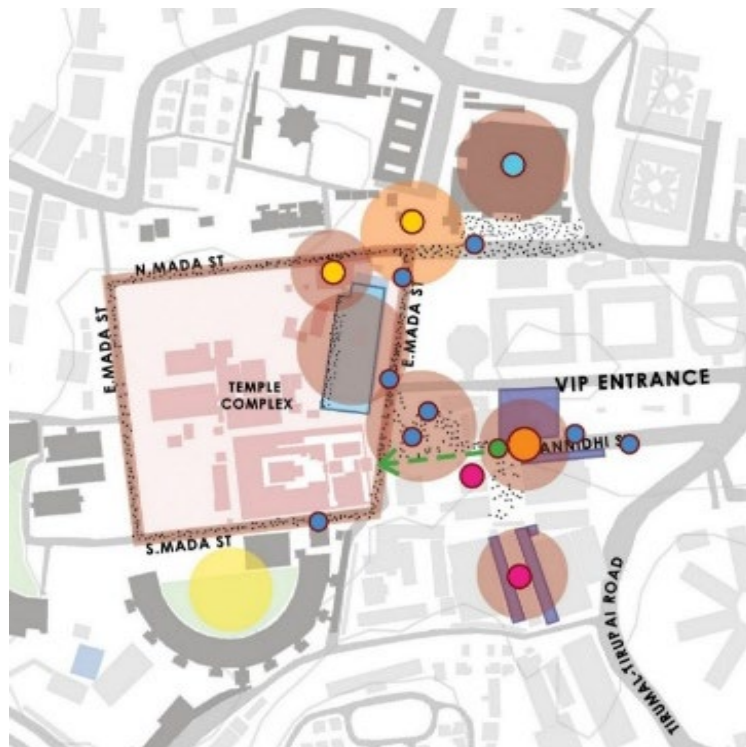

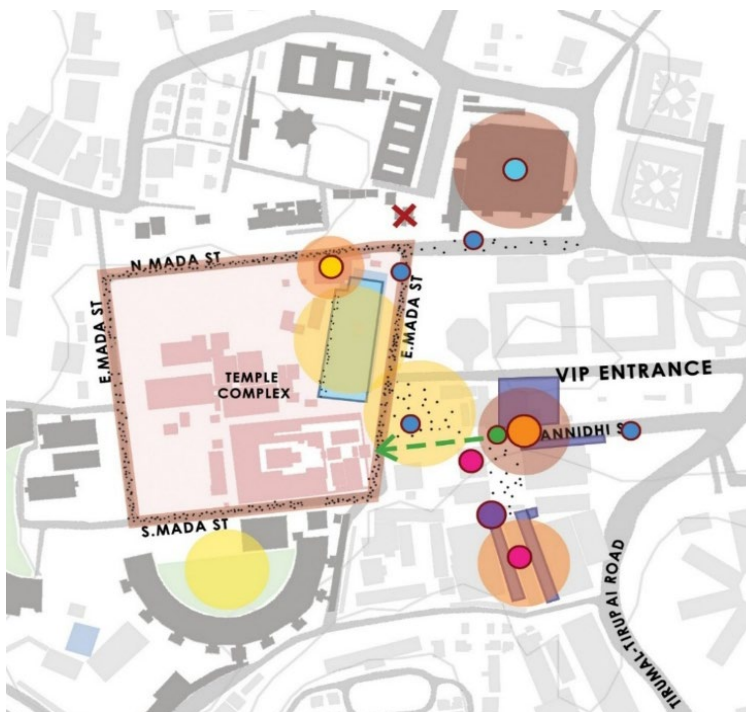Fig.6 Temporal Activities in the Temple Complex During 09.00 to 12.00 (Source: Author)

Fig.7 Temporal Activities in the Temple Complex During 12.00 to 15.00 (Source: Author)

E. Time Interval: 12.00 - 15.00

This period is comparatively quiet. Most pilgrims have completed *darshan* and are resting or eating. The temple continues its daily rituals, but public activity is lower. Some pilgrims seek shade under trees or near *mandapams*. The midday sun makes it uncomfortable to walk long distances, and vendors also slow down their sales. Inside the temple, some *sevas* continue for those who booked in advance. Priests perform *Naivedyam* and other offerings. Many pilgrims exit the complex after *darshan*, while others sit in silence or pray in small corners. This time is also used by staff for maintenance and cleaning.

