Spatial Planning for Q-commerce logistics in Tier-2 Cities: A case of Bhopal

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by

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under the supervision of

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I hereby certify that the work which is being presented in the thesis entitled "**SPATIAL PLANNING FOR Q-COMMERCE LOGISTICS IN TIER-2 CITIES: A CASE OF BHOPAL**" in partial fulfillment of the requirements for the award of the Master of Planning (Urban Planning) and submitted in the Department of Architecture and Planning of the Maulana Azad National Institute of Technology, Bhopal is an authentic record of my own work carried out during the period from 14/07/2025 to 10/07/2026 under the supervision of Dr. Bulbul Shukla, Professor, Department of Architecture and Planning, Maulana Azad National Institute of Technology, Bhopal.

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Dr.Bulbul Shukla
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Date :10/07/2026

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ABSTRACT

Recent events around the world have accelerated the growth of Q-commerce, completely changing the urban logistics systems in general and, particularly, last-mile delivery, the last link in the supply chain. This is a shift forced by the new logistics models, such as Q-commerce, into locating facilities, or "dark stores," deep within residential and urban areas. This spatial reorganization, in turn, creates negative externalities like congestion, environmental pollution, or road safety issues, and it also conflicts with the current land use regulations.

The paper investigates the growth of Q-commerce and its spatial implications in a major Indian city, filling an important gap in urban planning literature which has generally focused on passenger mobility over freight transport. It provides an extensive examination of variables that control last-mile delivery trip generation and the impact exerted through it on the urban fabric. Complex interfaces that exist between urban characteristics, logistics process, and socioeconomic elements are explored through a mixed-methods approach, incorporating an extensive literature review with a pilot case study. Their findings also pointed to a critical mismatch between the fast-evolving logistics industry and outdated frameworks within urban planning.

The findings of the research convey that the growth in last-mile travel is seriously exacerbating adverse environmental impacts, traffic congestion, and fragmented mobility in urban areas. It lists the policy and infrastructure recommendations based on the key implications of the study. These include modernizing land use regulations, utilizing a network of parcel lockers and micro-hubs, and promoting cooperation between public and private stakeholders. According to the study, Indian cities need to adopt a proactive, data-driven, integrated approach with planning to manage the rise in Q-commerce and foster fair, efficient, and sustainable city environments.

सारांश

दुनिया भर की हालिया घटनाओं ने ई-कॉमर्स की वृद्धि को तेज़ कर दिया है , जिसने शहरी रसद प्रणालियों (urban logistics systems), विशेष रूप से आपूर्ति श्रृंखला की अंतिम कड़ी, अंतिम-मील डिलीवरी (last-mile delivery) को पूरी तरह से बदल दिया है. क्यू-कॉमर्स (Q-commerce) जैसे नए लॉजिस्टिकल मॉडल के कारण आए इस प्रतिमान बदलाव (paradigm shift) के चलते, अब ऑपरेटरों को अपनी सुविधाओं, या "डार्क स्टोर" (dark stores), को आवासीय और शहरी क्षेत्रों के भीतर गहराई तक स्थापित करने के लिए मजबूर होना पड़ रहा है. शहरी योजनाकारों को बहुत कठिनाई का सामना करना पड़ता है क्योंकि यह स्थानिक पुनर्गठन (spatial reorganization) ट्रैफिक जाम, पर्यावरणीय प्रदूषण, और सड़क सुरक्षा मुद्दों जैसी नकारात्मक बाह्यताएँ (negative externalities) पैदा करता है, और यह वर्तमान भूमि उपयोग विनियमों (land use regulations) के साथ भी संघर्ष करता है.

यह शोध पत्र एक प्रमुख भारतीय शहर में ई-कॉमर्स की वृद्धि के स्थानिक प्रभावों (spatial implications) की जाँच करता है , जो शहरी नियोजन साहित्य में एक महत्वपूर्ण कमी (critical gap) को संबोधित करता है जिसने पारंपरिक रूप से माल ढुलाई (freight transport) पर यात्री गतिशीलता (passenger mobility) को प्राथमिकता दी है. यह अध्ययन अंतिम-मील डिलीवरी ट्रिप निर्माण को प्रभावित करने वाले चर (variables) और शहरी ताने-बाने पर पड़ने वाले परिणामस्वरूप प्रभावों की गहन जाँच प्रदान करता है. यह अध्ययन एक मिश्रित-पद्धति दृष्टिकोण (mixed-methods approach) का उपयोग करके शहरी विशेषताओं, लॉजिस्टिकल प्रक्रियाओं और सामाजिक-आर्थिक कारकों के बीच जटिल संबंधों की जाँच करता है , जो एक विस्तृत साहित्य समीक्षा को एक पायलट केस स्टडी के साथ जोड़ता है.

निष्कर्ष तेजी से विकसित हो रहे रसद उद्योग (logistics industry) और अप्रचलित शहरी नियोजन ढाँचों (outdated urban planning frameworks) के बीच एक महत्वपूर्ण विसंगति (critical disconnect) को उजागर करते हैं. शोध के अनुसार, अंतिम-मील यात्रा में वृद्धि से प्रतिकूल पर्यावरणीय प्रभाव बढ़ रहे हैं, ट्रैफिक बढ़ रहा है, और शहरी गतिशीलता खंडित हो रही है. यह पत्र अध्ययन के निष्कर्षों के आधार पर नीति और बुनियादी ढाँचे की सिफारिशों का एक सेट प्रदान करता है. इनमें भूमि उपयोग विनियमों का आधुनिकीकरण (modernizing), पार्सल लॉकर (parcel lockers) और माइक्रो-हब (micro-hubs) के एक नेटवर्क का उपयोग करना, और सार्वजनिक और निजी हितधारकों के बीच सहयोग को प्रोत्साहित करना शामिल है. अध्ययन के अनुसार, भारतीय शहरों को ई-कॉमर्स की वृद्धि को संभालने और न्यायसंगत, प्रभावी और टिकाऊ शहरी वातावरण को बढ़ावा देने के लिए एक सक्रिय (proactive), डेटा-संचालित, और एकीकृत नियोजन रणनीति (integrated planning strategy) अपनानी होगी.

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CERTIFICATE OF PLAGIARISM

This is to certify that the Thesis entitled "**Spatial Planning for Q-commerce logistics in Tier-2 Cities: A case of Bhopal**" is a piece of research work carried out by **Saumya Lalit Bhandari**, Scholar No.**24209011115** under my guidance and supervision for the degree of Master of Planning (Urban Planning) from the Department of Architecture and Planning of Maulana Azad National Institute of Technology, Bhopal (M.P.) India

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LIST OF ABBREVITIONS

Abbreviation	Full Form
B2B	Business-to-Business
B2C	Business-to-Consumer
CAGR	Compound Annual Growth Rate
CDPs	Collection and Delivery Points
CEP	Courier, Express, and Parcel
DE	Delivery Executives
DOD	Delivery-Oriented Development
E2W	Electric Vehicle (Two-Wheeler)
EBFS	Establishment Based Freight Survey
FDI	Foreign Direct Investment
FTG	Freight Trip Generation
FY	Financial Year
GFA	Gross Floor Area
GHG	Greenhouse Gas
GMV	Gross Merchandise Value
GWR	Geographically Weighted Regression
LMD	Last-Mile Delivery
LGVs	Light Goods Vehicles
LTL	Less-Than-Truckload
PLs	Parcel Lockers
PoCs	Proof of Concept
Q-commerce	Quick Commerce
UFT	Urban Freight Transport
UPI	Unified Payments Interface
VKT	Vehicle Kilometers Travelled

CHAPTER 1

INTRODUCTION

The rapid worldwide expansion of e-commerce has significantly transformed consumer purchasing behavior and business operations. Enabled by advances in digital technology and widespread internet access, online shopping has become a defining element of contemporary consumer culture. Companies ranging from emerging start-ups to established global enterprises now rely on e-commerce to broaden their market reach and streamline internal processes. As a result, e-commerce has evolved into a major catalyst for global economic growth and innovation, reshaping the retail sector. India's e-commerce market reflects this global momentum, with projections indicating that the country could become the world's second-largest market by 2034 (IBEF, 2022). The rise of this global digital economy has in turn generated substantial demand for doorstep delivery services. This surge in demand is especially concentrated in the Last-Mile Delivery (LMD) segment, which, despite being the final step of the logistics chain, remains the least efficient and most costly accounting for as much as 75% of overall logistics expenses (Viu-Roig & Alvarez-Palau, 2020). While Tier I cities traditionally handled the majority of online shipments, a notable shift occurred in 2021 when combined order volumes from Tier II and Tier III+ cities surpassed those of major metropolitan areas (Unicommerce, 2021).

As consumer expectations for faster delivery intensify, the e-commerce industry continues to evolve. This transformation accelerated sharply during the COVID-19 pandemic, which triggered a major rise in online purchasing across India. Demand increased for both essential and discretionary items (Habib & Hamadneh, 2021; Sardjono et al., 2021). E-commerce platforms became vital during lockdowns, ensuring access to necessities such as groceries, medicines, and personal care products (Statista, 2023). Meanwhile, the closure of physical stores compelled traditional retailers to move online, speeding up the broader shift toward digital shopping. This transition paved the way for a new sub-category within the industry referred to in India as "third-generation e-commerce" (Joseph, 2023). This model is characterized by "Q-commerce," or quick commerce, noted for its ultra-fast delivery timelines (Osheen, 2022; Ranjekar & Roy, 2023; Stojanov, 2022). Related terms such as "on-

demand delivery" (Duthie et al., 2023; Seghezzi et al., 2021) and "hyperlocal delivery" (Goritiyal, 2023; Guru et al., 2023; John, 2023; Sanghi et al., 2023) describe similar systems, and for the purposes of this discussion, all are collectively referred to as Q-commerce. These services offer delivery in minutes or hours rather than days, making them especially valuable for urgent orders of groceries, food, and pharmaceuticals. The increasing ease with which consumers place time-sensitive online orders has helped Q-commerce reshape the retail landscape a trend likely to continue as technology evolves.

This rapid shift from traditional retail to digital commerce has also significantly influenced urban planning, altering patterns of freight movement, logistics operations, and facility requirements. To reduce delays and boost operational efficiency, Q-commerce companies must locate delivery hubs close to their customers. This need has driven the widespread establishment of "dark stores" within residential and high-density urban areas. Dark stores are small, locally embedded micro-fulfillment facilities designed specifically for rapid delivery services and stocked with curated inventories of high-demand items. Their proliferation raises important regulatory and planning challenges. Key considerations include: whether these facilities align with existing land-use zoning; the spatial and operational requirements they present such as size limitations, parking provisions, and the number of facilities permitted within a given neighborhood; and their external impacts, including increased local freight traffic, loading and unloading complications, noise, emissions, and broader safety concerns.

Despite the sector's rapid expansion, research on Q-commerce particularly within the dense metropolitan regions of developing countries remains limited. Conventional urban planning frameworks focus largely on consumer-facing retail spaces and do not adequately address the needs of this new logistics infrastructure. This study therefore aims to address this gap by examining the modern Q-commerce ecosystem, with an emphasis on its last-mile component. The objective is to generate empirical insights into Q-commerce trends, characteristics, and impacts that can inform future planning and policy efforts. Understanding these dynamics will allow urban planners and decision-makers to more effectively regulate and accommodate the growing presence of e-commerce activities in cities. Historically, urban design has

prioritized passenger mobility while treating freight transport as secondary. This approach is increasingly recognized as insufficient for the complexities of today's e-commerce landscape, underscoring the need for more targeted spatial strategies. The present research seeks to bridge this disciplinary and functional divide by systematically modeling the interrelated factors that underpin efficient LMD planning.

1.1. Background of the topic

The rapid worldwide expansion of e-commerce has significantly transformed consumer purchasing behavior and retail operations, serving as a major catalyst for global economic innovation. Enabled by advancements in digital technology, widespread internet access, and shifting cultural patterns, online shopping has evolved into a necessity. Companies from emerging start-ups to global enterprises now rely on digital storefronts to streamline internal logistics and broaden market reach. This structural shift has generated an unprecedented demand for doorstep fulfillment, putting intense operational pressure on the last-mile delivery segment. Although the last mile represents the final step of the supply chain, it remains the least efficient, costliest, and most polluting, accounting for as much as 75% of overall logistics expenditures. While major metropolitan centers historically handled the largest share of online shipments, recent trends indicate that order volumes from Tier-2 and Tier-3 cities have surpassed those of major metropolitan areas, demanding localized spatial analysis. The rapid growth of e-commerce across the world has fundamentally changed the way people purchase goods and the manner in which businesses operate. With increasing access to the internet, the widespread adoption of smartphones, and continuous advancements in digital technologies, online shopping has become an integral part of everyday life rather than simply an alternative to traditional retail. Consumers now expect greater convenience, wider product choices, and faster delivery services, encouraging businesses of all sizes from local start-ups to multinational corporations to strengthen their digital presence and invest in technology-driven retail models.

This transformation has also reshaped the logistics sector. As online transactions continue to increase, companies are required not only to maintain efficient digital platforms but also to

develop robust supply chain networks capable of fulfilling customer expectations. Modern retail is no longer limited to selling products online; it increasingly depends on the ability to deliver those products quickly, accurately, and reliably. Consequently, logistics has emerged as a critical component of the e-commerce ecosystem, linking digital marketplaces with physical consumers through efficient distribution systems.

Among all stages of the supply chain, the last-mile delivery process has become the most challenging and resource-intensive. Although it represents the final stage in moving goods from a distribution facility to the customer, it involves complex operational requirements such as navigating urban traffic, serving dispersed demand, managing time-sensitive deliveries, and coordinating a large workforce of delivery riders. These factors make last-mile logistics the most expensive component of the supply chain, often contributing up to three-quarters of total logistics costs. In addition to its financial implications, inefficient last-mile operations increased fuel consumption, traffic congestion, and greenhouse gas emissions, making it a significant concern from both economic and environmental perspectives.

Until recently, the majority of e-commerce demand was concentrated in large metropolitan cities where higher population densities and established infrastructure supported online retail growth. However, the expansion of internet connectivity, digital payment systems, and smartphone penetration has accelerated e-commerce adoption in smaller urban centres. As a result, Tier-2 and Tier-3 cities have experienced a rapid increase in online shopping activity, with order volumes in many cases exceeding those recorded in major metropolitan regions. This shift highlights the growing importance of these cities as emerging markets for digital commerce and emphasizes the need to understand their unique spatial and infrastructural characteristics.

Unlike metropolitan areas, most Tier-2 cities have evolved without dedicated planning provisions for modern logistics infrastructure. Their road networks, land-use patterns, and transport systems were not originally designed to accommodate the increasing demand for high-frequency hyperlocal deliveries. Consequently, the rapid growth of e-commerce in these

cities has created new challenges related to accessibility, congestion, delivery efficiency, and the spatial distribution of logistics facilities. Addressing these challenges requires localized spatial analysis and planning-based interventions that consider the urban form, accessibility patterns, and development characteristics specific to Tier-2 cities. Such an approach is essential for creating sustainable and efficient logistics networks capable of supporting the continued expansion of e-commerce in India's rapidly urbanizing regions.

1.1.1. The rise of e-commerce and last mile delivery

E-commerce has profoundly restructured the geographical nature of commerce, with implications for a supportive logistics infrastructure. According to Hesse & Rodrigue (2004), the LMD problem arises as a consequence of consumer preference for home delivery, even when the high rate of failure to attain first-time delivery (Buldeo Rai et al., 2021) results in expensive redelivery attempts and inefficiencies.

In response, the sector uses two-echelon systems and innovations to cope with modern delivery demand, which is fragmented and with high frequencies. Key innovations are:
Collection and Delivery PointsCDPs/Parcel Lockers: Automated systems serving the function of consolidating deliveries, overcoming problems of failed delivery, and are strongly inspired by spatial factors like accessibility and proximity to travel routes (Ma et al., 2024)
Proximity Logistics and Dark Stores: This is a strategic shift away from logistics sprawl, in which facilities (such as dark stores or micro-hubs) are moved closer to demand clusters to fulfill instant or quick commerce or Q-commerce promises.

The rapid expansion of e-commerce has significantly altered the spatial organization of retail and distribution activities, leading to fundamental changes in the way logistics systems are planned and operated. Unlike conventional retail models, where customers travel to physical stores, e-commerce shifts this responsibility to logistics providers, who must ensure timely delivery of goods directly to consumers. This transformation has increased the importance of developing efficient and well-connected logistics infrastructure capable of supporting growing delivery demands while maintaining service quality.

One of the most critical challenges within this evolving system is the last-mile delivery (LMD) process. Hesse and Rodrigue (2004) explain that the increasing preference for home delivery has made the final stage of the supply chain considerably more complex. As consumers increasingly expect products to be delivered directly to their doorsteps, logistics operators face difficulties related to routing efficiency, delivery scheduling, and traffic conditions. These challenges become even more pronounced in densely populated urban areas, where congestion and limited access often reduce delivery efficiency.

A major operational issue associated with home delivery is the high incidence of unsuccessful first-attempt deliveries. When customers are unavailable to receive their orders, logistics providers are required to make additional delivery attempts, increasing transportation costs, fuel consumption, labour requirements, and overall operational inefficiency. Buldeo Rai et al. (2021) highlight that failed first-time deliveries represent a significant burden on urban logistics systems because they not only increase costs for service providers but also contribute to unnecessary vehicle movements and environmental impacts.

To overcome these challenges, the logistics industry has introduced innovative delivery models that improve efficiency while responding to the fragmented and high-frequency nature of modern e-commerce demand. Instead of relying solely on conventional warehouse-to-home delivery systems, companies are increasingly adopting decentralized logistics networks and intermediate delivery facilities that reduce travel distances and improve order fulfilment performance.

One such innovation is the development of Collection and Delivery Points (CDPs) and parcel lockers. These facilities provide customers with secure locations where parcels can be collected at their convenience rather than requiring direct home delivery. Automated parcel lockers and neighbourhood collection centres reduce the likelihood of failed deliveries by allowing customers to retrieve their orders at flexible times. In addition to improving delivery success rates, these facilities consolidate multiple deliveries into a single location, thereby reducing vehicle trips, delivery time, and operational costs. Their effectiveness largely

depends on strategic spatial planning, particularly with respect to accessibility, proximity to residential neighbourhoods, public transport, and major travel corridors (Ma et al., 2024).

Another significant development is the emergence of proximity logistics, which involves relocating logistics facilities closer to areas with high consumer demand. This approach represents a departure from the traditional practice of locating warehouses on the urban periphery, commonly referred to as logistics sprawl. Instead, smaller facilities such as dark stores, micro-fulfilment centres, and urban logistics hubs are established within or near residential neighbourhoods to support rapid order processing and fulfilment.

The concept of dark stores has become particularly important in the growth of quick commerce (Q-commerce), where customers expect deliveries within a very short time frame, often between 10 and 30 minutes. By positioning these facilities close to demand clusters, companies can significantly reduce travel distances, improve delivery speed, optimize rider productivity, and lower transportation costs. At the same time, proximity logistics contributes to a more balanced distribution of logistics infrastructure across urban areas, reducing excessive dependence on a few centralized warehouses.

These emerging logistics strategies demonstrate that the future of urban freight movement depends not only on operational improvements but also on careful spatial planning and infrastructure integration. The location of collection points, parcel lockers, dark stores, and micro-distribution hubs must be aligned with land-use patterns, accessibility, transport networks, and neighbourhood characteristics to create an efficient, sustainable, and resilient urban logistics system capable of meeting the rapidly growing demands of e-commerce.

1.1.2. The geography of logistics and urban sprawl

Logistics geography studies the spatial distribution of warehousing and freight infrastructure. The initial trend observed in the US and Europe was logistics sprawl, where logistics facilities migrated to peripheral areas seeking cheap land and highway access (Xiao et al., 2021). However, e-commerce has catalyzed a complex reversal:

- Centrality of Demand: LMD platforms must locate in proximity to high-density markets (Fried & Goodchild, 2023). Urban factors like population density, household income, and land-use configuration are strong predictors of parcel delivery demand, making sophisticated spatial analysis (like Geographically Weighted Regression) essential for planning placement (Touloumidis et al., 2025; Shin et al., 2023).
- Conflicts with Urban Space: The increasing fleet of LGVs required for LMD often operates at poor utilization rates, contributing significantly to urban congestion and noise. Studies in London highlight the massive parking and walking effort involved in urban rounds (Allen et al., 2018).

The field of logistics geography examines how freight activities, warehouses, distribution centres, and supporting infrastructure are spatially organized within urban and regional environments. It focuses on understanding the relationship between logistics systems and the physical structure of cities, highlighting how the location of logistics facilities influences transportation efficiency, accessibility, land use, and urban development. As consumer demand and economic activities evolve, the spatial patterns of logistics infrastructure also undergo significant transformation.

Historically, the dominant trend observed in many cities across the United States and Europe was logistics sprawl, a process in which warehouses and freight distribution centres gradually relocated from central urban areas to the outskirts of cities. This shift was primarily driven by the availability of inexpensive land, larger development parcels, and direct access to highways and regional transportation corridors. Peripheral locations enabled logistics operators to reduce land acquisition costs while accommodating larger storage facilities and freight operations. (Xiao et al.,2021) note that this outward movement became a defining characteristic of logistics development during the late twentieth century.

However, the rapid growth of e-commerce and the increasing demand for same-day and instant delivery services have significantly altered this traditional pattern. Unlike conventional retail supply chains, modern e-commerce requires distribution facilities to be positioned much closer to customers in order to reduce delivery times and improve service

reliability. As a result, logistics systems are increasingly shifting from large peripheral warehouses towards smaller, strategically located urban fulfilment centres, dark stores, and micro-distribution hubs. This emerging trend reflects a growing emphasis on proximity-based logistics, where accessibility to consumers has become more important than simply minimizing land costs.

One of the most significant drivers of this transformation is the centrality of demand. The success of last-mile delivery largely depends on the ability of logistics facilities to serve areas with high concentrations of consumers within the shortest possible time. Consequently, facilities are increasingly located near densely populated residential neighbourhoods and major commercial centres where delivery demand is consistently high. (Fried and Goodchild ,2023) emphasize that proximity to demand clusters has become a critical factor in determining the location of urban logistics facilities, particularly for quick-commerce operations that promise deliveries within a few minutes.

The spatial distribution of delivery demand is influenced by several urban characteristics. Population density, household income levels, land-use patterns, commercial activity, and accessibility all affect the volume and frequency of parcel deliveries within different neighbourhoods. Because these factors vary across the urban landscape, advanced spatial analysis techniques have become essential tools for logistics planning. Methods such as Geographically Weighted Regression (GWR) allow planners to identify local variations in delivery demand and determine optimal locations for logistics facilities based on spatial relationships rather than city-wide averages. Studies by (Toluamides et al., 2025) and Shin et al. (2023) demonstrate that incorporating such spatial analytical methods leads to more accurate demand forecasting and better-informed decisions regarding facility placement.

Despite the operational advantages of locating logistics infrastructure closer to consumers, this trend has also introduced several urban planning challenges. The increasing number of Light Goods Vehicles (LGVs) and delivery two-wheelers operating within cities has intensified pressure on urban transport systems. Many delivery vehicles undertake frequent short-distance trips with relatively low vehicle utilization, resulting in higher traffic volumes,

increased fuel consumption, and greater environmental impacts. The concentration of delivery activities around residential and commercial areas often creates congestion, roadside parking conflicts, and competition for limited curb space.

Research conducted in London by (Allen et al. ,2018) illustrates the extent of these challenges by demonstrating that urban delivery operations involve substantial time spent searching for parking, walking parcels to delivery locations, and navigating congested streets. These operational inefficiencies reduce delivery productivity while increasing congestion, noise pollution, and emissions. Such findings highlight that the success of urban logistics depends not only on operational improvements but also on the integration of logistics considerations into urban planning policies.

Overall, the evolution of logistics geography demonstrates a fundamental shift from peripheral freight distribution towards demand-oriented urban logistics networks. While this transformation enhances delivery speed and customer service, it also creates new planning challenges related to accessibility, land-use compatibility, traffic management, and infrastructure provision. Therefore, future urban development strategies must incorporate logistics infrastructure as an essential component of city planning to ensure that growing e-commerce demand can be accommodated without compromising urban mobility, environmental quality, or the efficient functioning of urban spaces.

1.1.3. Challenges in Indian urban context

The Indian urban landscape faces some unique challenges that heighten the LMD problem:
Third-Generation E-commerce: The complex models of e-commerce, such as Q-commerce, hyper-local, and integrated services, are fast-growing in Indian cities. These require higher responsiveness and decentralization of logistics nodes.

The infrastructure deficit is higher for Indian cities, which puts them in greater constriction of road network capacity, proliferation of illegal parking, and non-existent dedicated loading/unloading zones, making policy choice and implementation difficult (Akgün et al., 2019).

Complexity in Policy and Governance: The incorporation of UFT into city planning has generally become a major challenge for governance, needing the early integration of freight concerns and a harmonized engagement of stakeholders. Bjørgen & Ryghaug, 2022. For instance, local authorities face difficulties in prioritizing proper policy measures for UFT owing to conflicting policy objectives, resource constraints, and legitimacy requirements (Akgün et al., 2019).

The Indian urban environment presents several unique challenges that make the planning and management of last-mile delivery (LMD) systems more complex than in many developed countries. Rapid urbanization, increasing online shopping demand, and inadequate logistics infrastructure have created conditions that require localized planning approaches rather than conventional logistics solutions.

One of the most significant developments is the emergence of third-generation e-commerce, which includes quick commerce (Q-commerce), hyperlocal delivery services, and integrated digital platforms. Unlike conventional e-commerce, these models promise deliveries within a very short time, often within 10 to 30 minutes. To meet such expectations, logistics providers require a decentralized network of dark stores and micro-fulfilment centres located close to residential neighbourhoods. This shift has increased the need for strategically planned logistics infrastructure within urban areas.

Another major challenge is the infrastructure deficit found in many Indian cities. Limited road capacity, traffic congestion, illegal roadside parking, and the absence of dedicated loading and unloading zones significantly reduce the efficiency of delivery operations. These constraints not only increase delivery time and operational costs but also create conflicts between freight movement and other urban transport activities. Such infrastructure limitations make it difficult for city authorities to implement effective urban freight policies and improve last-mile logistics performance (Akgün et al., 2019).

In addition to physical infrastructure challenges, policy and governance remain critical issues in the development of urban freight systems. Freight transportation is often overlooked during

the preparation of master plans and urban development policies, resulting in poor coordination between logistics operators, planning agencies, and local authorities. Bjørgen and Ryghaug (2022) emphasize that successful urban freight planning requires the early integration of logistics considerations into city planning along with active collaboration among all stakeholders. However, local governments frequently struggle to prioritize freight-related policies because of competing development objectives, limited financial resources, and administrative constraints (Akgün et al., 2019). These challenges highlight the need for integrated planning frameworks that balance economic efficiency with sustainable urban development.

1.1.4. Impact of E-commerce

The academic literature outlines a wide array of consequences stemming from the expansion of e-commerce, which can be grouped into several broad categories: transportation, environmental impacts, economic effects, social changes, technological developments, and spatial transformations. The most direct implications emerge within transportation and logistics, especially concerning final-mile distribution. As online shopping has surged, so too has the number of delivery vehicles circulating through urban areas (Gharehgozli et al., 2017). What was once an occasional postal delivery has evolved into constant, repeated trips by multiple logistics operators, increasing Vehicle Kilometers Traveled (VKT) and exacerbating urban congestion, particularly during rush hours (Hooper, 2019). Empirical data illustrates this escalation: e-commerce is responsible for roughly one weekly delivery per household in the United States rising to 1.35 in New York and over 17% of all goods movements in cities such as Lyon are now linked to home deliveries (NHTS, 2019; Gardrat et al., 2016).

Freight flows are shaped by critical factors including cost, speed, time, flexibility, and the availability of information (Buldeo Rai, 2019; Janjevic & Winkenbach, 2020; Nguyen et al., 2018). For customers, delivery time is the most influential criterion in choosing a delivery option (Sprint Project, 2020). Failed deliveries often result in second or third attempts, creating additional administrative and logistical burdens that directly raise costs for service

providers (Haurillon, 2020). Furthermore, innovations designed to provide faster delivery create significant challenges for logistics companies, as they necessitate expensive rerouting, resource redistribution, and the reorganization of schedules to accommodate narrow delivery windows, evenings, and weekends.

A second major set of impacts involves economic considerations. Delivery cost remains the dominant factor shaping consumer decisions (Buldeo Rai et al., 2021; Janjevic et al., 2019; Nguyen et al., 2019; Sprint Project, 2020). The widespread expectation of "free delivery" drives continuous price negotiations between retailers and logistics providers, often generating unintended negative outcomes. This pricing model fuels impulsive consumption, inconsistent purchasing habits, and high return rates (Buldeo Rai et al., 2019). The promise of free shipping therefore contributes to inefficient delivery routing and compounds preexisting urban pressures. Studies further show that current policy frameworks do not consistently account for the broader societal impacts of last-mile logistics, which include health risks, noise, accidents, infrastructure degradation, and effects on overall urban livability (Buldeo Rai et al., 2017; He et al., 2017).