The temple complex remains orderly and calm. People avoid movement due to the heat, and public spaces begin to feel peaceful again. It is a brief pause between two busy parts of the day. Though the crowd is smaller, the spiritual mood remains.

F. Time Interval: 15.00 - 18.00

As the afternoon ends, pilgrims begin returning to the temple area. This is the time when those who rested earlier come back. The *Sarvadarshan* continues, and new devotees arrive. The shops and stalls reopen fully. Children, families, and groups move around the Mada Streets, creating a slow build-up in activity. The temple staff prepare for the evening rituals; some lighting and decorations are checked. The crowd starts increasing again after 4:30 PM, and pilgrims wait near the entry points while volunteers guide people towards the queue lines.
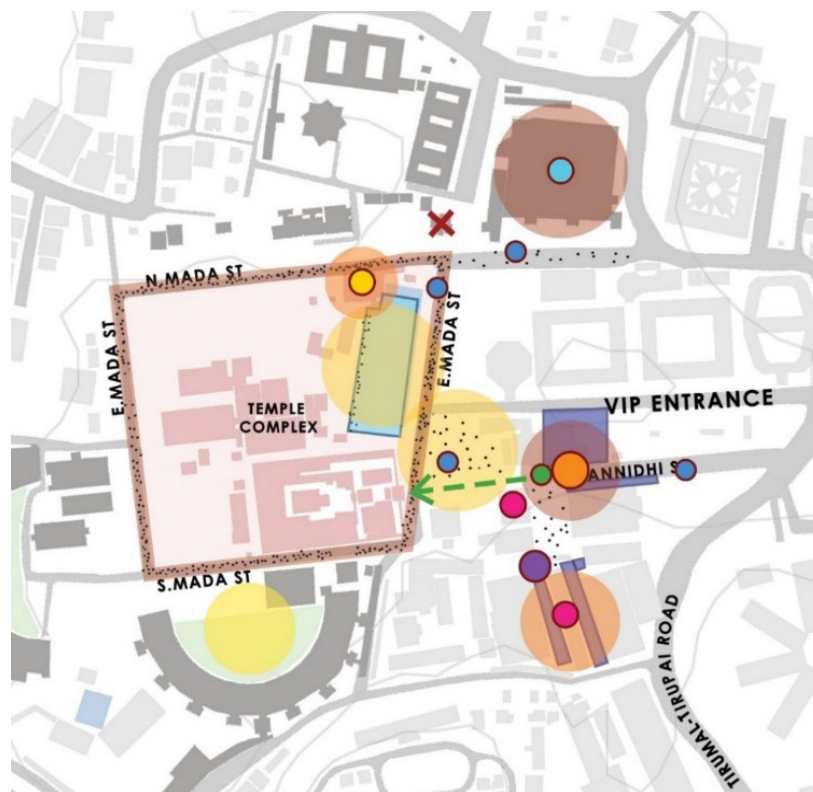

Fig.8 Temporal Activities in the Temple Complex During 15.00.00 to 18.00 (Source: Author)

Special prayers are sometimes held around 5:00 PM. The air begins to cool, making movement easier. The streets become lively again as the sounds of drums and chants increase. Devotees light lamps and make offerings. Many people buy *prasadam* or sit for group prayers. The sacred energy returns to the space. The temple feels active but not yet crowded.

G. Time Interval: 18.00 - 21.00

This time is full of energy and spiritual feeling. At 6:00 PM, the daily procession begins, often featuring decorated elephants and musical troupes. This leads to the closure of all four Mada Streets and results in a surge of pedestrian activity along key vantage points. Devotees line the streets to witness the spectacle, transforming the thoroughfares into vibrant processional corridors. Many pilgrims who rested during the day return to the temple. Devotees gather in large numbers to witness the evening aarti. The Mada Streets are again filled with movement and sound. The temple music grows louder. Shops selling lamps, flowers, and prasadam do good business. Families take photos near the entrance or sit on the steps. Temple volunteers help manage the queues and direct pilgrims. Some pilgrims visit smaller temples nearby. The temple feels full of life and devotion. The combination of lights, chants, and people creates a sacred atmosphere.
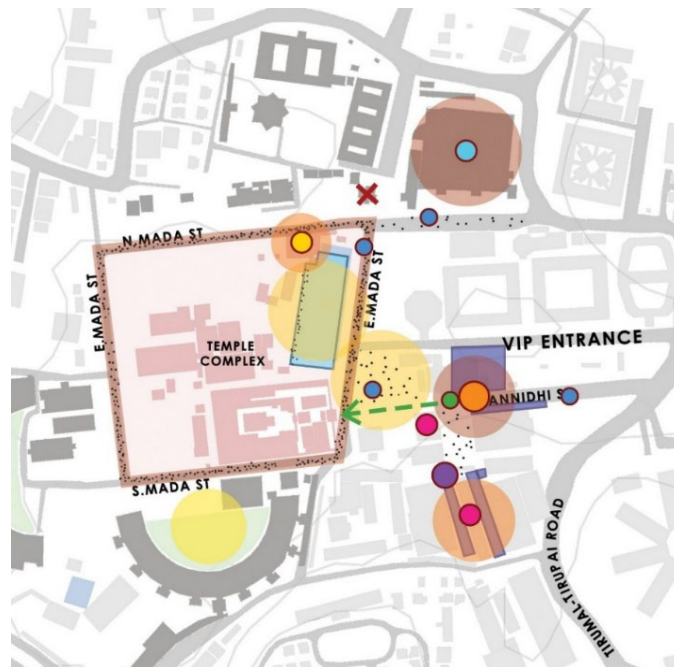
Fig.9 Temporal Activities in the Temple Complex During 18.00 to 21.00 (Source: Author)

H. Time Interval: 21.00 - 00.00

As night approaches, the number of pilgrims slowly decreases. The temple begins to wind down after a full day. The main darshan ends for most visitors, and the crowd near the sanctum diminishes. Some pilgrims still walk around the temple or sit quietly. Devotees chant or rest in the open spaces. Volunteers begin cleaning areas and closing gates. Shops on the Mada Streets shut down one by one, and the streets become quieter. The Ekanta Seva, the final ritual of the day, is performed if not done earlier. It symbolically puts the Lord to rest for the night. Security staff monitor the remaining visitors. Devotees who are staying overnight settle in nearby guest houses or open spaces. The temple complex enters a calm and peaceful phase. Therefore, the temporal mapping of the temple precinct reveals a dynamic interplay between ritual timings, pilgrim behavior, and spatial usage. Each segment of the day-from the pre-dawn quietude to the evening's vibrant processions-contributes to a layered experience of sacred urban life. Recognizing these time-bound patterns is crucial for informed spatial planning, crowd management, and for enhancing the cultural and spiritual atmosphere of the temple environment. This understanding serves as a foundational step toward developing context-sensitive strategies for pilgrimage infrastructure and heritage conservation.
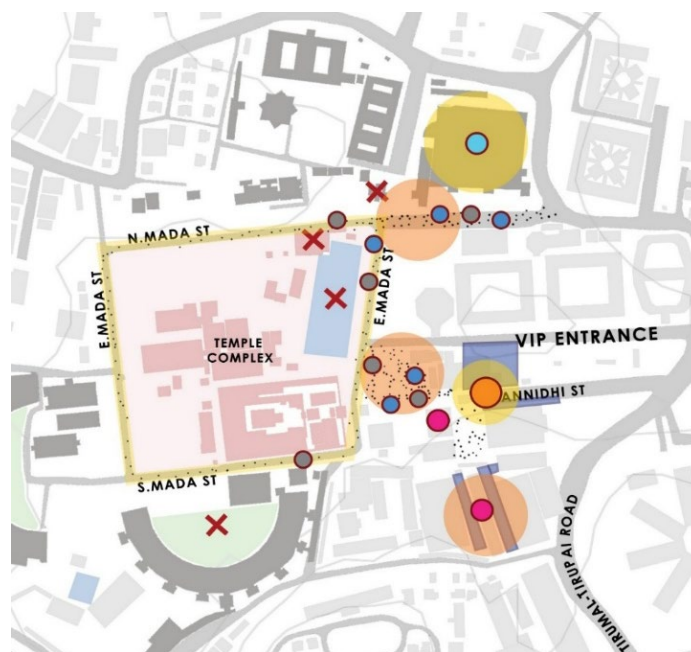

Fig.10 Temporal Activities in the Temple Complex During 21.00 to 00.00 (Source: Author)

TABLE I ANALYSIS OF TIME-BASED ACTIVITIES IN THE TEMPLE COMPLEX (SOURCE: AUTHOR)