Environmental repercussions represent a third important dimension. Consumer behaviors marked by spontaneous and frequent online purchases lead to a high number of delivery trips per household, increasing VKT and associated emissions. E-commerce's influence on sustainability differs markedly from that of traditional in-store shopping (Ma et al., 2022; Xie et al., 2023), producing a dual-sided environmental narrative. Some scholars argue that e-commerce can enhance environmental quality (Cheba et al., 2021) by reducing personal shopping trips and reliance on private automobiles a major source of carbon emissions (Chen & Reklev, 2014; Rao et al., 2021). Remote work and online purchasing are also cited as factors that may lower overall CO_2 output (Song et al., 2020). Conversely, critics contend that the ease of online purchasing increases consumption frequency, while customer expectations for rapid delivery encourage logistics providers to use faster and often more polluting—transport modes. This leads to higher fuel consumption (Yuan et al., 2022), ultimately undermining environmental sustainability.

Technological developments constitute another significant area of impact. Advancements in automation are expected to transform logistics operations by lowering labor costs and improving delivery performance, with predictions suggesting that autonomous delivery vehicles could manage nearly all global deliveries by 2025 (Joerss et al., 2016). Beyond operational changes, e-commerce reshapes consumer behavior, alters urban dynamics, and demands innovative approaches to logistics planning and metropolitan development. In light of rapid technological evolution, coordinated action among all stakeholders is essential for building a cohesive and efficient urban logistics ecosystem.

The final domain concerns spatial distribution and the physical structuring of e-commerce infrastructure. The sector's rapid growth has fundamentally reconfigured mobility patterns and the geographic placement of logistics facilities. Previously concentrated in major commercial hubs (Dablanc, 2021), e-commerce logistics have dispersed into residential and mixed-use neighborhoods, generating increasingly complex spatial patterns. This decentralization has prompted the development of new logistics real-estate categories (Rai et al., 2022), most notably urban warehouses now indispensable for large e-commerce firms (Dablanc, 2021; Hesse, 2004). These spatial shifts appear in two dominant forms: the expansion of very large ("XXL") fulfillment centers following traditional suburban-peripheral siting practices (Dallas et al., 2022), and the growing search for compact, strategically located spaces within dense urban environments (Dablanc, 2021). This trend has resulted in the proliferation of micro-hubs and rapid urban logistics sites small-scale facilities positioned within metropolitan zones to support last-mile operations and manage rising goods volumes.

Ultimately, ensuring that e-commerce growth aligns with sustainable urban development requires comprehensive policy frameworks and collaborative strategies that integrate logistics into broader planning agendas. Effective coordination among manufacturers, logistics operators, consumers, and government entities is essential for reducing vehicle numbers, lowering emissions, and minimizing costs (Cleophas et al., 2019; Poliak et al., 2022). Additionally, rigorous planning practices and strong compliance mechanisms are

crucial, with the spatial requirements and impacts of e-commerce logistics representing a key area in need of further scholarly investigation.

1.2. E-commerce in India

- The e-commerce sector in India is poised for substantial growth in the coming years. Starting from a 2024 valuation of ₹10,82,875 crore (US$125 billion), the industry is forecasted to reach ₹29,88,735 crore (US$345 billion) by 2030, reflecting a Compound Annual Growth Rate (CAGR) of 15%.
- Long-term forecasts are even more optimistic, with a joint study by ET Retail and ANAROCK predicting the industry could balloon to ₹47,64,650 crore (US$550 billion) by 2035. This high-growth trajectory is attributed to several factors: shifting consumer habits, increased digital usage across the population, growing disposable incomes, the rapid expansion of quick commerce (Q-commerce), and robust demand originating from Tier II and Tier III cities.
- In fact, the e-commerce market's overall expansion is occurring at an extremely high CAGR of 70-80%. Within this landscape, the Direct-to-Consumer (D2C) segment is also thriving, projected to exceed ₹8,70,500 crore (US$100 billion) in 2025 alone, with an anticipated growth rate between 17% and 22%. Furthermore, government initiatives are playing a major role in digital commerce adoption. The Government e-Marketplace (GeM) has facilitated transparent digital public procurement, surpassing a cumulative Gross Merchandise Value (GMV) of ₹15,00,000 crore (US$171.3 billion) since its inception in 2016 (as of August 2025).

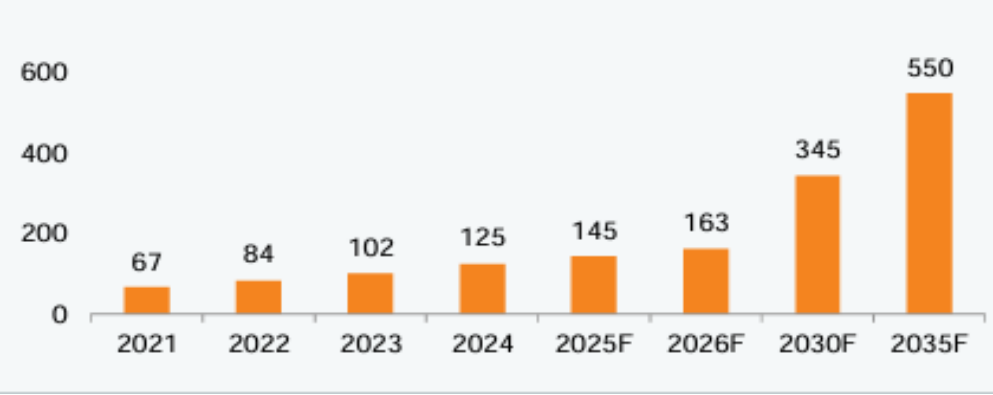


Figure 1: Indian E-commerce market (US$ billion) (Source:IBEF)

- The primary engines driving India's e-commerce industry are its massive consumer base of 500 million people and the continued expansion of internet penetration, particularly in rural areas. This growth trajectory is further supported by the projected rise in digital access: it is anticipated that the number of smartphone users will reach 1.18 billion by FY26, which is expected to significantly boost digital transaction volumes. Crucially, the majority of future demand over 60% is forecasted to originate from the rural sector, specifically within Tier 2, Tier 3, and Tier 4 towns.

1.2.1. Growth of E-commerce in India

- A recent analysis by EY India suggests that Generative Artificial Intelligence (GenAI) could boost the productivity of the Indian retail industry by a significant 35-37% by 2030. This potential is already driving corporate action, as evidenced by "An Idea of India (2025)" report, which notes that 48% of Indian companies have initiated GenAI proof-of-concept projects, with another 32% either budgeting for or planning to adopt AI solutions. This digital transformation is underpinned by robust payment infrastructure. The Unified Payments Interface (UPI) facilitated 20 billion transactions in August 2025, processing value exceeding ₹24,85,000 lakh crore (US$288.65 billion). This represents a substantial year-over-year growth of 34% in volume and 21% in value, with major players like PhonePe, Google Pay, and Paytm collectively dominating 85% of India's digital payments.

- India’s e-commerce sector sustained strong momentum, posting a 12% year-over-year growth to achieve a Gross Merchandise Value (GMV) of over ₹1.19 lakh crore (US$14 billion) in FY25. This expansion is fueled by an increasingly broad base of online shoppers. Between FY19 and FY26, the number of online shoppers is projected to rise significantly, particularly in rural regions (22% CAGR to 88 million) compared to urban areas (15% CAGR to 263 million). This demographic shift is evident in sales figures: Tier-2 and Tier-3 cities were major contributors to the 2025 summer sales, with Tier-3 cities alone accounting for 38% of order volumes and reporting a 21% year-over-year growth. Looking ahead to 2026, Tier 2, 3, and 4 towns are forecast to

generate over 60% of total e-commerce demand, driven by the high CAGR in shoppers and deepening internet and smartphone penetration.

- The quick commerce (Q-commerce) segment has experienced explosive growth, with Indians spending ₹64,000 crore (US$7.47 billion) on these platforms in FY25, more than doubling the spending from FY24. The industry is maturing, focusing on profitability through subscriptions, advertisements, fees, and technological efficiencies, with gross order value predicted to reach ₹2,00,000 crore (US$23.34 billion) by FY28. Meanwhile, the Government e-Marketplace (GeM) highlighted its critical role in public procurement by surpassing a GMV of ₹5 lakh crore (US$58.5 billion) in FY25, eighteen days before the fiscal year concluded. This growth was predominantly driven by services, which contributed 62% (₹2.54 lakh crore / US$29.7 billion), while products accounted for 38% (₹1.55 lakh crore / US$18.1 billion).

- India's booming e-commerce market is driven by affordable smartphones and low-cost data plans, leading major retail and consumer goods makers to increase their investments in the online space.

- According to a recent report by RedSeer, India's e-B2B market is projected to reach a GMV of US$ 100 billion by 2030 (IBEF, 2018).

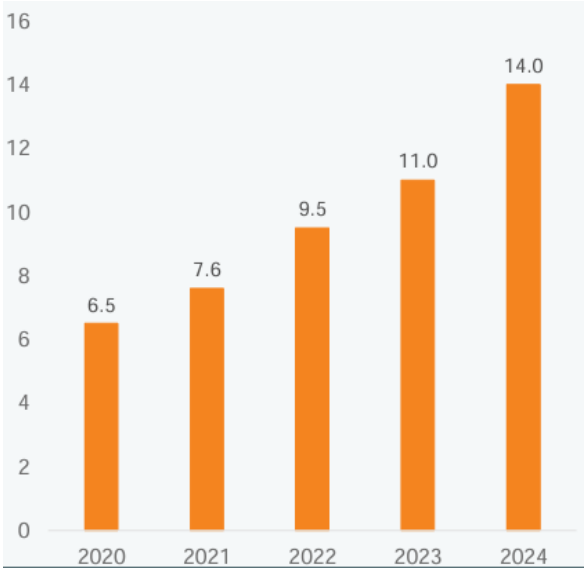


Figure 2: GMV of Indian Online Sales (Source:IBEF)

- India has the opportunity to significantly increase its share in the global B2C e-commerce market, which is projected to reach US$ 8 trillion by 2030. With current e-commerce exports at US$ 2 billion, there is substantial room for growth, particularly in high-demand products.

- India is on track to become the second-largest online consumer market globally by 2030, expected to boast around 600 million shoppers. This enormous growth is fueled by increasing smartphone accessibility and widespread urban adoption. Online retail is projected to significantly increase its share of the total retail market, rising from 25% to an estimated 37% within the same timeframe. This confidence in the sector is reflected in recent funding trends: in FY25, e-commerce attracted a substantial 31% of total start-up funding, securing ₹26,527 crore (US$3.1 billion) across 79 deals—a dramatic 128% jump compared to 2023. Investment was primarily concentrated in the hyperlocal and Business-to-Consumer (B2C) segments. Notably, a single deal, led by Zepto, accounted for a massive 44% of the e-commerce Private Equity/Venture Capital (PE/VC) investments, raising ₹11,980 crore (US$1.4 billion).

1.2.2. Online retail market

- In 2024, the Indian e-commerce sector secured a significant position in the investment landscape, ranking fifth with ₹38,865 crore (US$4.6 billion) in private equity and venture capital funding. This momentum accelerated into FY25, where e-commerce became a major catalyst for start-up investment. It accounted for 31% of all start-up funding, attracting ₹26,527 crore (US$3.1 billion) across 79 deals. This level of investment represents a massive 128% increase compared to 2023, which saw ₹11,980 crore (US$1.4 billion) distributed across 59 deals.

- India has cemented its status as a global leader in online retail, surpassing the United States to become the world's second-largest e-retail market with 270 million online buyers in 2024. Despite this size, online shopping currently accounts for only 5–6% of total retail spending, a figure significantly lower than those seen in the US and China, indicating immense potential for future expansion. The e-retail business is expected to maintain a robust annual growth rate of 23-25% in the coming years. This growth is driven by crucial factors such as improved digital access, greater affordability, and the development of comprehensive digital ecosystems.

- The online retail sector's share of the organized retail market is projected to expand from its current 25% to 37% by FY30. Overall, the size of India's e-retail business is anticipated to exceed US$160 billion by 2028, fueled by sustained post-pandemic development. Long-term analysis by JP Morgan analysts suggests the entire e-commerce industry will grow sevenfold over the decade spanning 2021-2030, eventually reaching US$300 billion. The next critical phases of growth will be propelled by e-grocery and demand originating from smaller communities.

- The specialized quick commerce segment is rapidly gaining traction. In FY25, the combined quick commerce sales across major fast-moving consumer goods (FMCG) players, including HUL, Britannia, AWL Agri-Business, Dabur, Tata Consumer Products, and Marico, exceeded ₹4,400 crore (US$515 million), underscoring the growing consumer shift toward rapid, on-demand delivery.

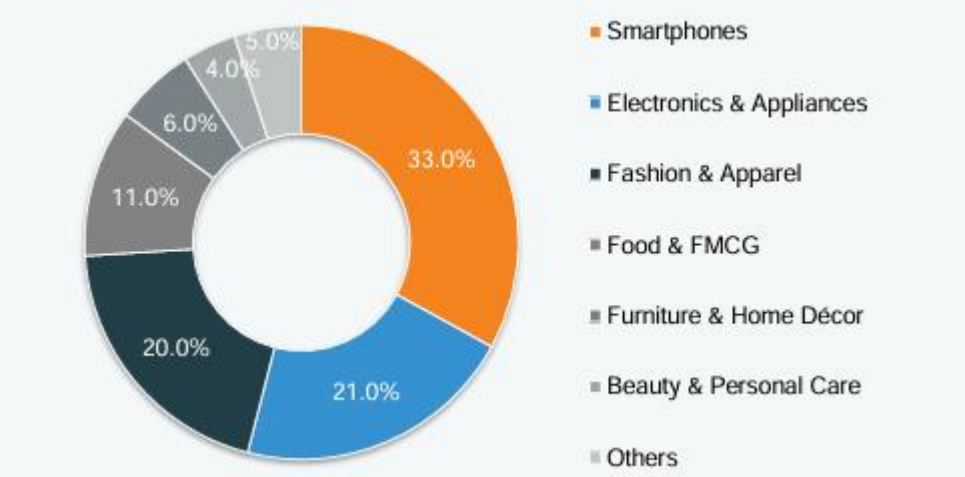


Figure 3: Share of various segments in E-commerce retail (2022) (Source: IBEF)

- The consistently rising internet penetration across India presents numerous opportunities for e-retail businesses to capitalize on a growing market. This trend is expected to significantly increase the overall market share of online retail, which is projected to double from 7% of India's total retail market in 2024 to 14% by 2030.

- This expansion is driven by robust growth in the consumer base across both urban and rural areas. Between 2019 and 2026, the number of online shoppers is forecasted to increase substantially:
    - Rural India: Expected to see a high Compound Annual Growth Rate (CAGR) of 22%, reaching 88 million online consumers.
    - Urban India: Projected to grow at a 15% CAGR, reaching 263 million online consumers.

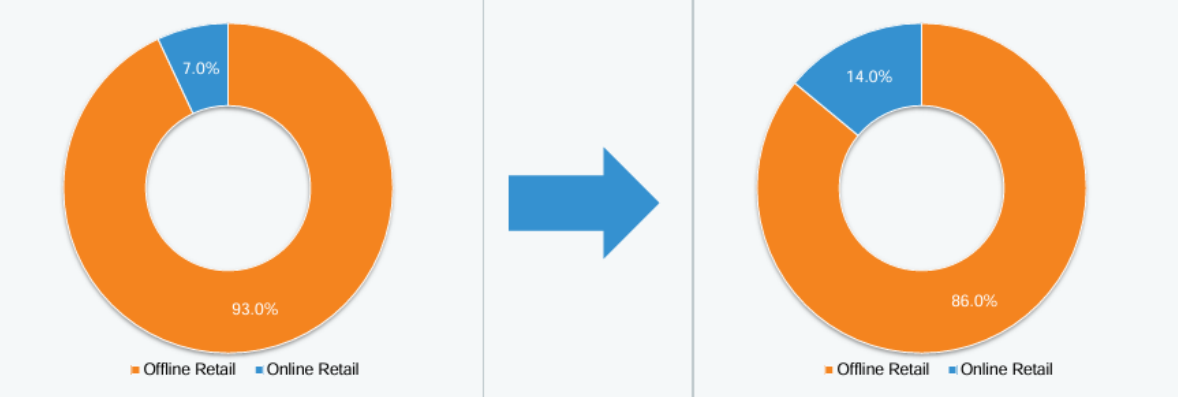


Figure 4: Online retail out of total retail in India in 2024 and in 2030F (Source: IBEF)

1.2.3. Growth drivers for E-commerce

➔ Government Initiatives:

- ◆ People are continuously being introduced to online commerce through government initiatives like Digital India.
- ◆ Important players are drawn to favorable FDI policies.
- ◆ The government has established a legal agenda on cross-border data transfer and proposed a "National E-commerce Policy," which states that no data will be shared with a foreign government agency without first receiving permission from the Indian government.

➔ Increasing awareness:

- ◆ E-commerce is becoming more and more popular as individuals become more conscious of utilizing the internet.

- An increasing number of people are adjusting to conducting business online, whether they are investors, buyers, sellers, or users.

➔ Investments:

- India is the country of occasions, and the expansion of e-commerce is being aided by rising FDI influx, domestic investment, and backing from important industry players.
- The Adani Group declared in February 2025 that it would invest Rs. 30,000 crore (US$3.46 billion) in Kerala over the following five years, with an emphasis on factory expansion, logistics, and infrastructure. The business, which currently operates Thiruvananthapuram International Airport and is building the Vizhinjam port, has committed an extra Rs. 20,000 crore (US$2.31 billion) to the port project in addition to investing Rs. 5,000 crore (US$577.1 million).

1.2.4. Factors driving E-commerce growth

➔ Growth of logistics and warehouses

- Of the approximately 100,000 pin codes in the nation, 24,000 are currently served by online shops.
- With Mumbai, Pune, and Delhi leading the demand boom, India's storage sector is expected to reach 516 million square feet by 2026 thanks to consumer demand and the growth of e-commerce.

➔ Internet content in local language

- With a large surge of mobile subscribers who are increasingly fluent in languages other than English, online retailers see this market as the next growth engine.
- As of January 2025, around 57% of internet users speak Indian.

➔ Mobile commerce

- An increase in mobile internet usage is the driving force behind online retailers' expanding presence in towns and cities outside of metropolitan areas.

More Indians are able to readily access shopping websites thanks to the rise in smartphone ownership.

- By 2030, there will be 887.4 million smartphone users in India.
- With 1.12 billion cellular connections and a mobile penetration rate of 76.6% in early 2025, mobile devices remain the main means of accessing the internet.

➔ Payment modernisation

- India has been in the forefront of the real-time digital payment infrastructure, supported by UPI and 24x7 NEFT.
- Due to a shift in consumer behavior from cash to cards, the COVID-19 epidemic has resulted in an additional increase in digital, contactless payments.

➔ Customer spending

- With a compound annual growth rate (CAGR) of 114%, UPI transactions in India increased from 92 crore in FY18 to 18,587 crores in FY25, with values ranging from Rs. 1,10,000 crore (US$17.07 billion) to Rs. 2,61,00,000 crore (US$31.02 trillion).
- Compared to larger cities, a higher percentage of consumers in Tier-3 cities spend more than Rs. 5,000 (US$58) a month on online buying. E-commerce is expanding quickly in these cities.

➔ Employment generation

- Building on its history of creating over 13 lakh direct and indirect employment possibilities in the nation, Amazon India hopes to create 20 lakh jobs by 2025. In the last year, it helped create 1.4 lakh jobs in a number of industries, including manufacturing, IT, e-commerce, logistics, content creation, and skill development.
- In order to increase inclusive recruiting and supply chain capacity ahead of the holiday season, Flipkart has established over 2.2 lakh seasonal positions as of August 2025 and wants to build 650 festive-only delivery hubs throughout tier II and III towns.

- With over 1.76 million retail businesses engaging in e-commerce, online sellers have created 15.8 million jobs in India, including 3.5 million for women.

1.3. Need for Study

Despite extensive research on LMD impacts, critical gaps remain, particularly relevant to developing world contexts and the complexity of policy-making:

- Contextual Data Gap: While the literature validates the link between LULC/demographics and LMD demand (Touloumidis et al., 2025; Cai et al., 2025), there is a limited body of academic work providing granular, spatially-validated models of this demand specifically for large Indian cities undergoing 3rd generation e-commerce transformation (Kumar & Chidambara, 2023).

- Structural Modeling Gap (Interdependency): The challenge in UFT planning is inherently complex, involving highly interconnected economic, social, technological, and infrastructural factors. Existing conceptual models often lack the methodological rigor to systematically map and prioritize the *driving power* and *interdependencies* among these policy factors (e.g., Causal Loop Diagrams hint at complexity but lack structure). A framework is needed to identify which variables a planner should target to achieve the maximum cascade effect through the system.

- Policy Prioritization Gap: Planners need practical tools to select effective policies under resource constraints. The current state lacks a structural model that integrates critical LMD drivers (e.g., Parcel Locker feasibility, clean fleet viability) with high-level planning objectives (e.g., congestion reduction, social equity) to yield a hierarchy for policy implementation.

CHAPTER 2

LITERATURE REVIEW

2.1 Understanding E-commerce

Individuals utilize e-commerce for a variety of reasons, with convenience being a primary motivator for many, even if it means paying a premium to acquire a diverse range of goods online. Another key driver is the expanded selection available, which provides access to items not stocked locally. For a significant portion of consumers, the affordability and competitive pricing offered by e-commerce platforms are crucial factors. Additionally, some people who prefer shopping in physical stores still turn to e-commerce for specific items, valuing the ease of not having to transport purchases home or avoiding travel to certain destinations. Finally, e-commerce serves a practical necessity for individuals without personal vehicles, offering a more sustainable shopping option.

Consumer delivery preferences and overall reasons for utilizing online shopping show considerable variation across different nations. The increasing familiarity with online retail throughout Europe, for example, is driving robust and sustained market growth. These evolving consumer behaviors are initiating a significant shift in the required performance and optimal design of retail supply chain systems, moving away from models solely focused on supplying physical storefronts. The enduring demand for convenience is expected to exert continued pressure on reducing delivery times and expanding practical delivery options, such as direct home delivery. Furthermore, the sustained growth of e-commerce will intensify the need for the adoption of sustainable solutions within the industry.

The rapid adoption of e-commerce has been largely driven by changing consumer preferences and expectations. One of the primary reasons people choose online shopping is the convenience it offers. Consumers can browse, compare, and purchase products at any time without the need to visit physical stores. This flexibility has become increasingly important in modern lifestyles, where time-saving and ease of access are valued. Many customers are

also willing to pay additional delivery charges in exchange for the convenience of receiving products directly at their doorstep.

Another important factor encouraging the growth of e-commerce is the wider range of products available online. Digital marketplaces provide access to goods that may not be available in local retail stores, allowing consumers to choose from multiple brands, price ranges, and product categories. Competitive pricing, frequent discounts, and promotional offers further enhance the attractiveness of online shopping, making it a preferred option for many households.

Although some consumers continue to prefer shopping in physical stores for certain products, they often rely on e-commerce for bulky items, specialty products, or purchases that would otherwise require significant travel. Home delivery eliminates the need to transport heavy goods and reduces the time and effort associated with conventional shopping. Online retail also provides an important alternative for individuals who do not own private vehicles or have limited access to transportation, making essential products more accessible while reducing unnecessary travel.

Consumer preferences for online shopping and delivery services vary across countries depending on factors such as digital infrastructure, purchasing habits, income levels, and urban development. In Europe, for example, increasing consumer confidence in online retail has contributed to the continuous expansion of the e-commerce market. Similar trends are now emerging in developing economies, where improvements in internet connectivity, smartphone usage, and digital payment systems are accelerating the adoption of online shopping.

These changing consumption patterns have significantly influenced the design and operation of retail supply chains. Traditional logistics systems were primarily developed to replenish physical retail stores, whereas modern e-commerce requires direct and frequent deliveries to individual customers. As a result, retailers and logistics providers are redesigning their distribution networks to improve delivery speed, reliability, and service quality. The growing

demand for same-day and next-day delivery has increased the importance of localized fulfilment centres, efficient last-mile logistics, and flexible delivery options such as doorstep delivery, parcel lockers, and neighbourhood collection points.

As e-commerce continues to expand, the pressure on urban logistics systems will also increase. Meeting rising consumer expectations while minimizing traffic congestion, delivery costs, and environmental impacts has become a major challenge for planners and logistics operators. Consequently, the future growth of e-commerce will depend not only on technological innovation but also on the adoption of sustainable logistics practices, improved urban freight planning, and well-integrated delivery infrastructure capable of supporting efficient and environmentally responsible last-mile distribution.



Figure 5: Reason for online shopping and major logistics preferences (Source: Urban Insight report, 2018)

2.2 Understanding the E-commerce supply chain

The supply chain for e-commerce can play a significant role in urban life and city development. We can better appreciate how e-commerce may impact urban life and city development by comprehending the e-commerce supply chain (Sommar & Mellander, 2018). The e-commerce supply chain has become an essential component of modern urban economies, influencing not only commercial activities but also the overall structure and functioning of cities. Unlike traditional retail supply chains, which primarily focus on delivering products to physical stores, e-commerce supply chains are designed to deliver goods directly to consumers through a network of warehouses, fulfillment centers,

distribution hubs, and last-mile delivery services. As online shopping continues to grow, these logistics networks are becoming increasingly integrated into urban environments, shaping the way goods move within cities and how urban spaces are planned and utilized. Understanding the structure and operation of the e-commerce supply chain is crucial for evaluating its broader impact on urban life and city development.

According to Sommar and (Mellander.,2018), the expansion of e-commerce has transformed traditional logistics systems by increasing the demand for faster deliveries, more localized storage facilities, and efficient transportation networks. This transformation has led to the emergence of new logistics infrastructure, such as urban fulfillment centers, micro-distribution hubs, and hyperlocal delivery systems, which are strategically located closer to consumers to reduce delivery times.

The rapid growth of e-commerce also influences several aspects of urban life, including traffic patterns, land use, environmental sustainability, and consumer accessibility. An increase in delivery vehicles operating within cities can contribute to road congestion, parking challenges, and higher greenhouse gas emissions if logistics operations are not properly managed. At the same time, e-commerce provides significant benefits by improving access to products, supporting local businesses through digital marketplaces, and offering greater convenience for consumers. These contrasting impacts highlight the need for well-planned logistics strategies that balance economic efficiency with environmental and social sustainability.

Furthermore, city planners and policymakers are increasingly recognizing the importance of integrating e-commerce logistics into urban development plans. Efficient supply chain planning can improve freight movement, reduce transportation costs, optimize warehouse locations, and support sustainable last-mile delivery solutions. As cities continue to expand and consumer expectations for rapid delivery increase, understanding the dynamics of the e-commerce supply chain becomes essential for creating resilient, accessible, and sustainable urban environments. Therefore, a comprehensive understanding of the e-commerce supply chain provides valuable insights into how online retail influences urban growth and helps

guide future planning decisions aimed at improving both city logistics and the quality of urban life.

2.2.1 Addressing new supply chain challenges

E-commerce has emerged as the most significant factor driving changes in retail logistics and physical distribution networks in developed nations over the last four decades. Historically, supply chains were designed primarily for Business-to-Business (B2B) delivery, which naturally limited the service extension to the point of sale, such as a retail outlet. In this traditional model, logistics mainly involved store replenishment.

The introduction of Business-to-Consumer (B2C) e-commerce has introduced substantial new challenges to the supply chain. Tasks traditionally handled by the customer in a physical store namely, order fulfillment at the individual item level and last-mile transportation must now be managed entirely by the e-commerce supply chain (Sommar & Mellander, 2018). Consequently, the process of moving aggregated goods from large, centralized warehouses to storefronts has been supplanted by complex systems of parcel hubs and individual parcel deliveries from e-retailers' centers directly to consumers. Furthermore, e-commerce necessitates managing an entirely new flow: customer returns, which must be processed and routed back to warehouses.

To adapt to these changes, e-commerce logistics requires either new or significantly redesigned operational systems that are deeply integrated into metropolitan areas. The increase in handling and the resulting decrease in transport fill rates undermine the efficiency of warehousing, transportation, and logistics networks, ultimately leading to negative impacts within the urban environment.

2.2.2 From manufacture to consumer

From a logistical standpoint, e-commerce operations typically rely on an e-fulfillment center, where customer orders are picked, packed, and subsequently dispatched to a parcel hub for sorting and delivery to a location near the end consumer. For heavy or unusually large items, the transportation is managed through specialized Less-Than-Truckload (LTL) networks (Sommar & Mellander, 2018).

When short delivery times are critical, urban fulfillment centers are employed; these smaller facilities are supplied by the more centralized e-fulfillment centers. The critical "last mile" phase involves the final leg of transport from the local parcel delivery center or LTL terminal to the customer's doorstep. This final leg is generally executed by light trucks or vans operating out of package sorting facilities located strategically near major cities.