Time	Rituals	Informal activities	Movement pattern	Crowd density
00.00 – 03.00	Ekanta seva	Resting	Nil	Low (< 500)
03.00 – 06.00	Suprabhatam, Tomala seva	Arrival, prayers	Towards temple	Moderate (500 – 1000)
06.00 – 09.00	Kalyanotsavam	Offerings	Around the temple	High (1000 – 2000)
09.00 – 12.00	Arijitha sevas	Prasadam	Across mandapas	Very high (> 2000)
12.00 – 15.00	Annaprasasam	Relaxing	Towards annaprasad	Moderate (500 – 1000)
15.00 – 18.00	Arijitha seva	Exploring around	Around the temple	High (1000 – 2000)
18.00 – 21.00	Sahasradeepam & Procession	Lamp lighting	Exiting the temple	Moderate (500 – 1000)
21.00 – 00.00	Nil	Resting	Nil	Low (< 500)

VIII. TIME LAPSE STUDY

This study is based on time-lapse observations of the temple precinct over a 24-hour cycle to understand the changing patterns of activity, movement, and spatial use. By documenting key rituals, pilgrim behavior, vendor activities, and environmental shifts, the study aims to capture the temporal rhythm of the space.

A. Temple Area

In the morning, the forecourt is calm and spacious, with light pilgrim movement and a quiet atmosphere. As the afternoon arrives, activity intensifies, with growing crowds occupying pathways and shaded areas. By evening, the space is filled with a warm, reflective energy as pilgrims gather in larger numbers under the setting sun. Throughout the day, the space transitions smoothly, adapting to changing rhythms while retaining its sacred essence. Table II. Spatial activity matrix of the temple area (Source: Author).

B. Mada Streets

In Tirumala's Mada Streets, the day begins with a gentle flow of devotees in the morning, moving with calm devotion along the sacred route. As time progresses, the crowd gradually increases, with more pilgrims joining through the afternoon, bringing a steady rhythm to the space. By evening, the street reaches its peak vibrancy during the idol procession, filled with the sounds of drums, chants, and the dense presence of devotees. This slow transformation from quiet movement to collective celebration reflects the street's evolving spiritual and social intensity throughout the day.

Fig.11 Images from the Time Lapse of the Temple Area (Source: Author)

TABLE II SPATIAL ACTIVITY MATRIX OF THE TEMPLE AREA (SOURCE: AUTHOR)

Spatial Activity	Mornings	Afternoons	Evenings	Nights
Crowd density	High (> 1000)	Moderate (500 - 1000)	High (> 1000)	Moderate (500 - 1000)
Related activity	Opening and start of darshans	-	Mallayappa vigraha procession	Closing of the temple
Purpose	Towards & from Darshanam	Pass through	Towards & from Darshanam	Rest
Spillover activity	Leisure movement along the mandapas	Relaxing and interactions	Viewing the procession	Sleeping in the premises

TABLE III SPATIAL ACTIVITY MATRIX OF THE MADA STREETS (SOURCE: AUTHOR)

Spatial Activity	Mornings	Afternoons	Evenings	Nights
Crowd density	Moderate(500-1000)	Low(<500)	High(1000-2000)	Low(<500)
Related activity	Holy Circambulation	-	Holy Circambulation and procession	-
Purpose	Pass through	Rest	Viewing the procession	Rest
Spill over activity	Entry to nearby shrines	Drying clothes	Entry to nearby shrines	-

Fig.12 Images from the Time Lapse of the Mada Streets (Source: Author)

C. Pushkarini

TABLE IV SPATIAL ACTIVITY MATRIX OF THE PUSHKARINI (SOURCE: AUTHOR)

Spatial Activity	Mornings	Afternoons	Evenings	Nights
Crowd density	High(1000-2000)	Moderate(500-1000)	High(1000-2000)	None
Related activity	Temple darshanam & Bathing	Temple darshanam & Bathing	Temple darshanam & Bathing	-
Purpose	Religious belief	Religious belief	Religious belief	-
Spill over activity	Drying clothes	Drying clothes and resting	Drying clothes	None

Fig.13 Images from the Time Lapse of the Pushkarini (Source: Author)

At the Pushkarni temple tank, mornings are calm, with few devotees engaged in quiet rituals. As the day progresses, the space sees a steady increase in visitors who use it for rest and reflection. By evening, it becomes livelier, with families and groups gathering around the water. The tank transforms from a peaceful ritual space into a vibrant social setting as the day unfolds.

D. Anjani Bedi Temple

Near the coconut-breaking area by the temple, the morning begins with a dense and energetic crowd, as devotees perform offerings in quick succession before their darshan. The space is bustling with motion, rituals, and layered interactions. As the day moves toward evening, the intensity softens, the crowd becomes more dispersed, and the space opens up, allowing slower movement and moments of pause. This transition marks a shift from high ritual urgency to a more relaxed, reflective atmosphere as the day winds down.