A further logistical complexity arises because, in the absence of a physical store, returns must also be processed entirely through the logistics network, generally utilizing the same transportation channels. E-fulfillment centers often incorporate the returns procedure directly into their operations, ensuring that returned merchandise is inspected and quickly restocked for subsequent sales.



Figure 6: Comparison of Traditional supply chain and E-commerce supply chain (Source: Urban Insight Report, 2018)

2.3 E-commerce in Indian Urban Areas

E-commerce in India is experiencing exponential growth, driven by deep smartphone penetration, affordable mobile data, and a young demographic. However, the impact on Indian cities is unique, driven by factors like highly dense populations, complex traffic, and a large unorganized retail sector. The transition is not just a logistics challenge but a major urban planning and infrastructure concern.

E-commerce has become one of the fastest-growing sectors in India, transforming the way consumers purchase goods and services. This rapid expansion has been supported by several factors, including widespread smartphone adoption, affordable internet connectivity, digital payment systems, and a large population of young, technology-savvy consumers. The increasing accessibility of online shopping platforms has enabled people from both urban and rural regions to participate in the digital marketplace, making e-commerce an integral part of India's economic growth.

Despite these positive developments, the growth of e-commerce has created a distinct set of challenges for Indian cities. Unlike many developed countries, Indian urban areas are characterized by high population density, congested road networks, limited parking facilities, and rapidly expanding metropolitan boundaries. These conditions make the movement of goods more complex, particularly during the final stage of delivery to customers. Frequent traffic congestion, inadequate logistics infrastructure, and uneven road conditions often increase delivery times and operational costs for e-commerce companies.

Another important aspect of the Indian market is the presence of a large unorganized retail sector. Millions of small neighborhood stores continue to play a vital role in meeting daily consumer needs. As online retailers expand their market share, these traditional businesses face increasing competition, creating both economic and social implications. At the same time, many e-commerce companies are exploring partnerships with local retailers to improve delivery efficiency and strengthen customer service, resulting in new forms of collaboration within the retail ecosystem.

The rapid growth of e-commerce has also placed greater pressure on urban infrastructure. Higher volumes of delivery vehicles contribute to road congestion, increased fuel consumption, and rising carbon emissions. In addition, the growing demand for warehouses, fulfillment centers, and distribution hubs is changing patterns of land use in and around cities. These developments require urban planners and policymakers to reconsider transportation systems, logistics networks, and environmental sustainability while supporting continued economic growth.

Therefore, the expansion of e-commerce in India should not be viewed solely as a technological or commercial advancement. It represents a broader urban development challenge that requires coordinated planning across transportation, infrastructure, environmental management, and public policy. Developing sustainable logistics solutions, improving urban mobility, and integrating digital commerce with city planning will be essential to ensuring that the long-term benefits of e-commerce are realized while minimizing its impact on urban environments.

2.3.1 Citizens and customers perspective

The Indian e-commerce consumer profile is highly diverse, influenced by city tier (Tier 1, 2, 3), age, income, and access to technology (Table 1). The motivations and challenges differ significantly from the European profiles described in the report (Sommar & Mellander, 2018).

Table 1: Key Indian Customers Preferences (Source: Author)

European Context	Indian Context	Key Differences & Preferences
The Internet-Mature Student (Hansi, Germany)	The Savvy Metro Youth	Price-sensitive, heavy user of mobile apps for shopping (not just websites). Purchases include fashion, electronics, and food. Prefers Digital payments (UPI) and is willing to accept longer delivery times for free shipping (unless it's express food delivery).
The Juggling Urban Parent (Susan, UK)	The Time-Constrained Nuclear Family	Time-saving and convenience for heavy/bulky items (groceries, appliances) is paramount. Home delivery is essential due to high traffic and difficulty carrying purchases. Prefers scheduled slots

		for groceries and is likely to use subscription services.
The Mobile Business Couple (Michele & Camille, France)	The High-Earning Urban Professional	Flexibility is critical. Will pay a premium for quick, guaranteed delivery (e.g., same-day) to home or office. Security is a lesser concern than reliability. Uses e-commerce for niche, high-value, and cross-border items.
The Conservative Retired Woman (Ingrid, Sweden)	The Newly Digitized Senior	Low internet maturity but is slowly adopting for essentials like medicine and books, often guided by family. Still relies heavily on the local kirana store (traditional shop). Prefers Cash on Delivery (COD) and collection from a familiar local shop (if not home delivery).

2.3.2 Understanding the E-commerce supply chain in India

While the generic e-commerce supply chain (E-fulfilment → Parcel Hub → Parcel Delivery Centre → Consumer) is similar, the Indian context introduces complexity:

- Fragmented Fulfillment: Many sellers operate through marketplaces, leading to de-consolidated shipments from numerous small vendors, unlike the centralized European models.

- The Dominance of Returns: Like in Europe where clothing returns are 30-50%, returns are a massive logistical challenge in India, particularly due to the high volume of Cash on Delivery (COD) orders that often lead to failed deliveries and returns. This reverse logistics significantly increases costs and traffic.

- Need for Urban Hubs: Given the high density and traffic, India needs more small, strategically located Urban Depots/Micro-fulfillment Centres to serve as close-proximity staging points, which is a recognized solution in the European report.

2.3.3 Solutions for Delivery: The last mile challenge in India

The "last mile" is universally cited as the most expensive, least efficient, and most polluting part of the supply chain. In India, this inefficiency is exacerbated by: poor road quality, traffic congestion, and a lack of standardized building addresses/layouts (Sommar & Mellander, 2018)(Table 2).

Table 2: Last mile solutions and Indian adaptation (Source: Author)

Last Mile Solution	Indian Adaptation & Challenges
Home Delivery	Most preferred option. Relies heavily on two-wheelers (bikes/scooters) rather than vans due to traffic and narrow lanes. The main challenge is finding the recipient ("pata"/address issues) and the high rate of failed deliveries (customer unavailable, high-rise security gate restrictions).
Collection Point/PUDO	Less formalized than in Nordic countries. Often relies on local kirana (corner) stores or small mobile phone shops acting as unofficial pick-up points. Capacity limitations during peak season are severe, similar to the European collection points mentioned.
Letter Box / Parcel Locker	Not widely used for large items due to a lack of standardization in apartment buildings and security concerns. The concept of a dedicated, personal parcel box (like in Germany) is largely absent in existing multi-story/skyscraper blocks.

Click and Collect (Store)	Growing, especially for fashion and electronics. Allows customers to inspect the product and avoid delivery charges. The advantage of piggybacking on existing store logistics is crucial for smaller Indian retailers.
Click-and-Drive	Extremely limited outside of major organized retail malls due to the low car ownership rate and severe urban traffic congestion, making the French model difficult to replicate.

2.3.4 Effects of E-commerce on Indian urban areas

➔ Increased Traffic and Congestion: A surge in last-mile delivery vehicles, predominantly two-wheelers and small vans, dramatically increases congestion in residential areas and central business districts. The sheer volume of small, fragmented shipments from numerous e-tailers makes poor fill rates a major problem.

➔ Real Estate and Infrastructure Shift:

- ◆ Warehousing: The "centre of gravity" of the supply chain moves closer to the consumer , driving demand for smaller, urban logistics spaces (urban depots).
- ◆ Retail Points: The decline of mid-range city malls is likely, while high-end centers may survive by transforming into showrooms or "experience centers".
- ◆ Recipient Properties: There's a growing need for domestic logistics reception capability in new construction (e.g., dedicated delivery areas, security protocols) to manage the volume of parcels.

➔ Environmental Impact: While studies suggest e-commerce can save energy compared to personal car travel for shopping in some cases , the increased use of low-capacity, older vehicles and excessive packaging waste (from single-item fulfillment) presents a significant environmental challenge for waste management.

2.4 The Evolving Geography of Urban Freight and the Last-Mile Challenge

The integration of e-commerce into the urban economy has necessitated a fundamental shift in how cities manage the movement of goods, moving freight management from a peripheral concern to a central challenge in contemporary spatial planning (Cui, Dodson, & Hall, 2015; Sanchez-Diaz & Browne, 2018). Traditionally, urban transport planning focused primarily on the movement of people through road networks, public transportation, and pedestrian facilities. Freight transport, although essential to economic activity, received comparatively less attention in city planning strategies. However, the rapid growth of online retail has substantially increased the frequency of deliveries, particularly through last-mile logistics, where goods are transported directly to consumers' homes or workplaces. This growing demand has resulted in a higher number of delivery vehicles operating within urban areas, increasing pressure on existing transportation infrastructure.

The rise in freight activity has introduced several challenges for cities, including traffic congestion, parking shortages for delivery vehicles, increased emissions, and competition for limited road space. In densely populated urban areas, these issues are often intensified by narrow streets, mixed land-use patterns, and high levels of pedestrian and vehicular movement. Consequently, freight transport is no longer viewed solely as a logistics concern but as a critical component of sustainable urban development that directly influences mobility, environmental quality, and the efficiency of city operations.

This transformation has also highlighted the need for integrated planning approaches that consider freight movement alongside passenger transportation, land-use planning, and infrastructure development. Urban planners are increasingly exploring solutions such as urban consolidation centers, micro-fulfillment hubs, dedicated loading zones, smart traffic management systems, and sustainable last-mile delivery methods to improve logistics efficiency while minimizing negative impacts on urban environments. These strategies aim to balance the growing demand for rapid deliveries with the broader objectives of reducing congestion, lowering emissions, and enhancing the quality of life for urban residents.

As e-commerce continues to expand, freight management has become an essential element of modern spatial planning. Rather than treating logistics as a separate operational activity, cities are increasingly recognizing the importance of incorporating freight considerations into long-term urban development plans. Such an integrated approach enables policymakers to develop more resilient, efficient, and sustainable cities capable of supporting economic growth while addressing the complex logistical demands created by the digital economy.

2.4.1 E-commerce as a Disruptive Force in Urban Mobility

E-commerce has fundamentally reorganized the traditional geography of commerce (Hesse & Rodrigue, 2004). Initially, the rise of online shopping was hypothesized to lead to a significant substitution effect, replacing personal shopping trips with fewer, more efficient freight trips (Rotem-Mindali & Weltevreden, 2013; Visser, Nemoto, & Browne, 2014). However, empirical evidence has largely revealed a more complex reality, demonstrating complementary or neutral effects on overall mobility (Allen et al., 2018; Rotem-Mindali & Weltevreden, 2013).

This complexity arises because the e-commerce supply chain creates demand characterized by fragmentation: goods are shipped in small volumes but at high delivery frequency to residential areas (Fadhlansyah & Nahry, 2022; Visser et al., 2014). This results in a massive upsurge in the use of Light Goods Vehicles (LGVs) for parcel deliveries in urban centres, leading to poor vehicle utilization and duplication of delivery services as competitors vie for business (Allen et al., 2018).

2.4.2 The Economic Burden and Operational Inefficiency of the Last-Mile

The Last-Mile Delivery (LMD) segment the final stage from the distribution center to the customer's preferred destination is consistently identified as the most critical and least efficient link in the supply chain (Olsson, Hellström, & Pålsson, 2019; Viu-Roig & Alvarez-Palau, 2020).

- High Costs and Effort: LMD accounts for a disproportionately high share of total logistics costs (often cited up to 75% of total logistics cost in the introductory phase of the report) due to the low drop density and the high effort required per delivery stop. A London case study highlighted that walking alone can account for 62% of the total vehicle round time (Allen et al., 2018).

- Failed Deliveries: A major source of inefficiency is the failed first-time delivery problem (Buldeo Rai, Verlinde, & Macharis, 2021), leading to costly redelivery attempts, additional VKT (Vehicle Kilometers Travelled), and customer dissatisfaction. Solutions such as Collection and Delivery Points (CDPs), Parcel Lockers (PLs) (Ma, Teo, & Wong, 2024), and technology like smart locks have emerged to mitigate this operational strain (Buldeo Rai et al., 2021).

- Developing World Context: For Indian cities, these inherent LMD challenges are intensified by infrastructure deficits (e.g., poor road networks, lack of dedicated loading zones) and the unique characteristics of rapidly evolving demand (Kumar & Chidambara, 2023).

2.5 New Logistical Paradigms: From Sprawl to Proximity

The necessity for speed and efficiency has fundamentally altered the locational dynamics of logistics facilities, leading to a tension between suburban sprawl and urban proximity. The increasing demand for faster and more reliable e-commerce deliveries has significantly changed the way logistics facilities are planned and located within urban regions. As consumers increasingly expect same-day or next-day delivery services, logistics providers are under constant pressure to reduce delivery times while maintaining operational efficiency. This has transformed the traditional approach to warehouse and distribution center location, making proximity to customers a critical factor in logistics planning.

Historically, large warehouses and distribution centers were established on the outskirts of cities where land was more affordable, readily available, and capable of accommodating large-scale operations. While these suburban locations offered economic advantages, they

also resulted in longer delivery distances and increased travel times to densely populated urban areas. As customer expectations for rapid delivery continue to rise, this conventional logistics model has become less effective in meeting the requirements of modern e-commerce.

To improve delivery speed, many logistics companies are now seeking locations closer to city centers by developing urban warehouses, micro-fulfillment centers, and smaller distribution hubs. These facilities reduce the distance between products and consumers, enabling quicker last-mile deliveries and greater responsiveness to fluctuating demand. However, locating logistics infrastructure within cities presents several challenges, including high land prices, limited availability of suitable sites, zoning restrictions, and potential conflicts with residential and commercial land uses.

As a result, cities are experiencing a growing tension between maintaining large logistics facilities in suburban areas and establishing smaller distribution hubs within urban neighborhoods. Suburban facilities continue to offer lower operating costs and greater storage capacity, whereas urban logistics centers provide the proximity needed to support fast and efficient deliveries. Balancing these competing priorities has become a significant challenge for both logistics companies and urban planners.

This evolving pattern highlights the need for integrated urban planning strategies that consider logistics infrastructure as an essential component of city development. Policymakers must carefully balance economic efficiency, land-use planning, transportation networks, and environmental sustainability when determining the location of logistics facilities. Achieving this balance is crucial for supporting the continued growth of e-commerce while minimizing congestion, reducing delivery-related emissions, and improving the overall efficiency of urban freight transport.

2.5.1 The Traditional View vs. New Centrality

The historical trend of logistics was characterized by "logistics sprawl," the outward migration of warehousing facilities to peripheral areas seeking cheap land, high-speed

highway access, and minimal local regulation (Hesse & Rodrigue, 2004; Xiao, Yuan, Sun, & Sun, 2021). However, e-commerce has catalyzed a complex reversal, driving a trend towards centrality (Fried & Goodchild, 2023; Xiao et al., 2021).

- Last-Mile Proximity: Facilities dedicated to LMD (Level 3 platforms in e-commerce networks) are strategically positioned closer to consumer markets than upstream distribution platforms, sacrificing lower rent for expedited access to demand (Fried & Goodchild, 2023).

- Logistics Space Reorganization: This internal pressure drives the reorganization of logistics space, forcing multi-story facilities, renovation of obsolete buildings, and consolidation of services within existing urban footprints to match the accelerating e-tailing requirements (Xiao et al., 2021).

2.5.2 Quick Commerce (Q-commerce) and Dark Store Deployment

The most radical manifestation of this drive for proximity is Quick Commerce (Q-commerce), defined by ultra-fast delivery promises (often 20 minutes or less) (Huang & Yen, 2021).

- Dark Stores: Q-commerce relies on a tight network of "dark stores"small, store-like micro-fulfillment centres designed solely for online order processing (Buldeo Rai et al., 2023; Huang & Yen, 2021; Luthher, 2022).

- Transportation Intensity: Dark stores, despite their small size, are transportation-intensive facilities, generating a high volume of vehicle movements per day, though often relying on electric two-wheelers in dense urban environments (Buldeo Rai et al., 2023).

- Zoning Conflict: The critical planning conflict arises because dark stores seek locations in commercially active or residential areas for proximity, often resulting in non-conforming land use (Kumar & Chidambara, 2023). This ambiguity over whether

a dark store is a retail outlet or a warehouse creates a significant management gap in urban planning documents (Kumar & Chidambara, 2023).

2.6 Modeling E-commerce Freight Demand and Spatial Heterogeneity

Effective spatial planning requires reliable models to predict and locate e-commerce demand and its subsequent freight flows. This necessitates moving beyond traditional aggregate models to capture localized and complex spatial relationships. The rapid growth of e-commerce has increased the need for more accurate methods of predicting where online shopping demand will occur and how goods will move through urban areas. Effective spatial planning depends on a clear understanding of consumer demand patterns, delivery destinations, and freight movement across different parts of a city. Without reliable forecasting models, it becomes difficult for urban planners and logistics providers to make informed decisions regarding the location of warehouses, distribution hubs, and transportation infrastructure. As a result, demand prediction has become a critical component of planning efficient and sustainable e-commerce logistics systems.

Traditional planning models were primarily designed to estimate freight demand at a broad regional or citywide level. While these aggregate models provide useful information for general planning purposes, they often fail to capture the detailed variations that exist between neighborhoods or local communities. E-commerce demand is highly dynamic and is influenced by several localized factors, including population density, household income, land-use characteristics, consumer purchasing behavior, accessibility, and the availability of transportation networks. Consequently, relying solely on aggregated data may overlook important spatial differences that directly affect delivery operations and logistics performance.

The increasing complexity of urban freight systems requires planning approaches that can identify and analyze these localized spatial patterns. Advanced spatial models enable planners to predict where demand is likely to increase, estimate delivery volumes at finer

geographic scales, and evaluate the movement of freight within different urban zones. Such models also help identify areas that may experience higher levels of delivery activity, traffic congestion, or infrastructure demand, allowing planners to develop targeted interventions before operational problems arise.

Furthermore, localized demand forecasting supports more strategic decisions regarding the placement of logistics facilities such as urban fulfillment centers, micro-distribution hubs, parcel lockers, and last-mile delivery stations. By understanding the spatial distribution of e-commerce demand, logistics companies can optimize delivery routes, reduce travel distances, improve service efficiency, and lower transportation costs. At the same time, city authorities can use these insights to integrate freight considerations into land-use planning, transportation policies, and sustainable urban development strategies.

Therefore, effective spatial planning for e-commerce requires moving beyond conventional aggregate forecasting methods toward more detailed and location-sensitive analytical models. These advanced approaches provide a better understanding of complex spatial relationships within cities, enabling planners and policymakers to design logistics systems that are more efficient, resilient, and responsive to the evolving demands of digital commerce. Such improvements contribute to enhanced urban mobility, reduced environmental impacts, and better integration of freight transport into future urban development plans.

2.6.1 The Shift to Geospatial Demand Modeling

Traditional mobility models were not designed to accommodate the dispersed, consumer-driven nature of LMD (Fadhlansyah & Nahry, 2022). Modern research shifts focus to Freight Trip Generation (FTG) modeling at the residential and neighborhood level (Fadhlansyah & Nahry, 2022; Shin et al., 2023). FTG is a function of socio-demographic factors, behavioral preferences, and urban spatial attributes (Shin et al., 2023; Touloumidis et al., 2025).

Traditional mobility models were primarily developed to analyze passenger transportation and conventional freight movement, making them less effective in representing the dispersed and consumer-oriented nature of last-mile delivery (LMD) associated with e-commerce

(Fadhlansyah & Nahry, 2022). With the rapid growth of online shopping, recent studies have shifted toward Freight Trip Generation (FTG) models that estimate freight demand at the residential and neighborhood levels. These models recognize that freight movement is influenced by socio-demographic characteristics, consumer behavior, and urban spatial factors, providing a more accurate understanding of delivery patterns (Shin et al., 2023; Touloumidis et al., 2025).

Researchers have also introduced methodologies to estimate the number of shipments by different commodity types, such as groceries, clothing, and electronics, even when only total parcel volumes are available. This approach helps identify opportunities for shipment consolidation and improves logistics efficiency (Caspersen, Arrieta-Prieto, & Wang, 2023). In addition, consumer characteristics including income level, educational background, household composition, and proximity to urban centers significantly influence online shopping behavior and the frequency of parcel deliveries, making these variables important predictors in modern freight demand models (Caspersen et al., 2023).

- Latent Counts: Methodologies have been developed to infer the frequency of shipments by commodity type (e.g., groceries, electronics) when only total parcel counts are observable, revealing unexploited consolidation opportunities in logistics networks (Caspersen, Arrieta-Prieto, & Wang, 2023).

- Behavioral Predictors: Consumer behavior models confirm that factors such as income, education, presence of children, and distance to urban centers influence both the propensity to shop online and the number of shipments received (Caspersen et al., 2023).

2.6.2 Spatial Heterogeneity as a Core Predictor

A key finding in the literature is that the impact of socio-economic and land-use factors on e-commerce demand varies geographically (Cai, Chen, & Li, 2025; Shin et al., 2023; Touloumidis et al., 2025).

- Localized Effects: Global regression models (OLS) often fail to accurately predict LMD demand because they assume constant relationships across space. By contrast, Geographically Weighted Regression (GWR) models, which allow coefficients to vary locally, show significantly higher predictive accuracy (Touloumidis et al., 2025). This confirms that a "one-size-fits-all" planning approach is inadequate (Touloumidis et al., 2025).

- Demand Drivers: Key localized predictors include:
    - Population Density: The strongest universal predictor of demand concentration (Cai et al., 2025; Touloumidis et al., 2025).
    - Workforce/Employment: Highly influential in mixed-use and institutional areas, driving daytime deliveries (Touloumidis et al., 2025).
    - Commercial Interaction: The density of certain commercial facilities (e.g., convenience stores acting as parcel pickup points) can have a complementary effect, while others (e.g., supermarkets) may exert a substitutive effect on online purchasing (Cai et al., 2025).

Recent studies indicate that the influence of socio-economic characteristics and land-use patterns on e-commerce demand is not uniform across different geographic areas (Cai, Chen, & Li, 2025; Shin et al., 2023; Touloumidis et al., 2025). Instead, these relationships vary depending on local urban conditions, highlighting the need for location-specific planning approaches.

Traditional global regression models, such as Ordinary Least Squares (OLS), assume that the relationship between demand and its influencing factors remains constant throughout the study area. However, this assumption often leads to inaccurate predictions of last-mile delivery demand. Geographically Weighted Regression (GWR) addresses this limitation by allowing relationships to vary across locations, resulting in more reliable and accurate demand estimation. This demonstrates that uniform planning strategies are insufficient for managing the spatial complexity of urban freight systems (Touloumidis et al., 2025).

Among the various factors affecting e-commerce demand, population density consistently emerges as the strongest predictor of delivery concentration, with densely populated neighborhoods generating higher parcel volumes (Cai et al., 2025; Touloumidis et al., 2025). Employment and workforce density also play a significant role, particularly in mixed-use commercial and institutional areas where daytime delivery demand is higher (Touloumidis et al., 2025). In addition, the distribution of commercial facilities influences online shopping behavior in different ways. For example, convenience stores that function as parcel collection points can complement e-commerce activities, whereas the presence of supermarkets may reduce online grocery purchases by encouraging in-store shopping (Cai et al., 2025).

2.7 The Collision with Urban Space: Externalities and Governance

The increasing freight demand induces several costly and complex negative externalities that are usually difficult for the available governance structures to deal with effectively, especially for developing economies.

2.7.1 Traffic, Safety, and Environmental Externalities

The visible impacts of LMD on urban systems are across all the pillars of sustainability (Viu-Roig & Alvarez-Palau, 2020):

- Environmental: LMD is a significant contributor of GHG emissions and local air pollution. High frequency of small volume deliveries creates a cycle of increased VKT and resultant emission.

- Traffic and Safety: Increased commercial traffic aggravates urban congestion, leading to rising road safety risks; this is frequently spatially concentrated around logistics facilities.

- Social Equity: Due to the siting of freight infrastructure and corridors in low-income neighborhoods, often vulnerable populations bear most of the negative impacts.

2.7.2 Governance Gaps and Policy Integration Barriers

Integration of UFT in city planning is considered to be a core challenge of governance. According to (Bjørgen & Ryghaug 2022), policy responses are hampered by deeper structural problems:

- Lack of Strategic Planning: Most of the local authorities lack a strategic approach, as they operate without detailed data or dedicated UFT personnel and without any clear link between high-level goals and operational policy measures.

- Policy Constraints: The availability of resources-real-financial and human-and the need for legitimacy and political acceptability among competing stakeholders are major constraints to decisions. (Akgün et al., 2019)

- Developing Economy Barriers: In many countries, such as India, the task is further complicated by rapid, usually unplanned urbanization and deficiencies in policy instruments developed at a formal level. Usually, ad-hoc, restrictive measures are being developed instead of proactive integrated planning. According to Hidayatno et al. (2019) and Kumar & Chidambara (2023), early incorporation of freight considerations into policy development processes is necessary, along with stakeholder engagement, if coordination is to be effective. (Bjørgen & Ryghaug:,2022)

2.8 Research Gaps and the Need for a Structural Framework

A review of the literature substantiates that e-commerce logistics is indeed causing a permanent spatial and functional reorganization of the city. Though global research presents various solutions on CDPs, EVs, and optimization models, their successful implementation in high-growth but spatially constrained markets like India is constrained by three different gaps, which this dissertation attempts to address:

- Limited Availability of FTG Models with Granular and Localized Resolution: Unless FTG models validated in unique socio-economic and structural conditions relative to

Indian cities are available, planners cannot correctly forecast LMD demand or locate high-stress zones.

- Structural Interdependency Gap: Exiting literature indicates a complex, cause-effect network of interrelated factors-economic, environmental, social, and technical-that determine LMD (Huang & Yen, 2021). Yet, what is lacking in the literature is a rigorous, structural approach to systematically map and quantify for the causal hierarchy and interdependencies among those policy factors that guide intervention strategy.

- Policy prioritization gap: Considering the resource and governance constraints in Indian cities, as stated by Akgün et al. (2019) and Kumar & Chidambara (2023), there has been an emerging need to provide a framework synthesizing the complex modeling inputs into an actionable, prioritized hierarchy for spatial and regulatory policy implementation.

The review of existing literature reveals several important research gaps that this dissertation seeks to address. One of the major limitations is the lack of Freight Trip Generation (FTG) models that provide detailed and localized demand estimation for Indian cities. Most existing FTG models have been developed and validated in developed countries with different socio-economic conditions, urban structures, and travel behaviors. Consequently, these models may not accurately represent the characteristics of Indian urban environments, making it difficult for planners to forecast last-mile delivery demand or identify areas likely to experience high freight activity and logistics-related congestion.

Another significant gap is the limited understanding of the structural relationships among the factors influencing last-mile delivery. Previous studies acknowledge that economic, environmental, social, technological, and infrastructural factors collectively shape urban freight systems (Huang & Yen, 2021). However, there is limited research that systematically examines the causal relationships and interdependencies among these variables. A comprehensive structural framework is therefore needed to identify the hierarchy of

influencing factors and support more effective decision-making for urban freight management.

In addition, the literature highlights a policy prioritization gap, particularly in the context of developing countries such as India. Urban local bodies often face financial, institutional, and governance constraints that limit their ability to implement multiple interventions simultaneously (Akgün et al., 2019; Kumar & Chidambara, 2023). Despite the availability of advanced analytical models, there is a lack of practical frameworks that translate research findings into clear policy priorities. This dissertation addresses this gap by proposing an integrated decision-support framework that helps policymakers identify and prioritize the most effective spatial planning and regulatory strategies for improving the sustainability and efficiency of last-mile delivery systems in Indian cities.

This research fills these gaps by developing a structural framework that quantifies the relationships between local urban spatial attributes and e-commerce logistics outcomes, offering a new and needed tool for DOD in metropolitan areas within India.

CHAPTER 3

RESEARCH DESIGN

3.1 Aim

To develop a spatial planning framework for integrating Q-commerce logistics into the urban planning structure of Tier-2 cities using Total Interpretive Structural Modelling (TISM), spatial analysis, and empirical survey assessment.

3.2 Research questions

1) How must urban spatial planning frameworks in Indian cities be restructured to effectively integrate and manage the spatial demands of e-commerce last-mile logistics, minimizing negative externalities while maximizing urban efficiency?
2) What are the key operational characteristics, infrastructure requirements, and spatial footprints of current e-commerce logistics, specifically last-mile delivery, within the urban fabric?
3) What is the observable correlation between existing urban spatial patterns (e.g., density, road hierarchy, land-use mix) and the efficiency, cost, and speed of last-mile e-commerce delivery?
4) What is the quantified impact of specific e-commerce logistics factors on key urban spatial elements (e.g., traffic congestion, parking demand, land-use change, environmental quality) across various Indian cities?
5) What are the major spatial and operational factors influencing Q-commerce logistics in Tier-2 cities?
6) How does urban morphology affect last-mile delivery efficiency in Bhopal?
7) What are the causal relationships between urban logistics variables?
8) How can planning standards and logistics frameworks improve hyperlocal delivery systems?

3.3 Objectives

3.3.1 Phase-I

1) To understand the E-commerce logistics in an urban fabric.
2) To identify the correlation between urban spatiality and E-commerce logistics.
3) To analyse the impact of factors related to E-commerce logistics affecting the urban spatiality in Indian cities.