TABLE V SPATIAL ACTIVITY MATRIX OF THE ANJANI BEDI TEMPLE (SOURCE: AUTHOR)

Spatial Activity	Mornings	Afternoons	Evenings	Nights
Crowd density	Moderate (500-1000)	Moderate (500-1000)	High (1000-2000)	Low (<500)
Related activity	Aarti, pooja	Coconut breaking	Coconut breaking & Diya lighting	-
Purpose	Worship	Pass through	Worship	-
Spill over activity	Putting naamam	Resting	Commercial activity	Resting

Fig.14 Images from the Time Lapse of the Anjani Bedi Temple (Source: Author)

IX. RESULTS

The observational study conducted within the temple precinct revealed significant temporal fluctuations in pilgrim activity, with marked peaks during ritual hours, particularly in the early morning and evening slots. These peak periods were associated with major rituals such as Suprabhatam, Thomala, and Ekanta Sevas, creating high-density zones that disrupted smooth pedestrian movement and generated bottlenecks near sacred entrances and transitional spaces. Conversely, during off-peak hours-particularly late at night and early in the morning-the precinct experienced minimal activity, exposing underutilized spaces and inefficiencies in spatial programming. Another major challenge identified was the conflict between sacred and commercial uses within and around the precinct. The proliferation of vending zones and shops near the temple boundaries, while economically beneficial, contributed to a dilution of the spiritual ambiance and increased functional ambiguity. Furthermore, a lack of designated rest areas led to the informal occupation of circulation paths, especially during off-peak hours, affecting the overall flow and safety of pilgrims during transition times.

Despite these challenges, the study also uncovered opportunities to enhance spatial efficiency and the sacred character of the precinct. Time-sensitive spatial zoning can accommodate varying crowd intensities, prioritizing ritual circulation during peak hours and promoting contemplative or educational uses during quieter periods. The design of flexible, multi-use public spaces-such as shaded pavilions or stepped seating-can cater to both movement and pause, allowing the precinct to adapt to changing pilgrim behaviors throughout the day.

X. CONCLUSION

This study investigated the temporal dynamics and activity patterns of pilgrims in the Tirumala Temple Complex, focusing on how ritual schedules, pilgrim behavior, and movement patterns shape spatial use across different times of the day. Conducted over a 15-day off-season period in the core precinct surrounding the main shrine, the research, employing site observations, spatial mapping, and 24-hour time-lapse studies, revealed that sacred spaces in Tirumala undergo both predictable congestion cycles and fluid transformations to accommodate evolving pilgrim activities. The temporal mapping of Tirumala's temple precinct reveals a deeply cyclical yet adaptive spatial system, where ritual schedules orchestrate fluctuations in pilgrim density, ranging from fewer than 500 individuals during nocturnal Sevas to over 2,000 at peak morning Darshan hours. These rhythms indicate predictable surges in congregation zones, with bottlenecks forming around transitional corridors and ritual nodes, while quieter midday and late-night phases expose underutilized areas. At the same time, such fluctuations create a layered experience of sacred intensity and spatial transformation: morning rituals charge the precinct with devotional urgency, afternoons provide a pause of reflective calm, and evenings animate the streets with processions, chants, and collective celebration.

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Findings reaffirm that the spatial and temporal organization of the temple complex is intrinsically linked to the cyclical nature of religious rituals, influencing congregation densities, circulation efficiency, and spatial adaptability. This understanding has broader implications for pilgrimage towns, where crowd flows, infrastructure capacity, and cultural preservation must be balanced. By aligning design and management interventions with the temporal rhythms of sacred activity, urban designers, policymakers, and heritage planners can develop responsive frameworks that sustain both the functional performance and cultural significance of pilgrimage spaces.

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ETHICAL APPROVAL

This study strictly followed ethical guidelines to ensure the rights, dignity, and privacy of all the participants. Informed consent was obtained from each participant, who was made aware of the study's purpose and procedures. The personal data were anonymised and stored securely to maintain confidentiality. This research aligns with the guidelines of the Institutional Ethics Committee and international ethical standards.

Declaration of Conflicting Interests
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ORCID
S. Iswarya Lakshmi https://orcid.org/0009-0000-2528-671X
D. Prathyusha Reddy https://orcid.org/0009-0006-8053-8290
Karteek Guturu https://orcid.org/0000-0002-6402-3266

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