3.3.2 Phase-II

1) To identify and establish the causal hierarchy and interdependency of critical logistics variables influencing Q-commerce operations in Tier-2 cities using the Total Interpretive Structural Modelling (TISM) approach.
2) To analyse the existing spatial distribution of dark stores and identify operational inefficiencies through primary survey and spatial mapping.
3) To evaluate accessibility gaps, corridor dependency, congestion patterns, and delivery constraints affecting last-mile delivery systems in Bhopal.
4) To develop a spatial planning framework consisting of planning standards, suitability criteria, logistics zoning, and corridor-based interventions for Q-commerce logistics in Tier-2 cities.

3.4 Research methodology

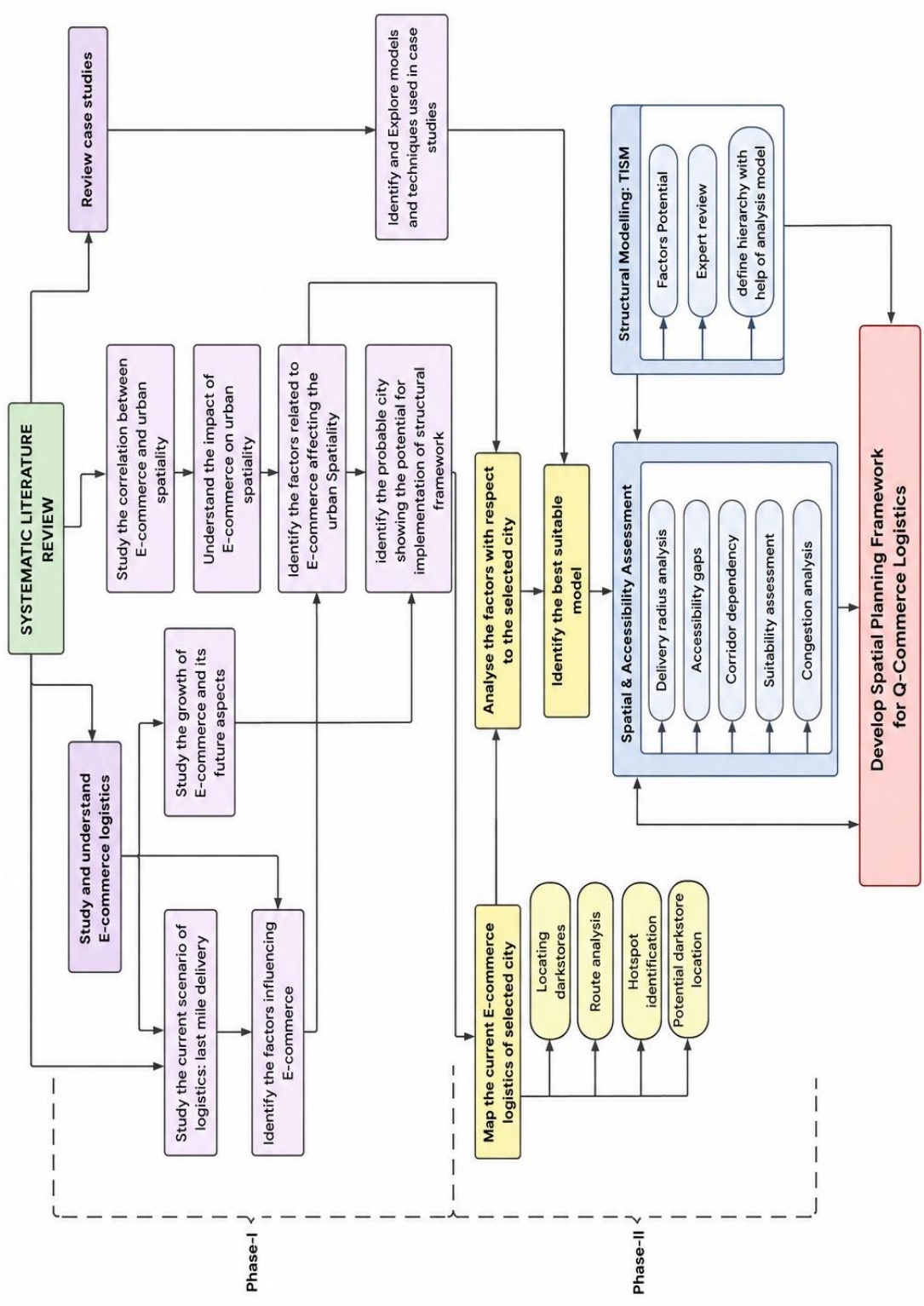


Figure 7: Methodology (Source: Author)

1) Step 1: E-commerce Logistics in Urban Fabric - Definition
    - Systematic review of literature on last-mile delivery components, such as dark stores, sorting centers, vehicle types, and operational flow in high-density urban settings, focusing on emerging economies like India. Also, a comprehensive set of definitional and operational characteristics of the E-commerce logistics system. (Kumar & Chidambara, 2023; Fried & Goodchild, 2023; Xiao et al., 2021; Boysen et al., 2020; Lim et al., 2018; Viu-Roig & Alvarez-Palau, 2020; Allen et al., 2018)

2) Step 2: Identify Spatial-Logistics Correlates
    - Review the research linking the urban spatial metrics (zoning, road layout, density, land use mix) to logistics performance based on speed, cost, congestion. Initial list of critical factors/variables that theoretically link urban spatiality with logistics outcomes. It will be refined and used as an input for the analysis model. (Viu-Roig & Alvarez-Palau, 2020; Habib & Hamadneh, 2021; Sardjono et al., 2021; Gharehgozli et al., 2017; Buldeo Rai, 2019; Janjevic & Winkenbach, 2020; Nguyen et al., 2018; Sprint Project, 2020)

3) Step 3: Impact Analysis and Causal Relationship
    - Perform an in-depth analysis, qualitative and quantitative, of the direct and indirect impacts that the validated logistics factors from Step 2 have on urban spatial problems such as pollution and congestion. Provide a matrix of identified cause-and-effect relationships between the logistics factors and the urban spatial outcomes.

4) Step 4: Map Current E-commerce Logistics
    - Utilize a mixed-method approach by integrating:
    - Plotting key logistics infrastructure (warehouses, micro-hubs) in the urban plan of the selected city.
    - Mapping peak hour delivery routes; identifying recurring congestion and informal parking hotspots linked with delivery operations.

- It includes thematic maps and descriptive statistics that show the spatial distribution and flow of e-commerce logistics, pointing out the conflicting spots with existing urban functions.

5) Step 5: Assess Local Impact Factors
    - The magnitude and nature of the impact of logistics activities on urban spatiality can be ascertained through collection of local primary data in the form of survey, interviews with local planners/delivery personnel, and secondary municipal data such as traffic challans, land-use change records. A prioritized and validated list of crucial factors specific to case study city driving the urban-logistics relationship.

6) Step 6: Analysis and Scaling via a Structural Model
    - Apply a structural modeling technique or a similar decision-making tool that relies on expert input, herein generally referred to as the "Analysis Model") to the critical factors. This includes:
    - Gathering qualitative input from a panel of urban and logistics experts for the identification of the contextual relationship between every factor pair.
    - Processing expert input using the model matrix algebra to produce a framework.

7) Step 7: Prepare the Structural Framework
    - Use the outcomes from the Analysis Model in Step 6 to create a prescriptive structural framework:
    - Define the structural elements of the framework, based on the results obtained from the analysis model.
    - Detail specific spatial and regulatory planning interventions, such as micro-hub zoning, timed access, and dedicated loading zones.

- Based on these findings, develop a final proposal for integrating this logistics framework into the selected city's existing master plan and regulatory policy instruments.

3.5 Scope

- The study will be limited to a single Indian metropolitan area with evident congestion and active Q-commerce operations, serving as an intensive case study to derive locally relevant data and transferrable framework insights.

- The primary focus is on B2C (Business-to-Consumer) Last-Mile Delivery (LMD) and Q-commerce logistics, specifically the spatial and operational footprint of CEP (Courier, Express, and Parcel) establishments, dark stores, and micro-hubs.

- The analysis will concentrate on modeling the interdependencies and causal relationships between quantifiable logistics factors and urban spatial outcomes, utilizing a structural modeling technique (referred to as the "Analysis Model") to derive a prioritized hierarchy for policy implementation.

- The framework developed will be prescriptive, focusing on actionable interventions for micro-level spatial and regulatory policy (e.g., zoning, vehicle access, loading/unloading) aimed at mitigating externalities.

The scope of this study is confined to Bhopal, an Indian city experiencing rapid growth in Q-commerce activities and increasing urban mobility challenges, which serves as the case study for developing locally relevant planning strategies. The research focuses specifically on Business-to-Consumer (B2C) last-mile delivery operations, examining the spatial and operational characteristics of courier, express, and parcel (CEP) facilities, including dark stores and micro-hubs. The analysis investigates the interdependencies and causal relationships among key logistics, transportation, and urban planning variables using a structural modelling approach to establish a prioritized hierarchy of factors influencing delivery efficiency. Based on these findings, the study proposes a prescriptive planning framework comprising practical spatial and regulatory interventions, such as guidelines for

dark store location, zoning compatibility, vehicle access, and loading and unloading infrastructure, with the objective of improving the efficiency, sustainability, and integration of Q-commerce logistics within the urban environment.

3.6 Limitations

- Obtaining real-time, transactional E-commerce/CEP flow data and establishment-level operational data (e.g., precise dark store locations, manifest information) is challenging due to its proprietary nature. The study must rely on primary survey data (EBFS) and secondary proxies (e.g., GFA, DE) for modeling.

- Structural modeling inherently simplifies complex, non-linear system dynamics, relying heavily on expert input and validation for establishing causal relationships, which may limit generalizability to other city contexts without local recalibration.

- The core spatial mapping and modeling primarily represent a snapshot of the urban-logistics relationship, potentially omitting full insight into seasonal peaks or minute-by-minute dynamic traffic management issues.

- The study's focus on spatial planning means that deep dives into internal supply chain management optimization (e.g., in-warehouse robot routing) or intricate behavioral economics of consumer choice are constrained.

The study is subject to certain limitations that should be considered while interpreting the findings. Obtaining real-time transactional data, establishment-level operational information, and detailed Q-commerce logistics records, such as precise dark store locations and delivery manifests, is challenging due to their proprietary nature. Consequently, the analysis relies primarily on data collected through establishment-based freight surveys (EBFS) and secondary indicators such as Gross Floor Area (GFA) and the number of Delivery Executives (DE) for modelling purposes. Furthermore, the structural modelling approach simplifies the complex and dynamic interactions within urban logistics systems and depends on expert interpretation and validation to establish causal relationships, which may limit the direct applicability of the framework to other cities without local calibration. The spatial analysis

also represents a snapshot of existing conditions and may not fully capture seasonal demand fluctuations, temporal variations, or real-time traffic conditions. Additionally, the scope of the research is confined to urban spatial planning and last-mile logistics, without examining detailed internal supply chain operations, warehouse management processes, or consumer behavioural aspects of Q-commerce.

3.7 Expected outcomes

- Structural Interdependency Map: A synthesized structural framework depicting the validated causal hierarchy and interdependencies amongst critical E-commerce logistics factors (economic, social, environmental, spatial) impacting urban fabric, guiding planners on where to target interventions for maximum cascade effect.

- Localized E-commerce FTG Model: A quantified regression model (FTG) customized for the Indian B2C sector that links the easily available establishment attributes (such as GFA and Delivery Executives (DE) to outbound freight trip generation at the local level, thus providing a practical planning tool.

- Spatial Stress Diagnosis: Thematic mapping of the spatial distribution of logistic infrastructure alongside diagnosed areas of high stress/conflict zones, for instance, zones of high illegal parking, traffic safety risk, or congestion hotspots, in relation to movements of deliveries.

- Prescriptive policy framework: a clear set of place-based planning recommendations and regulatory mechanisms for inclusion in municipal master plans, focusing on
    - Micro-Zoning Standards for Dark Store and micro-hub placement.
    - Guidelines for the integration of two-wheeler and Electric Vehicle (E2W) charging/loading/unloading into public right-of-way
    - Policy mechanisms for achieving sustainable modal shift in the last mile.

The study develops a structural interdependency framework that illustrates the validated causal relationships and hierarchical interactions among the key economic, social, environmental, and spatial factors influencing Q-commerce logistics. This framework helps

identify the most influential variables, enabling planners to prioritize interventions that generate broader system-wide improvements. A localized E-commerce Freight Trip Generation (FTG) model is also proposed, specifically adapted to the Indian B2C context, linking readily available establishment characteristics such as Gross Floor Area (GFA) and the number of Delivery Executives (DE) with outbound freight trip generation, thereby providing a practical tool for urban freight planning. In addition, the study presents a spatial stress diagnosis through thematic GIS mapping of logistics infrastructure, identifying areas experiencing high levels of congestion, illegal parking, traffic safety concerns, and delivery-related operational conflicts. Finally, the research proposes a prescriptive policy framework comprising place-based planning recommendations for municipal authorities, including micro-zoning standards for the location of dark stores and micro-hubs, guidelines for integrating two-wheeler and electric vehicle (E2W) charging, loading, and unloading facilities within the public right-of-way, and policy measures to encourage sustainable last-mile freight mobility and modal shift.

3.8 Inferences Drawn

The description states that there has been a significant paradigm shift in urban logistics, primarily driven by the rapid expansion of e-commerce and the rise of Q-commerce. This acceleration, to meet customer demand for ultra-fast delivery, has forced operators to establish facilities-both "dark stores" and micro-fulfillment centers-deep into residential areas and densely populated areas. This intentional spatial reconfiguration creates a significant planning dilemma, as mainstream urban design has always fostered passenger mobility while completely disregarding freight transport as a derivative function. Therefore, the growing fleet of two-wheelers and Light Goods Vehicles (LGVs) used for LMD often violates existing land-use regulations and results in negative externalities in the form of traffic congestion, higher vehicle emissions, and road safety hazards. As many as 75% of all logistical costs have been attributed to the LMD segment, which continues to be the costliest and most inefficient part of the supply chain. The inefficiency in the Indian context is further exacerbated by the general infrastructural deficiency and the presence of nonexistent specific loading zones.

The present system has very high levels of operational fragmentation, which in turn results in low vehicle fill rates because many small-volume B2C package deliveries to dispersed residential destinations replace integrated B2B transports. Furthermore, high percentages of failed first-time deliveries add to these costs and increase VKT from subsequent attempts. This illustrates a severe mismatch between outdated urban planning frameworks and the rapidly growing logistics sector. A proactive, data-driven, integrated approach to planning, according to the report, is necessitated by the need to manage this growth and progress towards sustainable urban environments. To achieve appropriate spatial integration, updating land-use regulations, strategic deployment of a network of CDPs, parcel lockers, and micro-hubs, and stimulating collaboration between public and private parties are recommended.

CHAPTER 4

FACTORS IDENTIFICATION AND TISM ANALYSIS

Identifying the critical spatial and operational factors influencing Q-commerce logistics systems in Bhopal city. The identified factors were derived through literature review, case-study analysis, field observations, and primary surveys. These variables were further analysed using Total Interpretive Structural Modelling (TISM) to understand the hierarchical and causal relationship between urban spatial conditions and delivery efficiency (Sushil, 2012).

The chapter establishes the structural relationship between urban morphology, accessibility, congestion, land use, and logistics operations to develop a planning-oriented understanding of Q-commerce systems in Tier-2 cities (Rodrigue, 2020).

Based on an extensive literature review, case studies, and preliminary field observations, several spatial and operational factors influencing the performance of Q-commerce logistics were identified. The development of an integrated urban freight framework for Bhopal required the systematic identification of variables that affect the efficiency of last-mile delivery operations within the city's diverse urban environment. To achieve this, urban freight literature, planning documents, the Bhopal Master Plan, field observations, and pilot surveys were comprehensively reviewed to identify the key factors governing hyperlocal logistics.

A total of ten core variables were selected, representing both the physical characteristics of the built environment and the operational conditions experienced by delivery networks. These variables provide a comprehensive basis for analysing the interactions between urban form, transport infrastructure, land-use patterns, and delivery performance. The selection of these factors was based on their frequency of occurrence in previous studies, their observed influence on logistics and delivery systems, and their relevance to the spatial and operational

context of Bhopal. The identified variables are presented in the analytical matrix below for subsequent TISM modelling and interpretation.

4.1 Factors Identification

Based on literature review, case studies, and preliminary field observations, several spatial and operational factors influencing Q-commerce logistics were identified. Developing an integrated urban freight framework requires identifying the spatial and operational variables that influence quick-commerce logistics within the city of Bhopal. Through a systematic evaluation of urban freight literature, local master plans, field observations, and initial pilot surveys, ten core variables were isolated. These factors capture both the physical constraints of the built environment and the operational realities of last-mile delivery networks, as summarized in the analytical matrix below:

The factors were selected on the basis of:

- frequency of occurrence in literature,
- observed impact on delivery systems,
- and relevance within the urban context of Bhopal city.

The variables are presented in table below.

Table 3: Identified factors affecting Q-commerce logistics (Source: Author)

Code	Factor	Description
F1	Topographical Fragmentation	Influence of lakes and terrain on accessibility
F2	Road Hierarchy	Availability of arterial and collector roads
F3	Traffic Congestion	Delay caused due to traffic conditions
F4	Land Use Compatibility	Compatibility of dark stores with surrounding land use
F5	Demand Density	Concentration of delivery demand
F6	Parking/Staging Availability	Space for rider waiting and loading
F7	Accessibility	Ease of reaching delivery sectors
F8	Delivery Radius	Service area efficiency

F9	Zoning Compliance	Compatibility with planning regulations
F10	Delivery Efficiency	Final delivery performance outcome

The identified factors collectively represent both spatial and operational dimensions of Q-commerce logistics systems (Allen et al., 2018).

4.2 Rationale of Factor selection

- The selected variables were considered important because they directly influence hyperlocal logistics efficiency and delivery movement patterns.
- Topographical fragmentation was identified as a major variable because Bhopal's lakes and uneven terrain create corridor dependency and accessibility barriers (Marshall, 2005).
- Road hierarchy and accessibility were included because efficient last-mile delivery systems depend heavily on arterial connectivity and movement penetration (Conway et al., 2016).
- Traffic congestion and parking availability were selected because they significantly affect rider waiting time, curbside loading, and delivery delay (Buldeo Rai et al., 2019).
- Land-use compatibility and zoning compliance were included to understand the planning implications of integrating dark stores within mixed-use and residential sectors (Dablanc, 2007).
- Delivery efficiency was identified as the final dependent outcome variable influenced by all other spatial and operational conditions.

The variables included in the TISM analysis were selected based on their direct influence on hyperlocal logistics performance and last-mile delivery efficiency. Topographical fragmentation was considered a key variable because Bhopal's lakes and uneven terrain restrict connectivity, creating corridor dependency and accessibility barriers that affect delivery movement (Marshall, 2005). Road hierarchy and accessibility were incorporated as efficient last-mile logistics rely on well-connected arterial and collector road networks to

ensure timely deliveries (Conway et al., 2016). Traffic congestion and parking availability were included due to their significant impact on travel time, rider waiting periods, curbside loading, and overall delivery delays (Buldeo Rai et al., 2019). Furthermore, land-use compatibility and zoning compliance were considered essential for assessing the suitability of dark store locations within residential, commercial, and mixed-use areas, ensuring better integration of logistics facilities into the urban environment (Dablanc, 2007). Delivery efficiency was identified as the final dependent variable, representing the cumulative outcome of the interactions among all spatial, infrastructural, and operational factors.

4.3 Introduction of TISM

Total Interpretive Structural Modelling (TISM) is a structural modelling technique used to analyse complex interrelationships among multiple variables through interpretive logic and hierarchical structuring (Sushil, 2012).

The methodology helps identify:

- driving variables,
- dependent variables,
- intermediate variables,
- and causal relationships.

Unlike conventional statistical techniques, TISM establishes directional relationships between variables and explains how one factor influences another within a structured hierarchy (Yadav & Sushil, 2014).

In this study, TISM was used to understand how urban spatial conditions collectively influence delivery efficiency within Q-commerce systems.

Total Interpretive Structural Modelling (TISM) is a structured analytical technique used to examine complex interrelationships among multiple variables by developing a hierarchical framework based on interpretive logic (Sushil, 2012). The methodology identifies driving, dependent, and intermediate variables while establishing the causal relationships among them. Unlike conventional statistical approaches that primarily measure correlations, TISM explains the direction and influence of one variable on another, providing a systematic

understanding of the underlying structure of a complex system (Yadav & Sushil, 2014). In this study, TISM was applied to analyse the interactions between urban spatial characteristics, land-use patterns, accessibility, transportation conditions, and operational factors, thereby identifying the key drivers influencing delivery efficiency in Bhopal's Q-commerce logistics network. The results provide a hierarchical framework that supports the formulation of planning strategies and logistics interventions for improving last-mile delivery performance.

4.4 Development of Structural Self-Interaction Matrix (SSIM)

The contextual relationship between identified variables was analysed using expert interpretation and literature-supported logic. It defines the direction of influence between factor pairs (i and j)

Table 4: Structural Self-Interactive Matrix (SSIM) (Source: Author)

Factors	F8	F7	F6	F5	F4	F3	F2
F1: Topography	V	V	O	O	O	V	O
F2: Zoning	O	V	V	V	O	O	-
F3: Road Hierarchy	V	V	X	A	O	-	
F4: Demand Density	X	V	O	V	-		
F5: Real Estate Availability	O	V	X	-			
F6: Parking Capacity	A	V	-				
F7: Delivery Speed	A	-					
F8: Traffic Dynamics	-						

V: Factor i influences Factor j

A: Factor j influences Factor i

X: Both factors influence each other

O: No relationship

- F3-F6 (X): A high-capacity Road Hierarchy allows for better Parking/Staging areas (like service lanes). Conversely, if a dark store has massive parking capacity, it prevents delivery bikes from spilling onto the main road, keeping the road hierarchy functional. F4-F8 (X): High Demand Density (more orders) creates more Traffic. However,

persistent traffic in an area can actually increase demand density because people prefer ordering in rather than driving out themselves.

- F5-F6 (X): The type of Real Estate available (e.g., a basement with a ramp) determines the Parking Capacity. In turn, a high need for parking forces operators to seek specific types of real estate.
- F3-F5 (A): While roads usually dictate where buildings go, in a Logistics Sprawl reversal, the availability of large Real Estate Gaps can force the city to upgrade the Road Hierarchy in that specific patch to handle truck movements.
- F6-F8 (A): High Traffic Dynamics (congestion) makes it impossible for bikes to park on the street, forcing a higher dependency on internal Parking Capacity.
- F7-F8 (A): Traffic is the enemy of Delivery Speed. Jams negatively impact fulfillment.
- F1-F3 (V): Bhopal's lakes are permanent physical barriers that force the Road Hierarchy to follow specific corridors (like VIP Road or Polytechnic Square), creating inevitable bottlenecks.
- F2-F5 (V): Zoning is the primary factor. If BDP 2031 does not recognize dark stores as a legal land use in residential zones, the Real Estate Availability for micro-hubs drops to zero.

The SSIM was prepared to establish pairwise relationships among all identified variables (Sushil, 2012).

4.5 Transition to initial reachability matrix

The SSIM was converted into a binary reachability matrix to identify driving and dependence power among variables.

The matrix helped determine:

- variables with high driving power,
- variables with high dependence,
- and operational interaction between factors.

The analysis revealed that topographical fragmentation and zoning compliance possess high driving power, whereas delivery efficiency exhibits high dependence.

Converting these symbols into the Binary (1s and 0s) table for your report.

Conversion Rules:

- If (i, j) is V: (i, j) = 1; (j, i) = 0
- If (i, j) is A: (i, j) = 0; (j, i) = 1
- If (i, j) is X: (i, j) = 1; (j, i) = 1
- If (i, j) is O: (i, j) = 0; (j, i) = 0

Table 5: Reachability matrix (Source: Author)

Factors	F1	F2	F3	F4	F5	F6	F7	F8
F1	1	0	1	0	0	0	1	1
F2	0	1	0	0	1	1	1	0
F3	0	0	1	0	0	1	1	1
F4	0	0	0	1	1	0	1	1
F5	0	0	1	0	1	1	1	0
F6	0	0	1	0	1	1	1	0
F7	0	0	0	0	0	0	1	0
F8	0	0	0	1	0	1	1	1

4.6 Factors Identification

Level partitioning was conducted to classify variables into hierarchical levels based on their driving and dependence characteristics.

The process helped identify:

- strategic variables,
- operational variables,
- and outcome variables.

The analysis demonstrated that:

- topography and zoning act as primary drivers,
- accessibility and congestion function as intermediate operational variables,

- and delivery efficiency acts as the final dependent variable.

➢ Level I: Final Outcome
  - F7: Delivery Speed (Fulfilment Time): It is the result of all other factors working together.

➢ Level II: Direct Impact Factors
  - F8: Traffic Congestion Dynamics: Directly influences how fast the last mile can be completed.
  - F4: Hyperlocal Demand Density: Dictates where the pressure on the system is highest.

➢ Level III: Operational Constraints
  - F6: Parking & Staging Capacity: If there is no space for bikes, they spill into traffic (F8).
  - F5: Real Estate Availability: The availability of underutilized urban spaces such as vacant plots, residual land parcels, and basement-level areas presents opportunities for accommodating dark store facilities within the existing urban fabric.
  - F3: Road Network Hierarchy: Determines the veins of the delivery system narrow lanes vs. arterial roads.

➢ Level IV: Strategic Drivers (Root Causes)
  - F1: Topographical Fragmentation (Lakes): that forces traffic into specific bottlenecks.
  - F2: Zoning Compliance (BDP 2031): that decides if a dark store is even allowed to exist in a neighbourhood.

4.7 Interpretation of TISM result

- The TISM analysis indicates that delivery inefficiency in Bhopal is primarily a spatial planning issue rather than only an operational issue.
- Topographical fragmentation creates forced movement corridors and accessibility limitations, increasing travel dependency on selected arterial roads (Marshall, 2005).
- Zoning compliance and land-use compatibility influence the spatial distribution of dark stores and determine whether logistics systems integrate efficiently within urban areas (Dablanc, 2007).

- Operational variables such as congestion, parking deficiency, and accessibility gaps further affect rider movement and delivery speed.
- The analysis establishes that improving delivery efficiency requires spatial planning interventions alongside operational improvements.

The TISM analysis indicates that delivery inefficiency in Bhopal is influenced more by spatial planning deficiencies than by operational factors alone. The city's fragmented urban form and topographical constraints create limited movement corridors, forcing delivery traffic onto a few major arterial roads and reducing network accessibility (Marshall, 2005). In addition, land-use compatibility and zoning regulations play a significant role in determining the location of dark stores and their integration within the urban fabric, directly affecting logistics performance (Dablanc, 2007). Operational factors such as traffic congestion, inadequate parking facilities, and accessibility barriers further increase travel time and reduce delivery efficiency. Overall, the analysis highlights that sustainable improvements in Q-commerce logistics require integrated spatial planning measures supported by operational enhancements, rather than focusing solely on delivery operations.

CHAPTER 5

SPATIAL ANALYSIS AND SURVEY ASSESSMENT

Analysing the existing spatial structure of Q-commerce logistics in Bhopal through GIS-based mapping and primary survey assessment. The chapter evaluates the relationship between dark store distribution, accessibility, congestion, delivery behaviour, and urban morphology to identify major operational and spatial constraints affecting hyperlocal logistics systems (Rodrigue, 2020).

The analysis integrates:

- spatial mapping,
- delivery pattern analysis,
- accessibility assessment,

and empirical survey findings.

The chapter establishes the spatial understanding required for developing planning standards and logistics framework recommendations (Taniguchi & Thompson, 2014).

This chapter presents a comprehensive analysis of the existing spatial structure and operational characteristics of the quick commerce (Q-commerce) logistics network in Bhopal through the integration of Geographic Information System (GIS)-based spatial mapping and primary survey data collected from delivery partners and dark store operators.

The analysis examines the spatial distribution of dark stores, their service coverage, accessibility to different urban zones, traffic congestion patterns, delivery behaviour, and the influence of urban morphology on last-mile logistics performance. Particular attention is given to understanding how factors such as road network configuration, land-use characteristics, population density, commercial activity, and residential development patterns affect delivery efficiency and the ability of Q-commerce platforms to meet rapid delivery timelines (Rodrigue, 2020). The chapter combines spatial mapping techniques, accessibility analysis, delivery pattern assessment, and empirical survey findings to identify the major

operational and spatial constraints within the existing logistics system. These include service overlap in central areas, limited logistics penetration in peripheral neighbourhoods, congestion-induced delays, and accessibility challenges in dense and gated communities. By establishing a detailed understanding of the current logistics landscape, the chapter provides the analytical foundation for the subsequent development of planning standards, site selection criteria, and an optimized urban logistics framework aimed at improving the efficiency, equity, and sustainability of Q-commerce operations in Bhopal (Taniguchi & Thompson, 2014).

5.1 Methodological flowchart for survey

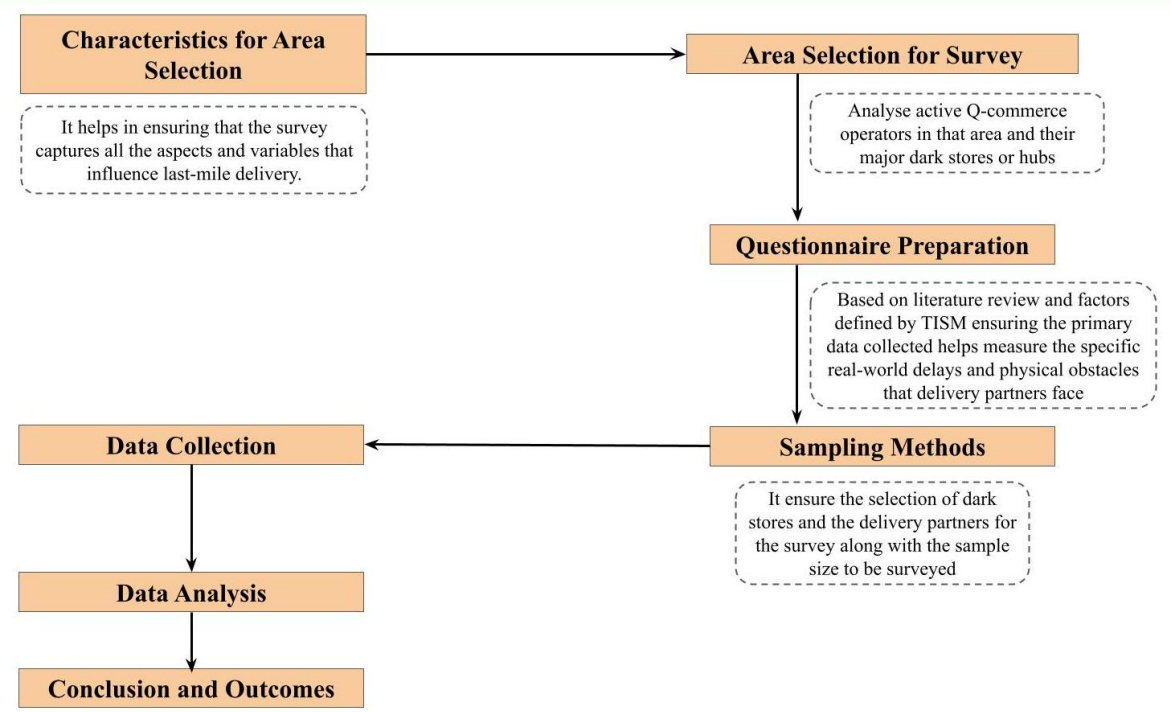


Figure 8: Survey Flowchart (Source: Author)

5.2 Characteristics for area selection

- Organic High-Density & Spatially Constrained Zones

  Area with organic growth patterns create topological complexity that directly hinders the 10-minute delivery promise.
- Planned Residential & HIG/MIG Demographics

High-income, digitally connected community are the primary drivers of Q-commerce demand density.

- Commercial Hubs & Floating Populations

  High employment density leads to parking stress and day-time surges that differ from residential evening peaks

- Emerging Peripheral & Gated Communities

  Modern gated complexes create a Service Time penalty that is independent of road travel time.

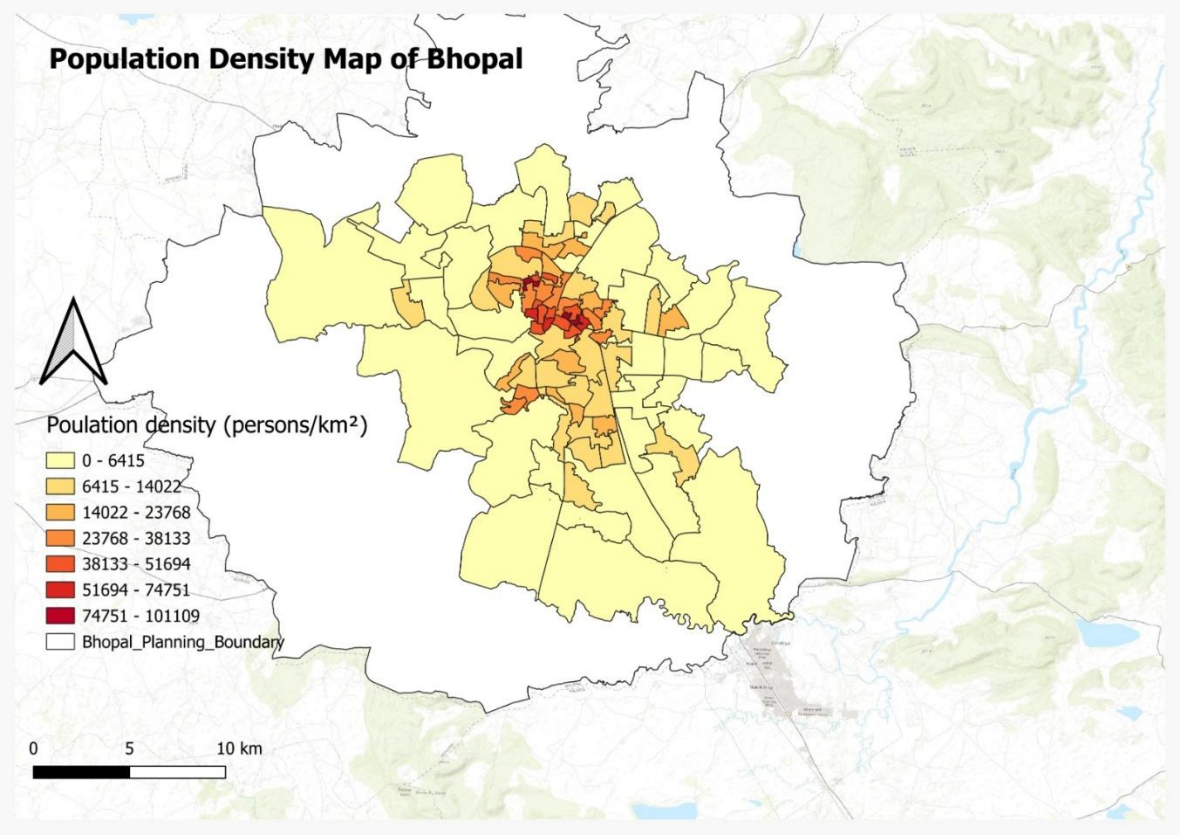


Figure 9: Population density map of Bhopal (Source: Author)

5.2.1 Land uses mix Entropy analysis

The Land Use Mix Entropy map measures the diversity of land uses within each grid cell. Areas exhibiting higher entropy values indicate a balanced mixture of residential, commercial, institutional, and recreational land uses.

A diverse land-use structure is considered advantageous for Q-commerce because:

- residential areas generate consumer demand,
- commercial activities increase order frequency,
- mixed-use neighbourhoods maintain demand throughout the day.

The map indicates that central Bhopal contains relatively higher entropy values, whereas peripheral regions are dominated by homogeneous land uses.

Therefore, high-entropy areas were considered more suitable for Q-commerce service coverage.

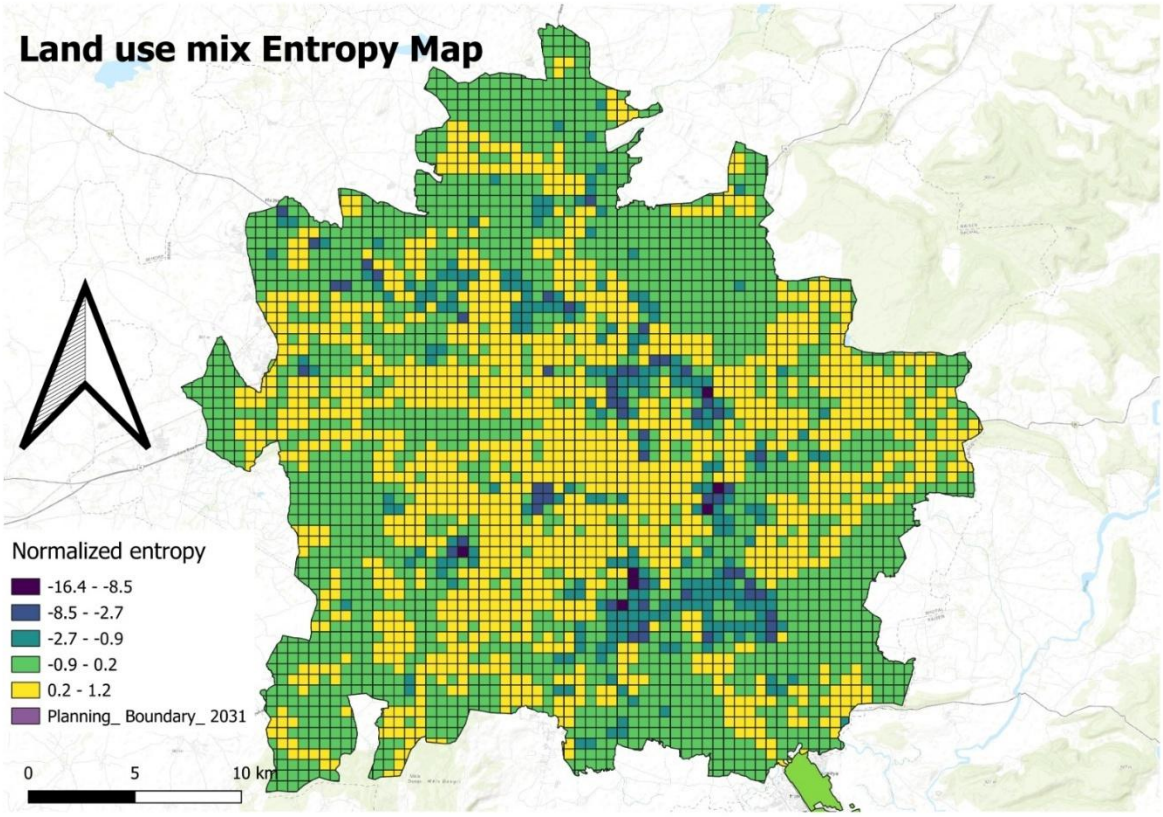


Figure 10: Land use mix Entropy Map (Source: Author)

5.2.2 Land use mix index

The normalized Land Use Mix Index was used to further evaluate the spatial balance of urban functions.

Areas with index values approaching 1 indicate highly integrated urban environments where residential and commercial activities coexist.

Such environments are favourable because they:

- reduce travel distance,
- improve delivery efficiency,
- support continuous demand generation.

The analysis reveals that central and south-central Bhopal exhibit the highest land-use mix, while peripheral regions remain largely mono-functional.

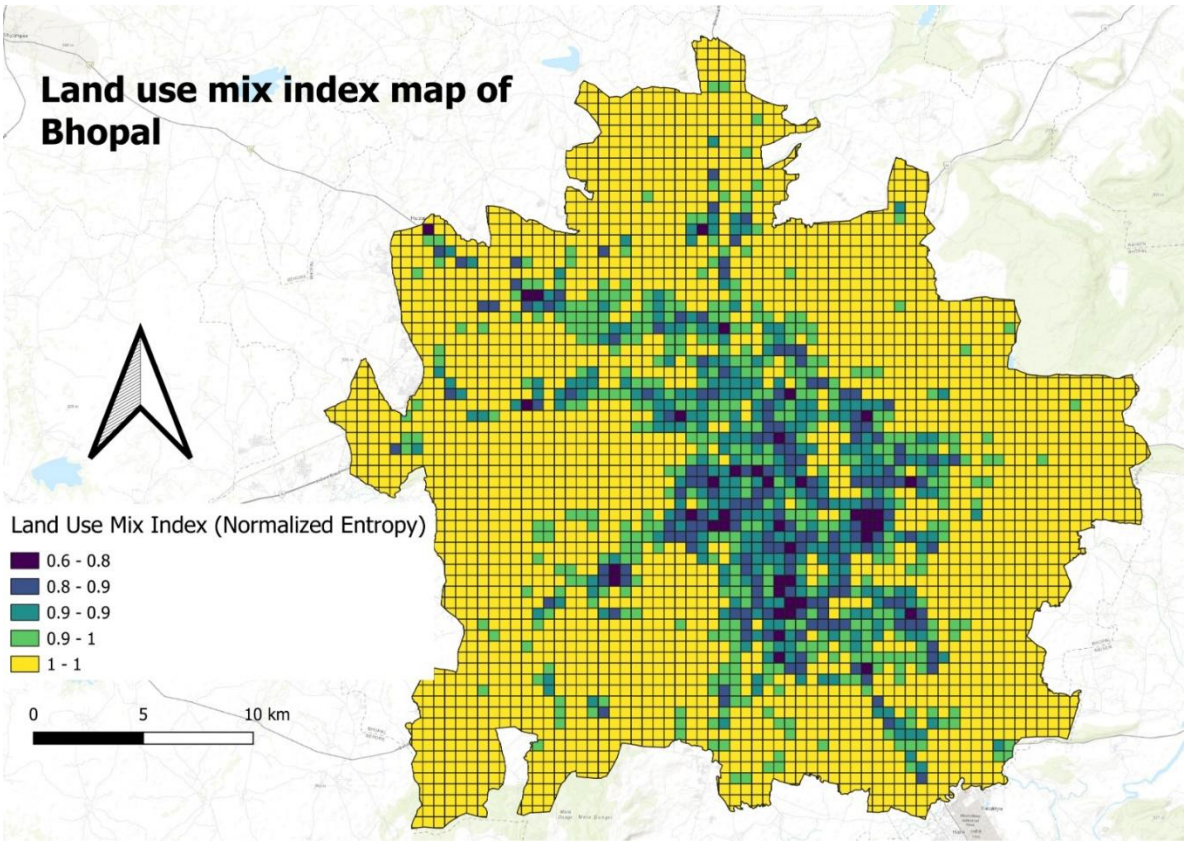


Figure 11: Land use mix index map of Bhopal (Source: Author)

5.2.3 Population Density Analysis

Population density represents the concentration of potential customers.

Higher population density generally translates into:

- higher order frequency,
- improved fleet utilization,
- shorter delivery intervals,

- better economic viability of dark stores.

The population density map shows that:

- the highest densities occur in the central urban core,
- medium densities extend toward eastern and southern Bhopal,
- peripheral regions exhibit sparse settlement patterns.

Therefore, high-density zones were identified as priority demand areas.

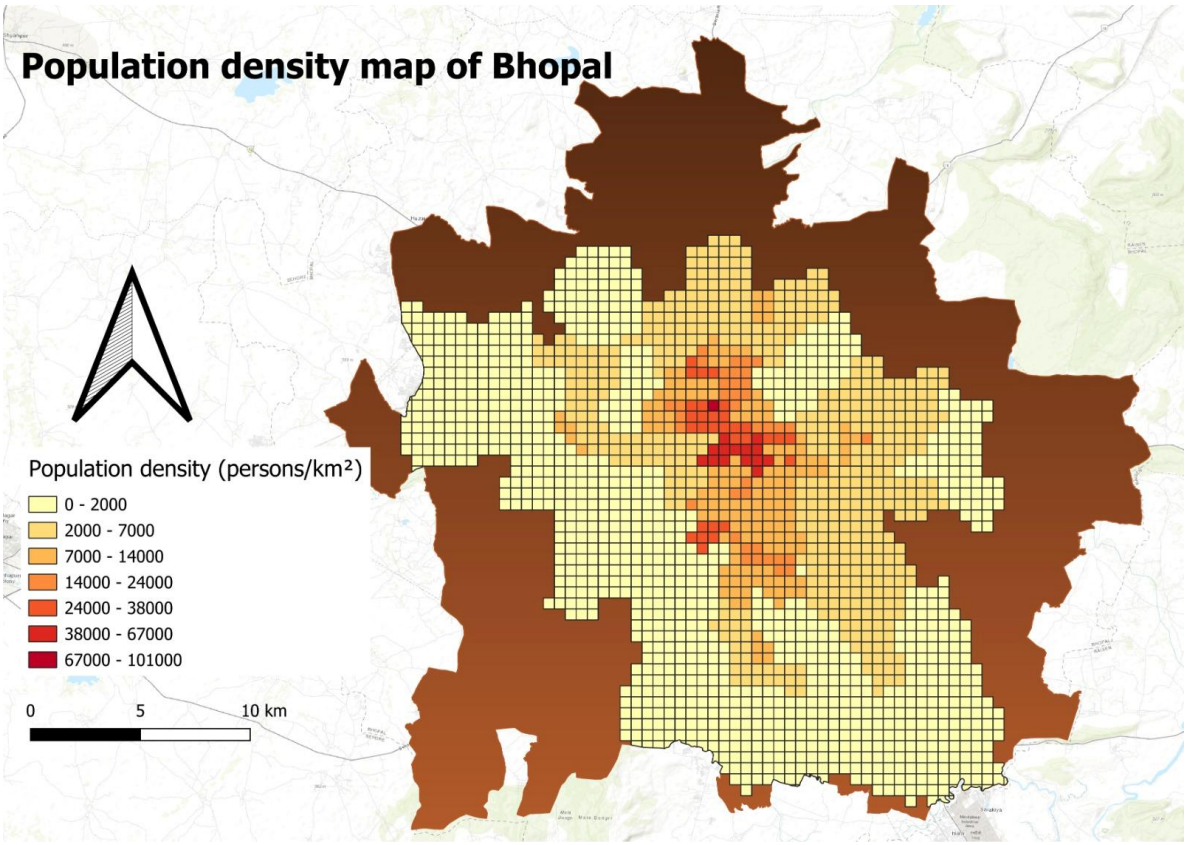


Figure 12: Population density map of Bhopal as per grid (Source: Author)

5.2.4 Road density analysis

Road density represents the availability and connectivity of the transport network.

High road density offers several operational advantages:

- multiple route alternatives,
- reduced travel distance,
- improved delivery reliability,

- better resilience during traffic congestion.

The map indicates that:

- central Bhopal possesses the highest road density,
- arterial corridors form strong connectivity across the city,
- peripheral regions have limited network coverage.

Since Q-commerce delivery performance depends heavily on travel time, road density was considered a major supply-side indicator.

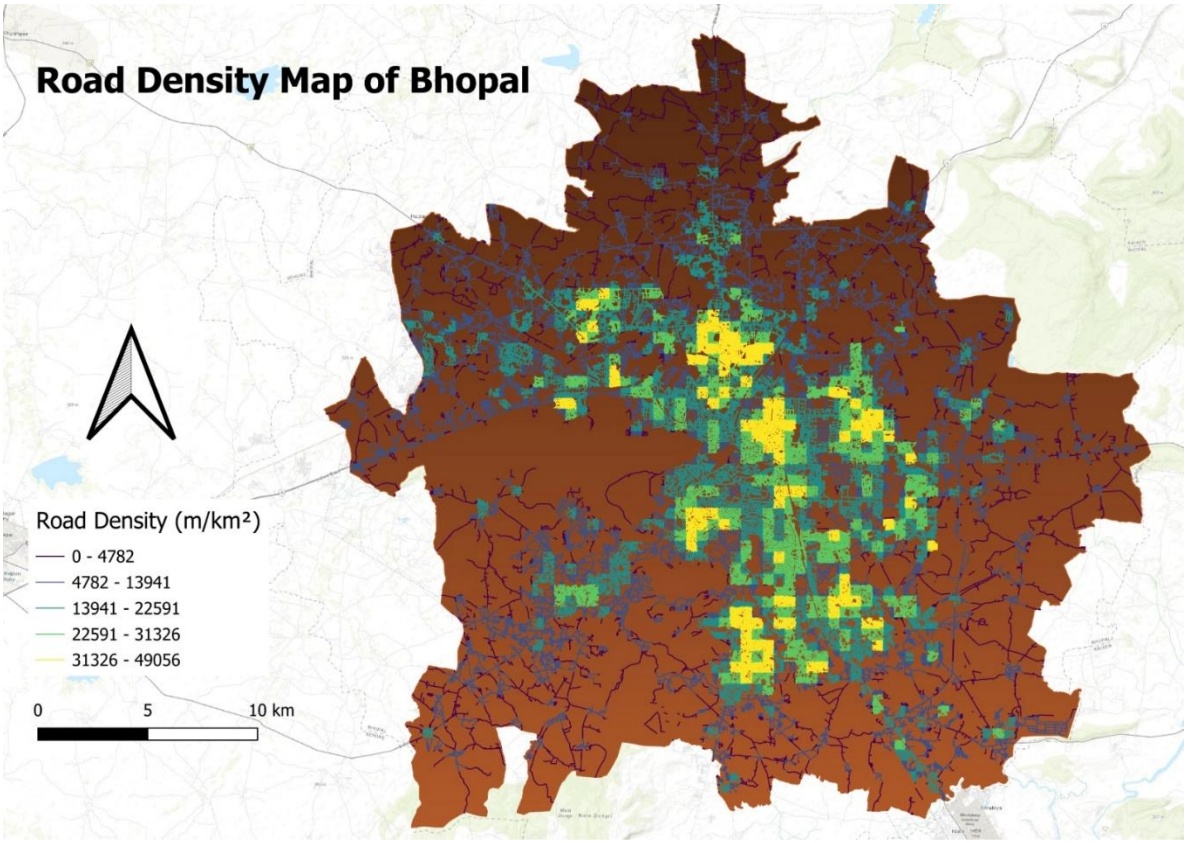


Figure 13: Road Density Map of Bhopal (Source: Author)

5.2.5 Urban Accessibility Index

The Urban Accessibility Index evaluates how easily different parts of the city can be reached through the existing transportation network.

Higher accessibility indicates:

- shorter travel times,

- improved connectivity,
- greater service coverage,
- lower transportation costs.

The highest accessibility values occur in central Bhopal and along major transportation corridors.

These areas are capable of supporting rapid delivery operations within the desired service time.

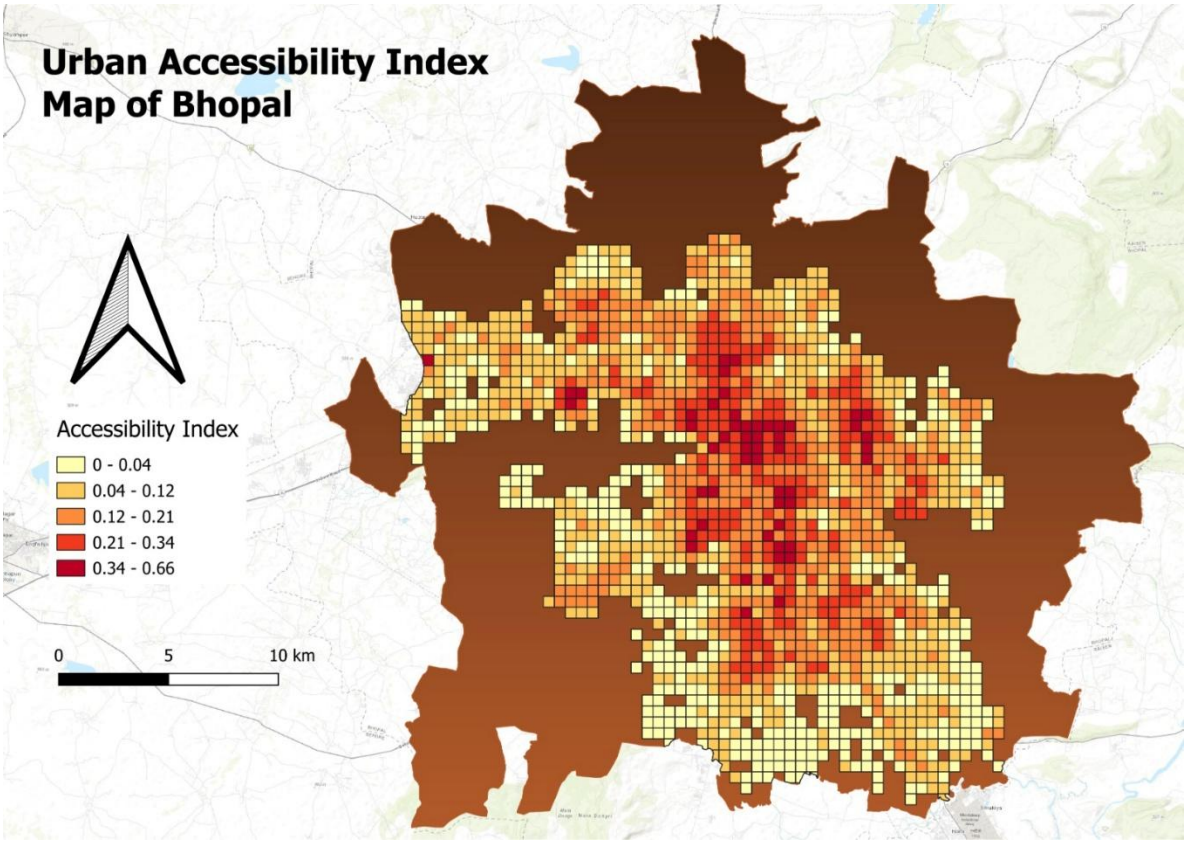


Figure 14: Urban Accessibility Index Map of Bhopal (Source: Author)

5.2.6 Q-commerce demand heatmap

The Q-commerce Demand Heatmap was developed by integrating demographic characteristics with urban activity patterns.

The demand index highlights locations where rapid grocery and essential goods delivery is expected to be highest.

The highest demand concentrations are observed within:

- central Bhopal,
- south-central corridor,
- eastern commercial districts.

These locations coincide with:

- dense residential neighbourhoods,
- mixed land use,
- commercial activity,
- high accessibility.

This confirms that demand is spatially concentrated rather than evenly distributed.

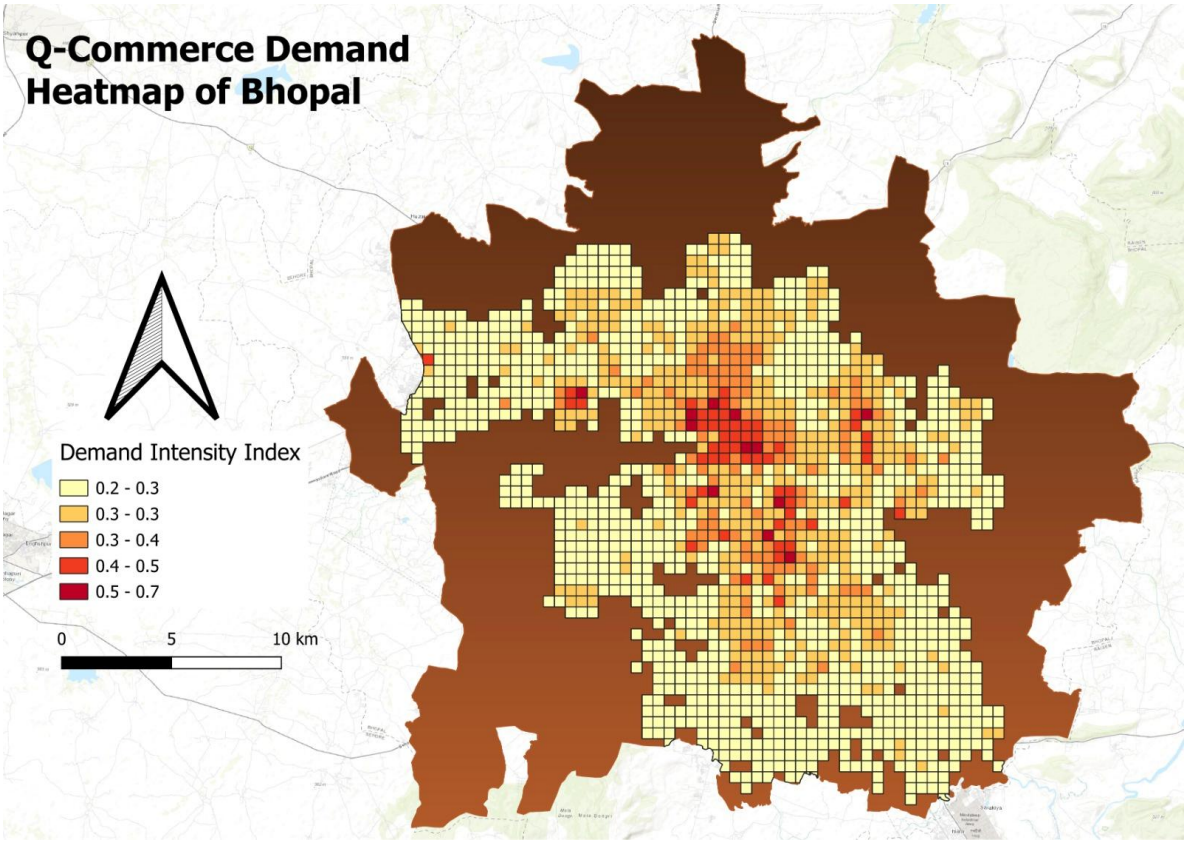


Figure 15: Q-commerce Demand heatmap of Bhopal (Source: Author)

The study area was classified into four major urban typologies based on land use and spatial characteristics. Organic high-density and spatially constrained zones were identified as areas with irregular street networks and dense development patterns that increase route complexity and hinder the efficiency of 10-minute deliveries. Planned residential areas, particularly High-Income Group (HIG) and Middle-Income Group (MIG) neighbourhoods, were

recognised as key demand generators due to higher digital adoption and purchasing power. Commercial hubs and areas with significant floating populations experience high daytime demand, traffic congestion, and parking constraints, creating delivery patterns that differ from those in residential areas. Additionally, emerging peripheral and gated communities were identified as locations where restricted access and internal circulation increase service time, thereby affecting delivery efficiency beyond the impact of road travel time alone.

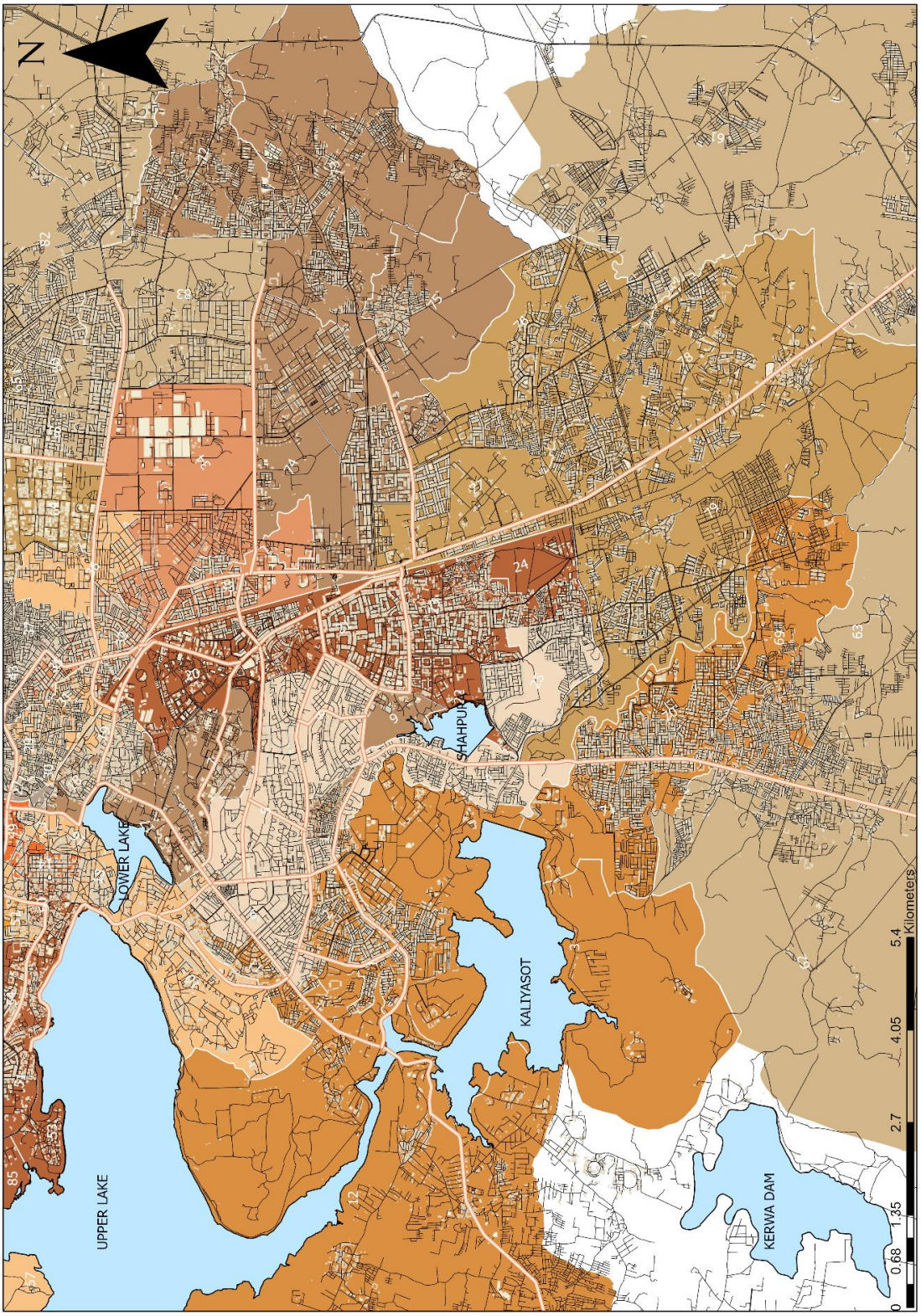


Figure 16: Base Map (Source: Author)

5.3 Questionnaire preparation

- Delivery Partner Personal Profile based Questions.
- Delivery partner Professional Profile including:
  - Experience as delivery partner?
  - Employment type?
  - Primary delivery platform
  - Working time frame in a day
  - Average working time per day
- Trip generation characteristics:
  - Average number of delivery trip per day
  - Peak delivery time frame
  - Typical delivery service area from dark store or pick-up point
  - Average waiting time at dark store between two deliveries
- Route choice and travel behaviour
  - Primary route selection method
  - Average number of turns or intersection per delivery
- Order hotspot area for that specific darkstore?
- Interventions which would most reduce delivery time?
- Delivery difficulties is highest in (old dense neighbourhood, planned residential colonies, apartment complexes, mixed use commercial streets, peripheral growth areas)

The primary survey questionnaire was designed to collect information on the personal and professional profiles of delivery partners, including their work experience, employment type, primary delivery platform, daily working schedule, and average working hours. The survey also captured trip generation characteristics such as the average number of deliveries completed per day, peak delivery time periods, typical delivery service area from the assigned dark store, and average waiting time between consecutive deliveries. In addition, respondents were asked about their route choice and travel behaviour, including the method used for route selection and the average number of turns or intersections encountered during each delivery.

The questionnaire further identified order hotspot locations associated with each dark store, the major operational challenges faced in different urban settings such as dense neighbourhoods, planned residential colonies, apartment complexes, commercial streets, and peripheral growth areas, and gathered suggestions on interventions that could help reduce delivery time and improve delivery efficiency.

5.4 Sampling method

- Cluster Sampling (for Dark store/hub selection)
  Selecting major dark stores (Blinkit, Swiggy Instamart) from the selected area for primary survey.
- Quota Sampling (selection of delivery partner for survey)
  To avoid bias data selecting the first 15-20 delivery partners from each dark store for survey
- **Sampling Size justification:**
  By using Slovin's Formula to justify number based on the estimated population of delivery partners in Bhopal (approx. 2,000-3,000)

$$n = \frac{N}{1 + N(e^2)}$$

N = Estimated total delivery partners in Bhopal

e = Margin of error (usually 0.05)

So based on this for a city like Bhopal, a sample of 150-200 responses will be statistically significant for the study

Cluster sampling was adopted to select major dark stores and fulfillment hubs, including Blinkit and Swiggy Instamart outlets, within the selected study area for the primary survey. Subsequently, quota sampling was used to select delivery partners from each dark store, with approximately 15-20 respondents surveyed from every location to ensure balanced representation and minimize sampling bias. The sample size was justified using Slovin's Formula, considering the estimated population of 2,000-3,000 delivery partners in Bhopal

and a margin of error of 5%. Based on this calculation, a sample size of approximately 150-200 delivery partners was considered statistically adequate to provide reliable and representative findings for the study.

5.5 Survey outcomes

- The survey reveals a significant rush of the logistics workforce, with 80% of delivery partners concentrated in the evening time slot.
- This data validates a high Peak-Hour Demand Intensity, where q-commerce activity synchronizes with the Return-to-Home commuter window.
- Despite the Employment Fluidity inherent in the gig economy where riders theoretically possess total temporal autonomy the workforce exhibits a Structured Participation Pattern: 40-50% operate as full-time equivalents (Primary Employment), while the remaining 50% function as part-time secondary labor.
- This concentration in the evening, regardless of individual choice, serves as a direct proxy for identifying Evening Surge Hotspots, indicating that the city's logistical network faces its highest Spatial-Temporal Stress during these hours.

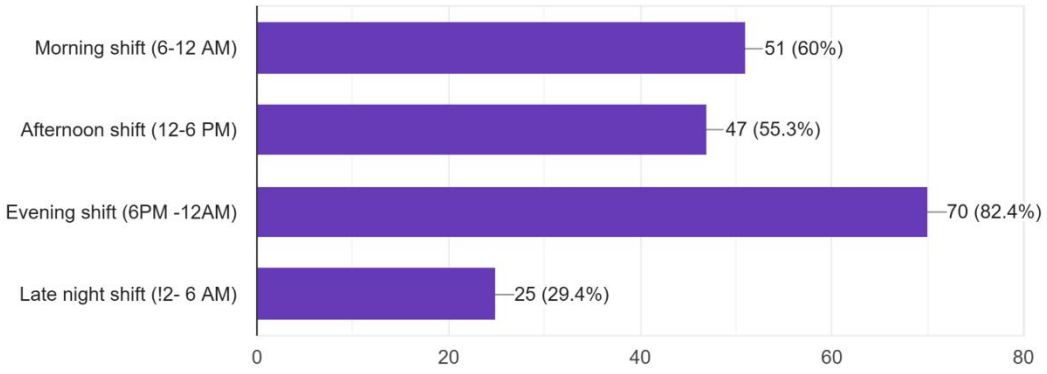


Figure 17: Working time frame (Source: Author)

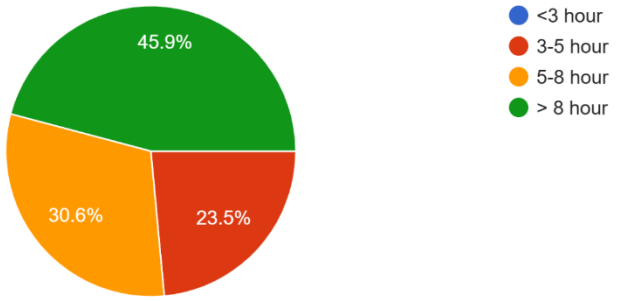


Figure 18: Average working time (Source: Author)

- Typically rider handles moderate but consistent load with a range of 10-30 delivery trip/ day/ delivery partner.
- This indicates system is near capacity but not overloaded by evaluating this with working time frame which comes out to be 8-12 hours of shift per day.
- Through this we can also conclude that the riders are on their peak efficiency now to overcome the growing demand their should be enhancement in route optimization and dark store location.

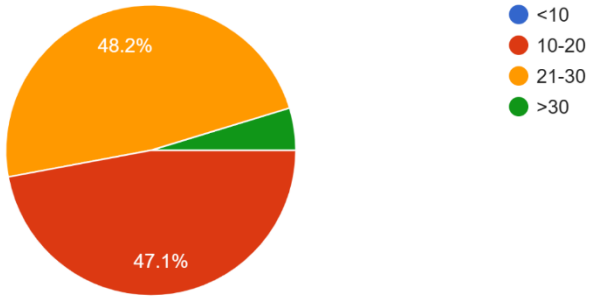


Figure 19: Average number of delivery trips per day (Source: Author)

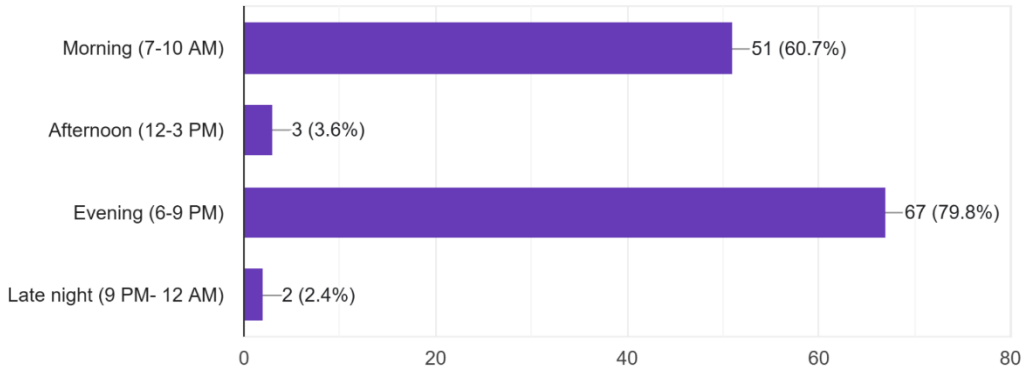


Figure 20: Peak delivery period (Source: Author)

- The Q-commerce model is currently Logistically Sprawled rather than Hyperlocal as typically delivery partner has to travel more than 3 km for the deliveries which is preferred to be 2-3 km as per the delivery time frame consideration of 10-15 minutes delivery for Q-commerce industry.
- As delivery range is greater than 3 km significantly increases Vehicle Kilometers Traveled (VKT) and exposure to traffic bottlenecks.
- Which indicate towards dark store density inefficiency as per hotspot areas, stating poor spatial distribution of fulfillment centers.

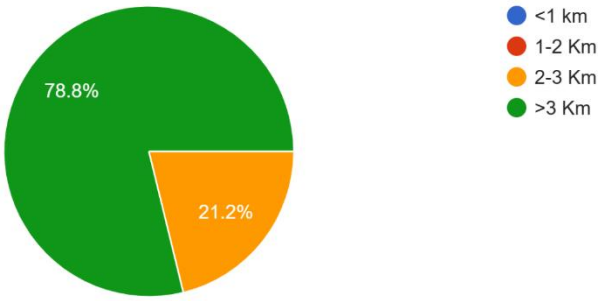


Figure 21: Typical delivery service area from pickup point (Source: Author)

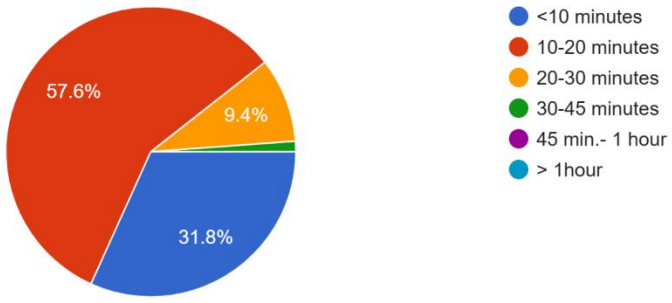


Figure 22: Average waiting time at dark store between two deliveries (Source: Author)

- The last mile in Bhopal is non-linear and spatially complex, with over 90% of trips requiring at least 5 major directional changes.
- As intersection counts ranging between 5-15 turns per trip directly correlate with Signal Waiting Time and Intersection Delays identified in constraints data.

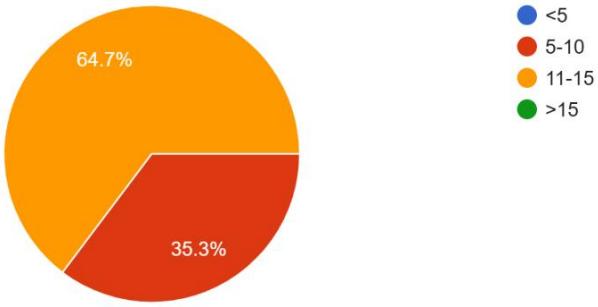


Figure 23: Average number of turn/intersections per delivery (Source: Author)

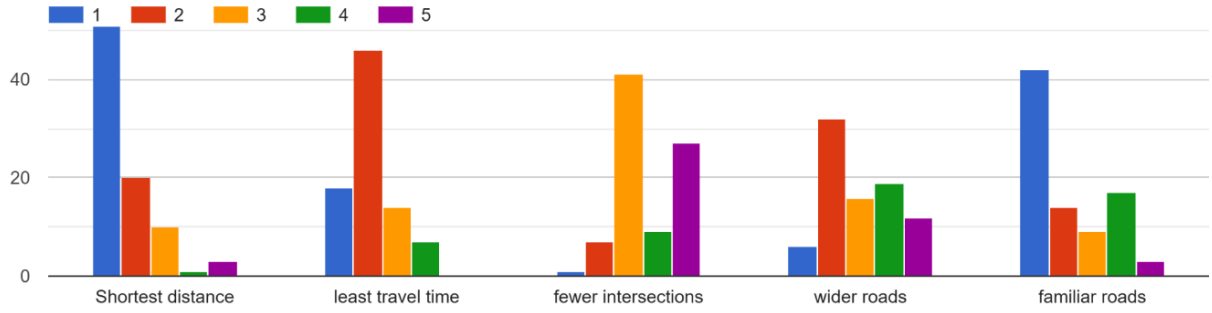


Figure 24: Preference in route choice (hierarchy) (Source: Author)

- Delivery partners believe that managing how vehicles move (traffic/signals) is more effective than building new roads.
- Since demand peaks in the evening, Peak Hour Management is seen as the important constraint for efficiency.
- High turn counts make intersection delays a primary cause in the rider's journey.

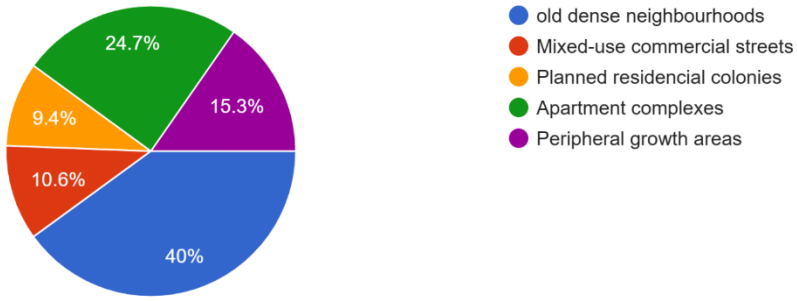


Figure 25: Delivery difficulty is highest (Source: Author)

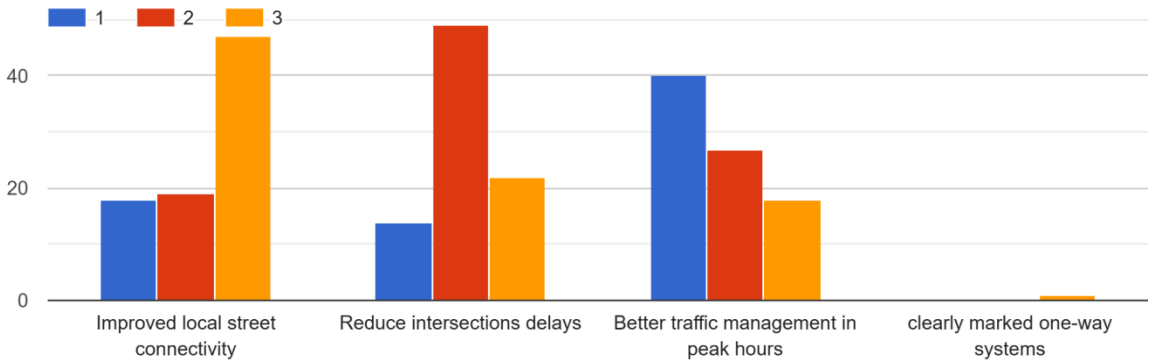


Figure 26: Which interventions would most reduce delivery time? (top-3) (Source: Author)

The rider survey provides important insights into the operational characteristics of the Q-commerce delivery network in Bhopal. The results show that approximately 80% of delivery partners are active during the evening time slot, indicating a strong concentration of logistics activity during peak demand hours. This pattern coincides with the evening commuter period, suggesting that the logistics network experiences its highest operational pressure when delivery demand overlaps with regular urban traffic. Although delivery work in the gig economy offers flexible working hours, the survey reveals a structured participation pattern in which nearly half of the riders work full-time while the remainder operate on a part-time

basis. This workforce concentration during evening hours highlights the need for improved traffic management and logistics planning during peak periods.

The survey further indicates that most delivery partners complete between 10 and 30 deliveries per day while typically working shifts of 8 to 12 hours. This suggests that the current logistics system is operating close to its practical capacity, with riders maintaining consistent productivity throughout their shifts. As demand for quick-commerce services continues to increase, further improvements in route optimization and a more balanced distribution of dark stores will be necessary to maintain delivery efficiency without increasing rider workload.

Analysis of delivery service areas shows that many riders regularly travel beyond the preferred hyperlocal delivery radius of 2-3 km, with deliveries frequently extending to distances greater than 3 km. Such extended service areas increase travel distance, exposure to traffic congestion, and overall vehicle kilometres travelled, reducing the operational efficiency of last-mile delivery. This finding also suggests that the existing distribution of dark stores is spatially inefficient, particularly in high-demand areas where additional fulfilment facilities may be required to shorten delivery distances.

The survey also highlights the complexity of last-mile movement within the city. More than 90% of delivery trips require at least five major turns or intersections, indicating that delivery routes are highly non-linear and strongly influenced by the existing road network. A greater number of intersections increases signal delays, travel uncertainty, and delivery time, particularly during congested periods. Rider responses further reveal a preference for using higher-order roads wherever possible, emphasizing the importance of road hierarchy in determining route choice and delivery efficiency.

Finally, delivery partners identified traffic management measures, including better signal coordination and improved vehicle movement, as more effective solutions than constructing new roads. Since delivery demand reaches its peak during evening hours, respondents considered peak-hour traffic management to be one of the most important interventions for

improving logistics performance. The combination of long delivery distances, frequent intersections, and congestion-related delays demonstrates that enhancing traffic operations, optimizing dark store locations, and improving route planning would significantly reduce delivery times and strengthen the efficiency of Bhopal's Q-commerce logistics network.

5.6 Existing Dark store distribution analysis

Existing dark stores operating within Bhopal city were mapped to analyse their spatial distribution and service coverage patterns.

The analysis included:

- Blinkit dark stores,
- Instamart dark stores,
- Jiomart delivery centres,
- and other hyperlocal fulfillment nodes.

The mapping revealed that most dark stores are concentrated along major arterial corridors such as:

- MP Nagar,
- Hoshangabad Road,
- Kolar Road,
- and New Market areas.

These corridors exhibit higher accessibility, commercial activity, and demand concentration, making them favorable for logistics operations (Allen et al., 2018).

The analysis further identified that central urban sectors exhibit overlapping service radii, whereas peripheral areas remain underserved and outside efficient delivery coverage.

Key Findings:

- Dark stores are corridor dependent.
- Central areas show excessive service overlap.
- Peripheral sectors lack logistics penetration.
- Existing systems follow accessibility rather than balanced distribution.

Existing dark stores operating within Bhopal were mapped to analyse their spatial distribution and service coverage patterns. The assessment included facilities operated by Blinkit, Instamart, Jiomart, and other hyperlocal fulfilment providers. The mapping revealed that most dark stores are concentrated along major arterial corridors, particularly in MP Nagar, Hoshangabad Road, Kolar Road, and the New Market area. These locations offer better accessibility, strong commercial activity, and higher customer demand, making them attractive for logistics operations (Allen et al., 2018).

The spatial analysis further showed that central parts of the city have a high concentration of dark stores with overlapping service areas, while several peripheral neighborhoods remain underserved and fall outside efficient delivery coverage. This uneven distribution indicates that the current logistics network is largely driven by accessibility and market demand rather than a balanced spatial planning approach. Overall, the findings highlight a strong dependence on major transport corridors, excessive service overlap in central areas, and inadequate logistics penetration in the city's peripheral sectors.

5.7 Delivery radius analysis

Delivery radius analysis was conducted to understand the operational reach and efficiency of existing dark stores.

The assessment revealed that several dark stores operate beyond the efficient hyperlocal delivery radius of approximately 2-3 km. Extended delivery radius increases:

- rider travel distance,
- operational delay,
- fuel consumption,
- and congestion exposure (Buldeo Rai et al., 2019).

The analysis further indicated that sectors located away from arterial roads experience higher delivery time due to limited accessibility and fragmented road structure.

Key Findings

- Several delivery zones exceed efficient service radius.
- Peripheral sectors experience delayed delivery response.

- Accessibility reduces with increasing distance from arterial roads.

Delivery radius analysis was conducted to evaluate the operational reach and efficiency of existing dark stores across Bhopal. The assessment revealed that several facilities serve areas extending beyond the optimal hyperlocal delivery radius of approximately 2-3 km. Operating beyond this efficient service range increases rider travel distance, delivery time, fuel consumption, and exposure to traffic congestion, ultimately reducing the overall efficiency of last-mile logistics operations (Buldeo Rai et al., 2019). The analysis also showed that neighborhoods located farther from major arterial roads experience longer delivery times because of limited accessibility, fragmented road networks, and indirect travel routes.

Overall, the findings suggest that the current service areas of several dark stores exceed their efficient operational radius, resulting in delayed delivery responses, particularly in peripheral sectors. Accessibility also declines with increasing distance from arterial roads, highlighting the need for a more balanced spatial distribution of dark stores to improve service coverage and delivery efficiency.

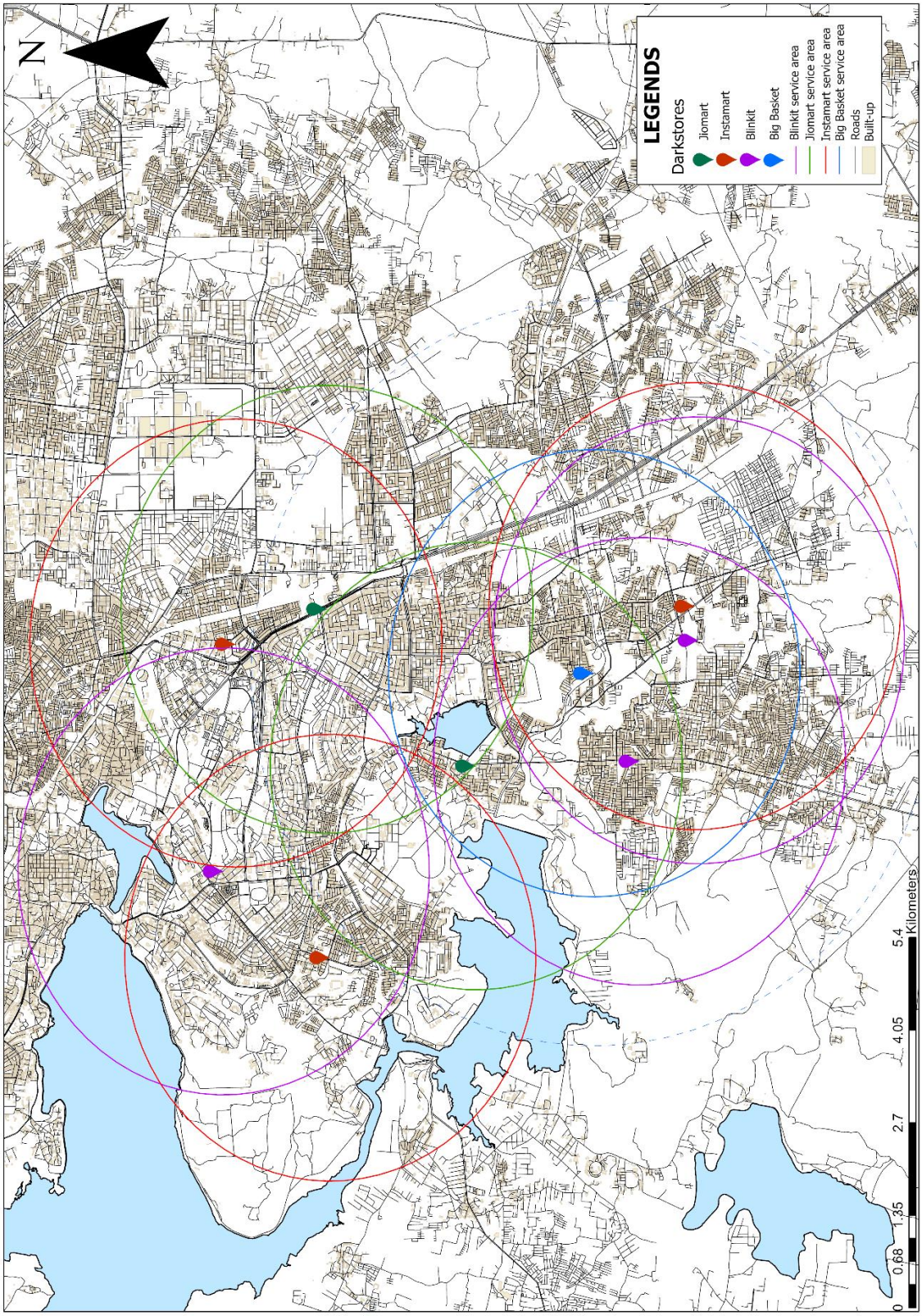


Figure 27: Existing darkstore location and service area (Source: Author)

5.8 Corridor dependency analysis

The study identified strong corridor dependency within the existing Q-commerce network. Major delivery movement was concentrated along:

- Hoshangabad Road,
- VIP Road,
- MP Nagar Corridor,
- and Kolar Corridor.

The presence of lakes and fragmented urban growth creates limited cross-connectivity, forcing delivery movement onto selected arterial routes (Marshall, 2005).

The analysis revealed that congestion bottlenecks are concentrated around:

- major intersections,
- mixed-use commercial sectors,
- and corridor transition points.

Key Findings

- Delivery movement is concentrated along arterial corridors.
- Limited alternate connectivity increases congestion dependency.
- Corridor intersections act as logistics stress points.

The spatial analysis identified a strong corridor dependency within Bhopal's existing Q-commerce logistics network. Most delivery movements are concentrated along major arterial corridors, including Hoshangabad Road, VIP Road, the MP Nagar Corridor, and the Kolar Corridor, where accessibility and commercial activity are comparatively higher. The city's physical geography, particularly the presence of lakes and fragmented patterns of urban development, limits cross-connectivity between different areas and forces delivery traffic onto a few primary routes (Marshall, 2005). As a result, these corridors experience a high volume of logistics movement and serve as the backbone of the current delivery network.

The analysis further revealed that congestion bottlenecks are primarily located at major intersections, mixed-use commercial areas, and corridor transition points where traffic from multiple directions converges. This concentration of delivery activity increases pressure on the existing road network, particularly during peak hours, and reduces the efficiency of last-

mile logistics operations. Overall, the findings indicate that the heavy reliance on a limited number of arterial corridors, combined with insufficient alternative routes, contributes to recurring congestion and creates logistics stress points across the city's transportation network.

5.9 Accessibility assessment

Accessibility assessment was conducted to identify underserved areas and evaluate the efficiency of the existing logistics network.

The analysis examined:

- accessibility to dark stores,
- delivery penetration,
- connectivity,
- and service efficiency.

The assessment demonstrated that:

- central sectors have high accessibility,
- while peripheral residential sectors remain underserved.

Organic settlements and narrow-road sectors showed lower accessibility efficiency because of movement restrictions and route complexity (Conway et al., 2016).

Key Findings

- Uneven accessibility distribution.
- Peripheral accessibility gaps.
- Reduced efficiency in organic settlements.
- High accessibility near arterial roads.

Accessibility assessment was conducted to evaluate the efficiency of the existing logistics network and identify areas with limited access to Q-commerce services. The analysis considered accessibility to dark stores, delivery coverage, road connectivity, and overall service efficiency across different parts of the city. The results indicate that central urban sectors benefit from relatively high accessibility due to a greater concentration of dark stores and well-connected road networks. In contrast, several peripheral residential areas remain

underserved, resulting in lower service coverage and longer delivery distances. Organic settlements and areas characterized by narrow road networks also exhibited lower accessibility because of movement restrictions, limited road capacity, and complex route configurations, which reduce the efficiency of last-mile delivery operations (Conway et al., 2016).

Overall, the assessment highlights an uneven spatial distribution of accessibility, with significant service gaps in peripheral areas. While locations near major arterial roads demonstrate higher delivery efficiency, accessibility remains comparatively poor in dense organic settlements, emphasizing the need for more balanced and strategically planned logistics infrastructure.

5.10 Traffic congestion and operational constraints

Traffic congestion analysis was conducted using field observations and rider survey responses.

The study identified that:

- signal intersections,
- mixed traffic movement,
- roadside parking,
- and commercial activity

significantly affect delivery movement and rider efficiency.

Field observations revealed that several dark stores lack dedicated rider staging and parking space, resulting in:

- curbside spillover,
- rider waiting conflicts,
- and localized congestion.

Congestion was found to be highest during evening peak periods because of overlapping commuter traffic and delivery demand (Buldeo Rai et al., 2019).

Key Findings

- Congestion delays delivery efficiency.
- Lack of staging space creates roadside conflicts.

- Peak-hour periods increase operational delay.

Traffic congestion analysis was conducted using field observations and responses collected through the rider survey. The findings indicate that delivery operations are significantly influenced by signalized intersections, mixed traffic conditions, roadside parking, and intense commercial activities, all of which contribute to delays in last-mile deliveries. Field observations further revealed that many existing dark stores do not provide dedicated rider staging or parking facilities, forcing delivery personnel to occupy roadside spaces. This results in curbside spillover, conflicts between riders and other road users, and localized traffic congestion around logistics facilities. The analysis also showed that congestion is most severe during evening peak hours, when regular commuter traffic coincides with high delivery demand, leading to increased travel times and reduced operational efficiency (Buldeo Rai et al., 2019).

Overall, the findings demonstrate that traffic congestion is a major factor affecting delivery performance. The lack of designated staging space around dark stores further intensifies roadside conflicts, while peak-hour traffic conditions significantly increase delivery delays, highlighting the need for better logistics infrastructure and traffic management measures.

5.11 Spatial synthesis of findings

The combined spatial and survey analysis demonstrates that Q-commerce logistics efficiency in Bhopal is strongly dependent on:

- accessibility,
- road hierarchy,
- urban morphology,
- and congestion conditions.

The findings indicate that existing logistics systems are:

- spatially uneven,
- corridor dependent,
- and operationally stressed in high-demand sectors.

The study further establishes that:

- delivery inefficiency is linked with urban structure,
- several areas remain underserved,
- and existing dark store placement lacks planning integration.

The spatial synthesis highlights the need for:

- decentralized fulfilment systems,
- logistics-compatible zoning,
- accessibility-based dark store planning,
- and infrastructure-supported delivery systems (Taniguchi & Thompson, 2014).

The combined spatial and survey analysis demonstrates that the efficiency of Q-commerce logistics in Bhopal is largely influenced by accessibility, road hierarchy, urban morphology, and prevailing congestion conditions. The findings reveal that the existing logistics network is spatially uneven, with a high concentration of facilities along major transport corridors and increasing operational pressure in high-demand urban sectors. The study also establishes that delivery performance is closely associated with the city's spatial structure, with several peripheral areas remaining underserved while the location of existing dark stores reflects market-driven expansion rather than planned spatial integration.

These findings emphasize the need for a more strategic approach to urban logistics planning. The study recommends the adoption of decentralized fulfilment systems, logistics-compatible zoning, accessibility-based dark store location planning, and supporting infrastructure to improve the efficiency, equity, and sustainability of last-mile delivery operations (Taniguchi & Thompson, 2014).

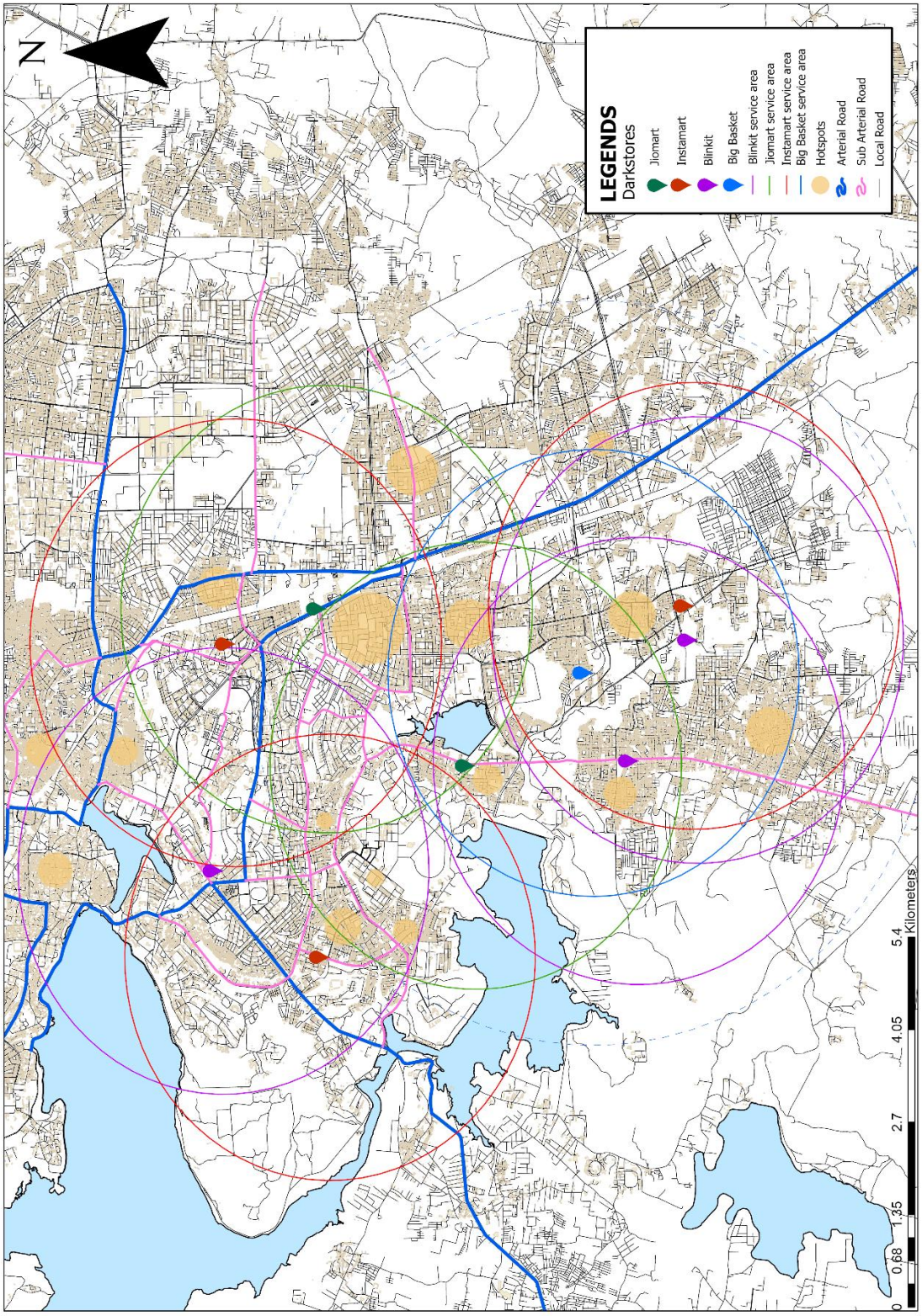


Figure 28: Road hierarchy and demand hotspots (Source: Author)

CHAPTER 6
SPATIAL PLANNING FRAMEWORK AND PROPOSAL

This chapter presents the final outcome of the study in the form of a spatial planning framework for integrating Q-commerce logistics into Tier-2 urban systems. The framework has been developed using findings derived from TISM analysis, spatial assessment, accessibility analysis, and primary survey investigation conducted within Bhopal city.

The previous chapters established that the existing Q-commerce logistics system in Bhopal is highly dependent on arterial corridors, spatially uneven, and operationally constrained due to fragmented urban morphology, congestion, accessibility gaps, and lack of logistics-compatible planning regulations. The study further identified that delivery inefficiency is not solely an operational issue but a consequence of urban spatial structure and infrastructure limitations (Rodrigue, 2020).

This chapter presents the final outcome of the research by proposing a comprehensive spatial planning framework for the integration of quick-commerce (Q-commerce) logistics into the urban structure of Tier-2 cities. The framework has been formulated by synthesizing the findings obtained from the Total Interpretive Structural Modelling (TISM) analysis, spatial distribution assessment, accessibility analysis, and primary surveys conducted across selected Q-commerce facilities in Bhopal. Each stage of the research contributed to identifying the critical spatial, operational, and planning-related factors that influence the efficiency of hyperlocal delivery systems.

The analyses carried out in the previous chapters indicate that the existing Q-commerce network in Bhopal has evolved primarily in response to market demand rather than through planned urban development. As a result, the location of dark stores and fulfilment centres is concentrated along major arterial roads, while several residential neighbourhoods remain

underserved. This uneven spatial distribution has created disparities in delivery coverage and has increased pressure on already congested transport corridors. The absence of planning guidelines for logistics infrastructure has further intensified operational challenges, leading to inefficient rider movement, roadside parking conflicts, and longer delivery routes.

The study also demonstrates that the performance of Q-commerce logistics is closely linked to the spatial characteristics of the city. Factors such as road hierarchy, land-use distribution, accessibility to residential areas, availability of vacant land, and supporting infrastructure collectively influence delivery efficiency. Therefore, issues related to delayed deliveries or traffic congestion cannot be viewed only as operational concerns; they are largely the result of urban spatial structure, inadequate infrastructure, and the lack of logistics-sensitive planning policies. These findings support the argument that sustainable hyperlocal delivery systems require interventions at the planning stage rather than relying solely on improvements in logistics operations (Rodrigue, 2020).

Based on these observations, the study moves beyond conventional operational optimization approaches and proposes a planning-oriented logistics framework that integrates urban planning principles with the functional requirements of Q-commerce. The framework brings together multiple planning components, including land-use planning, accessibility assessment, urban freight management, delivery-support infrastructure, and zoning regulations. Instead of treating logistics facilities as isolated commercial establishments, the proposed approach recognizes them as an essential element of contemporary urban infrastructure that must be systematically incorporated into city planning and development control mechanisms.

The framework emphasizes the creation of a decentralized and balanced logistics network in which dark stores are strategically distributed across the urban area according to population density, service demand, accessibility, and transport connectivity. Such an approach minimizes excessive dependence on a limited number of logistics hubs, reduces delivery travel distances, improves service reliability, and enhances operational resilience. Furthermore, integrating logistics infrastructure with existing and future land-use planning

ensures that rapid urban expansion is supported by efficient delivery systems without creating additional traffic or environmental burdens.

In addition to addressing present-day operational challenges, the proposed framework establishes a foundation for future planning policies that can be adopted by urban local bodies, planning authorities, and private developers. The recommendations are intended to guide the systematic inclusion of Q-commerce infrastructure within development plans, zoning regulations, and neighbourhood-level planning standards. By promoting accessibility, efficient freight movement, and compatible land-use integration, the framework contributes towards building sustainable, organized, and resilient hyperlocal logistics systems suitable for rapidly growing Tier-2 Indian cities. The overall approach aligns with the principles of urban freight planning advocated by Taniguchi and Thompson (2014), emphasizing that logistics infrastructure should form an integral part of urban planning rather than being introduced as a reactive response to market growth.

Therefore, instead of proposing isolated operational optimization measures, the study proposes a planning-oriented logistics framework integrating:

- land use,
- accessibility,
- urban freight systems,
- delivery infrastructure,
- and zoning mechanisms.

The proposed framework aims to establish a balanced, decentralized, and accessibility-oriented hyperlocal logistics network suitable for Tier-2 Indian cities (Taniguchi & Thompson, 2014).

6.1 Conceptual bases of planning framework

The proposed framework is based on the understanding that Q-commerce logistics functions as an emerging urban service infrastructure similar to public transport, utilities, and commercial systems. However, unlike conventional urban infrastructure, Q-commerce

systems currently operate without dedicated spatial planning standards, resulting in unregulated concentration of dark stores and inefficient logistics movement.

The framework is conceptually derived from the relationship established through TISM analysis:

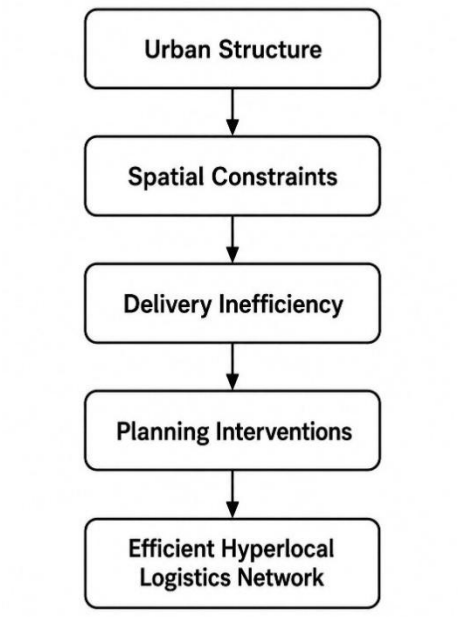


Figure 29: TISM analysis (Source: Author)

The framework recognizes that:

- urban morphology influences accessibility,
- accessibility influences delivery movement,
- and delivery movement influences operational efficiency.

Therefore, improving logistics efficiency requires interventions at both:

- spatial planning level, and
- operational infrastructure level.

The framework combines:

- spatial suitability,
- accessibility efficiency,
- population demand,
- logistics zoning,

- and infrastructure integration

to create a planning-based approach for Q-commerce logistics systems (Allen et al., 2018).

6.2 Population based dark store requirement framework

One of the major findings of the study was that the existing distribution of dark stores in Bhopal follows market-driven expansion rather than balanced service accessibility. Several central sectors showed excessive overlap of delivery areas while peripheral areas lacked adequate logistics coverage.

To address this imbalance, the study proposes a population-based dark store requirement framework.

The framework establishes indicative infrastructure standards based on:

- population concentration,
- service demand,
- accessibility conditions,
- and delivery radius efficiency.

One of the major findings of the study was that the current distribution of dark stores in Bhopal is primarily driven by market demand rather than equitable service accessibility. As a result, several central urban sectors exhibit a high concentration of dark stores with overlapping delivery catchments, whereas many peripheral areas remain underserved despite increasing residential growth. This uneven spatial distribution reduces the overall efficiency of the logistics network and creates disparities in access to hyperlocal delivery services.

To address this imbalance, the study proposes a population-based dark store requirement framework that estimates future logistics infrastructure needs based on population concentration, expected service demand, accessibility conditions, and optimal delivery radius. By considering these spatial and demographic factors, the framework provides a rational basis for determining the number and location of dark stores required across different parts of the city. This approach supports a more balanced distribution of logistics infrastructure, improves service accessibility, and facilitates more efficient and sustainable expansion of hyperlocal delivery networks.

Table 6: Population-Based Dark Store Requirement (Source: Author)

Population Range	Proposed Logistics Infrastructure
25,000-40,000	1 Nano/Micro Hub
40,000-80,000	1 Standard Dark Store
80,000-1.5 lakh	2-3 Dark Stores
>1.5 lakh	Cluster-Based Logistics Network

Nano/Micro Hubs

Nano hubs are small-scale logistics points intended for compact neighbourhoods and moderate demand sectors. These hubs primarily support:

- low-volume delivery,
- EV-based movement,
- and quick rider access.

They are particularly suitable for:

- old city areas,
- compact neighborhoods,
- and low-road-width sectors.

Standard Dark Stores

Standard dark stores are proposed for medium-density residential and mixed-use sectors having:

- adequate road accessibility,
- moderate-to-high demand,
- and arterial connectivity.

These facilities operate as the primary hyperlocal fulfilment centres within urban sectors.

Cluster-Based Logistics Network

High-density urban sectors require multiple interconnected dark stores and micro-hubs operating as cluster-based systems. Such systems reduce excessive delivery radius and improve localized accessibility.

Planning Significance

The framework shifts logistics planning from arbitrary commercial growth toward planned infrastructure distribution. Linking logistics infrastructure with population thresholds ensures:

- balanced service accessibility,
- reduced rider travel distance,
- lower congestion pressure,
- and improved delivery efficiency (Buldeo Rai et al., 2019).

Proposal Outcomes

- Reduction in overlapping service areas.
- Better penetration in underserved sectors.
- Improved hyperlocal accessibility.
- Reduced delivery dependency on central corridors.

6.3 Dark store suitability criteria

The study identified that several existing dark stores are located within unsuitable urban conditions, including:

- narrow streets,
- congested mixed-use sectors,
- and ecologically sensitive areas.

Such locations create:

- curbside congestion,
- rider staging conflicts,
- accessibility inefficiency,
- and environmental pressure.

Therefore, the study proposes suitability criteria for future dark store integration.

The spatial analysis conducted in this study indicates that several existing dark stores have been established in locations that are not suitable for intensive last-mile logistics operations. In many cases, these facilities have emerged in response to market demand rather than through strategic urban planning, resulting in their concentration within narrow street networks, congested mixed-use neighborhoods, and environmentally sensitive areas. Although such locations may provide close proximity to consumers, they often fail to support efficient logistics operations and create significant challenges for urban mobility and land-use management. The mismatch between logistics activities and local spatial characteristics has increased the pressure on urban infrastructure and reduced the overall efficiency of hyperlocal delivery systems.

The presence of dark stores in unsuitable locations has generated a range of operational and environmental issues. Frequent loading and unloading activities along narrow roads contribute to curbside congestion, while the accumulation of delivery riders in limited public spaces creates conflicts with pedestrians, local residents, and other road users. Inadequate road capacity further reduces accessibility for both logistics vehicles and general traffic, leading to delays and inefficient delivery operations. Moreover, the establishment of logistics facilities within environmentally sensitive areas increases pressure on fragile ecosystems and may negatively affect the surrounding urban environment through increased traffic, noise, and emissions.

To address these challenges, the study proposes a Dark Store Location Suitability Framework that provides planning guidance for the future integration of logistics facilities. The framework recommends that the selection of dark store locations should be based on a comprehensive assessment of spatial suitability rather than solely on commercial considerations. Suitable locations should possess adequate road accessibility, sufficient road width to accommodate delivery activities, and compatibility with surrounding land uses, particularly within commercial and mixed-use areas where logistics operations can function with minimal disruption. Future site selection should also consider proximity to areas with high e-commerce demand in order to improve delivery efficiency while minimizing travel

distances. At the same time, environmentally sensitive zones, historic neighborhoods, lake-edge areas, and densely built organic settlements should be avoided because of their limited carrying capacity and greater vulnerability to logistics-related impacts. Adequate space for rider parking, loading activities, and supporting infrastructure should also be available to ensure safe and efficient logistics operations.

The proposed framework promotes a more proactive and evidence-based approach to urban logistics planning by incorporating spatial suitability criteria into the approval process for future dark store development. Rather than allowing logistics facilities to emerge in response to market demand alone, planning authorities can use these criteria to guide development toward locations that are operationally efficient, environmentally appropriate, and compatible with surrounding urban functions. This approach supports more balanced urban growth while improving the performance and sustainability of last-mile delivery systems. By encouraging the strategic placement of logistics facilities, the framework is expected to reduce congestion, improve accessibility, minimize land-use conflicts, protect environmentally sensitive areas, and strengthen the long-term integration of hyperlocal logistics within urban planning policies.

Table 7:Proposed Suitability Criteria (Source: Author)

Parameter	Recommended Criteria	Planning Justification
Minimum Road Width	12-18 m	Reduces curbside conflict and improves staging
Land Use	Mixed-use / commercial	Compatible with logistics activity
Service Radius	2-3 km	Supports 10-15 min delivery model
Distance from Major Roads	Within 300-500 m	Reduces route penetration into local streets

Parking Provision	Mandatory staging space	Reduces roadside congestion
Population Density	Medium to high	Ensures demand viability
Accessibility	Direct arterial/sub-arterial access	Improves operational efficiency
Environmental Sensitivity	Avoid lake-edge zones	Prevents ecological conflict

Road Width

Road width directly affects rider movement, delivery accessibility, and roadside congestion. Roads narrower than 9 m were found unsuitable because:

- delivery vehicles obstruct movement,
- rider waiting creates spillover,
- and emergency accessibility reduces.

Therefore, roads between 12-18 m were identified as optimal for dark store integration.

Land-Use Compatibility

Dark stores function more efficiently within:

- mixed-use sectors,
- commercial corridors,
- and transition zones

because such areas already possess:

- higher accessibility,
- commercial activity,
- and infrastructure support.

Pure residential sectors were found unsuitable for high-intensity logistics operations due to parking conflicts and noise generation (Dablanc, 2007).

Accessibility

The study identified that proximity to arterial roads significantly improves delivery efficiency. Therefore, dark stores should preferably remain within:

- 300-500 m from major arterial corridors.

This reduces:

- rider travel complexity,
- local street penetration,
- and congestion exposure.

Service Radius

The analysis established that delivery efficiency reduces significantly beyond a 2-3 km radius. Therefore, the proposed service radius ensures:

- faster delivery response,
- reduced rider fatigue,
- and lower operational inefficiency.

Parking and Staging

Several existing dark stores lack organized rider waiting areas. This creates:

- curbside congestion,
- informal parking,
- and pedestrian obstruction.

Hence, dedicated staging infrastructure is proposed as a mandatory planning requirement.

Environmental Sensitivity

Bhopal's lake-edge zones and ecological sectors possess environmental vulnerability and limited carrying capacity. Therefore, such areas are proposed as restricted logistics zones.

Planning Significance

The suitability framework establishes planning standards for integrating Q-commerce systems into urban planning structures rather than allowing unregulated logistics concentration.

Proposal Outcomes

- Reduced congestion spillover.
- Better delivery accessibility.
- Improved operational efficiency.
- Reduced land-use conflicts.

6.4 Logistics zoning framework

The study proposes logistics-compatible zoning categories for integrating hyperlocal logistics infrastructure into future development plans.

The absence of logistics zoning within existing planning systems has resulted in:

- unregulated dark store concentration,
- mixed land-use conflict,
- and operational spill over into residential sectors.

Th The rapid expansion of hyperlocal e-commerce has created new demands for urban logistics infrastructure that are not adequately addressed within conventional land-use planning systems. Existing zoning regulations generally do not recognize logistics facilities such as dark stores, micro-fulfillment centers, or rider staging areas as distinct land-use components. Consequently, the absence of logistics-specific zoning has contributed to the unregulated concentration of dark stores, conflicts between logistics operations and surrounding residential uses, and operational spill over into neighborhoods that were not designed to accommodate high delivery activity. To address these challenges, this study proposes a logistics-compatible zoning framework that integrates hyperlocal logistics infrastructure into future urban development plans.

The proposed framework classifies urban areas into four logistics-sensitive zoning categories based on accessibility, land-use compatibility, environmental sensitivity, and carrying capacity. Rather than applying uniform regulations across the city, the framework encourages location-specific planning interventions that balance logistics efficiency with sustainable urban development. therefore, the proposed framework introduces logistics-sensitive urban zoning categories.

Table 8: Proposed Logistics Zones (Source: Author)

Zone Type	Characteristics	Proposed Regulation
Logistics Support Zone	Commercial and mixed-use corridors	High logistics compatibility

Controlled Logistics Zone	Moderate residential sectors	Controlled logistics integration
Restricted Logistics Zone	Dense organic/ecological sectors	Limited logistics operations
Future Logistics Reservation Zone	Peripheral expansion areas	Reserved future logistics infrastructure

- **Logistics Support Zones**

These zones include:

- mixed-use corridors,
- commercial spines,
- and arterial-access sectors.

These areas possess:

- adequate accessibility,
- wider roads,
- and commercial compatibility.

Such areas are suitable for:

- standard dark stores,
- rider staging,
- and shared logistics infrastructure.

- **Controlled Logistics Zones**

Moderate residential sectors are proposed as controlled logistics zones where:

- delivery operations remain permitted,
- but intensity is regulated.

These zones require:

- parking standards,

- restricted operating conditions,
- and smaller logistics infrastructure.

➢ **Restricted Logistics Zones**

Old city areas, lake-edge sectors, and dense organic settlements were categorized as restricted logistics zones because of:

- narrow road width,
- environmental sensitivity,
- and low carrying capacity.

Such areas are more suitable for:

- nano hubs,
- EV-based delivery,
- and low-intensity logistics systems.

➢ **Future Logistics Reservation Zones**

Peripheral urban growth sectors should reserve land for future logistics integration to avoid future congestion and spatial inefficiency.

➢ **Planning Significance**

The zoning framework integrates logistics systems into land-use planning and helps regulate future growth of Q-commerce systems (Taniguchi & Thompson, 2014).

➢ **Proposal Outcomes**

- Controlled logistics expansion.
- Reduced land-use conflict.
- Better freight management.
- Protection of environmentally sensitive sectors.

Logistics Support Zones

Logistics Support Zones are recommended for commercial corridors, mixed-use districts, and areas located along major arterial roads. These locations generally possess wider road networks, better accessibility, and land-use characteristics that are compatible with freight activities. As a result, they are well suited for accommodating standard dark stores, rider staging facilities, parcel consolidation centers, and shared logistics infrastructure.

Concentrating logistics activities within these zones can improve delivery efficiency while minimizing conflicts with surrounding urban functions.

Controlled Logistics Zones

Moderate-density residential areas are proposed as Controlled Logistics Zones, where logistics activities remain permissible but are subject to planning regulations that limit their operational intensity. Appropriate development controls may include designated parking requirements for delivery vehicles, restrictions on operating hours, limits on facility size, and traffic management measures. Such regulations enable residents to benefit from hyperlocal delivery services while reducing potential disturbances related to noise, congestion, and increased vehicle movement.

Restricted Logistics Zones

Areas characterized by dense organic settlements, historic neighborhoods, environmentally sensitive locations, and lake-edge developments are identified as Restricted Logistics Zones. These areas typically have narrow streets, limited accessibility, fragile environmental conditions, and lower carrying capacity, making them unsuitable for intensive logistics operations. Instead of conventional dark stores, these locations are better served through low-impact logistics solutions such as nano-fulfillment hubs, electric vehicle (EV)-based deliveries, and small-scale distribution systems that minimize traffic congestion and environmental impacts while maintaining accessibility.

Future Logistics Reservation Zones

The study also recommends establishing Future Logistics Reservation Zones within peripheral urban expansion areas. As cities continue to grow, reserving land for logistics infrastructure during the planning stage can prevent future shortages of suitable logistics space and reduce the need for costly redevelopment. Integrating logistics facilities into long-term land-use plans will support efficient freight movement, improve accessibility, and reduce congestion associated with unplanned logistics development.

Planning Significance

The proposed zoning framework introduces logistics as an integral component of urban land-use planning rather than treating it as a secondary commercial activity. By incorporating logistics-compatible zoning into planning regulations, local authorities can better manage the spatial growth of hyperlocal commerce, regulate the location and intensity of logistics facilities, and reduce conflicts between freight operations and surrounding land uses. This approach supports more balanced urban development while improving the efficiency and sustainability of last-mile delivery systems (Taniguchi & Thompson, 2014).

The implementation of this zoning strategy is expected to generate several positive planning outcomes. It will facilitate controlled expansion of logistics infrastructure, reduce land-use conflicts between commercial and residential activities, improve urban freight management through better spatial organization, and protect environmentally sensitive and historically significant areas from excessive logistics-related development. Overall, the framework provides a practical planning approach for integrating hyperlocal logistics into future urban growth while promoting sustainable and resilient urban development.

6.5 Area typology-based framework

Different urban typologies require different logistics interventions because of variations in accessibility, density, and urban morphology.

Table 9: Area Typology-Based Interventions (Source: Author)

Urban Typology	Proposed Intervention
Old City Areas	Nano hubs + EV delivery
Planned Residential Areas	Standard dark stores
Commercial Corridors	Shared logistics infrastructure
Peripheral Growth Areas	Reserved logistics land

The proposed strategy ensures that logistics infrastructure responds according to spatial conditions and carrying capacity (Marshall, 2005).

Proposal Outcome

- Context-sensitive planning.
- Improved accessibility.
- Reduced congestion impact.
- Efficient localized delivery systems

The study recognizes that a single logistics strategy cannot effectively address the diverse spatial characteristics found within urban areas. Variations in population density, road connectivity, land-use patterns, and urban morphology require different planning approaches to ensure efficient and sustainable last-mile delivery. Therefore, logistics interventions should be designed according to the specific characteristics and functional requirements of each urban typology.

In older city areas, where narrow streets, dense built-up structures, and limited road accessibility restrict the movement of conventional delivery vehicles, the adoption of nano-fulfillment hubs supported by electric vehicle (EV) deliveries is recommended. These systems require less space, improve accessibility within compact neighborhoods, and reduce environmental impacts while maintaining efficient delivery services.

Planned residential areas, which generally possess organized road networks and adequate accessibility, are well suited for the development of standard dark stores. These facilities can effectively serve surrounding residential populations within an optimal delivery radius while minimizing unnecessary travel distances for delivery riders.

Commercial corridors experience high concentrations of retail activity and freight movement throughout the day. In such locations, the establishment of shared logistics infrastructure, including common loading bays, parcel collection points, and rider staging facilities, can improve operational efficiency while reducing roadside congestion and conflicts between delivery vehicles and general traffic.

For peripheral urban growth areas, where future residential and commercial development is anticipated, the study recommends reserving land specifically for logistics infrastructure during the planning stage. Early allocation of logistics space allows future freight facilities to be integrated with transportation networks and land-use plans, preventing accessibility problems and reducing the need for costly infrastructure modifications as urban expansion continues.

These location-specific interventions demonstrate that logistics planning should respond to the spatial characteristics and carrying capacity of different urban environments rather than following a uniform citywide approach (Marshall, 2005). By aligning logistics infrastructure with local urban conditions, cities can develop more efficient, resilient, and sustainable freight systems that support the continued growth of e-commerce.

The proposed planning strategy offers several important outcomes. It promotes context-sensitive urban planning by recognizing the unique characteristics of different neighborhoods, improves accessibility to logistics services through appropriately located infrastructure, reduces traffic congestion by distributing freight activities more efficiently, and supports the development of localized delivery systems that enhance operational performance while contributing to sustainable urban mobility.

6.6 Delivery staging and infrastructure recommendations

The study identified that lack of rider staging and parking infrastructure creates significant roadside conflicts and operational inefficiencies.

Therefore, the proposal recommends:

- dedicated rider waiting areas,
- shared staging infrastructure,
- integrated parking spaces,
- and loading/unloading provisions.

Suggested Planning Standards

- Minimum internal staging space.
- Shared rider facilities.

- Mandatory loading access.
- EV-based delivery support.

Infrastructure-supported logistics systems improve delivery efficiency while reducing congestion spillover around dark stores (Allen et al., 2018).

Proposal Outcome

- Reduced curbside conflict.
- Organized rider movement.
- Improved operational efficiency.

The study revealed that one of the major operational challenges associated with quick-commerce logistics is the absence of dedicated infrastructure for delivery riders. In many existing dark store developments, riders are forced to wait, park, and collect orders along public roads due to the lack of designated spaces within the premises. This results in roadside congestion, obstructed pedestrian movement, traffic conflicts, and inefficient delivery operations. Such conditions not only affect the surrounding urban environment but also reduce the overall efficiency of last-mile logistics.

To address these issues, the proposed planning framework recommends the provision of dedicated rider support infrastructure as an integral component of future dark store developments. The inclusion of designated rider waiting areas would provide a safe and organized space where delivery personnel can wait between orders without occupying public streets or footpaths. These spaces should be designed to accommodate peak-hour demand while ensuring rider comfort and operational convenience.

The framework further recommends the development of shared staging infrastructure where delivery riders can assemble, receive orders, and prepare for dispatch in an organized manner. Instead of informal gathering along roadsides, centralized staging zones would streamline rider movement and improve coordination between warehouse staff and delivery personnel. This approach can significantly reduce unnecessary delays during order collection and dispatch.

Another important recommendation is the integration of dedicated parking facilities within the site layout. Sufficient two-wheeler parking should be provided to prevent random roadside parking, which is often responsible for traffic bottlenecks around dark stores. Properly planned parking spaces can improve internal circulation while enhancing the safety of both riders and pedestrians.

The proposal also emphasizes the need for clearly identified loading and unloading areas. Separate access points for goods movement allow supply vehicles to operate efficiently without interfering with delivery riders or customer movement. This separation improves operational safety and reduces internal traffic conflicts within the logistics facility.

To support sustainable urban logistics, the framework encourages the incorporation of electric vehicle (EV) infrastructure, including charging points for electric delivery bikes. As many delivery platforms are gradually transitioning towards electric mobility, integrating EV charging facilities into future developments will contribute to lower carbon emissions, reduced fuel dependency, and environmentally responsible logistics operations.

Suggested Planning Standards

Based on the findings of the study, the following planning standards are proposed for future quick-commerce developments:

Provision of adequate internal staging space for delivery riders based on operational demand. Development of shared rider facilities, including waiting areas, seating, drinking water, washrooms, and sheltered spaces. Mandatory loading and unloading zones with separate access from rider circulation routes. Integration of dedicated parking facilities for delivery vehicles within the site. Installation of EV charging infrastructure to support electric delivery fleets and promote sustainable transportation. These recommendations are supported by the work of Allen et al. (2018), who highlighted that well-planned logistics infrastructure improves delivery performance while minimizing congestion, roadside conflicts, and operational disruptions around urban distribution facilities.

Expected Outcomes of the Proposal

The implementation of the proposed infrastructure framework is expected to generate several operational and urban planning benefits. Organized rider facilities will significantly reduce curbside conflicts and illegal roadside parking, thereby improving traffic conditions around dark stores. Clearly defined circulation and staging areas will facilitate smoother rider movement and reduce waiting times during order collection. Dedicated loading facilities will improve warehouse efficiency by separating freight operations from rider activities. Collectively, these interventions will enhance overall operational performance while creating a safer, more organized, and sustainable environment for hyperlocal delivery services in rapidly growing Tier-2 cities.

6.7 Proposed planning framework outcome

The proposed framework aims to achieve:

- balanced logistics distribution,
- reduced delivery congestion,
- improved accessibility,
- reduced rider travel dependency,
- and efficient hyperlocal delivery systems.

The framework also establishes indicative planning standards that can support future integration of Q-commerce logistics within Tier-2 urban development plans.

The proposed planning framework has been developed to address the growing challenges associated with hyperlocal commerce and urban logistics in rapidly expanding Tier-2 cities. It focuses on creating a well-balanced distribution network by strategically locating logistics facilities in a manner that serves different neighbourhoods efficiently while avoiding unnecessary concentration in a single area. This balanced approach helps ensure that delivery demand is distributed more evenly across the city.

Another important objective of the framework is to minimize delivery-related congestion. By reducing travel distances between dark stores, fulfilment centres, and customers, the framework aims to decrease the number of delivery trips on major roads, thereby easing traffic pressure and improving overall road efficiency. At the same time, the proposed

locations are selected to enhance accessibility, ensuring that essential services remain easily reachable for both delivery personnel and local residents.

The framework also seeks to reduce the travel dependency of delivery riders. Instead of requiring riders to cover long distances to fulfil multiple orders, the proposed network enables shorter and more efficient delivery routes. This not only improves operational efficiency but also reduces travel time, fuel consumption, and associated carbon emissions, contributing to a more sustainable urban environment.

In addition, the framework supports the development of an efficient hyperlocal delivery system capable of meeting the increasing demand for quick-commerce services. By integrating logistics infrastructure into the urban planning process, the proposed model promotes faster order fulfilment while maintaining compatibility with existing residential and commercial land-use patterns.

Beyond addressing current operational needs, the study establishes a set of indicative planning standards that can guide future urban development. These standards provide a practical reference for planners, local authorities, and developers to incorporate quick-commerce logistics infrastructure into upcoming neighbourhoods and city expansion projects. The framework therefore serves not only as a solution for present-day challenges but also as a planning tool that encourages sustainable, organized, and resilient urban growth in Tier-2 cities.

6.8 Proposed Plan

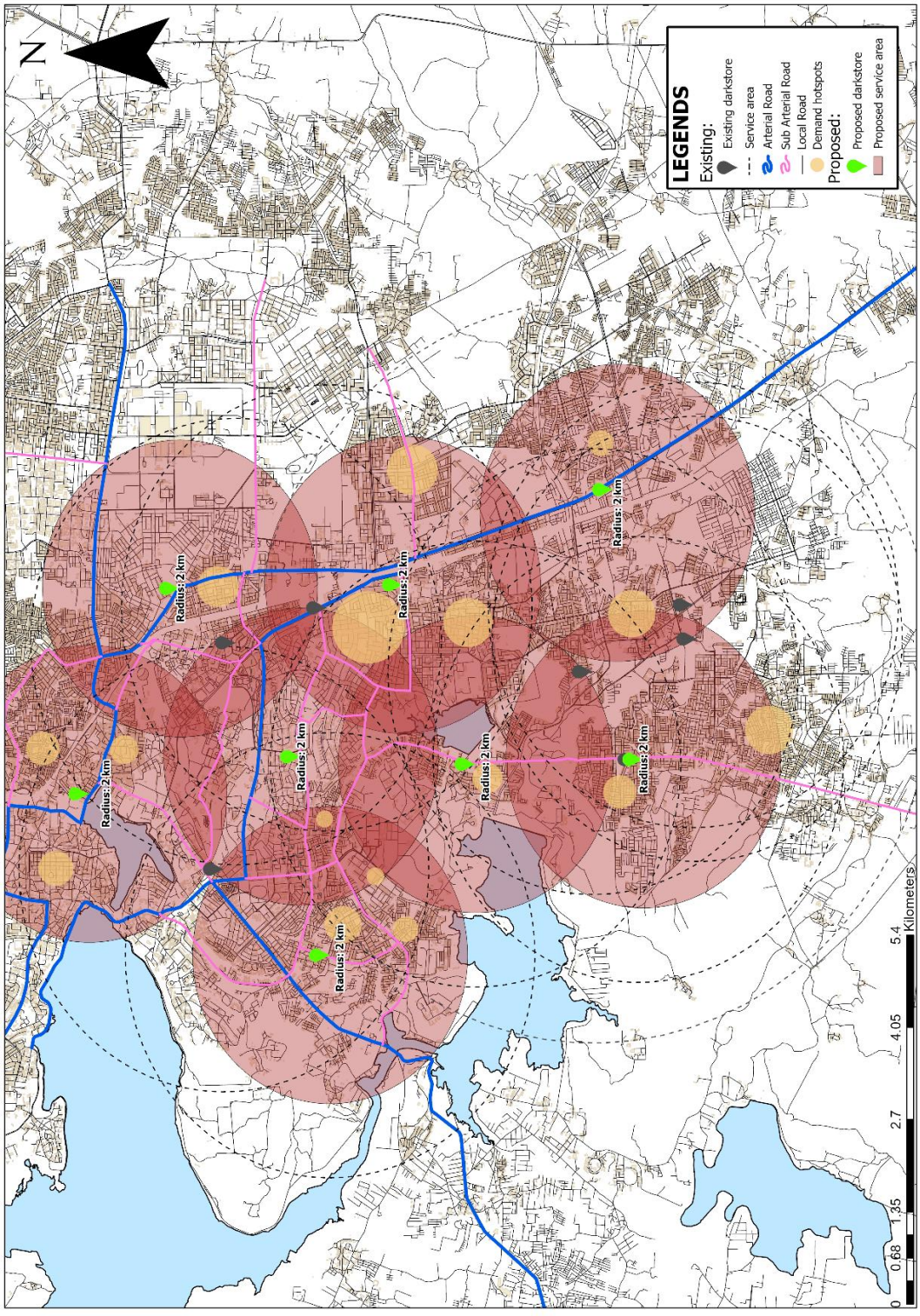


Figure 30: Proposed Plan (Source: Author)

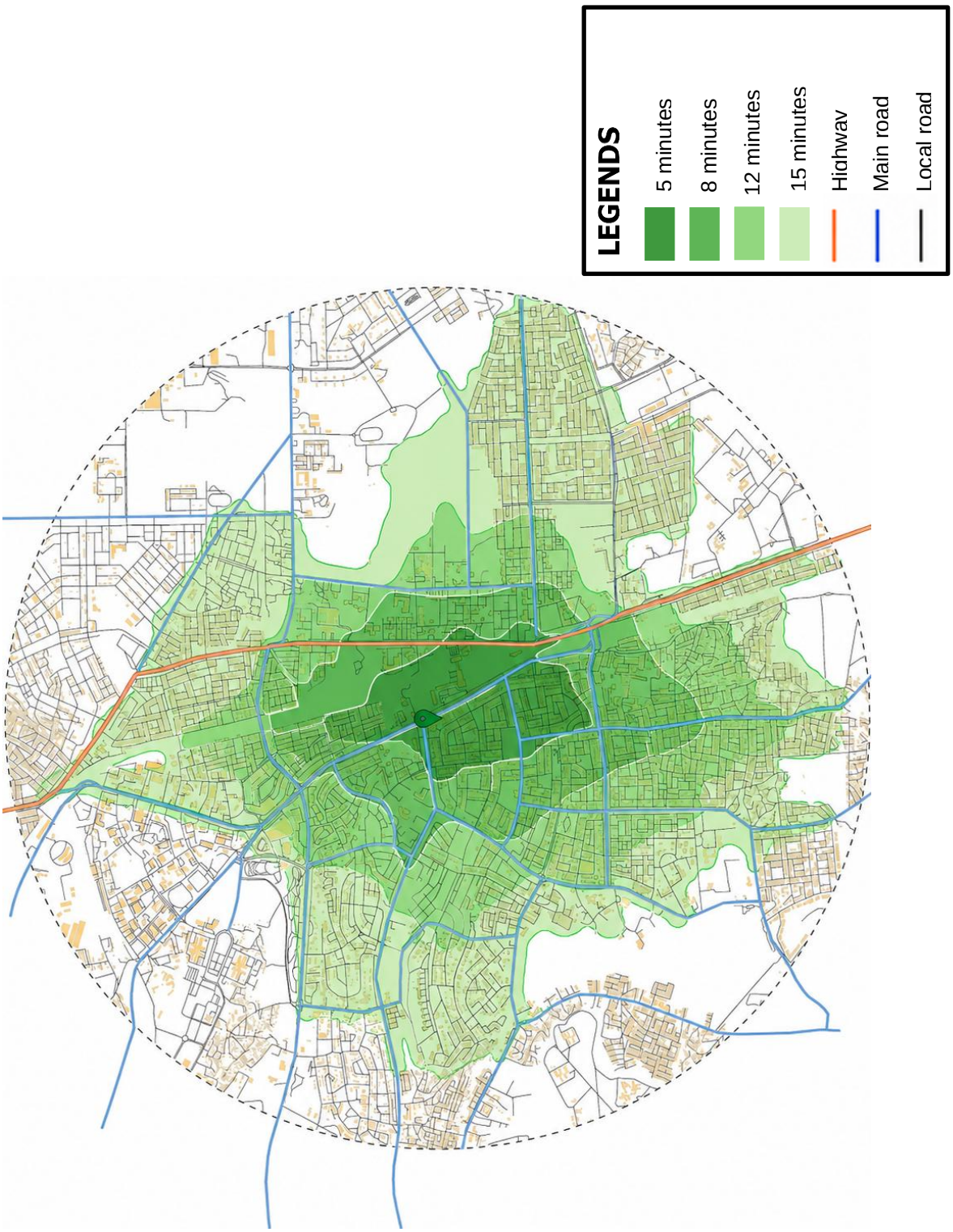


Figure 31: Reachability Area (Source: Author)

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

The study examined the relationship between urban spatial structure and Q-commerce logistics systems in Bhopal city and established that delivery efficiency is strongly influenced by accessibility, urban morphology, congestion conditions, and infrastructure availability. The analysis revealed that the existing Q-commerce network in Bhopal is highly dependent on major arterial corridors such as MP Nagar, Hoshangabad Road, Kolar Road, and VIP Road, resulting in uneven logistics distribution and increased pressure on selected urban corridors (Rodrigue, 2020).

The spatial assessment demonstrated that central urban sectors experience overlapping service coverage while peripheral sectors remain underserved. Several dark stores were found operating beyond efficient delivery radius limits, resulting in increased rider travel distance and reduced operational efficiency. The study also identified that fragmented urban morphology created by lakes, uneven terrain, and limited cross-connectivity significantly affects movement efficiency and accessibility conditions within the city (Marshall, 2005).

The primary survey findings indicated that most riders perform between 10–30 deliveries per day while operating under congestion-heavy conditions. The survey further revealed that narrow roads, parking deficiencies, and signal intersections significantly affect delivery efficiency and rider movement. Lack of dedicated rider staging and loading infrastructure was observed as a major cause of curbside congestion and localized operational conflicts near dark stores (Buldeo Rai et al., 2019).

The TISM analysis established that topographical fragmentation, zoning compliance, and road hierarchy act as major driving variables influencing congestion, accessibility, and delivery performance. The analysis demonstrated that delivery inefficiency is not only an

operational issue but a spatial planning issue emerging from inadequate integration of logistics systems within urban planning frameworks (Sushil, 2012).

Based on these findings, the study proposed a spatial planning framework integrating logistics infrastructure with land-use planning, accessibility systems, and urban freight management. The framework introduced population-based dark store requirements, suitability-oriented infrastructure criteria, logistics zoning, corridor-based logistics planning, and decentralized fulfillment systems. The proposed approach aims to create a balanced and accessibility-oriented hyperlocal logistics network suitable for Tier-2 cities (Taniguchi & Thompson, 2014).

The study recommends that future urban development plans should incorporate logistics-compatible zoning and urban freight infrastructure standards to regulate dark store concentration and reduce land-use conflicts. Dedicated rider staging infrastructure, loading bays, and delivery waiting spaces should be integrated within major logistics corridors to improve operational efficiency and reduce curbside congestion. The study also recommends that dark store placement should be linked with population density, road accessibility, and service radius efficiency rather than purely market-driven expansion.

The research further suggests that environmentally sensitive areas and dense organic settlements should adopt low-intensity logistics systems such as nano hubs and EV-based delivery networks. Future urban expansion sectors should reserve land for logistics infrastructure to prevent future accessibility imbalance and operational inefficiency. Integration between municipal authorities, logistics operators, transport agencies, and urban planners is necessary for effective implementation of logistics-oriented planning strategies.

The study concludes that Q-commerce systems should be treated as an emerging urban infrastructure requiring dedicated planning integration similar to transport and commercial systems. The proposed framework therefore establishes a planning-oriented approach for integrating hyperlocal logistics systems into Tier-2 urban development and contributes toward the emerging field of urban freight planning in Indian cities (Dablanc, 2007).

This study examined the relationship between urban spatial structure and the functioning of quick commerce (Q-commerce) logistics systems in Bhopal. The findings demonstrate that the efficiency of hyperlocal deliveries is closely associated with urban accessibility, road network characteristics, land-use patterns, congestion levels, and the availability of supporting logistics infrastructure. The analysis showed that the existing Q-commerce network is concentrated along major arterial corridors such as MP Nagar, Hoshangabad Road, Kolar Road, and VIP Road. While these corridors provide better accessibility, they also experience a high concentration of logistics activities, resulting in increased traffic pressure and an uneven distribution of delivery services across the city.

The spatial analysis further revealed significant differences in service accessibility within the urban area. Central parts of the city are served by multiple overlapping delivery zones, whereas peripheral neighborhoods have comparatively limited coverage. In several locations, dark stores were operating beyond their optimal delivery radius, increasing rider travel distances and reducing overall operational efficiency. The city's physical characteristics, including the presence of lakes, undulating terrain, and discontinuous road connectivity, further influence delivery performance by restricting direct movement between different parts of the city.

The primary survey conducted among delivery riders provided valuable insights into day-to-day operational challenges. Most riders reported completing between 10 and 30 deliveries per day while frequently encountering traffic congestion. Narrow roads, inadequate parking facilities, frequent signalized intersections, and the absence of dedicated loading and waiting spaces were identified as major factors reducing delivery efficiency. These operational issues often lead to curbside congestion around dark stores and create conflicts with other road users.

The Total Interpretive Structural Modeling (TISM) analysis highlighted that topographical constraints, road hierarchy, zoning regulations, and urban accessibility function as the key driving variables influencing logistics performance. The results indicate that many of the challenges associated with last-mile delivery are not merely operational but are closely linked

to deficiencies in urban spatial planning. The absence of dedicated logistics planning within existing development frameworks has contributed to inefficient freight movement and unequal service accessibility.

Based on these findings, the study developed a spatial planning framework that integrates logistics infrastructure with land-use planning and urban freight management. The proposed framework recommends determining dark store requirements based on population distribution, accessibility, and service radius rather than relying solely on market demand. It also emphasizes logistics zoning, corridor-based freight planning, decentralized fulfillment centers, and location suitability criteria to support a more balanced and efficient hyperlocal logistics network for Tier-2 cities.

The study recommends that future master plans should formally incorporate logistics-compatible zoning regulations and urban freight infrastructure standards. The provision of dedicated rider waiting areas, loading bays, and staging spaces along major logistics corridors would improve delivery operations while reducing roadside congestion. In addition, decisions regarding the location of dark stores should consider population density, road connectivity, accessibility, and delivery efficiency to ensure equitable service coverage across the city.

From an environmental perspective, sensitive ecological areas and densely built neighborhoods should adopt sustainable logistics solutions such as electric vehicle-based deliveries, nano-fulfillment hubs, and low-impact distribution systems. Future urban expansion areas should reserve land for logistics infrastructure during the planning stage to avoid future accessibility constraints and support long-term freight efficiency. Successful implementation of these measures will require coordinated efforts among municipal authorities, urban planners, transport agencies, and private logistics operators.

Overall, the study concludes that Q-commerce logistics should be recognized as an emerging component of urban infrastructure rather than merely a commercial service. Similar to transportation and utility networks, hyperlocal logistics systems require dedicated

consideration within urban planning and policy frameworks. By integrating logistics planning with land-use management, transportation planning, and infrastructure development, cities can improve delivery efficiency while reducing congestion, enhancing accessibility, and supporting sustainable urban growth. The planning framework proposed in this research provides a practical approach for integrating Q-commerce logistics into the development of Tier-2 Indian cities and contributes to the growing body of knowledge on urban freight planning and sustainable city development.

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ANNEXURE

- **Plagiarism Report**



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- **Primary Survey Questionnaire**

Questionnaire for Q-commerce Delivery Partners

Purpose of study:

To understand delivery trip characteristics, route choice behaviour, network constraints, and planning level factors affecting Q-commerce deliveries in Bhopal.

Section A: Delivery Partner Personal Profile

1. Age group

( ) <20 ( ) 20-25 ( ) 26-30 ( ) 31-40 ( ) >40

2. Earning members in family

( ) 1 ( ) 2 ( ) 3 ( ) >3

3. Family Size

( ) Nuclear Family ( ) Joint Family

4. Family income

( ) <20k ( ) 20k-25k ( ) 25k-30k ( ) >30k

Section B: Delivery Partner Professional Profile

5. Experience as delivery partner

( ) <3 months ( ) 3-6 months ( ) 6-12 months ( ) > 1 year

6. Employment type

( ) Full time ( ) Part time/Gig

7. Primary delivery platform (Check all that apply)

[ ] Blinkit [ ] Zepto [ ] Swiggy Instamart [ ] Bigbasket Now

[ ] Other: _____

8. Source of Income

( ) Only delivery

( ) Other: _____

9. Working time frame (Check all that apply)

[ ] Morning shift (6-12 AM) [ ] Afternoon shift (12-6 PM)

[ ] Evening shift (6PM -12AM) [ ] Late night shift (12 - 6 AM)

10. Average working time

( ) <3 hour ( ) 3-5 hour ( ) 5-8 hour ( ) > 8 hour

11. Working days in a week

( ) 5 ( ) 6 ( ) 7

12. Average leave per month

( ) 1 ( ) 2 ( ) 3 ( ) >3

13. Are you satisfied with your earnings?

( ) Yes ( ) No

Section C: Trip Generation Characteristics

14. Average number of delivery trips per day

( ) 0 ( ) 10-20 ( ) 21-30 ( ) >30

15. Peak delivery periods (Check all that apply)

[ ] Morning (7-10 AM) [ ] Afternoon (12-3 PM)

[ ] Evening (6-9 PM) [ ] Late night (9 PM - 12 AM)

16. Average number of trips per hour during peak periods

( ) <3 ( ) 3-4 ( ) 5-6 ( ) >6

17. Average number of orders per trip

( ) 1 ( ) 2 ( ) 3 ( ) >3

18. Typical delivery service area from pickup point

( ) <1 km ( ) 1-2 Km ( ) 2-3 Km ( ) >3 Km

19. Average waiting time at darkstore between two deliveries

( ) <10 minutes ( ) 10-20 minutes ( ) 20-30 minutes

( ) 30-45 minutes ( ) 45 min. - 1 hour ( ) > 1 hour

Section D: Route Choice and Travel Behaviour

20. Primary route selection method

( ) App-suggested route ( ) Personal experience

( ) Google maps ( ) Combination

21. Frequency of route deviation from app suggestion

( ) Never ( ) Rarely ( ) Sometimes ( ) Often

22. Average number of turns/intersections per delivery

( ) <5 ( ) 5-10 ( ) 11-15 ( ) >15

Section E: Route Impedance & Network Constraints

23. Preference in route choice (Rank 1 to 5, where 1 is highest priority)

Parameters / Scale	**1**	**2**	**3**	**4**	**5**
Shortest distance	( )	( )	( )	( )	( )
Least travel time	( )	( )	( )	( )	( )
Fewer intersections	( )	( )	( )	( )	( )
Wider roads	( )	( )	( )	( )	( )
Familiar roads	( )	( )	( )	( )	( )

Section F: Built Environment & Urban Form Effects

24. Constraints (Rate importance: 1 = Least Important, 5 = Most Important)

Parameters / Scale	**1**	**2**	**3**	**4**	**5**
Traffic congestion	( )	( )	( )	( )	( )
Intersection delays	( )	( )	( )	( )	( )
Narrow streets	( )	( )	( )	( )	( )
Road surface conditions	( )	( )	( )	( )	( )
One way street restrictions	( )	( )	( )	( )	( )
Informal encroachments	( )	( )	( )	( )	( )
Signal waiting time	( )	( )	( )	( )	( )

25. Delivery difficulty is highest in

( ) Old dense neighbourhoods

( ) Mixed-use commercial streets

( ) Planned residential colonies

( ) Apartment complexes

( ) Peripheral growth areas

26. Average time lost due to access issues near delivery locations

( ) <2 min ( ) 2-5 min ( ) 5-10 min ( ) >10 min

27. Common last 100 meter challenges (Check all that apply)

[ ] Narrow access lanes [ ] Inaccurate address

[ ] Congested frontage [ ] Entry restrictions

[ ] Customer unavailability

Section G: Planning & Network Level Improvements

28. Which interventions would most reduce delivery time? (Rank 1 to 3)

Parameters / Scale	**1**	**2**	**3**
Improved local street connectivity	( )	( )	( )
Reduce intersections delays	( )	( )	( )
Better traffic management in peak hours	( )	( )	( )
Clearly marked one-way systems	( )	( )	( )
Designated stopping zones near residences	( )	( )	( )

29. Should cities include fast grocery and retail delivery (like 10-20 minute delivery services) in their official plans for traffic and roads?

( ) Strongly agree ( ) Agree

( ) Neutral ( ) Disagree

30. Which planning scale matters most for optimization?

( ) Neighbourhood street design

( ) Corridor-level traffic management

( ) City wide network planning

Section H: Open Insights for Modeling

31. Orders hotspot area

_____

32. Locations in Bhopal where delivery trips are most delayed:

_____

33. Major reason for increased delivery trips in your area:

34. Suggestion to improve route efficiency without increasing travel distance: