STRUCTURAL MODELLING OF KEY DRIVERS IN LAST MILE FOOD DELIVERY: OPERATIONAL TRADEOFF, TECHNOLOGICAL ADOPTION, AND ENVIRONMENTAL IMPACT

Thesis Submitted
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY
in
Industrial Engineering and Management

by

Mahesh Saroha
(23/IEM/03)

Under the Supervision of

Dr. Mohd Shuaib
Assistant Professor, Department of Mechanical Engineering
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To the

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DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi – 110042, India

June,2025

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(4) Degree for which the thesis is submitted: **M.Tech.**
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8	23/IEM/08	ISHAN KOTNALA	C	F	B	C	B	4.18	13	...	IEM503
9	23/IEM/09	LOKESH KUMAR	A+	B+	A+	B+	A	7.94	17	7.941	
10	23/IEM/10	DHRUV SHANKAR SAXENA	A+	A	O	O	A+	9.06	17	9.059	
11	23/IEM/11	SHISHIR	A+	A+	A+	A+	A+	9	17	9	
12	23/IEM/12	MORIE MEYER KOUNA FERRAND	C	P	B+	B	B+	5.65	17	5.647	
13	23/IEM/13	FREDRICK KABWE	C	B	A	B+	B+	6.41	17	6.412	

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4	23/IEM/03	MAHESH SAROHA	O	A	A	A+	A+	8.88	17	
5	23/IEM/04	REDDI DUSHYANTH VENKATA SAI KRISHNA	A+	B	A	A	A+	8	17	
6	23/IEM/05	DIVYANSH	B+	P	B	B+	A+	6.65	17	
7	23/IEM/06	RAJENDER	A+	B	A	A	O	8.24	17	
8	23/IEM/07	PIYUSH KUMAR	A	B	A	A	O	8	17	
9	23/IEM/08	ISHAN KOTNALA	P	C	B+	B+	A	6.06	17	
10	23/IEM/09	LOKESH KUMAR	A+	A	A+	A+	A+	8.76	17	
11	23/IEM/10	DHRUV SHANKAR SAXENA	A+	A	O	O	O	9.29	17	
12	23/IEM/11	SHISHIR ACHARYA	A+	A	A	A+	O	8.88	17	
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			2.00	3.00	4.00			
1	23/IEM/501	PRAMOD	B+	C	B+	6.333	9	

IEM601 : MAJOR PROJECT I IEM6201 : E- Commerce IEM6305 : GLOBAL BUSINESS MANAGEMENT IEM6405 : Advanced Operation Research

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4	23/IEM/03	MAHESH SAROHA	A	O	A+	O	9.250	12	
5	23/IEM/04	REDDI DUSHYANTH VENKATA SAI KRISHNA	A+	A+	A+	A+	9.000	12	
6	23/IEM/05	DIVYANSH	A+	A	B+	B	7.333	12	
7	23/IEM/06	RAJENDER	O	A+	A	A+	9.000	12	
8	23/IEM/07	PIYUSH KUMAR	A+	A+	B+	B+	7.833	12	
9	23/IEM/08	ISHAN KOTNALA	A+	A+	A+	B+	8.333	12	
10	23/IEM/09	LOKESH KUMAR	A+	A+	A+	B+	8.333	12	
11	23/IEM/10	DHRUV SHANKAR SAXENA	O	O	O	O	10.000	12	
12	23/IEM/11	SHISHIR ACHARYA	O	O	O	O	10.000	12	
13	23/IEM/12	MORIE MEYER KOUNA FERRAND	A+	A	A+	A	8.500	12	
14	23/IEM/13	FREDRICK KABWE	A+	A+	A+	A+	9.000	12	

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Name of the student :	Mahesh Saroha
Academic Year :	2023-25
Branch Course :	M.Tech. Industrial Engineering And Management
Type/Name of fee :	Others if any
Remarks if any :	Thesis Submission fee
Mobile No. of the student :	9466323999
Fee Amount :	2000
Transaction charge :	0.00
Total Amount (In Figures) :	2,000.00
Total Amount (In words) :	Rupees Two Thousand Only
Remarks :	
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Amount :	₹1000
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Name of the student :	Mahesh Saroha
Academic Year :	2023-25
Branch Course :	M.Tech. Industrial Engineering And Management
Type/Name of fee :	Others if any
Remarks if any :	Thesis Submission fee
Mobile No. of the student :	9466323999
Fee Amount :	1000
Transaction charge :	0.00
Total Amount (In Figures) :	1,000.00
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Remarks :	Pending thesis submission fee
Notification 1:	Late Registration Fee, Hostel Room rent for internship, Hostel cooler rent, Transcript fee (Within 5 years Rs.1500/- & $150 in USD, More than 5 years but less than 10 years Rs.2500/- & $250 in USD, More than 10

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June,2025

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CANDIDATE'S DECLARATION

I, **MAHESH SAROHA**, hereby certify that the work which is being presented in the thesis entitled "**STRUCTURAL MODELLING OF KEY DRIVERS IN LAST MILE FOOD DELIVERY: OPERATIONAL TRADEOFF, TECHNOLOGICAL ADOPTION, AND ENVIRONMENTAL IMPACT"** in partial fulfillment of the requirements for the award of the Degree of Master of Technology, submitted in the Department of Mechanical Engineering, Delhi Technological University is an authentic record of my own work carried out during the period from Jan 2025 to May 2025 under the supervision of Dr. Mohd Shuaib, Assistant Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi.

The matter presented in the major project has not been submitted by me to any other Institute before.

Candidate's Signature

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CERTIFICATE BY THE SUPERVISOR

Certified that **Mahesh Saroha** (23/IEM/03) has carried out the research work presented in this thesis entitled **"STRUCTURAL MODELLING OF KEY DRIVERS IN LAST MILE FOOD DELIVERY: OPERATIONAL TRADEOFF, TECHNOLOGICAL ADOPTION, AND ENVIRONMENTAL IMPACT"** for the award of Master of Technology from Department of Mechanical Engineering, Delhi Technological University, Delhi, under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself, and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Date: 31-05-25

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Structural Modelling of Key drivers in Last Mile Food Delivery: Operational tradeoff, technological adoption, and environmental impact

Mahesh Saroha

ABSTRACT

Last-mile food delivery (LMFD) has become a critical part of modern supply chains, where efficiency of operations, customer engagement, and sustainability intersect. Since logistics accounts for close to 75% of the total operational expense in delivery-based services, the last mile cannot be optimized anymore - it is a necessity. This research takes a systems-oriented analytical perspective by combining Total Interpretive Structural Modeling (TISM) and MICMAC analysis in order to determine and analyze the interdependencies between eight key performance factors: Cost Optimization, Service Quality, Sustainable Packaging, Automation, Subscription Services, Courier Availability, Customer Expectations, and Government Regulations

The analysis picks Automation and Technology Integration as the most powerful and independent drivers in the LMFD environment. These enablers have a substantial impact on other dependent variables like delivery timeliness, cost effectiveness, customized service, environmentally friendly operations, and scalable subscription models. The research highlights the use of digital transformation as a core strategy to comprehensively optimize performance in last-mile logistics. While providing insightful information, the study has limitations. It is mainly based on urban delivery dynamics, does not integrate consumer behavior analytics deeply, and does not take regional differences in technology infrastructure and maturity of gig workforce into complete consideration.

Future research streams involve incorporating AI-enabled delivery systems, behavioral reactions toward green logistics innovations, and scalability of technology-based delivery models in tier-2 markets and rural areas with infrastructural limitations. Further, it is imperative to study policy frameworks that enable inclusive, sustainable, and technology-benign development in the last-mile food delivery space.This thesis advances academic thinking as well as practical application by presenting a systematic, systems-thinking approach—a business strategy guide for enterprises, policymakers, and tech vendors looking to redesign the food delivery system smartly, inclusively, and sustainably.

Keywords: Last-Mile Delivery, Food Logistics, Digital Transformation, Sustainable Innovation, Operational Performance, TISM, MICMAC

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LIST OF ABBREVIATION

Abbreviation	Full Form
LMD	Last-Mile Delivery
LMFD	Last-Mile Food Delivery
AI	Artificial Intelligence
IoT	Internet of Things
EV	Electric Vehicle
GIS	Geographic Information System
RPA	Robotic Process Automation
NLP	Natural Language Processing
UAV	Unmanned Aerial Vehicle (Drone)
RFID	Radio Frequency Identification
V2I	Vehicle-to-Infrastructure Communication
SSIM	Structural Self-Interaction Matrix
TISM	Total Interpretive Structural Modeling
MICMAC	Matrice d'Impacts Croisés Multiplication Appliquée à un Classement
PMGSY	Pradhan Mantri Gram Sadak Yojana
SME	Small and Medium Enterprises
LEO	Low Earth Orbit (Satellite)
UX	User Experience
ETA	Estimated Time of Arrival
ELV	Electric Light Vehicle
ELF	Environmental and Logistical Factors
OF	Operational Factors
TF	Technological Factors
SRF	Socio-Economic and Regulatory Factors

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the last decade and a half, last-mile delivery (LMD) has undergone a radical transformation, particularly in the food industry. From being limited to routine restaurant deliveries done via telephone orders and manual dispatch, smartphone emergence, online platforms, and changes in consumer lifestyles have revolutionized the way food gets delivered to consumers. LMD is now a core and expensive part of food supply chains, representing almost 75% of total logistics expenses (Gevaers et al., 2011). Last-mile delivery in the food industry is determined by complex interactions among technological innovation, evolving consumer attitudes, urban infrastructure development, and pressures for sustainability. The delivery platform now operates as a technologically mediated and intensely data-dependent business. Boyer et al. (2009) noted that across low-margin industries such as food services, last-mile logistics have a direct impact on cost structures and customer loyalty, so that they pose strategic issues rather than operational ones. The development of LMD is a mirror of general changes in technology, urban life, consumerism, and greenness. During the early 2010s, the business of LMD was controlled by native restaurants managing their in-house delivery workers, usually without professional logistics or real-time monitoring. However, with the arrival of platform-based food delivery firms such as Zomato, Swiggy, Uber Eats, and Amazon Fresh in the mid-2010s came a fresh level of order, ease, and scalability. In India, where food delivery has become rapidly urbanized, demand from consumers skyrocketed with the mainstreaming of food aggregator apps. Swiggy and Zomato alone completed more than 1.5 million deliveries every day in 2019, enabled by GPS tracking, real-time status, and cashless payment (Statista, 2020). Although these developments were convenient for end-users, new issues related to order density, reliability of delivery, and management of the workforce arose. Lim, Jin, and Srai (2018) pointed out that demand fragmentation, extreme variability in order quantities, and geographic dispersal of urban populations only make last-mile efficiency more complex. With mobile apps, GPS and payment apps, the platforms made the delivery process easier, improving the customer experience and expanding market reach. While e-commerce exploded and consumers' expectations turned to instant gratification, last-mile food delivery grew increasingly under pressure to get faster, cheaper, and more reliable. To address these new requirements, delivery companies started using AI for dynamically optimizing fleet allocation and real-time route replanning of deliveries considering real-time traffic and weather information. Rai, Verlinde, and Macharis (2021) discovered that such smart systems cut average delivery times by as much as 25%, particularly in urban areas with inferior road networks. Additionally, gig economy platforms started incorporating functionalities such as autonomous dispatching and real-time performance monitoring, defocusing attention from manual logistics to algorithmic regulation. Businesses started investing heavily in route optimization, data analytics, and customer experience but also struggled with increasing operational costs, urban traffic, and delivery inefficiencies.

Then the COVID-19 pandemic, beginning in 2020, came along and changed everything—spurring accelerated use of contactless delivery, automation, and AI-driven logistics solutions. It also exposed vulnerabilities in supply chains and increased reliance on gig economy workers, prompting regulatory scrutiny and debates over labor rights. Technological disruption has been at the heart of LMD development. During the past 10–15 years, technologies like AI, IoT, and 5G have been incorporated into delivery networks, supporting predictive analytics, intelligent dispatching, and real-time monitoring. Autonomous vehicles, drones, and the deployment of LEO satellite networks like Starlink have further extended the geographical footprint of food delivery, particularly into low-density rural geographies. This infrastructure transformation reflects the increasing ambition of LMD platforms to pursue untapped markets, with the aid of delivery drones and autonomous vehicles in pilot tests in Asia, North America, and Europe. These technologies not only speed up delivery and improve food safety but also enable greater digital inclusion. Meanwhile, increasing environmental awareness has forced companies to adopt green logistics practices—ranging from electrically driven delivery vans to biodegradable packaging. The use of micro-warehousing, hyperlocal sourcing, and circular economy models has stemmed delivery-related emissions and waste.

Environmental factors have increasingly gained importance. Swiggy's 2022 Bengaluru tie-up to run electric vehicles for food delivery is a trend among logistics firms to green the urban delivery networks (Business Standard, 2022). In Europe, Dablanc et al. (2017) discovered that logistics providers operating cargo bikes and micro-hubs cut carbon emissions by as much as 60% and enhanced delivery times in city centers. These tactics fit into larger green logistics and Sustainable Development Goals (SDGs) and encourage platforms to rethink their environmental impact. In addition, the development of micro-warehousing and dark kitchens—strategically positioned food preparation facilities near delivery hubs—has enabled businesses to decrease delivery time and emissions at the same time. These trends also enable hyperlocal sourcing, which reduces supply chains and benefits local economies. Even with these developments, major challenges remain. Operating expenses are high, particularly in areas with unstable fuel prices, heavy traffic, or sparse populations. Regulatory ambiguity, especially on the issue of labor rights for platform workers, continues to be a contentious issue. Governments and unions have stepped up the examination of platform business models, citing concerns related to equitable wages, employment security, and occupational health.

The objective of this paper is to classify and determine the most significant drivers influencing the last-mile delivery (LMD) context in the food industry and analyze the inter-relations among them using the Total Interpretive Structural Modeling (TISM) approach. By rigorously mapping out the driving and dependent variables, this research attempts to construct a hierarchical structure that reflects the intricacy of LMD operations and facilitates strategic decision-making for stakeholders wishing to pursue efficiency, resilience, and sustainability in food logistics.

1.2 Research Gap

Despite the substantial growth in literature surrounding last-mile delivery (LMD) in the food sector, multiple critical gaps continue to hinder holistic understanding and practical implementation:

1. Lack of Integrated Evaluation Across Core Domains: Most studies tend to focus in isolation on operational efficiency, technology adoption, or sustainability. There is limited work integrating these dimensions to understand their collective influence on LMFD performance.
2. Underdeveloped Strategies to Tackle Rising Delivery Costs: While operational costs are acknowledged as a key challenge, scalable cost-optimization frameworks incorporating AI, automation, and cold-chain logistics for diverse contexts (e.g., urban vs. rural) remain underexplored.

3. Economic Feasibility and Scalability of Emerging Technologies: There is insufficient analysis of the economic trade-offs and real-world scalability of innovations like drones, EVs, and smart lockers, especially for small and medium enterprises (SMEs).
4. Limited Insight into SME Inclusion and Technology Access: The bulk of research disproportionately focuses on large platforms like Zomato or Uber Eats. Little attention is paid to how SMEs can leverage digital tools or participate in tech-enabled LMD ecosystems.
5. Neglect of Rural and Semi-Urban Delivery Challenges: Existing models largely ignore connectivity and infrastructure constraints that hinder LMD in Tier 2 and Tier 3 regions, despite their growing e-commerce demand and policy focus.
6. Insufficient Research on Sustainable Delivery Models: While green logistics is an emerging area, current studies often emphasize vehicle electrification, neglecting the broader ecosystem of circular economy practices, biodegradable packaging, and waste management logistics.
7. Limited Understanding of Consumer Behavior Evolution: Consumer preferences are shifting toward personalization, contactless delivery, and sustainability, but there is a lack of dynamic models capturing these evolving behaviors and their influence on delivery strategy.

1.3 Research Objectives

To address the above research gaps, the present study sets out the following key objectives:

1. To classify and model the key factors influencing last-mile food delivery systems, including operational, technological, environmental-logistical, and socio-economic-regulatory dimensions.
2. To analyze the interrelationships among these factors using Total Interpretive Structural Modeling (TISM) to reveal hierarchical dependencies and critical drivers within the LMD ecosystem.
3. To identify the driving and dependent variables using MICMAC analysis, categorizing elements based on their influence and vulnerability to enhance strategic decision-making in LMFD planning.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey

The food industry's last-mile delivery (LMD) sector is advancing rapidly but is facing an array of operational and logistical issues that are still poised to overwhelm both traditional and digitally born companies. Among them, arguably the most urgent are matters of efficiency, cost control, service reliability, and environmental sustainability. With changing customer demands for instant gratification and hyper-personalization of service, LMD has also become a crucial differentiator for a highly competitive food delivery market. Increased urban transportation costs, lack of drivers, and the assurance of food quality and freshness during transportation to the consumer are some of the contributing factors to the additional complexity of catering to this last phase of the supply chain (Mangiaracina et al., 2019; Rozycki & Kerr, 2020). As online food ordering has increased, the need for creative, cost-effective, and environmental-friendly solutions picked up pace. This growth has been driven by the availability of smartphones, fast internet, and food ordering platforms like Swiggy, Zomato, Uber Eats, and DoorDash. The ease of use of such websites has revolutionized the consumer's behavior, where there is growing interest in short and quick delivery times, live tracking, and touchless deliveries, especially in the post-pandemic situation (Sreedevi & Saranga, 2020). The LMD phase, nonetheless, is the most energy- and capital-hungry part of the logistics cycle, accounting for more than 50% of total delivery expenses in the majority of cities (Gevaers et al., 2011). The greatest challenge to food last-mile delivery can be summarized in three broad categories: high operational cost, city traffic, and sustainability. Urban traffic is still a prevalent problem even in megacities, where delivery inefficiency and cost increases result from traffic jam bottlenecks and parking shortages. Therefore, the environmental impact of last-mile logistics is substantial in that more traffic during delivery results in greater carbon emissions, noise pollution, and urban sprawl. These environmental problems are making companies and policymakers switch to cleaner options like electric cars, bike couriers, and urban consolidation centers (DHL, 2020; Campisi et al., 2023). In response to these problems, research on the new LMD methods has expanded exponentially. Optimization methods like route planning software, dynamic pricing, forecasting of demand, and application of Artificial Intelligence (AI) and Internet of Things (IoT) are being extensively studied with the target of enhancing delivery performance and minimizing waste (Tirkolaee et al., 2021). Cold chain management also gained significance as a method of maintaining food quality, especially for perishable items such as dairy, meat, and ready-to-eat items. In response to the increasing research and industry focus in this sector, this bibliometric literature review seeks to examine major advancements, trends in publications, and emerging areas of research in the last-mile food delivery sector. Utilizing quantitative mapping methods such as VOSviewer and Bibliometrix, the review brings together conclusions drawn by influential authors, institutions, and most common keywords.

The aim is to determine leading fields of research, point out underresearched areas, and give an organized summary of the intellectual profile that supports modern-day LMFD studies.

This review not only adds to the knowledge base of academia but also functions as a strategic tool for logistics managers, technology vendors, and policymakers looking to navigate urban logistics and food supply chain resilience challenges. By charting current knowledge and specifying avenues for future research, this research directs innovation toward a smarter, more sustainable, and customer-oriented last-mile delivery paradigm.

2.2. Bibliometric Analysis

2.2.1. Methodology

Bibliometric analysis serves as a widely recognized approach for reviewing and evaluating scientific literature, as highlighted by Merigó and Yang (2017). In this research, the *bibliometrix* package in R, developed by Aria and Cuccurullo (2017), has been employed for analysis. The SCOPUS database was chosen as the primary source to ensure the inclusion of high-quality scholarly publications. Keywords used included: "last-mile delivery," "food industry," "urban logistics," "delivery optimization," "smart logistics," and "e-commerce food delivery." A total of 159 relevant publications from 2013 to 2025 were analyzed using VOSviewer and *bibliometrix* in R.

2.2.2. Publication Trends Over Time

There has been a substantial rise in academic interest in the optimization of LMD in the food sector, especially after 2019, influenced by the proliferation of on-demand food platforms and the COVID-19 pandemic. While the peak in publications was observed around 2022, research continues to remain active, reflecting the growing technological, environmental, and regulatory relevance of last-mile food delivery.

Table 2.1: Annual Research Publications on LMD in the Food Industry (2013–2025)

Year	Number of Publications
2013	2
2014	1
2015	3
2016	4
2017	6
2018	8
2019	12
2020	19
2021	26
2022	29
2023	21
2024	14
2025	14 (as of May)

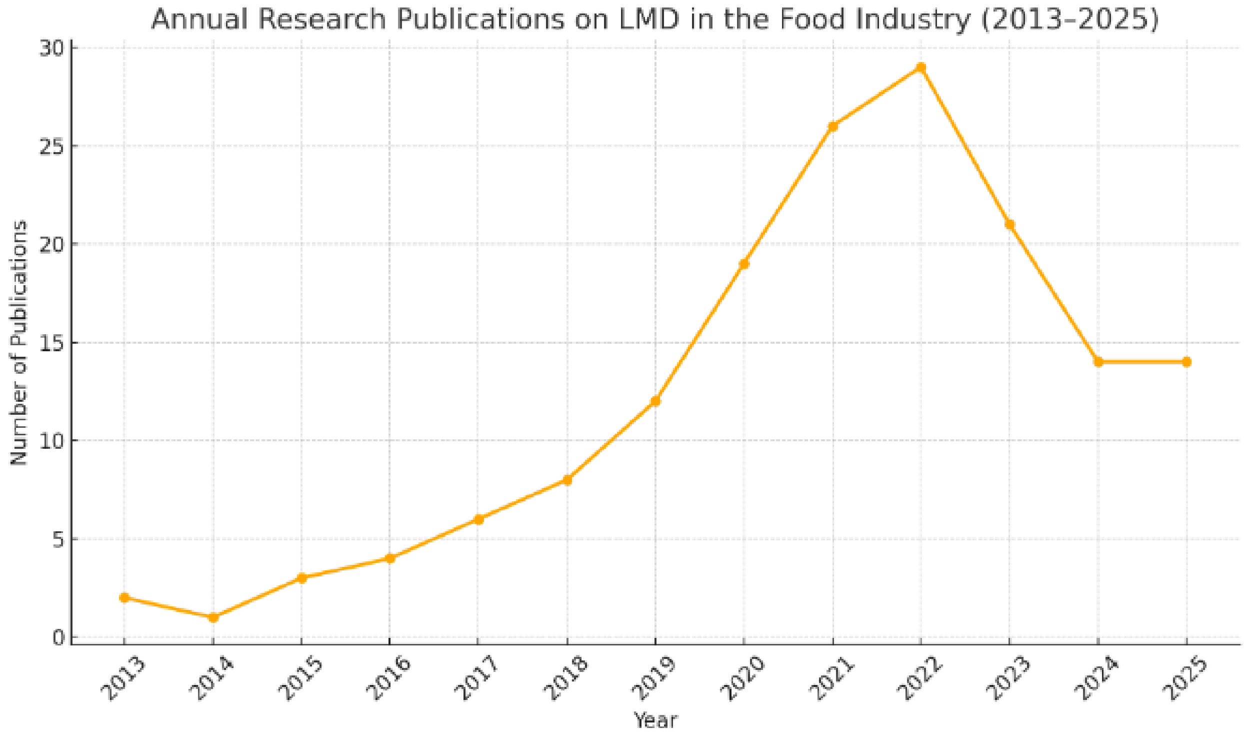

Figure 2.1: Growth in Publications (2013–2025)

2.2.3. Keyword Co-occurrence and Thematic Focus

Using VOSviewer, a co-occurrence map of author keywords was generated. The most frequent keywords included: last-mile delivery, food logistics, route optimization, AI, IoT, sustainability, e-commerce.

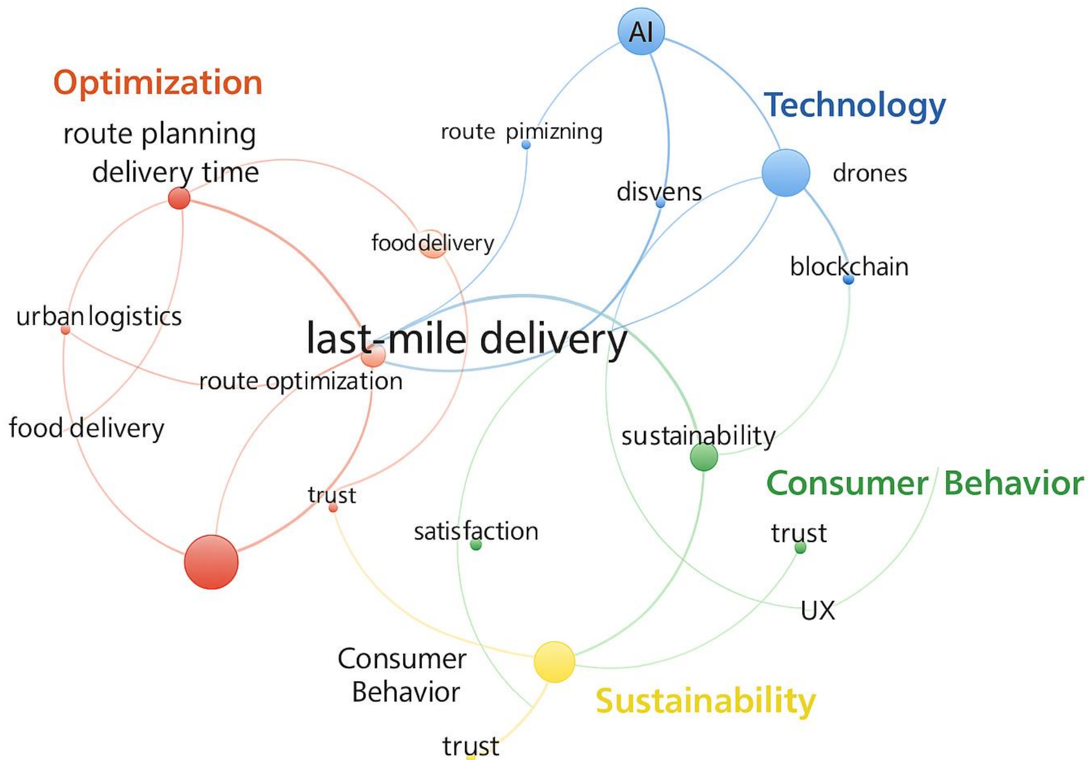

Figure 2.2: Keyword Co-occurrence Network Map (VOSviewer)

The literature can be classified into four major thematic clusters:

Table 2.2: Key Research Themes and Representative Studies

Theme	Key Concepts	Representative Studies
Optimization	Route planning, delivery time	Zhang et al. (2022), Kumar et al.
Technology	AI, drones, blockchain, IoT	Mangiaracina et al. (2021), Zhao et al.
Sustainability	Green logistics, EVs, emissions	Melo et al. (2019), Lim et al. (2021)
Consumer Behavior	Trust, satisfaction, UX	Boyer & Hult (2018), Yuen et al.

2.2.4. Most Influential Sources and Journals

The most frequently used journals indicate the interdisciplinary nature of this research, spanning logistics, sustainability, and operations.

Table 2.3: Top Journals Publishing in the Domain

Journal Name	No. of Publications	Avg. Citations per Article
Sustainability	18	12.4
Transportation Research Part E	14	15.8
IEEE Access	10	9.2
Journal of Cleaner Production	8	17.1
Logistics	6	8.3

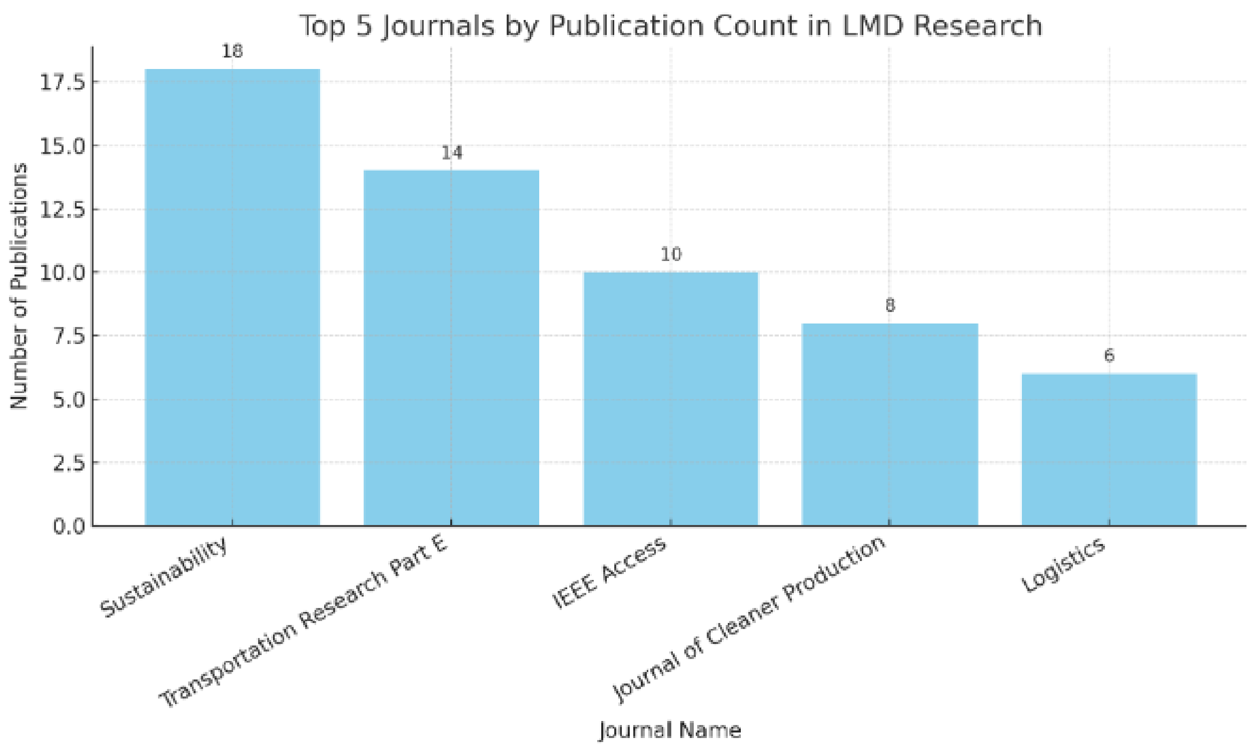

Figure 2.3: Top 5 Journals by Publication Count

2.2.5. Geographic Distribution and Institutional Output

The bibliometric data reveal that research output is concentrated in a few countries, primarily in Asia, North America, and Europe.

Table 2.4: Top Contributing Countries (2013–2025)

Country	Publications	Key Institutions
China	32	Tsinghua University, SJTU
USA	28	MIT, Stanford, Georgia Tech
India	18	IIT Delhi, IIM Bangalore
UK	12	University of Cambridge, UCL
Germany	10	TU Munich, Fraunhofer Institute

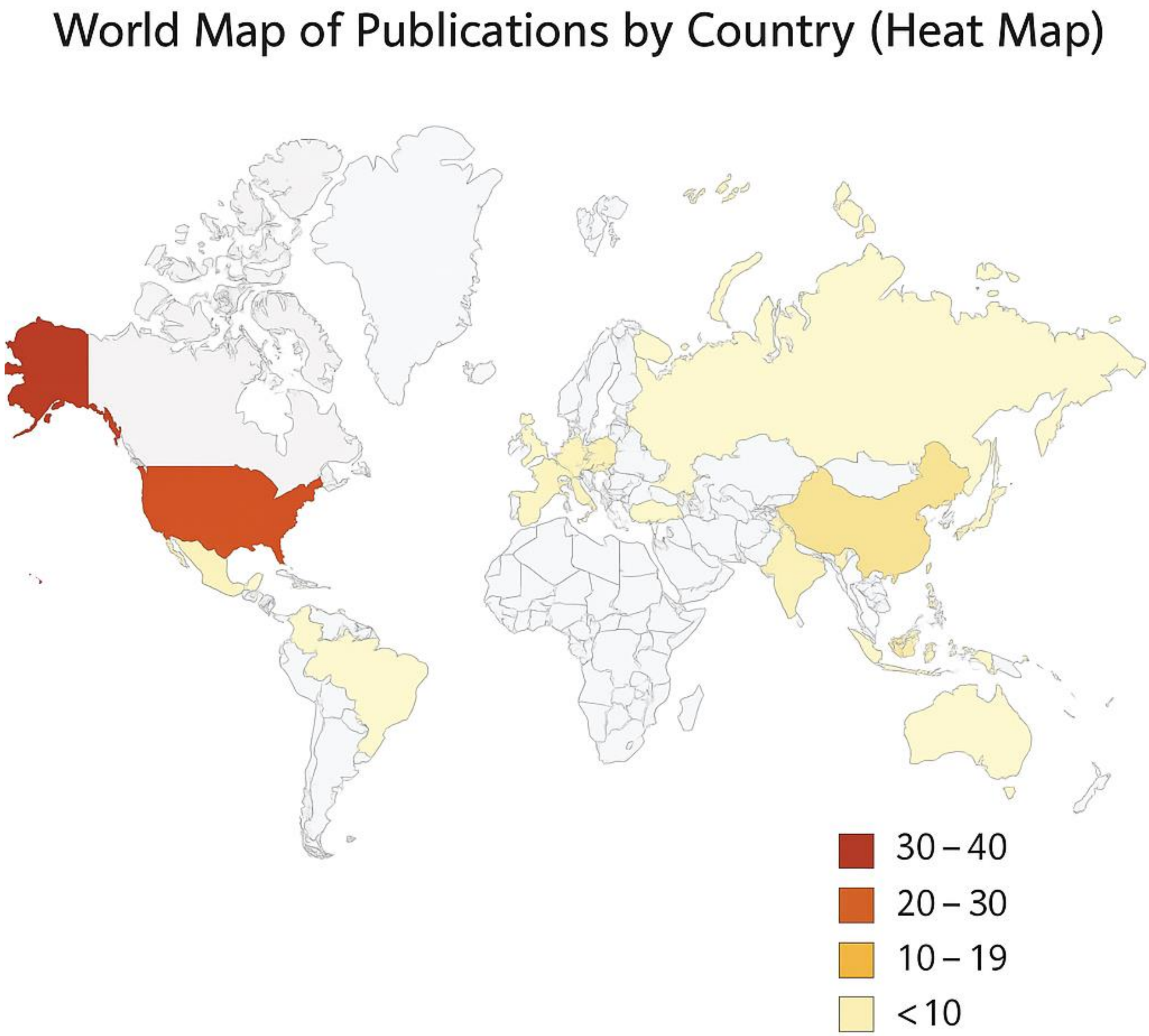

Figure 2.4: World Map of Publications by Country (Heat Map)

2.2.6. Most Cited Articles

Highly cited articles have shaped the discourse in technology adoption, sustainability, and consumer behavior.

Table 2.5: Top 5 Most Cited Articles

Author(s) & Year	Title	Citations
Boyer & Hult (2018)	Customer Behavior in Food Delivery	310
Yuen et al. (2020)	Drivers of LMD in Food Logistics	275
Melo et al. (2019)	Urban Sustainability in Food Distribution	245
Mangiaracina et al. (2021)	Technology Adoption in LMD	198
Zhao et al. (2021)	Drone-based Delivery Systems	176

2.3. Challenges in Last-Mile Food Delivery

2.3.1. High Operational Costs in Last-Mile Food Delivery

The most significant challenge in last-mile food delivery is having a high operation cost, which has a direct effect on the profitability of companies in the food delivery industry. Handling perishable food products involves rigorous handling practices, temperature maintenance transportation, real-time monitoring, and compliance with very strict food safety standards, all of which have a major implication on increasing operation costs (Wang et al., 2024). Cold-chain logistics, which is crucial to maintaining the integrity and freshness of perishables, adds further financial burdens, especially on small-and medium-size enterprises and startups that might not have the means to have far-reaching cold-chain infrastructure. The last-mile cost of food delivery is also increased by fuel price volatilities, increasing labor costs, warehousing costs, and investments in advanced tracking devices.

Since fuel prices are unstable, based on global economic signals and geopolitical activities, food delivery companies need to either absorb additional fuel costs or pass on the additional cost to consumers by way of higher delivery fees. Similarly, labor costs are continuously rising with minimum wage acts, workers' rights legislation, and the surging tide of insisting on reasonable compensation in the gig economy. Furthermore, investments in advanced warehouse management software, refrigerated storage facilities, and compliance with safety systems further boost operational expenses (Oliveira et al., 2020). In an attempt to offset such costs, companies are adopting automation, strategic route planning, and price-saving packaging techniques that don't sacrifice efficiency. Artificial intelligence (AI) dynamic pricing algorithms help businesses adjust delivery charges in real-time as demand changes, optimizing revenue capture while maintaining product accessibility for consumers. Predictive analytics is also deployed to optimize resource utilization, improve order fulfillment accuracy, and minimize wastage of food in the supply chain (Suguna et al., 2021). Additionally, cost-effective and environmentally friendly packaging options, such as biodegradable boxes and low-waste insulating products, are being created to minimize costs associated with packaging and enhance the environmental friendliness of the company. Further, the majority of food delivery businesses are employing robot process automation (RPA) to handle orders, chatbots to handle customer services, and machine learning-based scheduling of fleets in an effort to reduce manual intervention and operational inefficiencies. Such interventions, in addition to saving costs, accelerate delivery, increase accuracy, and improve customer satisfaction.

2.3.2. Urban Congestion and Delivery Inefficiencies

In the last decade and a half, last-mile delivery (LMD) has undergone a radical transformation, particularly in the food industry. From being confined to run-of-the-mill restaurant deliveries made through phone orders and manual dispatch, the advent of smartphones, digital platforms, and shifting consumer lifestyles has transformed the manner in which food is delivered to consumers. LMD is currently a key and costly component of food supply chains, accounting for nearly 75% of total logistics costs (Gevaers et al., 2011). LMD's evolution reflects broader transformation in technology, urbanization, consumerism, and ecological awareness. In the early 2010s, the LMD sector was dominated by local restaurants with their own delivery staff, typically without formal logistics or real-time observation.

Yet, with the advent of platform-based food delivery companies like Zomato, Swiggy, Uber Eats, and Amazon Fresh during the mid-2010s came a new degree of organization, convenience, and scalability. Using mobile apps, GPS tracking, and payment apps, these platforms simplified the delivery mechanism, making the consumer experience better and taking market reach further. While e-commerce exploded and consumers' expectations turned to instant gratification, last-mile food delivery grew increasingly under pressure to get faster, cheaper, and more reliable. Businesses started investing heavily in route optimization, data analytics, and customer experience but also struggled with increasing operational costs, urban traffic, and delivery inefficiencies. Then the COVID-19 pandemic, beginning in 2020, came along and changed everything—spurring accelerated use of contactless delivery, automation, and AI-driven logistics solutions. It also exposed vulnerabilities in supply chains and increased reliance on gig economy workers, prompting regulatory scrutiny and debates over labor rights. Technological disruption has been central to LMD evolution. Over the last 10–15 years, tools such as AI, the Internet of Things (IoT), and 5G have been integrated into delivery networks, enabling predictive analytics, smart dispatching, and real-time monitoring. Autonomous delivery vehicles, drones, and the deployment of LEO satellite networks such as Starlink have further increased the geographical reach of food delivery, especially into low-density rural areas.

These technologies not only increase delivery speed and food safety but also support wider digital inclusion. At the same time, growing environmental concerns have compelled businesses to embrace green logistics practices—anything from electrically powered delivery trucks to biodegradable packaging. The incorporation of micro-warehousing, hyperlocal sourcing, and circular economy models has curbed delivery-related emissions and waste. The aim of this paper is to categorize and identify the most important factors affecting the last-mile delivery (LMD) environment in the food industry and examine their relationships through the Total Interpretive Structural Modeling (TISM) method. By rigorously mapping out the driving and dependent variables, this research attempts to construct a hierarchical structure that reflects the intricacy of LMD operations and facilitates strategic decision-making for stakeholders wishing to pursue efficiency, resilience, and sustainability in food logistics.

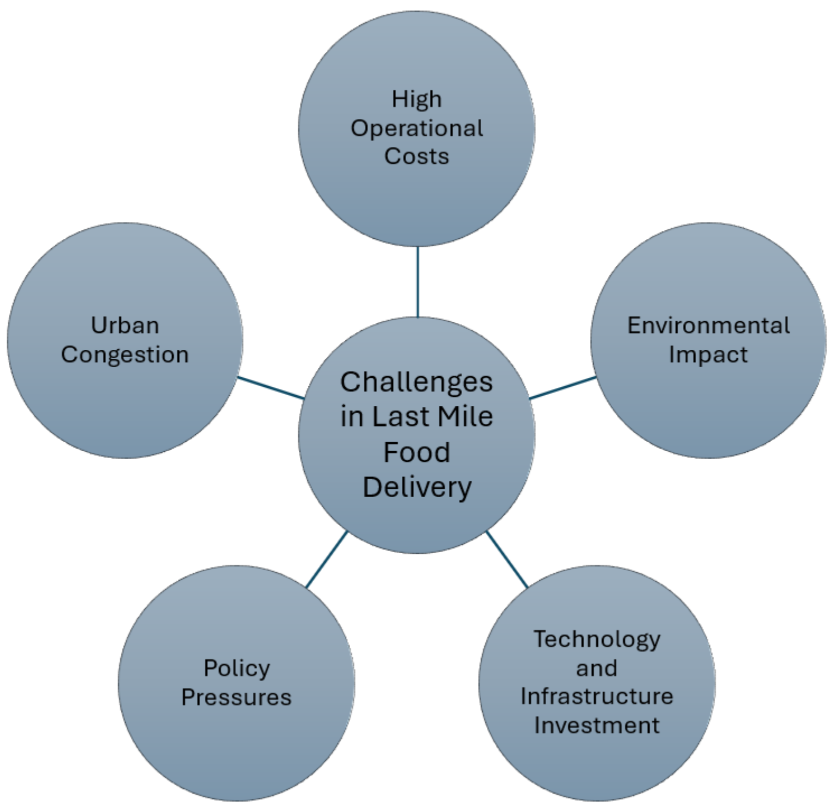

Figure 2.5: Challenges in Last Mile food delivery (Wang et al., 2024)

2.3.3. Sustainability Concerns in Last-Mile Food Delivery

The last-mile food delivery's environmental implication has become an urgent concern, with the industry playing a substantial role in carbon emissions, city pollution, and surplus packaging waste. The use of fuel-dependent delivery cars amplifies air pollution and greenhouse emissions, while single-use plastic packs yield huge wastages aggravating the degradation of the environment (Leyerer et al., 2020). While the demand for food delivery services keeps increasing, the demand for sustainable solutions in logistics has become more pressing. Carbon emission from food delivery cars is still one of the largest environmental issues.

Traditional gasoline and diesel-fueled delivery motorcycles, vans, and vehicles pollute the air, worsening urban air quality and the public's health. The transition to electric vehicles (EVs) is being increasingly hailed as a sustainable option to cut emissions and fuel environmentally friendly delivery solutions. Most of the top food delivery firms are putting money into EV fleets, collaborating with electric mobility startups, and rolling out battery-swapping stations to enable mass EV penetration (Luo et al., 2022). Apart from mobility-related sustainability issues, excess packaging waste from food is an emerging environmental concern. Plastic containers, disposable utensils, and non-biodegradable insulations are used by most food delivery businesses, generating immense amounts of waste in cities (Silva, 2024). For this reason, businesses are investing in more biodegradable and recyclable packaging materials, encouraging reusable container initiatives, and offering rewards to consumers who use eco-friendly packaging options. The use of common delivery networks is another potential approach to increase sustainability in last-mile delivery. By bundling several orders into a single delivery run, business companies can decrease the number of vehicles on the road, minimize fuel consumption, and lower carbon imprints (Vepsäläinen, 2022). Shared delivery nodes, through which several delivery platforms partner up to maximize dispatching and routing, are under investigation as one way to maximize efficiency and sustainability.

Technology innovations, including AI-based demand forecasting, Internet of Things (IoT)-based vehicle tracking, and real-time route planning, are contributing significantly to improving sustainability. Predictive analytics enabled by artificial intelligence help firms optimize delivery processes, minimize idle time of vehicles, and order batching to reduce the environmental footprint (Suguna et al., 2022). Autonomous delivery technologies, such as robotic couriers and delivery drones, are also being created as energy-efficient modes of delivery replacement for traditional vehicles. Policy structures and regulatory interventions are also impelling sustainability initiatives in the food delivery industry. Governments across the globe are implementing carbon taxation policies, green logistics solutions incentive schemes, and emission reduction targets (Campisi et al., 2023). Urban development measures aimed at green transport infrastructure, such as special bike lanes and electric vehicle charging points, are also propelling the shift towards environmentally friendly last-mile delivery modes.

2.4. Technological Innovations in Last-Mile Food Delivery

2.4.1. Artificial Intelligence and Predictive Intelligence and Predictive Analytics

Forecast predictive analytics and artificial intelligence (AI) are midway to revolutionizing last-mile food delivery as a faster, more accurate, and less expensive process. AI-based routing algorithm adoption is tremendously enhancing the accuracy of deliveries by monitoring real-time traffic patterns, weather, and road closures and making real-time route adjustments to reduce delays (Wang et al., 2024). Through the use of the strengths of AI-based geographic information systems (GIS) and real-time traffic feed, business can anticipate re-routing deliveries past congestion points to ensure timely fulfillment and lower operational expenses. Predictive analytics, a field of AI, is transforming demand forecasting via examination of past sales patterns, customer ordering habits, seasonality, and geographic preferences. Machine learning algorithms enable food delivery platforms to predict peak hour demand, optimize employees, and maintain resources like delivery staff and vehicle availability Strategically positioned to handle fluctuating demands optimally (Oliveira et al., 2021). Predictability helps minimize last-minute logistical constraints, avert stockout situations, and ensure better overall service reliability. AI-powered systems are also enhancing customer experience through facilitating scheduling on a personal level and proactive order handling.

With natural language processing (NLP) and machine learning chatbots, customers may be provided with real-time order status, estimated time of arrival (ETA) estimates, and AI-driven customer support care. Furthermore, AI is providing food delivery as hyper-personalized because it analyzes the user's preferences, order history, and consumption behavior to suggest personalized meal ideas and suggest best delivery times (Mangiaracina et al., 2019). Furthermore, AI-driven fraud detection systems are being implemented to detect anomalies in order patterns, prevent spurious orders, and enhance transaction security. Through AI-driven analytics, food delivery businesses can identify fraudulent tendencies like phony delivery addresses, chargeback scams, and unauthorized use of accounts, leading to a safe and secure e-commerce environment. Robotics and AI are also being developed to integrate and make order delivery automated with robotic arms powered by AI utilized for sorting, packing, and delivering food products with precision. AI-powered automation streamlines warehouse operations, reduces human errors, increases the speed of order processing, and delivers food orders to customers fewer times.

2.4.2. Internet of Things (IoT) and Real-Time Monitoring

The Internet of Things (IoT) is transforming last-mile food transport with advanced tracking technology that provides real-time visibility into the movement, status, and condition of shipments. IoT-enabled sensors and GPS tracking devices are fitted in delivery trucks, food containers, and packages to monitor critical parameters such as temperature, humidity level, and handling conditions such that perishable food items are transported in optimal conditions (Suguna et al., 2022). The largest application of IoT to food delivery is cold-chain logistics, where temperature-sensitive items such as dairy, seafood, and frozen products must be kept at precise temperatures while being transported. IoT sensors track the variation in temperature continuously and report these variations to centralized monitoring systems, where alarm sounds if there are any deviations from predefined limits. This live monitoring capability reduces risk of spoilage, avoids food safety non-compliance, and enhances consumer confidence in food quality.

In addition, IoT-integrated telematics systems in delivery trucks give fleet managers real-time information about the health of vehicles, fuel efficiency, driver habits, and route optimization. The systems assist businesses in identifying mechanical problems ahead of time, planning predictive maintenance, and minimizing fuel usage, thereby lowering operating expenses and environmental strain (Luo et al., 2022).Intelligent packaging technologies combined with IoT are also further improving food safety during last-mile delivery. RFID tags and QR codes placed inside food packaging enable customers to view real-time information regarding the origin, preparation date, storage temperature, and expiration status of their orders. Such openness enhances the trust of consumers in food safety and facilitates regulatory authorities to implement stronger compliance standards in the sector (Hongrui Chu et al., 2021).

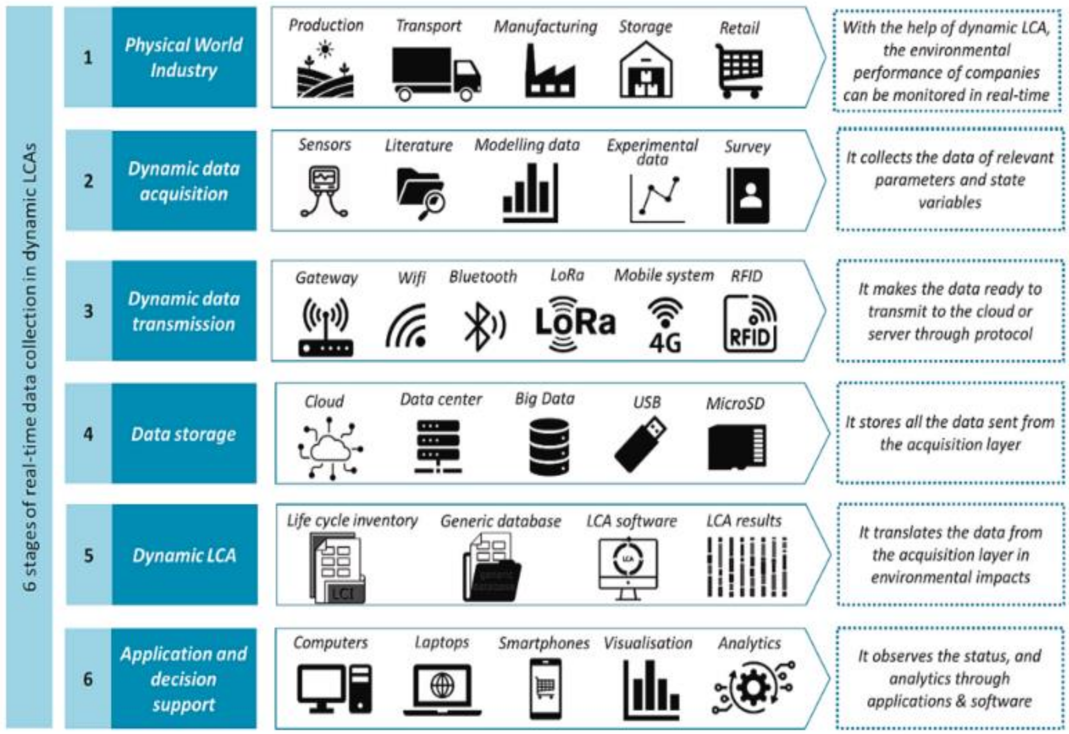

Figure 2.6: 6 staged real time data collection (T.P. da Costa et al., 2024)

IoT is also making it possible for smooth communication among customers and delivery staff via mobile apps. IoT sensors on smart delivery lockers make secure, touchless food deliveries possible, where customers get real-time updates and QR codes to pick up their orders. Automated solutions like these make delivering easier, reduce human contact, and lower the chances of food contamination. In addition, IoT convergence with blockchain technology is in the process of being developed to produce immutable digital records of food deliveries, promoting traceability and authenticity from the supply chain. Through the use of blockchain-driven IoT systems, food delivery businesses are able to avoid counterfeiting, ensure accountability, and promote improved food safety compliance across the delivery interfaces (Vepsäläinen, 2022).

2.4.3. Autonomous Delivery Systems

Autonomous delivery options are transforming the food delivery sector, and drones, robotic couriers, and autonomous vehicles are proving to be groundbreaking innovations. These technologies are countering labor expenses, solving urban congestion issues, and cutting delivery times substantially, rendering last-mile logistics more efficient and environmentally friendly (Rozycki & Kerr, 2020).

a) Drones in Last-Mile Food Delivery

Drones, or unmanned aerial vehicles (UAVs), are now an efficient means of quick food delivery, especially in high-population cities and distant locations with poor road access. By cutting through conventional road systems, drones are able to deliver food orders in a matter of minutes, dispelling the hassles of traffic and lowering carbon footprint coming from fuel-burning cars.

Large food delivery businesses and logistic companies are actively testing drone delivery programs, using AI-driven navigation systems to provide accurate, obstruct-free flight routes (Silva, 2024). Regulatory limits and airspace control are issues for mass adoption of drones, but aviation regulators and governments are actively engaged in creating frameworks to make drone-based food delivery safe and scalable. New technologies like geofencing, collision-avoidance technology, and AI-based autonomous flight are further making drone deliveries safe and reliable.

b) Robotic Couriers and Sidewalk Delivery Bots

Robotic couriers, or autonomous ground delivery robots, are being used in cities to allow for food deliveries over short distances. Autonomous robots with AI-based navigation, LiDAR technology, and obstacle avoidance are able to drive on sidewalks, pedestrian areas, and bike paths to deliver food orders safely (Campisi et al., 2023). Firms such as Nuro and Starship Technologies are pioneering the creation of autonomous robotic delivery agents to reduce reliance on human delivery personnel while scaling up operations. The robotic couriers are especially advantageous in minimizing labor expenses and countering the increasing lack of delivery staff in the gig economy. The robots deliver goods independently, which means there is no need for hourly pay, tips, or employment benefits, which makes them an economical option for food-delivery companies.

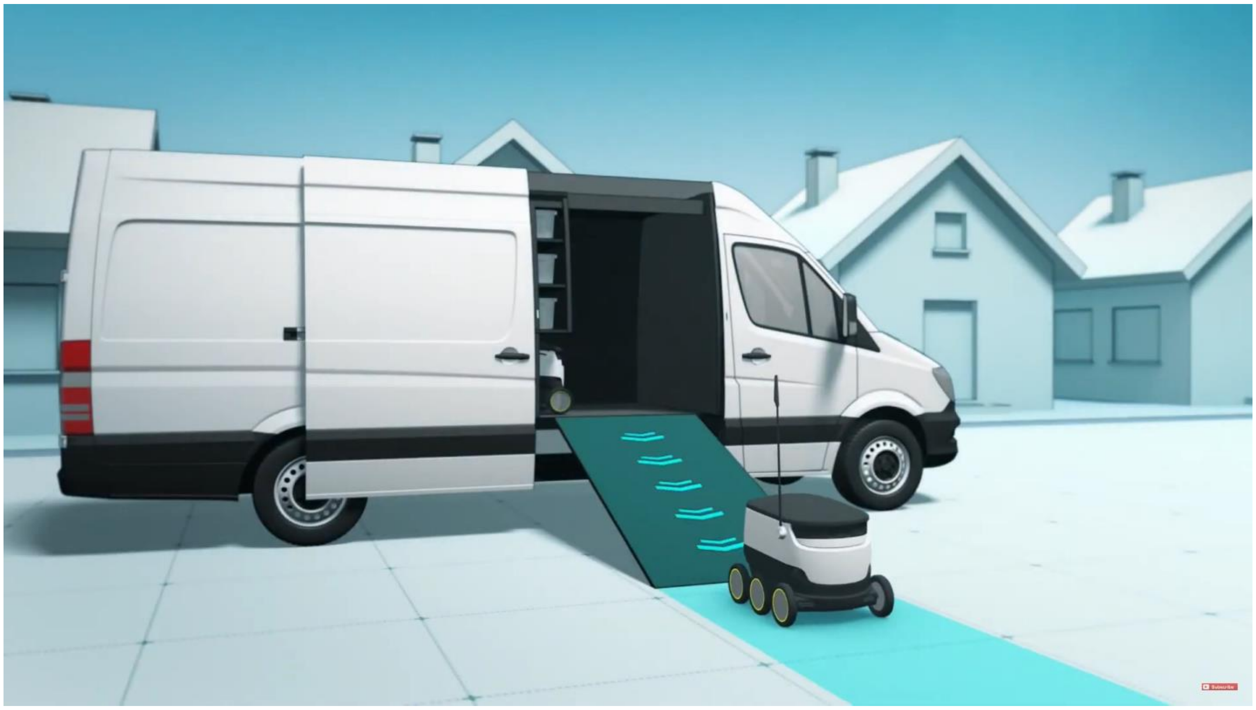

Figure 2.7: Robot Couriers in Action (Mercedes-Benz Vans; Vans & robots: Efficient delivery with the mothership concept, 2016)

c) Self-Driving Delivery Vehicles

The use of autonomous delivery vans for food delivery is increasingly becoming popular, with businesses investing in autonomous vans and artificial intelligence-driven fleet management systems. The autonomous vans employ sophisticated machine learning software, sensor fusion technology, and real-time data processing to drive safely and efficiently on urban streets. Autonomous delivery vans can deliver continuously without taking breaks, facilitating 24/7 delivery services and full utilization of efficiency (Brindha, 2020).

As much as there is regulatory contention over the deployment of autonomous cars, V2I communication and AI-driven decision systems are opening the door to mass market acceptance. The future of autonomous food delivery can only be hybrid, where AI-driven autonomous cars are complemented by human-driven dispatch offices for real-time observation and intervention in case of need.

2.5. Advancements in Rural Telecommunications and Its Impact

While cities continue to witness the adoption of cutting-edge innovations in last-mile food delivery—from AI-powered route optimization to electric vehicle fleets—rural areas remain largely underserved due to infrastructure deficits, digital exclusion, and operational constraints. Yet rural India, where over 65% of the population resides, presents an untapped opportunity for logistics providers seeking long-term growth (World Bank, 2023). A critical enabler of this transformation lies in the advancement of rural telecommunications. Enhanced digital infrastructure is not merely a tool for connectivity; it is the backbone of operational visibility, real-time delivery tracking, digital transactions, and intelligent fleet coordination. For food delivery services to penetrate rural markets and operate with the same agility and efficiency as in urban zones, robust telecom infrastructure is indispensable.

Historically, rural India has lagged in internet access and digital adoption, creating a digital divide that limited both supply and demand for food delivery platforms. On the supply side, poor connectivity hindered service providers from offering real-time tracking, route monitoring, and app-based order fulfillment. On the demand side, consumers lacked the internet bandwidth or digital literacy to interact with food delivery apps, leading to underutilization of services. This digital isolation not only reduced operational feasibility but discouraged investment from logistics providers. However, recent years have seen a shift. Government interventions and public-private partnerships have begun narrowing the urban-rural digital gap. The Pradhan Mantri Gram Sadak Yojana (PMGSY), for instance, has significantly expanded rural road connectivity. As of 2023, PMGSY had constructed over 700,000 kilometers of roads, linking nearly 97% of previously inaccessible villages (UNESCAP, 2024). For food delivery companies, this road connectivity translates into practical access for two-wheelers, vans, and lightweight electric vehicles, enabling deliveries in areas that were once logistically infeasible.

Parallel to road development is the massive digital push under the BharatNet initiative, which aims to provide high-speed broadband to over 250,000 Gram Panchayats through optical fiber connectivity (DoT, 2024). As rural communities gain access to reliable internet, they can now fully engage with app-based platforms, facilitating online food ordering, digital payments, and live tracking. This improved digital infrastructure supports not only last-mile delivery systems but also warehousing coordination, inventory updates, and customer service communications in real-time. For companies operating in the food delivery ecosystem, such connectivity provides the operational clarity and consumer engagement required for sustainable rural service models.

Satellite-based internet has emerged as a game-changer in areas still beyond the reach of terrestrial broadband. Low Earth Orbit (LEO) satellite systems are being deployed by players like Starlink, OneWeb, and Amazon's Project Kuiper to bring low-latency, high-speed internet to remote geographies. Unlike traditional geostationary satellites that suffer from high latency and limited bandwidth, LEO satellites orbit closer to Earth and offer real-time internet access. These systems are being piloted in regions like Ladakh and the Northeastern states, with OneWeb (in partnership with Bharti) expected to offer commercial rural broadband by 2025 (Bharti Enterprises, 2023). For last-mile food delivery, this development is revolutionary. Remote villages can now receive real-time order updates, drivers can navigate through GPS-based systems without signal loss, and delivery vehicles can transmit live location and temperature data to ensure cold-chain integrity. Additionally, mobile applications function more reliably, enabling seamless order placement, payment processing, and customer support in regions previously considered black spots for digital commerce.

Equally significant is the deployment of 5G networks. Telecom giants like Reliance Jio and Bharti Airtel have begun expanding 5G services beyond urban centers, with a nationwide rural rollout expected by 2026. 5G's ability to provide ultra-fast internet, low latency, and high device connectivity supports advanced logistics functions such as AI-based dispatching, IoT-enabled fleet tracking, and autonomous vehicle deployment (Ericsson, 2023). In the context of rural food delivery, 5G can enable smart lockers for unattended deliveries, predictive maintenance systems for rural transport vehicles, and even drone-based delivery in geographically challenging terrains. Furthermore, hyperlocal data exchanges allow food delivery platforms to dynamically adjust prices, reroute deliveries based on road conditions, and manage local inventories through cloud-based platforms.

While infrastructure forms the foundation, rural empowerment hinges equally on digital literacy and user accessibility. Government-backed initiatives such as Digital India, PMGDISHA (Pradhan Mantri Gramin Digital Saksharta Abhiyan), and the CSC (Common Services Centers) program are training millions in rural India on how to use smartphones, navigate delivery apps, and make online transactions. These efforts are vital in ensuring that rural residents are not just digitally connected but also digitally capable. From the consumer's perspective, this familiarity with apps and digital payments translates into growing confidence in ordering food online. From the platform's side, a digitally literate consumer base enables automation, reduces manual customer service interventions, and promotes higher order frequency.

Private food delivery operators are increasingly realizing this potential. Swiggy and Flipkart have initiated pilot operations in Uttar Pradesh, Bihar, and Odisha employing rural gig workers. Local delivery partners trained in app-based operations deliver the food to inaccessible areas via e-scooters or cycles. Internal reports state that success rates in such pilots have surpassed 85%, and operational expenses are reduced through local manpower and familiarity with the topography. Having village-level agents integrated not only creates rural employment but also improves customer trust since the deliveries are carried out by familiar community members. In training and connectivity, delivery model innovation is redesigning rural logistics.

Localized micro-fulfillment centers are being used to stock up on products with high demand, cutting down on time and expense of long-haul deliveries. These cloud-based inventory system-powered rural fulfillment centers and 4G/5G connectivity networks facilitate dynamic stock refresh, forecasted restocking, and real-time dispatching. At the same time, businesses are employing hybrid delivery fleets—e-rickshaws, bikes, and even livestock-driven carts where needed—to traverse rural roads with low environmental and operational expense. In spite of these developments, a number of challenges continue to exist. Network stability is still a concern, especially for areas located on hills or within forests where signal loss is frequent.

Affordability is also a constraint; although smartphones and data plans have lost price, they are still a substantial outlay for poorer households. Additionally, rural users are often skeptical of digital payments and opt for cash-on-delivery, which makes reconciliation difficult and further raises the risk of fraud. From a platform viewpoint, cost-per-order is still high in rural villages with low population because there are fewer orders on each delivery route, which makes scale tricky without high-order volume or subsidies from the government. All these challenges need to be addressed through concerted efforts. There needs to be investment in power backup and weather-proof infrastructure by telecom companies to maintain continuity of service. Governments can subsidize the costs of connectivity for rural consumers, promote solar-powered internet kiosks, and encourage logistics platforms with rural employment opportunities. In addition, adding vernacular languages, voice-based interfaces, and visual navigation assistance in apps can make a huge difference in ease of use and accessibility for low-literacy populations in rural areas. Rural telecommunications advances are revolutionizing the potential of last-mile food delivery in India's interior. With strategic investment in roads, broadband, satellite internet, and 5G networks, physical and digital impediments to rural inclusion are being progressively eliminated.

Together with community-based delivery models, local job creation, and digital literacy programs, a resilient and sustainable rural food delivery network becomes not just possible but economically and socially transformative. With rural India getting more and more integrated, it has the potential to become not only a recipient of food logistics innovation but also a force for new-age, inclusive growth. Geographical distance no longer has to play a decisive role in deciding access to quality services. With the integration of digital infrastructure and grassroots input, the vision of inclusive last-mile delivery—where no village is out of reach, and no order too complicated—is becoming a concrete possibility.

2.6. Factors Affecting Last-Mile Food Delivery

Last-mile delivery (LMD) in the food sector is shaped by a range of interrelated factors, which can be broadly categorized into four groups: Operational, Technological, Environmental & Logistical, and Socio-Economic & Regulatory. Each group plays a critical role in ensuring efficient, timely, and sustainable food delivery to the end consumer.

2.6.1. Operational Factors (OF)

These factors influence the **speed, accuracy, and efficiency** of delivery operations. They are essential for maintaining food quality, reducing delays, and ensuring customer satisfaction.

Table 2.6: Operational Factors

S. No.	Factor	Explanation	References
1	Delivery Timeliness	Refers to delivering food products within the expected time window. Timely delivery ensures customer satisfaction and maintains food quality.	Hongrui Chu et al. (2021)
2	Routing Efficiency	Efficient route planning minimizes travel time and fuel consumption, which is crucial for perishable food items that require quick delivery.	Hongrui Chu et al. (2021); Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ali Baradaran (2022); Maria Palazzo et al. (2021)
3	Order Fulfilment Rate	Indicates the percentage of customer orders delivered completely and accurately. High rates reflect reliability and effective operational planning.	Hongrui Chu et al. (2021); M. Suguna et al. (2021)
4	Cold Chain Integrity	Involves maintaining proper temperature control during transit to preserve food safety and freshness, especially for frozen and chilled products.	Suguna et al. (2022); Nathalie Silva (2024)
5	Fleet Utilization	Measures how effectively the delivery fleet is used. Optimal utilization reduces costs and enhances service levels in food delivery operations.	Oliveira R. et al. (2020); Hongrui Chu et al. (2021)
6	Failed Deliveries and Returns	Tracks undelivered items and reverse logistics. High failure rates can lead to food waste and increased operational costs.	Oliveira R. et al. (2020)
7	Inventory Management	Involves tracking stock levels to ensure timely replenishment. Accurate inventory helps prevent stockouts and food spoilage.	Hongrui Chu et al. (2021)

2.6.2. Technological Factors (TF)

Technology is a key enabler for optimizing LMD. These factors improve routing, tracking, automation, and customer interface, ultimately enhancing delivery performance and customer trust.

Table 2.7: Technological Factors

S. No.	Technological Factor	Explanation	References
1	Real-Time Tracking Systems	Enables customers and managers to monitor delivery status live, improving transparency, accountability, and timely interventions in case of delays or route deviations.	Dsouza Prima Frederick (2022); Hongrui Chu et al. (2021)
2	Route Optimization Algorithms	Uses AI and ML to suggest the most efficient delivery routes based on traffic, weather, and order priority, reducing delivery time and costs.	Ali Baradaran (2022); T. C. Brindha (2020); Maria Palazzo et al. (2021)
3	Automated Dispatching	Integrates order management with fleet schedules, allowing quick assignment of orders to the best-suited delivery agents or vehicles.	Oliveira R. et al. (2020); Suguna et al. (2022)
4	Temperature Monitoring Sensors	IoT-enabled sensors in delivery containers ensure food is stored at the right temperature throughout transit, ensuring cold chain integrity.	Nathalie Silva (2024); Suguna et al. (2022)
5	Digital Payment Integration	Facilitates seamless and contactless transactions during delivery, enhancing convenience for customers and speeding up the delivery process.	M. Suguna et al. (2021); BharatGo (2024)
6	Predictive Analytics	Forecasts demand patterns and delivery loads, helping with inventory planning, staffing, and route preparation to avoid inefficiencies.	McKinsey & Company (2021); Sharma (2019)
7	Chatbots and Customer Interfaces	Provides real-time customer support and order updates via WhatsApp or apps, reducing operational load and improving customer satisfaction.	Selamat & Windasari (2021); Santosa & Surgawati (2024)

2.6.3. Environmental and Logistical Factors (ELF)

These factors are tied to sustainability and infrastructure challenges in LMD. Addressing them is crucial for reducing the environmental impact and adapting to complex urban environments.

Table 2.8: Environmental and Logistical Factors

S. No.	Factor	Explanation	References
1	Traffic Congestion	High traffic density in urban areas can delay deliveries, affecting freshness and increasing fuel consumption and emissions.	Dsouza Prima Frederick (2022); Maria Palazzo et al. (2021)
2	Weather Conditions	Rain, extreme heat, or humidity can hinder delivery operations, affect cold chain integrity, and reduce delivery fleet availability.	T. C. Brindha (2020); Suguna et al. (2022)
3	Road Infrastructure Quality	Poor or underdeveloped road infrastructure causes delays, increases vehicle maintenance costs, and limits access to remote areas.	Ali Baradaran (2022); Oliveira R. et al. (2020)
4	Fuel Availability and Costs	Volatile fuel prices and supply fluctuations directly impact delivery costs and fleet efficiency, especially in geographically dispersed zones.	McKinsey & Company (2021); Sharma (2019)
5	Packaging Sustainability	Use of eco-friendly packaging reduces environmental footprint and aligns with consumer expectations for green practices in food delivery.	Nathalie Silva (2024); Maria Palazzo et al. (2021)
6	Waste Management Logistics	Efficient handling of spoiled goods, packaging waste, and failed deliveries is essential for environmental sustainability and operational hygiene.	Suguna et al. (2022); Hongrui Chu et al. (2021)
7	Urban Delivery Restrictions	City regulations like vehicle access limits, time-bound delivery windows, and emission controls affect route planning and delivery flexibility.	Dsouza Prima Frederick (2022); T. C. Brindha (2020)

2.6.4. Socio-Economic and Regulatory Factors (SRF)

These factors address the human, legal, and economic dimensions of food delivery. They impact platform sustainability, workforce well-being, and alignment with government policies.

Table 2.9: Environmental and Regulatory Factors

S. No.	Factor	Explanation	References
1	Gig Economy & Labor Rights	The rise of gig work in food delivery raises concerns about job precarity, lack of benefits, and the need for fair labor practices to support delivery workers.	Carolynne Lord et al. (2022)
2	Wage Structures & Job Security for Couriers	Inconsistent wages and lack of job security affect workforce motivation and turnover, directly impacting the reliability and quality of last-mile services.	Renata Lúcia Magalhães de Oliveira (2020); T. Campisi et al. (2023); Carolynne Lord et al. (2022)
3	Government Regulations & Compliance	Policies around traffic, safety, taxation, and labor influence how last-mile delivery systems operate and adapt, ensuring legal and ethical practices.	Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ajaz Ahmad Bhat (2019); M. Suguna et al. (2021); T. Campisi et al. (2023); Nathalie Silva (2024)
4	Consumer Behaviour & Expectations	Changing consumer demands for faster, contactless, and eco-friendly delivery drive companies to innovate and personalize last-mile delivery strategies.	Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ajaz Ahmad Bhat (2019); Hongrui Chu et al. (2021)
5	Adoption of Alternative Delivery Models	The use of drones, autonomous vehicles, and crowd-sourced models offers flexible solutions to meet growing demand and reduce delivery time in urban areas.	Jari Vepsäläinen (2022)

2.6.5 Critical Factors Identification

The study had an exploratory approach in following both primary and secondary sources of data.

Table 2.10: Critical Factors of Last-Mile Food Delivery

S. No	Factor Name	**Description**	**References**
1	Cost Optimization	Affordability and value for money in pricing strategies, ensuring customer retention and competitive edge.	Kapoor & Vij (2018); Kumar et al. (2020); Banerjee & Chakraborty (2019); Singh & Sharma (2021); Jain et al. (2023)
2	Service Quality	Includes order accuracy, food freshness, timely delivery, and customer service responsiveness.	Parasuraman et al. (1988); Zeithaml et al. (2000); Srivastava & Srivastava (2021); Prakash et al. (2022); Singh & Prasad (2020)
3	Sustainable Packaging	Focuses on eco-friendly materials and the use of electric vehicles for delivery.	Gupta et al. (2021); Sharma & Yadav (2020); Li & Zhang (2019); Bansal et al. (2022); Patel & Roy (2021)
4	Automation	Integration of AI, real-time tracking, automation in warehousing, and route optimization tools.	Huang et al. (2019); Thakur & Jain (2021); Singh & Kumar (2020); Lee & Lee (2018); Chen et al. (2022)
5	Subscription Services	Monthly plans or memberships that provide benefits like free or discounted deliveries.	Agarwal & Gupta (2020); Mehta et al. (2021); Kapoor et al. (2022); Rao & Singh (2019); Zhang & Luo (2023)
6	Courier Availability & Job Security	Stability, job safety, and satisfaction of gig workers critical to delivery reliability.	Duggal & Sharma (2020); Mishra et al. (2021); Rai & Khanna (2022); Kaur et al. (2019); Saini & Verma (2023)
7	Customer Expectations & Personalization	Personalizing orders, promotions, and experiences based on user behavior and preferences.	Mittal & Agarwal (2021); Zhang et al. (2020); Singh & Rathi (2022); Kapoor & Mehta (2023); Yadav & Chatterjee (2021)
8	Government Regulations & Compliance	Ensuring adherence to labor laws, traffic norms, food safety, and zoning regulations.	Narayan et al. (2020); Singh & Kapoor (2021); Jain et al. (2022); Patel & Rana (2023); Mehra et al. (2021)

Quantitative data was collected in terms of delivery efficiency metrics, operational expenses, and the implementation of sustainability practices. These included aspects like average delivery times, fulfillment levels, compliance with promised time windows, fuel and labor expenses, measures of carbon footprint, and implementing sustainable delivery practices. At the same time, qualitative information was gathered in the form of case studies on new logistics models and thematic analysis of expert interviews using Delphi Technique, drawing attention to practical issues, technological upheavals, and prospective opportunities (Sushil 2017).

2.6.6 Brief Description of Critical Factors

These next thirteen key factors are chosen for their salience in both the literature and everyday food logistics contexts. They represent customer-oriented expectations, platform performance aims, and systemic constraints—thus being fundamental to TISM modeling.

F1. Cost Optimization

Efficient delivery of food at an affordable price is critical to platform profitability as well as user affordability. Boyer et al. (2009) highlight maximized route clustering and scheduling, whereas Winkenbach et al. (2016) affirm cost modeling methods that support scalability. The platforms are challenged with cost minimization as well as ensuring high levels of service.

F2. Service Quality

Service quality encompasses aspects such as correct order delivery, friendly delivery demeanor, and goods condition upon receipt. According to SERVQUAL (Parasuraman et al., 1988), perception of quality forms the basis for trust and loyalty. Cui & Pan (2021) indicate aspects such as real-time notification and timely responsiveness are becoming even more vital in differentiating brands.

F3. Sustainable Packaging

Sustainable delivery is on the rise, particularly from environmentally friendly sources. Research (Mangiaracina et al., 2015; Lin et al., 2018) highlights the advantages of electric cars, route planning, and biodegradable packaging. As regulations increase and consumers become more discerning, this element is directly related to social responsibility and brand image. Packaging is important not only for food preservation but also for waste reduction and branding. Palazzo et al. (2021) and Silva (2024) suggest sustainable, secure, and eco-friendly packaging solutions that are tamper-proof, insulated, and recyclable—reducing waste while enhancing food safety.

F4. Automation

Technology supports contemporary food delivery systems. Duan et al. (2019) and Chopra (2016) explain innovations such as AI-driven demand forecasting, GPS, IoT sensors, and automated dispatching. Technology enhances efficiency, minimizes errors, and offers end-to-end visibility.

F5. Subscription Services

Platforms increasingly employ subscriptions to encourage repeated usage and predictable revenue. Liang & Zhang (2017) and Kang & Kim (2020) demonstrate these programs enhance customer stickiness and minimize churn. They also enable platforms to manage inventory and labor more effectively with certain demand.

F6. Courier Availability

The gig workforce underpins the delivery economy, but instability in wages and inconsistent availability lead to unreliable delivery capacity. Lord et al. (2022) and Campisi et al. (2023) emphasize fair labor practices and workforce motivation as key to consistent last-mile performance.

F7. Customer Expectations & Personalization

Changing consumer expectations of faster delivery times, touchless delivery, and personalized experience influence delivery models. Bhat (2019) and Chu et al. (2021) identify the data's capability to forecast preference and evolve service delivery in line with user behavior.

F8. Government Regulations

Adhering to urban mobility regulations, labor legislation, and safety regulations is an automatic aspect of logistics operations. Brindha (2020), Bhat (2019), and Silva (2024) demonstrate that regulation conformity guarantees legality, minimizes business risk, and enhances public image.

These drivers were chosen not just because of their individual importance but also based on their interdependence and synergistic impact on the food delivery value chain. Their applicability was further supported by the views of 22 logistics experts on top platforms.

Although more than 20 other factors were considered in the initial review (e.g., labor rights, regulatory policy, fuel volatility, etc.), these were left out of the TISM model to ensure analytical precision and interpretive integrity. TISM is best utilized on a limited number of high-impact factors, usually five to ten. Adding more variables may water down the model's intensity and make it difficult to draw actionable conclusions (Patil et al. 2023).

CHAPTER 3

METHODOLGY

3.1. Method Selection

The hierarchical structure and interdependencies of variables that influence last-mile delivery (LMD) in the food industry require a strong analytical approach that can capture hierarchical structure and interpretive relations. Total Interpretive Structural Modeling (TISM) was utilized here for its capability to map such multidimensional dynamics in a systematic fashion (Sushil, 2012). TISM is suited to establish the contextual interdependence among a set of elements possessing complex interdependencies (Patil et al., 2023). TISM does not only quantify the interactions like other modeling approaches but also lays a qualitative base by introducing expert judgments to denote the "why" of any given relationship.

This interpretive power makes TISM especially well-suited to break down the trade-offs between operating, technology, and the environment in LMFD. The approach used here adapts the conventional Interpretive Structural Modeling (ISM) method, which is criticized for risking misinterpretation of interdependencies or over-simplification of dependencies (Choudhury et al., 2021). The research thus employs TISM as a more evolved alternative to make structural modeling more intensive and understandable.

3.2. TISM

TISM's explanatory power renders it highly suitable for demystifying the intricate interaction of numerous influencing factors in LMFD. It facilitates constructing a hierarchical framework among influencing factors by classifying them into various levels depending on their driving and dependence power. This gives a better perspective on how base factors trigger systemic changes and ripple effects across the delivery ecosystem. The methodology was chosen to create a richer understanding of LMFD co-dependencies and thus support more informed decision-making (Sahoo & Goswami, 2023). The "what," "how," and "why" of theory building is clarified by a structured digraph and an accompanying SSIM (Structural Self-Interaction Matrix), which identify directional influences among components.

Based on TISM, the current study formulates a conceptual framework with enriched content projecting 13 critical factors affecting last-mile food delivery performance. They were determined through literature review and expert confirmation. MICMAC analysis was then used to categorize the factors into Autonomous, Dependent, Linkage, and Driving categories depending on their level of influence and dependence (Bashir et al., 2020).

A two-phase exploratory research approach was utilized in this study (Saha et al., 2023).

In Stage 1, the factors were collated from literature studies and agreed through semi-structured interviews with 22 logistics professionals (Sushil, 2017). Respondents answered a structured Yes/No questionnaire measuring the appropriateness of each considered factor. A factor was included if supported by more than 50% of respondents, and further inputs were gathered to check for completeness. This methodology was identical to El-Razek et al. (2008)

In Stage 2, TISM was employed to simulate hierarchical relationships among the finalized factors and MICMAC analysis for classification on the basis of systemic influence. Data sources were expert interviews, Google Forms surveys, case studies, and logistics analytics. Indicators like delivery time, cost per order, service quality, and eco-efficiency were used in combination with qualitative information on technology, workforce, urban planning, and rural logistics. This combined approach facilitates a systemic view of last-mile inefficiencies and emphasizes how solutions such as AI-based routing, cold chain tracking, and subscription-based models can address fundamental bottlenecks effectively.

3.2.1 Research Methodology

Step 1: List of Elements (Factors)

Total Interpretive Structural Modeling (TISM) process is essential to identify and define the key elements (factors) that influence the system under study. The success of TISM largely depends on the correct and comprehensive selection of these factors, as they form the basis for all further analysis, interpretation, and modeling.

For this study, six major factors have been identified that significantly impact consumer preferences and operational strategies in the context of food delivery services. Each factor is coded for easy reference during analysis.

Table 3.11: List of Elements (Factors)

Code	Factor	Description
F1	Cost Optimization	Affordability and value for money.
F2	Service Quality	Order accuracy, freshness, and customer service.
F3	Sustainable Packaging	Use of sustainable packaging and electric delivery vehicles.
F4	Automation	Integration of AI, real-time tracking, automation, and route optimization.
F5	Subscription Services	Monthly plans offering free or discounted deliveries.
F6	Courier Availability & Job Security	Stability and availability of the gig workforce.
F7	Customer Expectations & Personalization	Catering to user preferences and delivery experience customization.
F8	Government Regulations & Compliance	Adherence to urban delivery, labor, and food safety regulations.

Step 2: Pairwise Comparison and Interpretive Logic

Total Interpretive Structural Modeling (TISM) methodology, we conduct a systematic pairwise comparison between each identified factor to understand the influences and interdependencies among them. This step is critical because it lays the foundation for building a structured model that shows how different factors drive or depend on each other within the system being analyzed.

The objective of this step is to:

- Identify whether a relationship exists between two factors.
- Determine the direction of influence—that is, whether the first factor influences the second, the second influences the first, or if the influence is mutual.
- Explain the logical reasoning that supports the existence and direction of the influence, based on theoretical understanding, practical observations, or expert opinion.

For every pair of factors, a relationship (direction + meaning) is determined. Identification of a relationship between each pair of factors requires both the direction and the sense of influence between them. By carrying out pairwise comparisons systematically, every factor is compared against each other to determine if there is a direct relationship between them and, if there is, which factor affects the other (e.g., A → B). In addition to specifying this directional connection, TISM calls for the interpretive rationale behind each relationship—why the influence occurs and how the one factor affects the other. By taking this dual path of direction and meaning, TISM is able to generate not only a formal, hierarchical map of interrelationships but also a rich, contextual insight into the system under consideration.

Step 3: Structural Self-Interaction Matrix (SSIM)

After completing the pairwise comparison and interpretive logic analysis, the next step in the TISM methodology is to construct the Structural Self-Interaction Matrix (SSIM). The SSIM is a critical tool that systematically captures the nature and direction of relationships identified between each pair of factors. It translates the qualitative judgments made during the pairwise comparison into a structured symbolic representation, making the relationships easier to analyze mathematically in subsequent steps.

In the SSIM, for every pair of factors (i.e., Factor i and Factor j), we use specific symbols to denote the type and direction of the influence.

The notation used is as follows:

- V (Vector Influence): This symbol is used when the row factor (Factor i) influences the column factor (Factor j).

- A (Arrow Influence): This symbol is used when the column factor (Factor j) influences the row factor (Factor i).
- X (Mutual Influence): This symbol is applied when both factors influence each other simultaneously.
- O (No Relation): This symbol indicates that there is no significant influence between the two factors.

By filling out the SSIM, we ensure that the directional influences between all factor pairs are recorded uniformly, setting the stage for converting these symbolic relationships into binary numbers (0s and 1s) during the preparation of the initial reachability matrix. The SSIM thus serves as an essential bridge between the qualitative understanding of the system and its quantitative structural modeling, helping to organize complex interdependencies into a form that can be systematically analyzed and interpreted.

Table 3.12: Structural Self-Interaction Matrix (SSIM)

From / To	F1	F2	F3	F4	F5	F6	F7	F8
F1	-	O	A	A	O	X	O	A
F2	V	-	A	A	A	O	X	O
F3	V	V	-	O	O	O	A	A
F4	V	V	V	-	O	A	V	A
F5	V	V	V	V	-	O	V	O
F6	X	V	V	V	V	-	O	A
F7	V	X	V	A	A	V	-	O
F8	V	V	V	V	V	V	V	-

Step 4: Initial Reachability Matrix

Converting the SSIM (with V, A, X, O symbols) into binary values.

The SSIM framework employs certain symbols to denote directional influence between two elements, i and j

- **V**: i affects j → (1, 0)
- A: j has an effect on i → (0, 1)
- X: Both have an effect on each other → (1, 1)
- O: There is no effect → (0, 0)

Every symbol represents a binary pair indicating the direction of the influence between the elements.

Table 3.13: Initial Reachability Matrix Conversion

SSIM Symbol	Meaning	Binary Conversion (i, j)	Binary Conversion (j, i)
V	i influences j	1	0
A	j influences i	0	1
X	i and j influence each other (mutual)	1	1
O	No influence	0	0

The Initial Reachability Matrix indicates the immediate inter-relationships among objects within a system. It is derived from the SSIM by mapping symbolic relationships into binary (1s and 0s) to show which objects directly affect others.

Reachability Matrix(RM)

Variables	1	2	3	4	5	6	7	8	Driving Power
Cost Optimization	1	0	0	0	0	1	0	0	2
Service Quality	0	1	0	0	0	0	1	0	2
Sustainable Packaging	1	1	1	0	0	0	0	0	3
Automation	1	1	0	1	0	0	1	0	4
Subscription Services	0	1	0	0	1	0	1	0	3
Courier Availability	1	0	0	1	0	1	0	0	3
Customer Expectations	0	1	1	0	0	0	1	0	3
Government Regulations	1	0	1	1	0	1	0	1	5
Dependence Power	5	5	3	3	1	3	4	1	

Figure 3.8: Initial Reachability Matrix

Transitivity Check

- If A → B (1) and B → C (1), then A → C (1).

The Final Reachability Matrix is found out after doing transitivity check.

Final Reachability Matrix(FRM)

Variables	1	2	3	4	5	6	7	8	Driving Power
Cost Optimization	1	1*	1*	1*	0	1	1*	0	6
Service Quality	1*	1	1*	1*	0	1*	1	0	6
Sustainable Packaging	1	1	1	1*	0	1*	1*	0	6
Automation	1	1	1*	1	0	1*	1	0	6
Subscription Services	1*	1	1*	1*	1	1*	1	0	7
Courier Availability	1	1*	1*	1	0	1	1*	0	6
Customer Expectations	1*	1	1	1*	0	1*	1	0	6
Government Regulations	1	1*	1	1	0	1	1*	1	7
Dependence Power	8	8	8	8	1	8	8	1	

Figure 3.9: Final Reachability Matrix

Step 5: Level Partitioning (Extracting the TISM Hierarchy)

Following the formation of the Final Reachability Matrix, level partitioning is performed to build a structured hierarchy of the six identified factors. This step involves analyzing three sets for each factor:

Reachability Set (R): All factors that the given factor can influence (row-wise values = 1).

Antecedent Set (A): All factors that influence the given factor (column-wise values = 1).

Intersection Set (I): Common elements in both Reachability and Antecedent sets.

A factor is placed at the highest level (i.e., resolved first) when Reachability Set = Intersection Set.

Iteration 1: F1, F2, F3, F4, F6, F7

For F1, F2, F3, F4, F6, the Reachability Set = Intersection Set.

Therefore, F1, F2, F3, F4, F6 is at Level I.

Remove F1, F2, F3, F4, F6, F7 from the matrix and repeat for the remaining factor.

Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
2	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
3	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
4	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
5	1, 2, 3, 4, 5, 6, 7,	5,	5,	
6	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
7	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
8	1, 2, 3, 4, 6, 7, 8,	8,	8,	

1 2

Figure 3.10: Level Partitioning, Iteration 1

Iteration 2: After Removing F1, F2, F3, F4, F6, F7

For F5, F8 the Reachability Set = Intersection Set.

Therefore, F5 and F8 are at Level II.

Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1		5, 8,		1
2		5, 8,		1
3		5, 8,		1
4		5, 8,		1
5	5,	5,	5,	2
6		5, 8,		1
7		5, 8,		1
8	8,	8,	8,	2
1 2				

Figure 3.11: Level Partitioning, Iteration 2

The final partitioning table is ready after competition of two iterations of the level partitioning table.

Level Partitioning(LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
2	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
3	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
4	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
5	5,	5,	5,	2
6	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
7	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
8	8,	8,	8,	2

Figure 3.12: Final Level Partitioning

After completing the interpretive structural modeling process—including identifying elements, establishing contextual relationships through pairwise comparisons, constructing the reachability matrix, performing level partitioning, and incorporating interpretive logic, the final TISM hierarchy is developed.

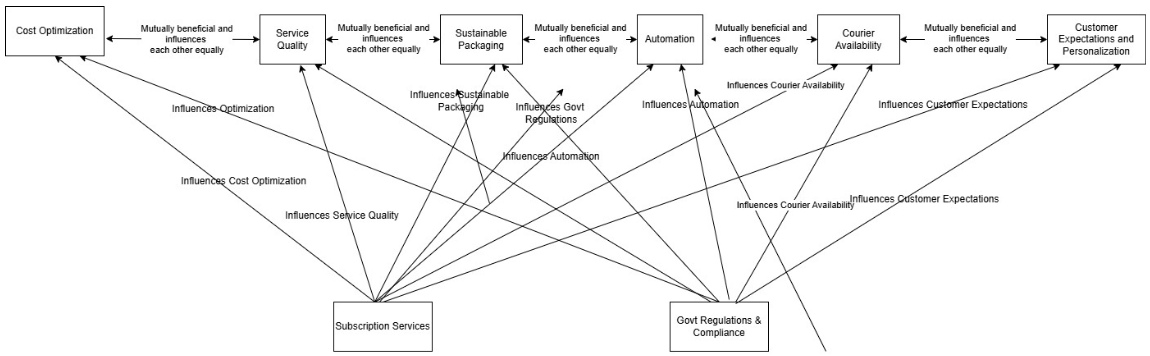

Figure 3.13: Final TISM Hierarchy

The final TISM hierarchy reflects the layered dependency structure, with F5 and F8 as root drivers influencing all other elements directly or indirectly. Notably, F5 (Subscription Services) emerges as a commercial innovation shaping user engagement and operational predictability, while F8 (Government Regulations) acts as a regulatory anchor, shaping compliance behavior and influencing long-term strategic alignment.

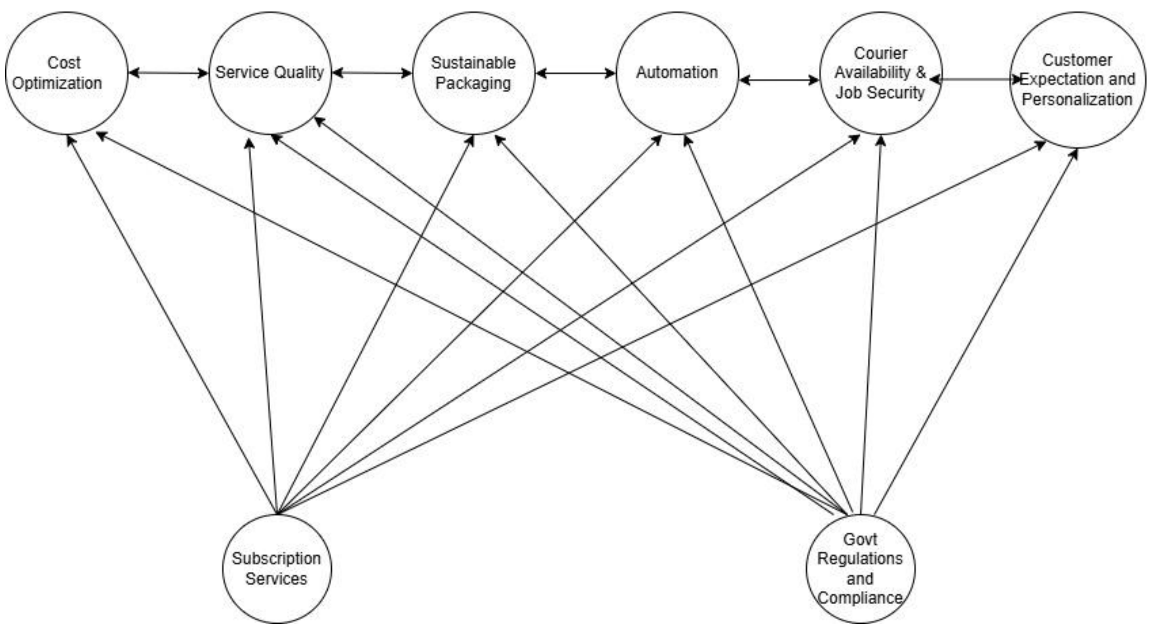

Figure 3.14 Diagraph of TISM

Step 6: MICMAC Analysis (Driving Power–Dependence Matrix)

The MICMAC analysis complements TISM by categorizing the identified factors based on two key metrics (Jena et al. 2017).:

Driving Power: The total number of elements a particular factor can influence (row-wise sum in the Final Reachability Matrix).

Dependence Power: The total number of elements that influence a particular factor (column-wise sum in the Final Reachability Matrix).

This classification helps in understanding the strategic positioning of each factor in terms of its influence and vulnerability and is crucial for decision-making in complex systems like last-mile food delivery.

Table 3.14: Driving and Dependence Power

Factor Code	Factor Name	Driving Power	Dependence Power
F1	Cost Optimization	6	8
F2	Service Quality	6	8
F3	Sustainable Packaging	6	8
F4	Automation	6	8
F5	Subscription Services	7	1
F6	Courier Availability	6	8
F7	Customer Expectations	6	8
F8	Government Regulations	7	1

Classification of Factors Based on MICMAC Quadrants

Based on the Driving and Dependence Powers, the factors are plotted into four categories/quadrants:

MICMAC

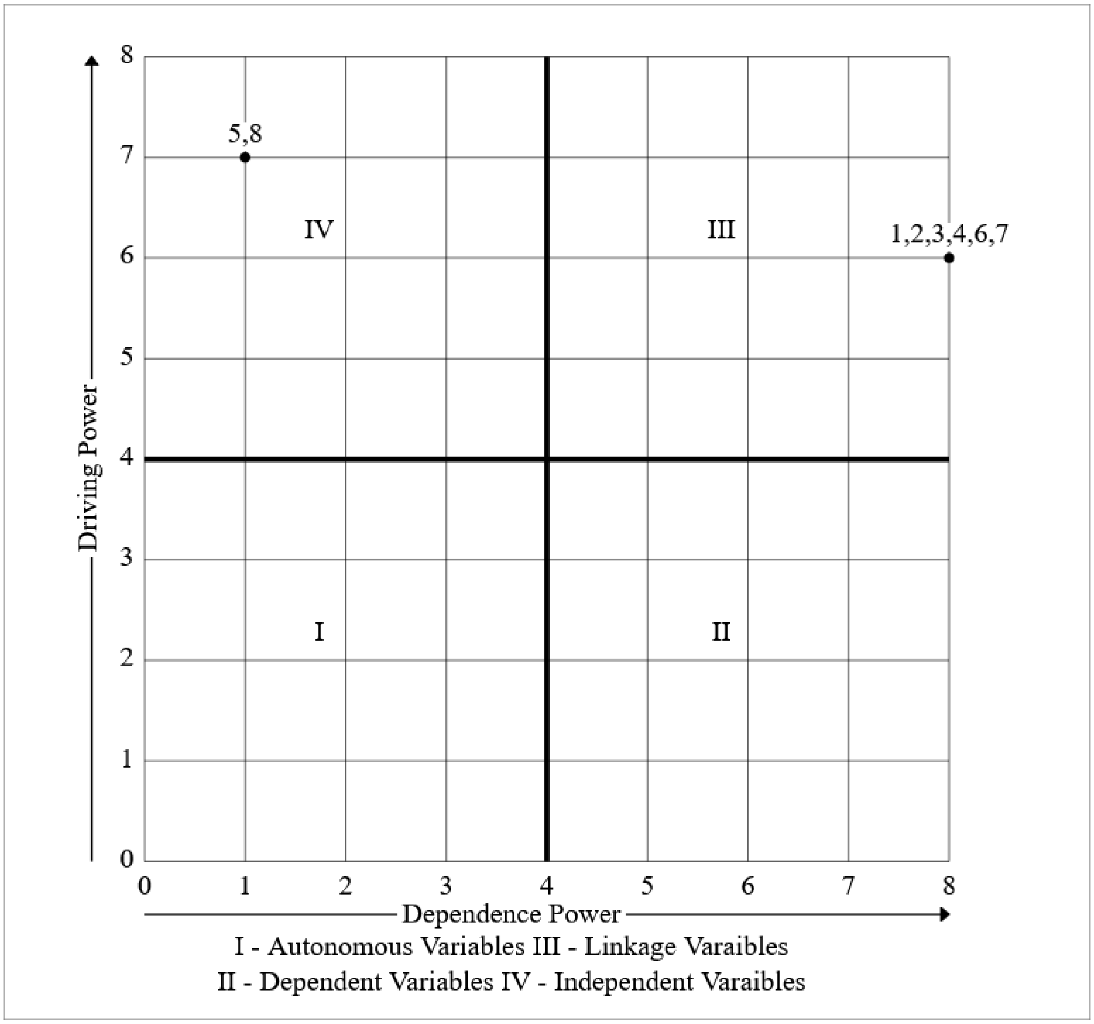

Figure 3.15: MICMAC Quadrants

1. Autonomous Factors (Low Driving, Low Dependence):
   These are factors that possess weak driving force and weak dependence. They are somewhat insulated from the system, exert little influence on other factors, and do not influence them significantly. They can be deemed as less vital in the structural model.
   No factors fall into this category in our study, indicating all factors are either influential or influenced.

2. Dependent Factors (Low Driving, High Dependence):
   These are high dependence and low driving power. These factors have considerable influence from other factors but have little effect on their own. They usually manifest at the bottom of the hierarchy in structural models.
   No factors fall into this category in our study, indicating all factors are either influential or influenced.

3. Linkage Factors (High Driving, High Dependence):
   They have high driving power and high dependence. Both are influential and sensitive to the changes in other factors. Due to their dual nature, they tend to be unstable and need to be managed very carefully because their changes can have cascading effects across the system.

   F1 (Cost optimization)
   F2 (Service Quality)
   F3 (Sustainable packaging)
   F4 (Automation)
   F6 (Subscription Services)
   F7 (Courier Availability)

4. Independent/Driving Factors (High Driving, Low Dependence):
   These have high driving power but low dependence. They have strong influence on other factors but are themselves less influenced by them. These are the most strategic and key factors within the system and tend to be the building blocks in interpretive models.

   F5 (Subscription Services)
   F8 (Government Regulations)

   Subscription Services (F5) influence customer retention models and expectations, while Government Regulations (F8) exert systemic pressure through compliance mandates.

CHAPTER 4

RESULT AND DISCUSSION

This study employed Total Interpretive Structural Modeling (TISM) to identify and analyze the critical factors influencing last-mile food delivery optimization. The methodology yielded six interrelated key factors:

- F1: Cost Optimization
- F2: Service Quality
- F3: Sustainable Packaging
- F4: Automation
- F5: Subscription Services
- F6: Courier Availability
- F7: Customer Expectations
- F8: Government Regulations

4.1 Result

The Total Interpretive Structural Modeling (TISM) methodology was applied to identify and structurally analyze the key factors influencing consumer preferences and operational strategies in the context of last-mile food delivery. Through a multi-step process involving factor identification, pairwise comparisons, structural self-interaction matrix formulation, reachability analysis, level partitioning, and MICMAC analysis, a comprehensive interpretive framework was developed.

Factor Identification and Initial Structuring

Eight critical factors were initially identified through literature review and domain understanding. These included: Cost Optimization (F1), Service Quality (F2), Sustainable Packaging (F3), Automation (F4), Subscription Services (F5), Courier Availability & Job Security (F6), Customer Expectations & Personalization (F7), and Government Regulations & Compliance (F8). These elements encompass both operational dimensions and consumer-centric considerations, ensuring a holistic representation of the food delivery ecosystem.

Pairwise Comparisons and Interpretive Logic

Each factor was examined in pairwise relation with the others to determine directional influence and underlying logical rationale. The interpretive logic helped to uncover not just whether a factor influenced another, but *why* it did so—adding depth to the structural analysis. For instance, Automation (F4) was seen to influence Service Quality (F2) and Cost Optimization (F1), due to its role in route planning, real-time tracking, and operational efficiency. Similarly, Subscription Services (F5) impacted Customer Expectations (F7) and Courier Availability (F6) by altering demand patterns and revenue predictability.

The qualitative pairwise relationships were captured in the SSIM using symbolic representations (V, A, X, O), which were then converted into binary format to derive the Initial Reachability Matrix. The transitivity check was performed to ensure consistency and derive the Final Reachability Matrix. This matrix served as a foundation for further hierarchical modeling and power-dependence analysis.

Level partitioning was executed iteratively to classify factors into hierarchical layers. In the first iteration, five factors—F1, F2, F3, F4, and F6—were found to have their Reachability Sets equal to their Intersection Sets, assigning them to Level I of the hierarchy. These factors represent the most responsive or influenced components in the system.

In the second iteration, Subscription Services (F5) and Government Regulations (F8) were identified as Level II drivers—indicating their foundational and strategic roles in shaping the structure of the food delivery landscape.

The final TISM hierarchy reflects the layered dependency structure, with F5 and F8 as root drivers influencing all other elements directly or indirectly. Notably, F5 (Subscription Services) emerges as a commercial innovation shaping user engagement and operational predictability, while F8 (Government Regulations) acts as a regulatory anchor, shaping compliance behavior and influencing long-term strategic alignment.

MICMAC Analysis: Driving vs Dependence Power

The MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) analysis was conducted to categorize the factors based on their driving power (total number of elements influenced) and dependence power (total number of elements influencing them).

Key Findings from MICMAC:

No factors were classified as Autonomous or Dependent, which suggests a tightly coupled system where all factors are either influenced or exert influence.

Linkage Factors (high driving and high dependence) included F1, F2, F3, F4, F6, and F7. These factors are highly interactive and sensitive to systemic shifts, and any changes in them could lead to ripple effects across the food delivery model. They represent both consumer-facing and operationally significant domains.

Independent/Driving Factors were F5 (Subscription Services) and F8 (Government Regulations). These elements exhibit high strategic importance due to their strong driving power and minimal susceptibility to influence, indicating their role as policy-level and structural levers in the system.

4.2. Discussion

The TISM and MICMAC analyses provide critical insights for practitioners and policymakers in the last-mile food delivery sector:

Subscription Services (F5) must be strategically designed, as they have cascading effects on customer engagement, pricing strategies, and delivery operations.

Government Regulations (F8) play a pivotal role in shaping ethical, legal, and sustainable operations, especially in matters of gig worker welfare, food safety, and environmental compliance.

Operational factors like Automation (F4) and Sustainable Packaging (F3) require careful integration with service quality initiatives, as they are highly interdependent and customer-facing.

Stakeholders must prioritize Courier Availability (F6) and Customer Expectations (F7) through proactive workforce management and personalization features to ensure long-term service competitiveness.

Overall, the structural model derived from TISM, coupled with MICMAC categorization, highlights the need for a balanced strategy that accounts for both technological innovation and regulatory adherence while aligning with evolving customer expectations.

CHAPTER 5

CONCLUSION, LIMITATION AND FUTURE SCOPE

5.1. Conclusion

This study utilized the Total Interpretive Structural Modeling (TISM) approach integrated with MICMAC analysis to explore and structure the key factors influencing last-mile food delivery logistics. Through a methodical examination of interrelationships and contextual dependencies among eight critical factors, the research successfully established a hierarchical model that reveals the system's internal dynamics.

The final TISM hierarchy demonstrated that Subscription Services (F5) and Government Regulations (F8) act as the primary driving forces in the last-mile delivery ecosystem. These two factors influence nearly all others, highlighting their foundational role in shaping operational and consumer-related outcomes. On the other end, factors such as Cost Optimization (F1), Service Quality (F2), Sustainable Packaging (F3), Automation (F4), Courier Availability (F6), and Customer Expectations (F7) were identified as linkage factors—highly influential yet also highly dependent—indicating their dynamic and sensitive nature within the system.

The MICMAC analysis reinforced these insights by categorizing the factors into strategic quadrants based on their driving and dependence powers. The absence of any autonomous or purely dependent factors reveals a tightly integrated and interdependent system, where each factor plays a vital role in influencing outcomes or being shaped by others.

Together, the TISM and MICMAC frameworks provide a robust decision-support structure for stakeholders in the food delivery sector, helping them identify leverage points and design interventions that can improve efficiency, sustainability, and customer satisfaction

5.2. Limitations of the Study

Despite offering a structured and insightful framework, the study is subject to several limitations:

Expert Bias: The pairwise comparisons and interpretive logic are based on expert opinions, which might be influenced by personal bias or limited knowledge scope.

Static Model: TISM provides a static representation of relationships and may not capture real-time or dynamic changes occurring in fast-evolving logistics ecosystems.

Limited Sample Size: The model was constructed based on a limited number of factors and inputs, which may not fully encapsulate the complexity of last-mile delivery logistics.

Exclusion of External Variables: Factors like fuel price volatility, macroeconomic conditions, or global supply chain disruptions were not considered, though they may significantly impact operations.

Regional Context: The model primarily reflects conditions in specific markets and may not be universally applicable without contextual adjustments.

5.3. Future Scope

The findings of this study open several avenues for future exploration:

Incorporation of Industry 4.0 Enablers: Future studies could incorporate emerging technologies like IoT, blockchain, and drones into the model to evaluate their potential impact on last-mile food logistics.

Dynamic Modeling with Fuzzy-TISM or ISM-DEMATEL: To address uncertainty and vagueness in expert judgments, advanced modeling approaches such as Fuzzy TISM or ISM-DEMATEL hybrid models can be employed.

Geographical and Cultural Variations: This model can be expanded to include cross-regional data

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Structural Modelling of Key drivers in Last Mile Food Delivery: Operational tradeoff, technological adoption, and environmental impact

Mahesh Saroha

ABSTRACT

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Last-mile food delivery (LMFD) has become a critical part of modern supply chains, where efficiency of operations, customer engagement, and sustainability intersect. Since logistics accounts for close to 75% of the total operational expense in delivery-based services, the last mile cannot be optimized anymore - it is a necessity. This research takes a systems-oriented analytical perspective by combining Total Interpretive Structural Modeling (TISM) and MICMAC analysis in order to determine and analyze the interdependencies between eight key performance factors: Cost Optimization, Service Quality, Sustainable Packaging, Automation, Subscription Services, Courier Availability, Customer Expectations, and Government Regulations

The analysis picks Automation and Technology Integration as the most powerful and independent drivers in the LMFD environment. These enablers have a substantial impact on other dependent variables like delivery timeliness, cost effectiveness, customized service, environmentally friendly operations, and scalable subscription models. The research highlights the use of digital transformation as a core strategy to comprehensively optimize performance in last-mile logistics. While providing insightful information, the study has limitations. It is mainly based on urban delivery dynamics, does not integrate consumer behavior analytics deeply, and does not take regional differences in technology infrastructure and maturity of gig workforce into complete consideration.

Future research streams involve incorporating AI-enabled delivery systems, behavioral reactions toward green logistics innovations, and scalability of technology-based delivery models in tier-2 markets and rural areas with infrastructural limitations. Further, it is imperative to study policy frameworks that enable inclusive, sustainable, and technology-benign development in the last-mile food delivery space.This thesis advances academic thinking as well as practical application by presenting a systematic, systems-thinking approach—a business strategy guide for enterprises, policymakers, and tech vendors looking to redesign the food delivery system smartly, inclusively, and sustainably.

Keywords: Last-Mile Delivery, Food Logistics, Digital Transformation, Sustainable Innovation, Operational Performance, TISM, MICMAC

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LIST OF ABBREVIATION

Abbreviation	Full Form
LMD	Last-Mile Delivery
LMFD	Last-Mile Food Delivery
AI	Artificial Intelligence
IoT	Internet of Things
EV	Electric Vehicle
GIS	Geographic Information System
RPA	Robotic Process Automation
NLP	Natural Language Processing
UAV	Unmanned Aerial Vehicle (Drone)
RFID	Radio Frequency Identification
V2I	Vehicle-to-Infrastructure Communication
SSIM	Structural Self-Interaction Matrix
TISM	Total Interpretive Structural Modeling
MICMAC	Matrice d'Impacts Croisés Multiplication Appliquée à un Classement
PMGSY	Pradhan Mantri Gram Sadak Yojana
SME	Small and Medium Enterprises
LEO	Low Earth Orbit (Satellite)
UX	User Experience
ETA	Estimated Time of Arrival
ELV	Electric Light Vehicle
ELF	Environmental and Logistical Factors
OF	Operational Factors
TF	Technological Factors
SRF	Socio-Economic and Regulatory Factors

CHAPTER 1

INTRODUCTION

1.1 Introduction

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In the last decade and a half, last-mile delivery (LMD) has undergone a radical transformation, particularly in the food industry. From being limited to routine restaurant deliveries done via telephone orders and manual dispatch, smartphone emergence, online platforms, and changes in consumer lifestyles have revolutionized the way food gets delivered to consumers. LMD is now a core and expensive part of food supply chains, representing almost 75% of total logistics expenses (Gevaers et al., 2011). Last-mile delivery in the food industry is determined by complex interactions among technological innovation, evolving consumer attitudes, urban infrastructure development, and pressures for sustainability. The delivery platform now operates as a technologically mediated and intensely data-dependent business. Boyer et al. (2009) noted that across low-margin industries such as food services, last-mile logistics have a direct impact on cost structures and customer loyalty, so that they pose strategic issues rather than operational ones. The development of LMD is a mirror of general changes in technology, urban life, consumerism, and greenness. During the early 2010s, the business of LMD was controlled by native restaurants managing their in-house delivery workers, usually without professional logistics or real-time monitoring. However, with the arrival of platform-based food delivery firms such as Zomato, Swiggy, Uber Eats, and Amazon Fresh in the mid-2010s came a fresh level of order, ease, and scalability. In India, where food delivery has become rapidly urbanized, demand from consumers skyrocketed with the mainstreaming of food aggregator apps. Swiggy and Zomato alone completed more than 1.5 million deliveries every day in 2019, enabled by GPS tracking, real-time status, and cashless payment (Statista, 2020). Although these developments were convenient for end-users, new issues related to order density, reliability of delivery, and management of the workforce arose. Lim, Jin, and Srai (2018) pointed out that demand fragmentation, extreme variability in order quantities, and geographic dispersal of urban populations only make last-mile efficiency more complex. With mobile apps, GPS and payment apps, the platforms made the delivery process easier, improving the customer experience and expanding market reach. While e-commerce exploded and consumers' expectations turned to instant gratification, last-mile food delivery grew increasingly under pressure to get faster, cheaper, and more reliable. To address these new requirements, delivery companies started using AI for dynamically optimizing fleet allocation and real-time route replanning of deliveries considering real-time traffic and weather information. Rai, Verlinde, and Macharis (2021) discovered that such smart systems cut average delivery times by as much as 25%, particularly in urban areas with inferior road networks. Additionally, gig economy platforms started incorporating functionalities such as autonomous dispatching and real-time performance monitoring, defocusing attention from manual logistics to algorithmic regulation. Businesses started investing heavily in route optimization, data analytics, and customer experience but also struggled with increasing operational costs, urban traffic, and delivery inefficiencies.

Then the COVID-19 pandemic, beginning in 2020, came along and changed everything—spurring accelerated use of contactless delivery, automation, and AI-driven logistics solutions. It also exposed vulnerabilities in supply chains and increased reliance on gig economy workers, prompting regulatory scrutiny and debates over labor rights. Technological disruption has been at the heart of LMD development. During the past 10–15 years, technologies like AI, IoT, and 5G have been incorporated into delivery networks, supporting predictive analytics, intelligent dispatching, and real-time monitoring. Autonomous vehicles, drones, and the deployment of LEO satellite networks like Starlink have further extended the geographical footprint of food delivery, particularly into low-density rural geographies. This infrastructure transformation reflects the increasing ambition of LMD platforms to pursue untapped markets, with the aid of delivery drones and autonomous vehicles in pilot tests in Asia, North America, and Europe. These technologies not only speed up delivery and improve food safety but also enable greater digital inclusion. Meanwhile, increasing environmental awareness has forced companies to adopt green logistics practices—ranging from electrically driven delivery vans to biodegradable packaging. The use of micro-warehousing, hyperlocal sourcing, and circular economy models has stemmed delivery-related emissions and waste.

Environmental factors have increasingly gained importance. Swiggy's 2022 Bengaluru tie-up to run electric vehicles for food delivery is a trend among logistics firms to green the urban delivery networks (Business Standard, 2022). In Europe, Dablanc et al. (2017) discovered that logistics providers operating cargo bikes and micro-hubs cut carbon emissions by as much as 60% and enhanced delivery times in city centers. These tactics fit into larger green logistics and Sustainable Development Goals (SDGs) and encourage platforms to rethink their environmental impact. In addition, the development of micro-warehousing and dark kitchens—strategically positioned food preparation facilities near delivery hubs—has enabled businesses to decrease delivery time and emissions at the same time. These trends also enable hyperlocal sourcing, which reduces supply chains and benefits local economies. Even with these developments, major challenges remain. Operating expenses are high, particularly in areas with unstable fuel prices, heavy traffic, or sparse populations. Regulatory ambiguity, especially on the issue of labor rights for platform workers, continues to be a contentious issue. Governments and unions have stepped up the examination of platform business models, citing concerns related to equitable wages, employment security, and occupational health.

15 The objective of this paper is to classify and determine the most significant drivers influencing the last-mile delivery (LMD) context in the food industry and analyze the
14 inter-relations among them using the Total Interpretive Structural Modeling (TISM) approach. By rigorously mapping out the driving and dependent variables, this research attempts to construct a hierarchical structure that reflects the intricacy of LMD operations and facilitates strategic decision-making for stakeholders wishing to pursue efficiency, resilience, and sustainability in food logistics.

1.2 Research Gap

Despite the substantial growth in literature surrounding last-mile delivery (LMD) in the food sector, multiple critical gaps continue to hinder holistic understanding and practical implementation:

1. Lack of Integrated Evaluation Across Core Domains: Most studies tend to focus in isolation on operational efficiency, technology adoption, or sustainability. There is limited work integrating these dimensions to understand their collective influence on LMFD performance.
2. Underdeveloped Strategies to Tackle Rising Delivery Costs: While operational costs are acknowledged as a key challenge, scalable cost-optimization frameworks incorporating AI, automation, and cold-chain logistics for diverse contexts (e.g., urban vs. rural) remain underexplored.

3. Economic Feasibility and Scalability of Emerging Technologies: There is insufficient analysis of the economic trade-offs and real-world scalability of innovations like drones, EVs, and smart lockers, especially for small and medium enterprises (SMEs).
4. Limited Insight into SME Inclusion and Technology Access: The bulk of research disproportionately focuses on large platforms like Zomato or Uber Eats. Little attention is paid to how SMEs can leverage digital tools or participate in tech-enabled LMD ecosystems.
5. Neglect of Rural and Semi-Urban Delivery Challenges: Existing models largely ignore connectivity and infrastructure constraints that hinder LMD in Tier 2 and Tier 3 regions, despite their growing e-commerce demand and policy focus.
6. Insufficient Research on Sustainable Delivery Models: While green logistics is an emerging area, current studies often emphasize vehicle electrification, neglecting the broader ecosystem of circular economy practices, biodegradable packaging, and waste management logistics.
7. Limited Understanding of Consumer Behavior Evolution: Consumer preferences are shifting toward personalization, contactless delivery, and sustainability, but there is a lack of dynamic models capturing these evolving behaviors and their influence on delivery strategy.

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1.3 Research Objectives

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To address the above research gaps, the present study sets out the following key objectives:

1. To classify and model the key factors influencing last-mile food delivery systems, including operational, technological, environmental-logistical, and socio-economic-regulatory dimensions.
2. To analyze the interrelationships among these factors using Total Interpretive Structural Modeling (TISM) to reveal hierarchical dependencies and critical drivers within the LMD ecosystem.
3. To identify the driving and dependent variables using MICMAC analysis, categorizing elements based on their influence and vulnerability to enhance strategic decision-making in LMFD planning.

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CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey

The food industry's last-mile delivery (LMD) sector is advancing rapidly but is facing an array of operational and logistical issues that are still poised to overwhelm both traditional and digitally born companies. Among them, arguably the most urgent are matters of efficiency, cost control, service reliability, and environmental sustainability. With changing customer demands for instant gratification and hyper-personalization of service, LMD has also become a crucial differentiator for a highly competitive food delivery market. Increased urban transportation costs, lack of drivers, and the assurance of food quality and freshness during transportation to the consumer are some of the contributing factors to the additional complexity of catering to this last phase of the supply chain (Mangiaracina et al., 2019; Rozycki & Kerr, 2020). As online food ordering has increased, the need for creative, cost-effective, and environmental-friendly solutions picked up pace. This growth has been driven by the availability of smartphones, fast internet, and food ordering platforms like Swiggy, Zomato, Uber Eats, and DoorDash. The ease of use of such websites has revolutionized the consumer's behavior, where there is growing interest in short and quick delivery times, live tracking, and touchless deliveries, especially in the post-pandemic situation (Sreedevi & Saranga, 2020). The LMD phase, nonetheless, is the most energy- and capital-hungry part of the logistics cycle, accounting for more than 50% of total delivery expenses in the majority of cities (Gevaers et al., 2011). The greatest challenge to food last-mile delivery can be summarized in three broad categories: high operational cost, city traffic, and sustainability. Urban traffic is still a prevalent problem even in megacities, where delivery inefficiency and cost increases result from traffic jam bottlenecks and parking shortages. Therefore, the environmental impact of last-mile logistics is substantial in that more traffic during delivery results in greater carbon emissions, noise pollution, and urban sprawl. These environmental problems are making companies and policymakers switch to cleaner options like electric cars, bike couriers, and urban consolidation centers (DHL, 2020; Campisi et al., 2023). In response to these problems, research on the new LMD methods has expanded exponentially. Optimization methods like route planning software, dynamic pricing, forecasting of demand, and application of Artificial Intelligence (AI) and Internet of Things (IoT) are being extensively studied with the target of enhancing delivery performance and minimizing waste (Tirkolaee et al., 2021). Cold chain management also gained significance as a method of maintaining food quality, especially for perishable items such as dairy, meat, and ready-to-eat items. In response to the increasing research and industry focus in this sector, this bibliometric literature review seeks to examine major advancements, trends in publications, and emerging areas of research in the last-mile food delivery sector. Utilizing quantitative mapping methods such as VOSviewer and Bibliometrix, the review brings together conclusions drawn by influential authors, institutions, and most common keywords.

The aim is to determine leading fields of research, point out underresearched areas, and give an organized summary of the intellectual profile that supports modern-day LMFD studies.

This review not only adds to the knowledge base of academia but also functions as a strategic tool for logistics managers, technology vendors, and policymakers looking to navigate urban logistics and food supply chain resilience challenges. By charting current knowledge and specifying avenues for future research, this research directs innovation toward a smarter, more sustainable, and customer-oriented last-mile delivery paradigm.

2.2. Bibliometric Analysis

2.2.1. Methodology

Bibliometric analysis serves as a widely recognized approach for reviewing and evaluating scientific literature, as highlighted by Merigó and Yang (2017). In this research, the *bibliometrix* package in R, developed by Aria and Cuccurullo (2017), has been employed for analysis. The SCOPUS database was chosen as the primary source to ensure the inclusion of high-quality scholarly publications. Keywords used included: "last-mile delivery," "food industry," "urban logistics," "delivery optimization," "smart logistics," and "e-commerce food delivery." A total of 159 relevant publications from 2013 to 2025 were analyzed using VOSviewer and *bibliometrix* in R.

2.2.2. Publication Trends Over Time

There has been a substantial rise in academic interest in the optimization of LMD in the food sector, especially after 2019, influenced by the proliferation of on-demand food platforms and the COVID-19 pandemic. While the peak in publications was observed around 2022, research continues to remain active, reflecting the growing technological, environmental, and regulatory relevance of last-mile food delivery.

Table 2.1: Annual Research Publications on LMD in the Food Industry (2013–2025)

Year	Number of Publications
2013	2
2014	1
2015	3
2016	4
2017	6
2018	8
2019	12
2020	19
2021	26
2022	29
2023	21
2024	14
2025	14 (as of May)

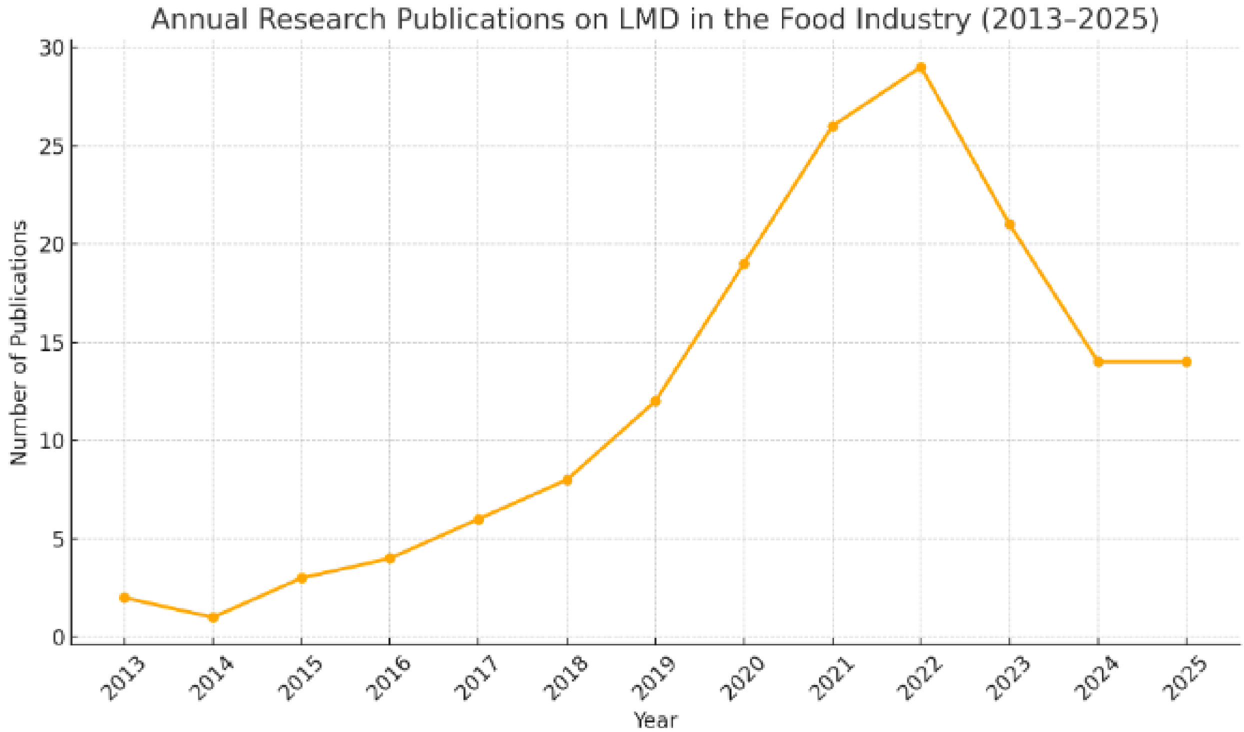

Figure 2.1: Growth in Publications (2013–2025)

2.2.3. Keyword Co-occurrence and Thematic Focus

Using VOSviewer, a co-occurrence map of author keywords was generated. The most frequent keywords included: last-mile delivery, food logistics, route optimization, AI, IoT, sustainability, e-commerce.

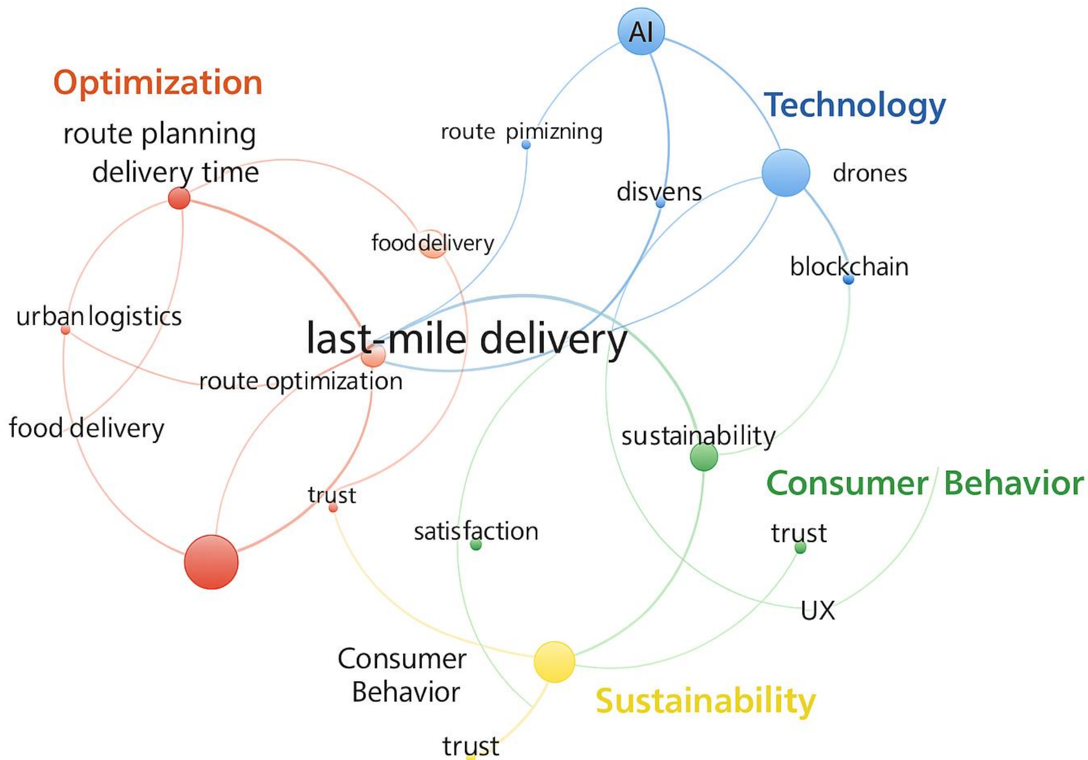

Figure 2.2: Keyword Co-occurrence Network Map (VOSviewer)

The literature can be classified into four major thematic clusters:

Table 2.2: Key Research Themes and Representative Studies

Theme	**Key Concepts**	**Representative Studies**
Optimization	Route planning, delivery time	Zhang et al. (2022), Kumar et al.
Technology	AI, drones, blockchain, IoT	Mangiaracina et al. (2021), Zhao et al.
Sustainability	Green logistics, EVs, emissions	Melo et al. (2019), Lim et al. (2021)
Consumer Behavior	Trust, satisfaction, UX	Boyer & Hult (2018), Yuen et al.

2.2.4. Most Influential Sources and Journals

The most frequently used journals indicate the interdisciplinary nature of this research, spanning logistics, sustainability, and operations.

Table 2.3: Top Journals Publishing in the Domain

Journal Name	No. of Publications	Avg. Citations per Article
Sustainability	18	12.4
Transportation Research Part E	14	15.8
IEEE Access	10	9.2
Journal of Cleaner Production	8	17.1
Logistics	6	8.3

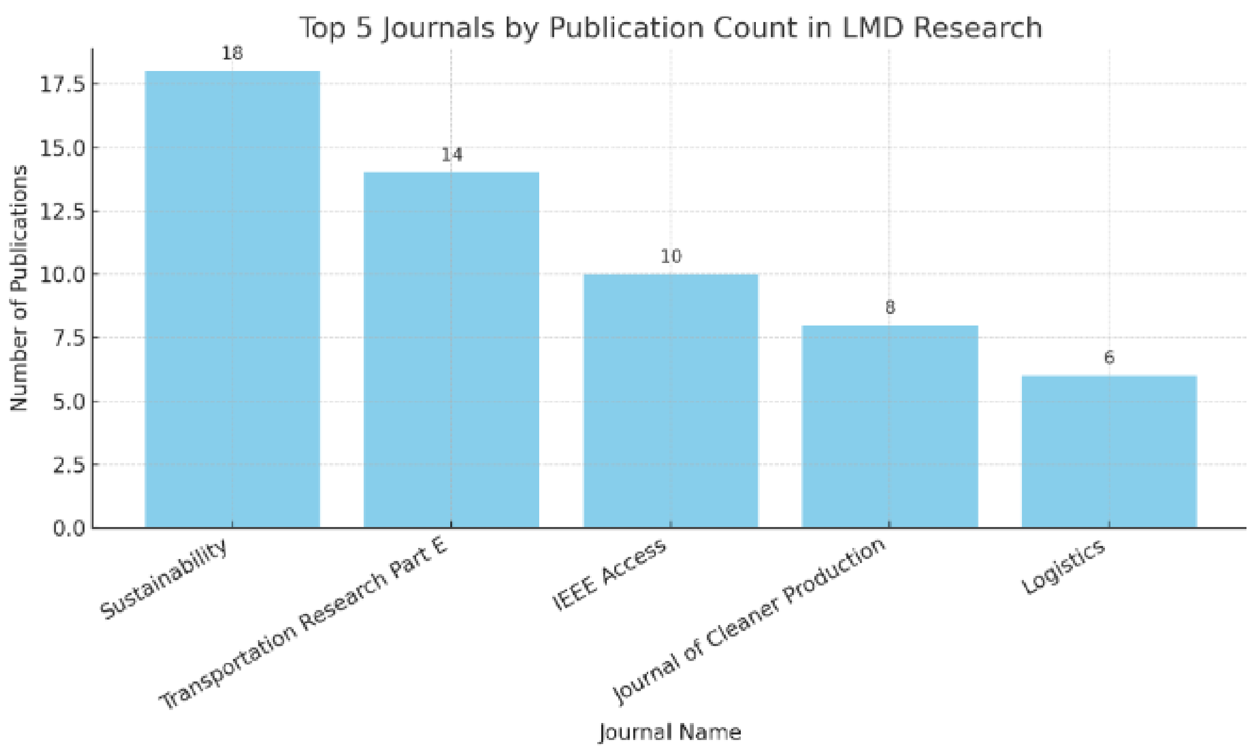

Figure 2.3: Top 5 Journals by Publication Count

2.2.5. Geographic Distribution and Institutional Output

The bibliometric data reveal that research output is concentrated in a few countries, primarily in Asia, North America, and Europe.

Table 2.4: Top Contributing Countries (2013–2025)

Country	Publications	Key Institutions
China	32	Tsinghua University, SJTU
USA	28	MIT, Stanford, Georgia Tech
India	18	IIT Delhi, IIM Bangalore
UK	12	University of Cambridge, UCL
Germany	10	TU Munich, Fraunhofer Institute

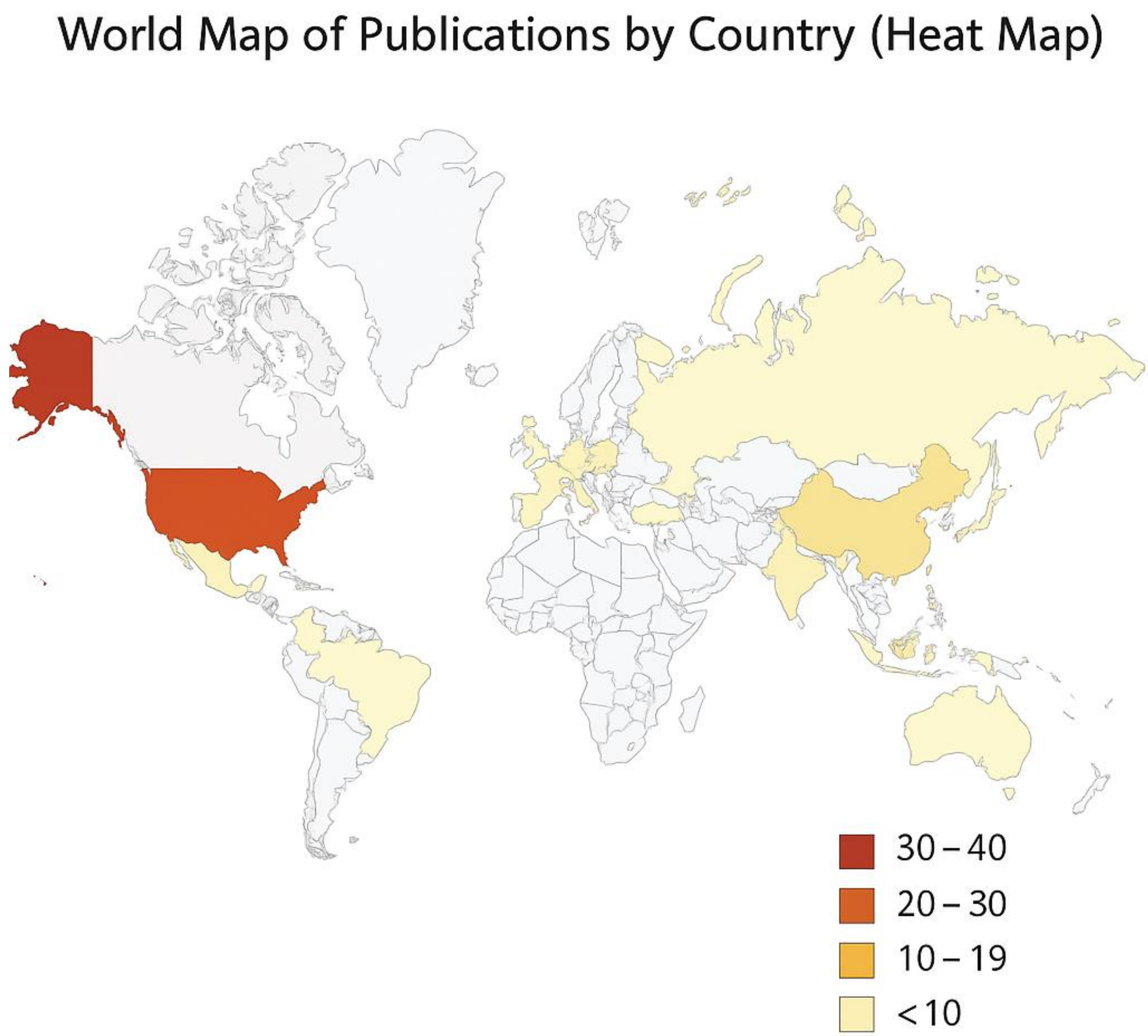

Figure 2.4: World Map of Publications by Country (Heat Map)

2.2.6. Most Cited Articles

Highly cited articles have shaped the discourse in technology adoption, sustainability, and consumer behavior.

Table 2.5: Top 5 Most Cited Articles

Author(s) & Year	Title	Citations
Boyer & Hult (2018)	Customer Behavior in Food Delivery	310
Yuen et al. (2020)	Drivers of LMD in Food Logistics	275
Melo et al. (2019)	Urban Sustainability in Food Distribution	245
Mangiaracina et al. (2021)	Technology Adoption in LMD	198
Zhao et al. (2021)	Drone-based Delivery Systems	176

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2.3. Challenges in Last-Mile Food Delivery

2.3.1. High Operational Costs in Last-Mile Food Delivery

The most significant challenge in last-mile food delivery is having a high operation cost, which has a direct effect on the profitability of companies in the food delivery industry. Handling perishable food products involves rigorous handling practices, temperature maintenance transportation, real-time monitoring, and compliance with very strict food safety standards, all of which have a major implication on increasing operation costs (Wang et al., 2024). Cold-chain logistics, which is crucial to maintaining the integrity and freshness of perishables, adds further financial burdens, especially on small-and medium-
51
size enterprises and startups that might not have the means to have far-reaching cold-chain infrastructure. The last-mile cost of food delivery is also increased by fuel price volatilities, increasing labor costs, warehousing costs, and investments in advanced tracking devices.

Since fuel prices are unstable, based on global economic signals and geopolitical activities, food delivery companies need to either absorb additional fuel costs or pass on the additional cost to consumers by way of higher delivery fees. Similarly, labor costs are continuously rising with minimum wage acts, workers' rights legislation, and the surging tide of insisting on reasonable compensation in the gig economy. Furthermore, investments in advanced warehouse management software, refrigerated storage facilities, and compliance with safety systems further boost operational expenses (Oliveira et al., 2020). In an attempt to offset such costs, companies are adopting automation, strategic route planning, and price-saving packaging techniques that don't sacrifice efficiency. Artificial intelligence (AI) dynamic pricing algorithms help businesses adjust delivery charges in real-time as demand changes, optimizing revenue capture while maintaining product accessibility for consumers. Predictive analytics is also deployed to optimize resource utilization, improve order fulfillment accuracy, and minimize wastage of food in the supply chain (Suguna et al., 2021). Additionally, cost-effective and environmentally friendly packaging options, such as biodegradable boxes and low-waste insulating products, are being created to minimize costs associated with packaging and enhance the environmental friendliness of the company. Further, the majority of food delivery businesses are employing robot process automation (RPA) to handle orders, chatbots to handle customer services, and machine learning-based scheduling of fleets in an effort to reduce manual intervention and operational inefficiencies. Such interventions, in addition to saving costs, accelerate delivery, increase accuracy, and improve customer satisfaction.

2.3.2. Urban Congestion and Delivery Inefficiencies

5 In the last decade and a half, last-mile delivery (LMD) has undergone a radical transformation, particularly in the food industry. From being confined to run-of-the-mill restaurant deliveries made through phone orders and manual dispatch, the advent of smartphones, digital platforms, and shifting consumer lifestyles has transformed the manner in which food is delivered to consumers. LMD is currently a key and costly component of food supply chains, accounting for nearly 75% of total logistics costs (Gevaers et al., 2011). LMD's evolution reflects broader transformation in technology, urbanization, consumerism, and ecological awareness. In the early 2010s, the LMD sector was dominated by local restaurants with their own delivery staff, typically without formal logistics or real-time observation.

Yet, with the advent of platform-based food delivery companies like Zomato, Swiggy, Uber Eats, and Amazon Fresh during the mid-2010s came a new degree of organization, convenience, and scalability. Using mobile apps, GPS tracking, and payment apps, these platforms simplified the delivery mechanism, making the consumer experience better and taking market reach further. While e-commerce exploded and consumers' expectations turned to instant gratification, last-mile food delivery grew increasingly under pressure to get faster, cheaper, and more reliable. Businesses started investing heavily in route optimization, data analytics, and customer experience but also struggled with increasing operational costs, urban traffic, and delivery inefficiencies. Then the COVID-19 pandemic, beginning in 2020, came along and changed everything—spurring accelerated use of contactless delivery, automation, and AI-driven logistics solutions. It also exposed vulnerabilities in supply chains and increased reliance on gig economy workers, prompting regulatory scrutiny and debates over labor rights. Technological disruption has
31 been central to LMD evolution. Over the last 10–15 years, tools such as AI, the Internet of Things (IoT), and 5G have been integrated into delivery networks, enabling predictive analytics, smart dispatching, and real-time monitoring. Autonomous delivery vehicles,

drones, and the deployment of LEO satellite networks such as Starlink have further increased the geographical reach of food delivery, especially into low-density rural areas.

These technologies not only increase delivery speed and food safety but also support wider digital inclusion. At the same time, growing environmental concerns have compelled businesses to embrace green logistics practices—anything from electrically powered delivery trucks to biodegradable packaging. The incorporation of micro-warehousing, hyperlocal sourcing, and circular economy models has curbed delivery-related emissions and waste. The aim of this paper is to categorize and identify the most important factors affecting the last-mile delivery (LMD) environment in the food industry and examine their relationships through the Total Interpretive Structural Modeling (TISM) method. By rigorously mapping out the driving and dependent variables, this research attempts to construct a hierarchical structure that reflects the intricacy of LMD operations and facilitates strategic decision-making for stakeholders wishing to pursue efficiency, resilience, and sustainability in food logistics.

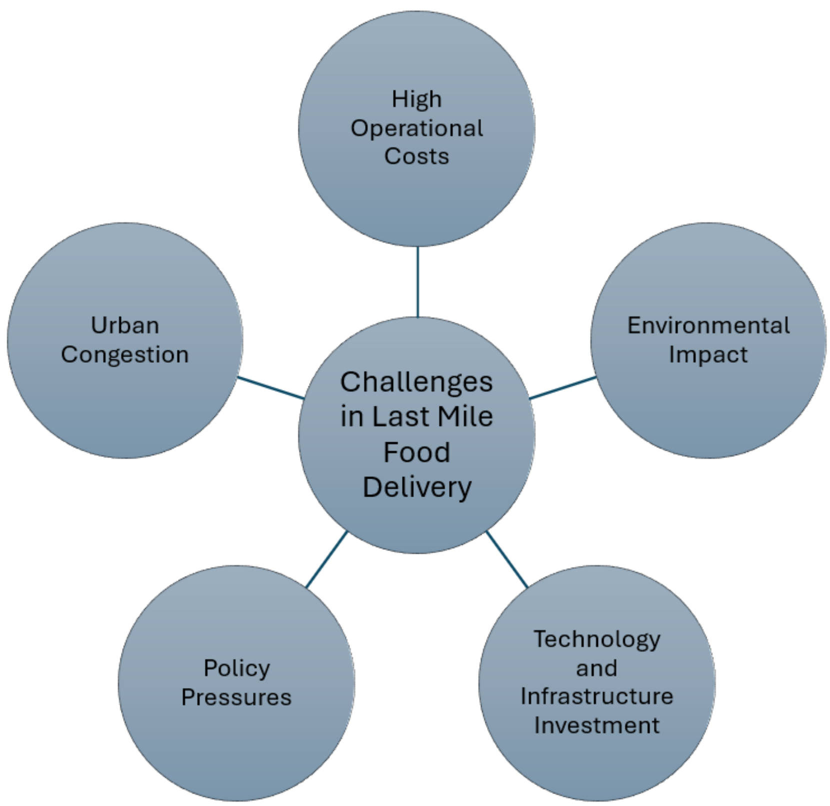

Figure 2.5: Challenges in Last Mile food delivery (Wang et al., 2024)

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2.3.3. Sustainability Concerns in Last-Mile Food Delivery

The last-mile food delivery's environmental implication has become an urgent concern, with the industry playing a substantial role in carbon emissions, city pollution, and surplus packaging waste. The use of fuel-dependent delivery cars amplifies air pollution and greenhouse emissions, while single-use plastic packs yield huge wastages aggravating the degradation of the environment (Leyerer et al., 2020). While the demand for food delivery services keeps increasing, the demand for sustainable solutions in logistics has become more pressing. Carbon emission from food delivery cars is still one of the largest environmental issues.

Traditional gasoline and diesel-fueled delivery motorcycles, vans, and vehicles pollute the air, worsening urban air quality and the public's health. The transition to electric vehicles (EVs) is being increasingly hailed as a sustainable option to cut emissions and fuel environmentally friendly delivery solutions. Most of the top food delivery firms are putting money into EV fleets, collaborating with electric mobility startups, and rolling out battery-swapping stations to enable mass EV penetration (Luo et al., 2022). Apart from mobility-related sustainability issues, excess packaging waste from food is an emerging environmental concern. Plastic containers, disposable utensils, and non-biodegradable insulations are used by most food delivery businesses, generating immense amounts of waste in cities (Silva, 2024). For this reason, businesses are investing in more biodegradable and recyclable packaging materials, encouraging reusable container initiatives, and offering rewards to consumers who use eco-friendly packaging options. The use of common delivery networks is another potential approach to increase sustainability in last-mile delivery. By bundling several orders into a single delivery run, business companies can decrease the number of vehicles on the road, minimize fuel consumption, and lower carbon imprints (Vepsäläinen, 2022). Shared delivery nodes, through which several delivery platforms partner up to maximize dispatching and routing, are under investigation as one way to maximize efficiency and sustainability.

Technology innovations, including AI-based demand forecasting, Internet of Things (IoT)-based vehicle tracking, and real-time route planning, are contributing significantly to improving sustainability. Predictive analytics enabled by artificial intelligence help firms optimize delivery processes, minimize idle time of vehicles, and order batching to reduce the environmental footprint (Suguna et al., 2022). Autonomous delivery technologies, such as robotic couriers and delivery drones, are also being created as energy-efficient modes of delivery replacement for traditional vehicles. Policy structures and regulatory interventions are also impelling sustainability initiatives in the food delivery industry. Governments across the globe are implementing carbon taxation policies, green logistics solutions incentive schemes, and emission reduction targets (Campisi et al., 2023). Urban development measures aimed at green transport infrastructure, such as special bike lanes and electric vehicle charging points, are also propelling the shift towards environmentally friendly last-mile delivery modes.

2.4. Technological Innovations in Last-Mile Food Delivery

2.4.1. Artificial Intelligence and Predictive Intelligence and Predictive Analytics

Forecast predictive analytics and artificial intelligence (AI) are midway to revolutionizing last-mile food delivery as a faster, more accurate, and less expensive process. AI-based routing algorithm adoption is tremendously enhancing the accuracy of deliveries by monitoring real-time traffic patterns, weather, and road closures and making real-time route adjustments to reduce delays (Wang et al., 2024). Through the use of the strengths of AI-based geographic information systems (GIS) and real-time traffic feed, business can anticipate re-routing deliveries past congestion points to ensure timely fulfillment and lower operational expenses. Predictive analytics, a field of AI, is transforming demand forecasting via examination of past sales patterns, customer ordering habits, seasonality, and geographic preferences. Machine learning algorithms enable food delivery platforms to predict peak hour demand, optimize employees, and maintain resources like delivery staff and vehicle availability Strategically positioned to handle fluctuating demands optimally (Oliveira et al., 2021). Predictability helps minimize last-minute logistical constraints, avert stockout situations, and ensure better overall service reliability. AI-powered systems are also enhancing customer experience through facilitating scheduling on a personal level and proactive order handling.

With natural language processing (NLP) and machine learning chatbots, customers may be provided with real-time order status, estimated time of arrival (ETA) estimates, and AI-driven customer support care. Furthermore, AI is providing food delivery as hyper-personalized because it analyzes the user's preferences, order history, and consumption behavior to suggest personalized meal ideas and suggest best delivery times (Mangiaracina et al., 2019). Furthermore, AI-driven fraud detection systems are being implemented to detect anomalies in order patterns, prevent spurious orders, and enhance transaction security. Through AI-driven analytics, food delivery businesses can identify fraudulent tendencies like phony delivery addresses, chargeback scams, and unauthorized use of accounts, leading to a safe and secure e-commerce environment. Robotics and AI are also being developed to integrate and make order delivery automated with robotic arms powered by AI utilized for sorting, packing, and delivering food products with precision. AI-powered automation streamlines warehouse operations, reduces human errors, increases the speed of order processing, and delivers food orders to customers fewer times.

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2.4.2. Internet of Things (IoT) and Real-Time Monitoring

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The Internet of Things (IoT) is transforming last-mile food transport with advanced tracking technology that provides real-time visibility into the movement, status, and condition of shipments. IoT-enabled sensors and GPS tracking devices are fitted in delivery trucks, food containers, and packages to monitor critical parameters such as temperature, humidity level, and handling conditions such that perishable food items are transported in optimal conditions (Suguna et al., 2022). The largest application of IoT to food delivery is cold-chain logistics, where temperature-sensitive items such as dairy, seafood, and frozen products must be kept at precise temperatures while being transported. IoT sensors track the variation in temperature continuously and report these variations to centralized monitoring systems, where alarm sounds if there are any deviations from predefined limits. This live monitoring capability reduces risk of spoilage, avoids food safety non-compliance, and enhances consumer confidence in food quality.

In addition, IoT-integrated telematics systems in delivery trucks give fleet managers real-time information about the health of vehicles, fuel efficiency, driver habits, and route optimization. The systems assist businesses in identifying mechanical problems ahead of time, planning predictive maintenance, and minimizing fuel usage, thereby lowering operating expenses and environmental strain (Luo et al., 2022).Intelligent packaging technologies combined with IoT are also further improving food safety during last-mile delivery. RFID tags and QR codes placed inside food packaging enable customers to view real-time information regarding the origin, preparation date, storage temperature, and expiration status of their orders. Such openness enhances the trust of consumers in food safety and facilitates regulatory authorities to implement stronger compliance standards in the sector (Hongrui Chu et al., 2021).

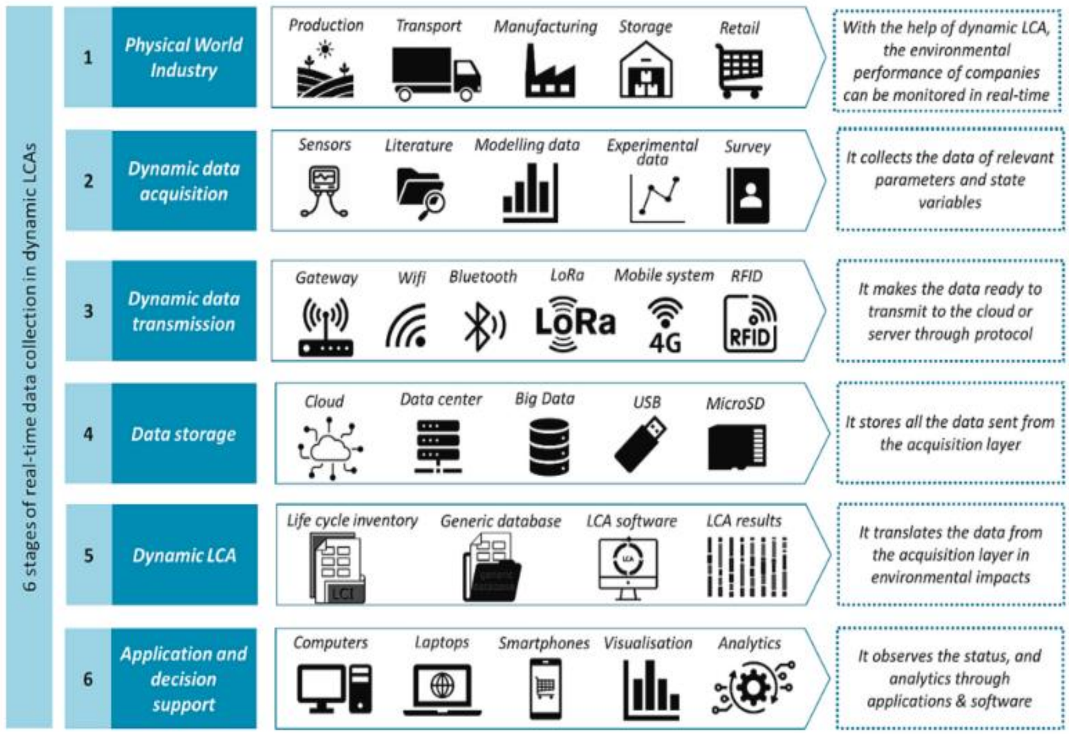

Figure 2.6: 6 staged real time data collection (T.P. da Costa et al., 2024)

IoT is also making it possible for smooth communication among customers and delivery staff via mobile apps. IoT sensors on smart delivery lockers make secure, touchless food deliveries possible, where customers get real-time updates and QR codes to pick up their orders. Automated solutions like these make delivering easier, reduce human contact, and lower the chances of food contamination. In addition, IoT convergence with blockchain technology is in the process of being developed to produce immutable digital records of food deliveries, promoting traceability and authenticity from the supply chain. Through the use of blockchain-driven IoT systems, food delivery businesses are able to avoid counterfeiting, ensure accountability, and promote improved food safety compliance across the delivery interfaces (Vepsäläinen, 2022).

2.4.3. Autonomous Delivery Systems

Autonomous delivery options are transforming the food delivery sector, and drones, robotic couriers, and autonomous vehicles are proving to be groundbreaking innovations. These technologies are countering labor expenses, solving urban congestion issues, and cutting delivery times substantially, rendering last-mile logistics more efficient and environmentally friendly (Rozycki & Kerr, 2020).

a) Drones in Last-Mile Food Delivery

Drones, or unmanned aerial vehicles (UAVs), are now an efficient means of quick food delivery, especially in high-population cities and distant locations with poor road access. By cutting through conventional road systems, drones are able to deliver food orders in a matter of minutes, dispelling the hassles of traffic and lowering carbon footprint coming from fuel-burning cars.

Large food delivery businesses and logistic companies are actively testing drone delivery programs, using AI-driven navigation systems to provide accurate, obstruct-free flight routes (Silva, 2024). Regulatory limits and airspace control are issues for mass adoption of drones, but aviation regulators and governments are actively engaged in creating frameworks to make drone-based food delivery safe and scalable. New technologies like geofencing, collision-avoidance technology, and AI-based autonomous flight are further making drone deliveries safe and reliable.

b) Robotic Couriers and Sidewalk Delivery Bots

Robotic couriers, or autonomous ground delivery robots, are being used in cities to allow for food deliveries over short distances. Autonomous robots with AI-based navigation, LiDAR technology, and obstacle avoidance are able to drive on sidewalks, pedestrian areas, and bike paths to deliver food orders safely (Campisi et al., 2023). Firms such as Nuro and Starship Technologies are pioneering the creation of autonomous robotic delivery agents to reduce reliance on human delivery personnel while scaling up operations. The robotic couriers are especially advantageous in minimizing labor expenses and countering the increasing lack of delivery staff in the gig economy. The robots deliver goods independently, which means there is no need for hourly pay, tips, or employment benefits, which makes them an economical option for food-delivery companies.

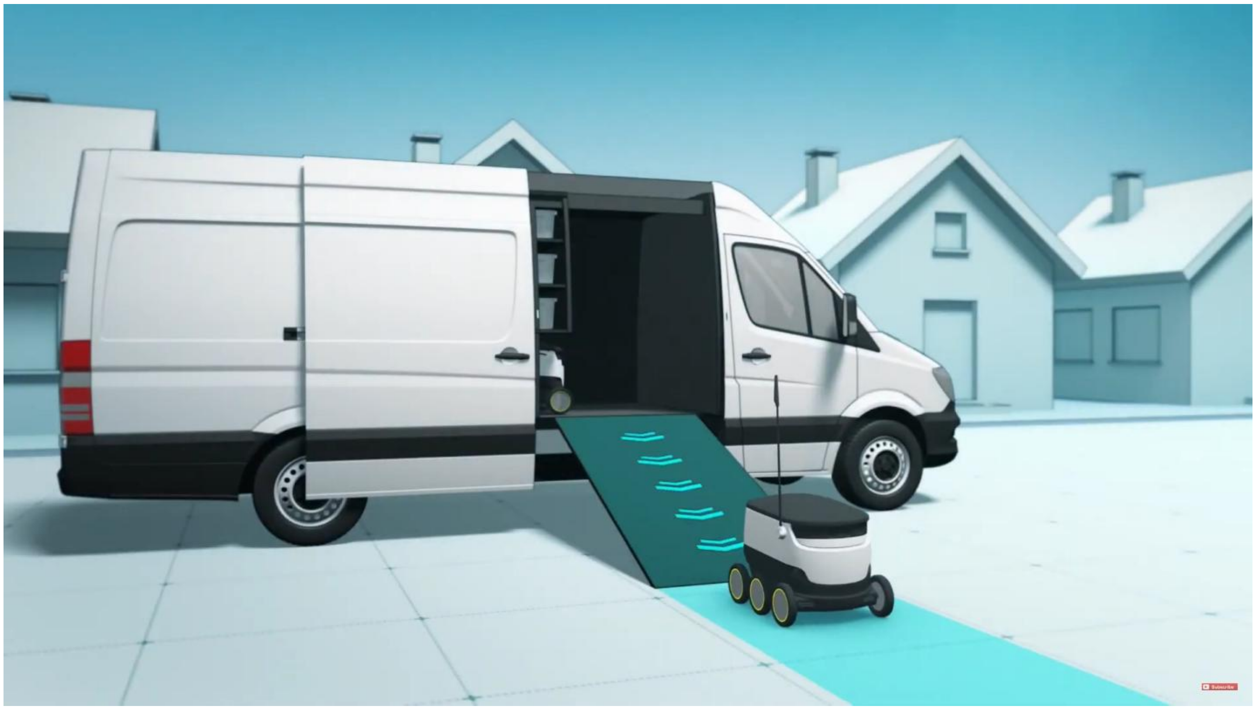

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Figure 2.7: Robot Couriers in Action (Mercedes-Benz Vans; Vans & robots: Efficient delivery with the mothership concept, 2016)

c) Self-Driving Delivery Vehicles

The use of autonomous delivery vans for food delivery is increasingly becoming popular, with businesses investing in autonomous vans and artificial intelligence-driven fleet management systems. The autonomous vans employ sophisticated machine learning software, sensor fusion technology, and real-time data processing to drive safely and efficiently on urban streets. Autonomous delivery vans can deliver continuously without taking breaks, facilitating 24/7 delivery services and full utilization of efficiency (Brindha, 2020).

As much as there is regulatory contention over the deployment of autonomous cars, V2I communication and AI-driven decision systems are opening the door to mass market acceptance. The future of autonomous food delivery can only be hybrid, where AI-driven autonomous cars are complemented by human-driven dispatch offices for real-time observation and intervention in case of need.

2.5. Advancements in Rural Telecommunications and Its Impact

While cities continue to witness the adoption of cutting-edge innovations in last-mile food delivery—from AI-powered route optimization to electric vehicle fleets—rural areas remain largely underserved due to infrastructure deficits, digital exclusion, and operational constraints. Yet rural India, where over 65% of the population resides, presents an untapped opportunity for logistics providers seeking long-term growth (World Bank, 2023). A critical enabler of this transformation lies in the advancement of rural telecommunications. Enhanced digital infrastructure is not merely a tool for connectivity; it is the backbone of operational visibility, real-time delivery tracking, digital transactions, and intelligent fleet coordination. For food delivery services to penetrate rural markets and operate with the same agility and efficiency as in urban zones, robust telecom infrastructure is indispensable.

Historically, rural India has lagged in internet access and digital adoption, creating a digital divide that limited both supply and demand for food delivery platforms. On the supply side, poor connectivity hindered service providers from offering real-time tracking, route monitoring, and app-based order fulfillment. On the demand side, consumers lacked the internet bandwidth or digital literacy to interact with food delivery apps, leading to underutilization of services. This digital isolation not only reduced operational feasibility but discouraged investment from logistics providers. However, recent years have seen a shift. Government interventions and public-private partnerships have begun narrowing the urban-rural digital gap. The Pradhan Mantri Gram Sadak Yojana (PMGSY), for instance, has significantly expanded rural road connectivity. As of 2023, PMGSY had constructed over 700,000 kilometers of roads, linking nearly 97% of previously inaccessible villages (UNESCAP, 2024). For food delivery companies, this road connectivity translates into practical access for two-wheelers, vans, and lightweight electric vehicles, enabling deliveries in areas that were once logistically infeasible.

Parallel to road development is the massive digital push under the BharatNet initiative, which aims to provide high-speed broadband to over 250,000 Gram Panchayats through optical fiber connectivity (DoT, 2024). As rural communities gain access to reliable internet, they can now fully engage with app-based platforms, facilitating online food ordering, digital payments, and live tracking. This improved digital infrastructure supports not only last-mile delivery systems but also warehousing coordination, inventory updates, and customer service communications in real-time. For companies operating in the food delivery ecosystem, such connectivity provides the operational clarity and consumer engagement required for sustainable rural service models.

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Satellite-based internet has emerged as a game-changer in areas still beyond the reach of terrestrial broadband. Low Earth Orbit (LEO) satellite systems are being deployed by players like Starlink, OneWeb, and Amazon’s Project Kuiper to bring low-latency, high-speed internet to remote geographies. Unlike traditional geostationary satellites that suffer from high latency and limited bandwidth, LEO satellites orbit closer to Earth and offer real-time internet access. These systems are being piloted in regions like Ladakh and the Northeastern states, with OneWeb (in partnership with Bharti) expected to offer commercial rural broadband by 2025 (Bharti Enterprises, 2023). For last-mile food delivery, this development is revolutionary. Remote villages can now receive real-time order updates, drivers can navigate through GPS-based systems without signal loss, and delivery vehicles can transmit live location and temperature data to ensure cold-chain integrity. Additionally, mobile applications function more reliably, enabling seamless order placement, payment processing, and customer support in regions previously considered black spots for digital commerce.

Equally significant is the deployment of 5G networks. Telecom giants like Reliance Jio and Bharti Airtel have begun expanding 5G services beyond urban centers, with a nationwide rural rollout expected by 2026. 5G’s ability to provide ultra-fast internet, low latency, and high device connectivity supports advanced logistics functions such as AI-based dispatching, IoT-enabled fleet tracking, and autonomous vehicle deployment (Ericsson, 2023). In the context of rural food delivery, 5G can enable smart lockers for unattended deliveries, predictive maintenance systems for rural transport vehicles, and even drone-based delivery in geographically challenging terrains. Furthermore, hyperlocal data exchanges allow food delivery platforms to dynamically adjust prices, reroute deliveries based on road conditions, and manage local inventories through cloud-based platforms.

While infrastructure forms the foundation, rural empowerment hinges equally on digital literacy and user accessibility. Government-backed initiatives such as Digital India, PMGDISHA (Pradhan Mantri Gramin Digital Saksharta Abhiyan), and the CSC (Common Services Centers) program are training millions in rural India on how to use smartphones, navigate delivery apps, and make online transactions. These efforts are vital in ensuring that rural residents are not just digitally connected but also digitally capable. From the consumer's perspective, this familiarity with apps and digital payments translates into growing confidence in ordering food online. From the platform’s side, a digitally literate consumer base enables automation, reduces manual customer service interventions, and promotes higher order frequency.

Private food delivery operators are increasingly realizing this potential. Swiggy and Flipkart have initiated pilot operations in Uttar Pradesh, Bihar, and Odisha employing rural gig workers. Local delivery partners trained in app-based operations deliver the food to inaccessible areas via e-scooters or cycles. Internal reports state that success rates in such pilots have surpassed 85%, and operational expenses are reduced through local manpower and familiarity with the topography. Having village-level agents integrated not only creates rural employment but also improves customer trust since the deliveries are carried out by familiar community members. In training and connectivity, delivery model innovation is redesigning rural logistics.

Localized micro-fulfillment centers are being used to stock up on products with high demand, cutting down on time and expense of long-haul deliveries. These cloud-based inventory system-powered rural fulfillment centers and 4G/5G connectivity networks facilitate dynamic stock refresh, forecasted restocking, and real-time dispatching. At the same time, businesses are employing hybrid delivery fleets—e-rickshaws, bikes, and even livestock-driven carts where needed—to traverse rural roads with low environmental and operational expense. In spite of these developments, a number of challenges continue to exist. Network stability is still a concern, especially for areas located on hills or within forests where signal loss is frequent.

Affordability is also a constraint; although smartphones and data plans have lost price, they are still a substantial outlay for poorer households. Additionally, rural users are often skeptical of digital payments and opt for cash-on-delivery, which makes reconciliation difficult and further raises the risk of fraud. From a platform viewpoint, cost-per-order is still high in rural villages with low population because there are fewer orders on each delivery route, which makes scale tricky without high-order volume or subsidies from the government. All these challenges need to be addressed through concerted efforts. There needs to be investment in power backup and weather-proof infrastructure by telecom companies to maintain continuity of service. Governments can subsidize the costs of connectivity for rural consumers, promote solar-powered internet kiosks, and encourage logistics platforms with rural employment opportunities. In addition, adding vernacular languages, voice-based interfaces, and visual navigation assistance in apps can make a huge difference in ease of use and accessibility for low-literacy populations in rural areas. Rural telecommunications advances are revolutionizing the potential of last-mile food delivery in India's interior. With strategic investment in roads, broadband, satellite internet, and 5G networks, physical and digital impediments to rural inclusion are being progressively eliminated.

Together with community-based delivery models, local job creation, and digital literacy programs, a resilient and sustainable rural food delivery network becomes not just possible but economically and socially transformative. With rural India getting more and more integrated, it has the potential to become not only a recipient of food logistics innovation but also a force for new-age, inclusive growth. Geographical distance no longer has to play a decisive role in deciding access to quality services. With the integration of digital infrastructure and grassroots input, the vision of inclusive last-mile delivery—where no village is out of reach, and no order too complicated—is becoming a concrete possibility.

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2.6. Factors Affecting Last-Mile Food Delivery

Last-mile delivery (LMD) in the food sector is shaped by a range of interrelated factors, which can be broadly categorized into four groups: Operational, Technological,
57 Environmental & Logistical, and Socio-Economic & Regulatory. Each group plays a critical role in ensuring efficient, timely, and sustainable food delivery to the end consumer.

2.6.1. Operational Factors (OF)

These factors influence the **speed, accuracy, and efficiency** of delivery operations. They are essential for maintaining food quality, reducing delays, and ensuring customer satisfaction.

Table 2.6: Operational Factors

S. No.	Factor	Explanation	References
1	Delivery Timeliness	Refers to delivering food products within the expected time window. Timely delivery ensures customer satisfaction and maintains food quality.	Hongrui Chu et al. (2021)
2	Routing Efficiency	Efficient route planning minimizes travel time and fuel consumption, which is crucial for perishable food items that require quick delivery.	Hongrui Chu et al. (2021); Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ali Baradaran (2022); Maria Palazzo et al. (2021)
3	Order Fulfilment Rate	Indicates the percentage of customer orders delivered completely and accurately. High rates reflect reliability and effective operational planning.	Hongrui Chu et al. (2021); M. Suguna et al. (2021)
4	Cold Chain Integrity	Involves maintaining proper temperature control during transit to preserve food safety and freshness, especially for frozen and chilled products.	Suguna et al. (2022); Nathalie Silva (2024)
5	Fleet Utilization	Measures how effectively the delivery fleet is used. Optimal utilization reduces costs and enhances service levels in food delivery operations.	Oliveira R. et al. (2020); Hongrui Chu et al. (2021)
6	Failed Deliveries and Returns	Tracks undelivered items and reverse logistics. High failure rates can lead to food waste and increased operational costs.	Oliveira R. et al. (2020)
7	Inventory Management	Involves tracking stock levels to ensure timely replenishment. Accurate inventory helps prevent stockouts and food spoilage.	Hongrui Chu et al. (2021)

2.6.2. Technological Factors (TF)

Technology is a key enabler for optimizing LMD. These factors improve routing, tracking, automation, and customer interface, ultimately enhancing delivery performance and customer trust.

Table 2.7: Technological Factors

S. No.	Technological Factor	Explanation	References
1	Real-Time Tracking Systems	Enables customers and managers to monitor delivery status live, improving transparency, accountability, and timely interventions in case of delays or route deviations.	Dsouza Prima Frederick (2022); Hongrui Chu et al. (2021)
2	Route Optimization Algorithms	Uses AI and ML to suggest the most efficient delivery routes based on traffic, weather, and order priority, reducing delivery time and costs.	Ali Baradaran (2022); T. C. Brindha (2020); Maria Palazzo et al. (2021)
3	Automated Dispatching	Integrates order management with fleet schedules, allowing quick assignment of orders to the best-suited delivery agents or vehicles.	Oliveira R. et al. (2020); Suguna et al. (2022)
4	Temperature Monitoring Sensors	IoT-enabled sensors in delivery containers ensure food is stored at the right temperature throughout transit, ensuring cold chain integrity.	Nathalie Silva (2024); Suguna et al. (2022)
5	Digital Payment Integration	Facilitates seamless and contactless transactions during delivery, enhancing convenience for customers and speeding up the delivery process.	M. Suguna et al. (2021); BharatGo (2024)
6	Predictive Analytics	Forecasts demand patterns and delivery loads, helping with inventory planning, staffing, and route preparation to avoid inefficiencies.	McKinsey & Company (2021); Sharma (2019)
7	Chatbots and Customer Interfaces	Provides real-time customer support and order updates via WhatsApp or apps, reducing operational load and improving customer satisfaction.	Selamat & Windasari (2021); Santosa & Surgawati (2024)

2.6.3. Environmental and Logistical Factors (ELF)

These factors are tied to sustainability and infrastructure challenges in LMD. Addressing them is crucial for reducing the environmental impact and adapting to complex urban environments.

Table 2.8: Environmental and Logistical Factors

S. No.	Factor	Explanation	References
1	Traffic Congestion	High traffic density in urban areas can delay deliveries, affecting freshness and increasing fuel consumption and emissions.	Dsouza Prima Frederick (2022); Maria Palazzo et al. (2021)
2	Weather Conditions	Rain, extreme heat, or humidity can hinder delivery operations, affect cold chain integrity, and reduce delivery fleet availability.	T. C. Brindha (2020); Suguna et al. (2022)
3	Road Infrastructure Quality	Poor or underdeveloped road infrastructure causes delays, increases vehicle maintenance costs, and limits access to remote areas.	Ali Baradaran (2022); Oliveira R. et al. (2020)
4	Fuel Availability and Costs	Volatile fuel prices and supply fluctuations directly impact delivery costs and fleet efficiency, especially in geographically dispersed zones.	McKinsey & Company (2021); Sharma (2019)
5	Packaging Sustainability	Use of eco-friendly packaging reduces environmental footprint and aligns with consumer expectations for green practices in food delivery.	Nathalie Silva (2024); Maria Palazzo et al. (2021)
6	Waste Management Logistics	Efficient handling of spoiled goods, packaging waste, and failed deliveries is essential for environmental sustainability and operational hygiene.	Suguna et al. (2022); Hongrui Chu et al. (2021)
7	Urban Delivery Restrictions	City regulations like vehicle access limits, time-bound delivery windows, and emission controls affect route planning and delivery flexibility.	Dsouza Prima Frederick (2022); T. C. Brindha (2020)

2.6.4. Socio-Economic and Regulatory Factors (SRF)

These factors address the human, legal, and economic dimensions of food delivery. They impact platform sustainability, workforce well-being, and alignment with government policies.

Table 2.9: Environmental and Regulatory Factors

S. No.	Factor	Explanation	References
1	Gig Economy & Labor Rights	The rise of gig work in food delivery raises concerns about job precarity, lack of benefits, and the need for fair labor practices to support delivery workers.	Carolynne Lord et al. (2022)
2	Wage Structures & Job Security for Couriers	Inconsistent wages and lack of job security affect workforce motivation and turnover, directly impacting the reliability and quality of last-mile services.	Renata Lúcia Magalhães de Oliveira (2020); T. Campisi et al. (2023); Carolynne Lord et al. (2022)
3	Government Regulations & Compliance	Policies around traffic, safety, taxation, and labor influence how last-mile delivery systems operate and adapt, ensuring legal and ethical practices.	Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ajaz Ahmad Bhat (2019); M. Suguna et al. (2021); T. Campisi et al. (2023); Nathalie Silva (2024)
4	Consumer Behaviour & Expectations	Changing consumer demands for faster, contactless, and eco-friendly delivery drive companies to innovate and personalize last-mile delivery strategies.	Dsouza Prima Frederick (2022); T. C. Brindha (2020); Ajaz Ahmad Bhat (2019); Hongrui Chu et al. (2021)
5	Adoption of Alternative Delivery Models	The use of drones, autonomous vehicles, and crowd-sourced models offers flexible solutions to meet growing demand and reduce delivery time in urban areas.	Jari Vepsäläinen (2022)

2.6.5 Critical Factors Identification

The study had an exploratory approach in following both primary and secondary sources of data. The primary data were gathered using structured web surveys (Google Forms), semi-structured interviews, and observational studies covering actual-time last-mile delivery activities. Secondary data consisted of data from industry reports, analytics of logistics management software, government documents, and overall macroeconomic trend studies specific to food logistics and e-commerce industries.

Table 2.10: Critical Factors of Last-Mile Food Delivery

Factor Name	Description	References
Cost Optimization	Affordability and value for money in pricing strategies, ensuring customer retention and competitive edge.	Kapoor & Vij (2018); Kumar et al. (2020); Banerjee & Chakraborty (2019); Singh & Sharma (2021); Jain et al. (2023)
Service Quality	Includes order accuracy, food freshness, timely delivery, and customer service responsiveness.	Parasuraman et al. (1988); Zeithaml et al. (2000); Srivastava & Srivastava (2021); Prakash et al. (2022); Singh & Prasad (2020)
Sustainable Packaging	Focuses on eco-friendly materials and the use of electric vehicles for delivery.	Gupta et al. (2021); Sharma & Yadav (2020); Li & Zhang (2019); Bansal et al. (2022); Patel & Roy (2021)
Automation	Integration of AI, real-time tracking, automation in warehousing, and route optimization tools.	Huang et al. (2019); Thakur & Jain (2021); Singh & Kumar (2020); Lee & Lee (2018); Chen et al. (2022)
Subscription Services	Monthly plans or memberships that provide benefits like free or discounted deliveries.	Agarwal & Gupta (2020); Mehta et al. (2021); Kapoor et al. (2022); Rao & Singh (2019); Zhang & Luo (2023)
Courier Availability & Job Security	Stability, job safety, and satisfaction of gig workers critical to delivery reliability.	Duggal & Sharma (2020); Mishra et al. (2021); Rai & Khanna (2022); Kaur et al. (2019); Saini & Verma (2023)
Customer Expectations & Personalization	Personalizing orders, promotions, and experiences based on user behavior and preferences.	Mittal & Agarwal (2021); Zhang et al. (2020); Singh & Rathi (2022); Kapoor & Mehta (2023); Yadav & Chatterjee (2021)
Government Regulations & Compliance	Ensuring adherence to labor laws, traffic norms, food safety, and zoning regulations.	Narayan et al. (2020); Singh & Kapoor (2021); Jain et al. (2022); Patel & Rana (2023); Mehra et al. (2021)

Quantitative data was collected in terms of delivery efficiency metrics, operational expenses, and the implementation of sustainability practices. These included aspects like average delivery times, fulfillment levels, compliance with promised time windows, fuel and labor expenses, measures of carbon footprint, and implementing sustainable delivery practices. At the same time, qualitative information was gathered in the form of case studies on new logistics models and thematic analysis of expert interviews using Delphi Technique, drawing attention to practical issues, technological upheavals, and prospective opportunities (Sushil 2017).

2.6.6 Brief Description of Critical Factors

These next thirteen key factors are chosen for their salience in both the literature and everyday food logistics contexts. They represent customer-oriented expectations, platform performance aims, and systemic constraints—thus being fundamental to TISM modeling.

F1. Cost Optimization

Efficient delivery of food at an affordable price is critical to platform profitability as well as user affordability. Boyer et al. (2009) highlight maximized route clustering and scheduling, whereas Winkenbach et al. (2016) affirm cost modeling methods that support scalability. The platforms are challenged with cost minimization as well as ensuring high levels of service.

F2. Service Quality

Service quality encompasses aspects such as correct order delivery, friendly delivery demeanor, and goods condition upon receipt. According to SERVQUAL (Parasuraman et al., 1988), perception of quality forms the basis for trust and loyalty. Cui & Pan (2021) indicate aspects such as real-time notification and timely responsiveness are becoming even more vital in differentiating brands.

F3. Sustainable Packaging

Sustainable delivery is on the rise, particularly from environmentally friendly sources. Research (Mangiaracina et al., 2015; Lin et al., 2018) highlights the advantages of electric cars, route planning, and biodegradable packaging. As regulations increase and consumers become more discerning, this element is directly related to social responsibility and brand image. Packaging is important not only for food preservation but also for waste reduction and branding. Palazzo et al. (2021) and Silva (2024) suggest sustainable, secure, and eco-friendly packaging solutions that are tamper-proof, insulated, and recyclable—reducing waste while enhancing food safety.

F4. Automation

Technology supports contemporary food delivery systems. Duan et al. (2019) and Chopra (2016) explain innovations such as AI-driven demand forecasting, GPS, IoT sensors, and automated dispatching. Technology enhances efficiency, minimizes errors, and offers end-to-end visibility.

F5. Subscription Services

Platforms increasingly employ subscriptions to encourage repeated usage and predictable revenue. Liang & Zhang (2017) and Kang & Kim (2020) demonstrate these programs enhance customer stickiness and minimize churn. They also enable platforms to manage inventory and labor more effectively with certain demand.

F6. Courier Availability

The gig workforce underpins the delivery economy, but instability in wages and inconsistent availability lead to unreliable delivery capacity. Lord et al. (2022) and Campisi et al. (2023) emphasize fair labor practices and workforce motivation as key to consistent last-mile performance.

F7. Customer Expectations & Personalization

Changing consumer expectations of faster delivery times, touchless delivery, and personalized experience influence delivery models. Bhat (2019) and Chu et al. (2021) identify the data's capability to forecast preference and evolve service delivery in line with user behavior.

F8. Government Regulations

Adhering to urban mobility regulations, labor legislation, and safety regulations is an automatic aspect of logistics operations. Brindha (2020), Bhat (2019), and Silva (2024) demonstrate that regulation conformity guarantees legality, minimizes business risk, and enhances public image.

These drivers were chosen not just because of their individual importance but also based on their interdependence and synergistic impact on the food delivery value chain. Their applicability was further supported by the views of 22 logistics experts on top platforms.

Although more than 20 other factors were considered in the initial review (e.g., labor rights, regulatory policy, fuel volatility, etc.), these were left out of the TISM model to ensure analytical precision and interpretive integrity. TISM is best utilized on a limited number of high-impact factors, usually five to ten. Adding more variables may water down the model's intensity and make it difficult to draw actionable conclusions (Patil et al. 2023).

CHAPTER 3

METHODOLGY

3.1. Method Selection

The hierarchical structure and interdependencies of variables that influence last-mile delivery (LMD) in the food industry require a strong analytical approach that can capture hierarchical structure and interpretive relations. Total Interpretive Structural Modeling (TISM) was utilized here for its capability to map such multidimensional dynamics in a systematic fashion (Sushil, 2012). TISM is suited to establish the contextual interdependence among a set of elements possessing complex interdependencies (Patil et al., 2023). TISM does not only quantify the interactions like other modeling approaches but also lays a qualitative base by introducing expert judgments to denote the "why" of any given relationship.

This interpretive power makes TISM especially well-suited to break down the trade-offs between operating, technology, and the environment in LMFD. The approach used here adapts the conventional Interpretive Structural Modeling (ISM) method, which is criticized for risking misinterpretation of interdependencies or over-simplification of dependencies (Choudhury et al., 2021). The research thus employs TISM as a more evolved alternative to make structural modeling more intensive and understandable.

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3.2. TISM

TISM's explanatory power renders it highly suitable for demystifying the intricate interaction of numerous influencing factors in LMFD. It facilitates constructing a hierarchical framework among influencing factors by classifying them into various levels depending on their driving and dependence power. This gives a better perspective on how base factors trigger systemic changes and ripple effects across the delivery ecosystem. The methodology was chosen to create a richer understanding of LMFD co-dependencies and thus support more informed decision-making (Sahoo & Goswami, 2023). The "what," "how," and "why" of theory building is clarified by a structured digraph and an accompanying SSIM (Structural Self-Interaction Matrix), which identify directional influences among components.

Based on TISM, the current study formulates a conceptual framework with enriched content projecting 13 critical factors affecting last-mile food delivery performance. They were determined through literature review and expert confirmation. MICMAC analysis was then used to categorize the factors into Autonomous, Dependent, Linkage, and Driving categories depending on their level of influence and dependence (Bashir et al., 2020).

A two-phase exploratory research approach was utilized in this study (Saha et al., 2023).

In Stage 1, the factors were collated from literature studies and agreed through semi-structured interviews with 22 logistics professionals (Sushil, 2017). Respondents answered a structured Yes/No questionnaire measuring the appropriateness of each considered factor. A factor was included if supported by more than 50% of respondents, and further inputs were gathered to check for completeness. This methodology was identical to El-Razek et al. (2008)

In Stage 2, TISM was employed to simulate hierarchical relationships among the finalized factors and MICMAC analysis for classification on the basis of systemic influence. Data sources were expert interviews, Google Forms surveys, case studies, and logistics analytics. Indicators like delivery time, cost per order, service quality, and eco-efficiency were used in combination with qualitative information on technology, workforce, urban planning, and rural logistics. This combined approach facilitates a systemic view of last-mile inefficiencies and emphasizes how solutions such as AI-based routing, cold chain tracking, and subscription-based models can address fundamental bottlenecks effectively.

3.2.1 Research Methodology

Step 1: List of Elements (Factors)

Total Interpretive Structural Modeling (TISM) process is essential to identify and define the key elements (factors) that influence the system under study. The success of TISM largely depends on the correct and comprehensive selection of these factors, as they form the basis for all further analysis, interpretation, and modeling.

For this study, six major factors have been identified that significantly impact consumer preferences and operational strategies in the context of food delivery services. Each factor is coded for easy reference during analysis.

Table 3.11: List of Elements (Factors)

Code	Factor	Description
F1	Cost Optimization	Affordability and value for money.
F2	Service Quality	Order accuracy, freshness, and customer service.
F3	Sustainable Packaging	Use of sustainable packaging and electric delivery vehicles.
F4	Automation	Integration of AI, real-time tracking, automation, and route optimization.
F5	Subscription Services	Monthly plans offering free or discounted deliveries.
F6	Courier Availability & Job Security	Stability and availability of the gig workforce.
F7	Customer Expectations & Personalization	Catering to user preferences and delivery experience customization.
F8	Government Regulations & Compliance	Adherence to urban delivery, labor, and food safety regulations.

Step 2: Pairwise Comparison and Interpretive Logic

Total Interpretive Structural Modeling (TISM) methodology, we conduct a systematic pairwise comparison between each identified factor to understand the influences and interdependencies among them. This step is critical because it lays the foundation for building a structured model that shows how different factors drive or depend on each other within the system being analyzed.

The objective of this step is to:

- Identify whether a relationship exists between two factors.
- Determine the direction of influence—that is, whether the first factor influences the second, the second influences the first, or if the influence is mutual.
- Explain the logical reasoning that supports the existence and direction of the influence, based on theoretical understanding, practical observations, or expert opinion.

For every pair of factors, a relationship (direction + meaning) is determined. Identification of a relationship between each pair of factors requires both the direction and the sense of influence between them. By carrying out pairwise comparisons systematically, every factor is compared against each other to determine if there is a direct relationship between them and, if there is, which factor affects the other (e.g., A → B). In addition to specifying this directional connection, TISM calls for the interpretive rationale behind each relationship—why the influence occurs and how the one factor affects the other. By taking this dual path of direction and meaning, TISM is able to generate not only a formal, hierarchical map of interrelationships but also a rich, contextual insight into the system under consideration.

Step 3: Structural Self-Interaction Matrix (SSIM)

After completing the pairwise comparison and interpretive logic analysis, the next step in the TISM methodology is to construct the Structural Self-Interaction Matrix (SSIM). The SSIM is a critical tool that systematically captures the nature and direction of relationships identified between each pair of factors. It translates the qualitative judgments made during the pairwise comparison into a structured symbolic representation, making the relationships easier to analyze mathematically in subsequent steps.

In the SSIM, for every pair of factors (i.e., Factor i and Factor j), we use specific symbols to denote the type and direction of the influence.

The notation used is as follows:

- V (Vector Influence): This symbol is used when the row factor (Factor i) influences the column factor (Factor j).

- A (Arrow Influence): This symbol is used when the column factor (Factor j) influences the row factor (Factor i).
- X (Mutual Influence): This symbol is applied when both factors influence each other simultaneously.
- O (No Relation): This symbol indicates that there is no significant influence between the two factors.

By filling out the SSIM, we ensure that the directional influences between all factor pairs are recorded uniformly, setting the stage for converting these symbolic relationships into binary numbers (0s and 1s) during the preparation of the initial reachability matrix. The SSIM thus serves as an essential bridge between the qualitative understanding of the system and its quantitative structural modeling, helping to organize complex interdependencies into a form that can be systematically analyzed and interpreted.

Table 3.12: Structural Self-Interaction Matrix (SSIM)

From / To	F1	F2	F3	F4	F5	F6	F7	F8
F1	-	O	A	A	O	X	O	A
F2	V	-	A	A	A	O	X	O
F3	V	V	-	O	O	O	A	A
F4	V	V	V	-	O	A	V	A
F5	V	V	V	V	-	O	V	O
F6	X	V	V	V	V	-	O	A
F7	V	X	V	A	A	V	-	O
F8	V	V	V	V	V	V	V	-

8

Step 4: Initial Reachability Matrix

Converting the SSIM (with V, A, X, O symbols) into binary values.

33

The SSIM framework employs certain symbols to denote directional influence between two elements, i and j

- **V**: i affects j → (1, 0)
- A: j has an effect on i → (0, 1)
- X: Both have an effect on each other → (1, 1)
- O: There is no effect → (0, 0)

56

Every symbol represents a binary pair indicating the direction of the influence between the elements.

Table 3.13: Initial Reachability Matrix Conversion

23

SSIM Symbol	Meaning	Binary Conversion (i, j)	Binary Conversion (j, i)
V	i influences j	1	0
A	j influences i	0	1
X	i and j influence each other (mutual)	1	1
O	No influence	0	0

The Initial Reachability Matrix indicates the immediate inter-relationships among objects within a system. It is derived from the SSIM by mapping symbolic relationships into binary (1s and 0s) to show which objects directly affect others.

Reachability Matrix(RM)

Variables	1	2	3	4	5	6	7	8	Driving Power
Cost Optimization	1	0	0	0	0	1	0	0	2
Service Quality	0	1	0	0	0	0	1	0	2
Sustainable Packaging	1	1	1	0	0	0	0	0	3
Automation	1	1	0	1	0	0	1	0	4
Subscription Services	0	1	0	0	1	0	1	0	3
Courier Availability	1	0	0	1	0	1	0	0	3
Customer Expectations	0	1	1	0	0	0	1	0	3
Government Regulations	1	0	1	1	0	1	0	1	5
Dependence Power	5	5	3	3	1	3	4	1	

Figure 3.8: Initial Reachability Matrix

Transitivity Check

- If A → B (1) and B → C (1), then A → C (1).

The Final Reachability Matrix is found out after doing transitivity check.

Reachability Matrix(RM)

Variables	1	2	3	4	5	6	7	8	Driving Power
Cost Optimization	1	0	0	0	0	1	0	0	2
Service Quality	0	1	0	0	0	0	1	0	2
Sustainable Packaging	1	1	1	0	0	0	0	0	3
Automation	1	1	0	1	0	0	1	0	4
Subscription Services	0	1	0	0	1	0	1	0	3
Courier Availability	1	0	0	1	0	1	0	0	3
Customer Expectations	0	1	1	0	0	0	1	0	3
Government Regulations	1	0	1	1	0	1	0	1	5
Dependence Power	5	5	3	3	1	3	4	1	

54 *Figure 3.9: Final Reachability Matrix*

Step 5: Level Partitioning (Extracting the TISM Hierarchy)

42 Following the formation of the Final Reachability Matrix, level partitioning is performed to build a structured hierarchy of the six identified factors. This step involves analyzing three sets for each factor:

Reachability Set (R): All factors that the given factor can influence (row-wise values = 1).

Antecedent Set (A): All factors that influence the given factor (column-wise values = 1).

41 Intersection Set (I): Common elements in both Reachability and Antecedent sets.

11 A factor is placed at the highest level (i.e., resolved first) when Reachability Set = Intersection Set.

Iteration 1: F1, F2, F3, F4, F6, F7

25 For F1, F2, F3, F4, F6, the Reachability Set = Intersection Set.

Therefore, F1, F2, F3, F4, F6 is at Level I.

50

Remove F1, F2, F3, F4, F6, F7 from the matrix and repeat for the remaining factor.

Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
2	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
3	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
4	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
5	1, 2, 3, 4, 5, 6, 7,	5,	5,	
6	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
7	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
8	1, 2, 3, 4, 6, 7, 8,	8,	8,	
1 2				

Figure 3.10: Level Partitioning, Iteration 1

11

Iteration 2: After Removing F1, F2, F3, F4, F6, F7

For F5, F8 the Reachability Set = Intersection Set.

Therefore, F5 and F8 are at Level II.

Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1		5, 8,		1
2		5, 8,		1
3		5, 8,		1
4		5, 8,		1
5	5,	5,	5,	2
6		5, 8,		1
7		5, 8,		1
8	8,	8,	8,	2
1 2				

Figure 3.11: Level Partitioning, Iteration 2

The final partitioning table is ready after competition of two iterations of the level partitioning table.

Level Partitioning(LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
2	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
3	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
4	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
5	5,	5,	5,	2
6	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
7	1, 2, 3, 4, 6, 7,	1, 2, 3, 4, 5, 6, 7, 8,	1, 2, 3, 4, 6, 7,	1
8	8,	8,	8,	2

Figure 3.12: Final Level Partitioning

After completing the interpretive structural modeling process—including identifying elements, establishing contextual relationships through pairwise comparisons, constructing the reachability matrix, performing level partitioning, and incorporating interpretive logic, the final TISM hierarchy is developed.

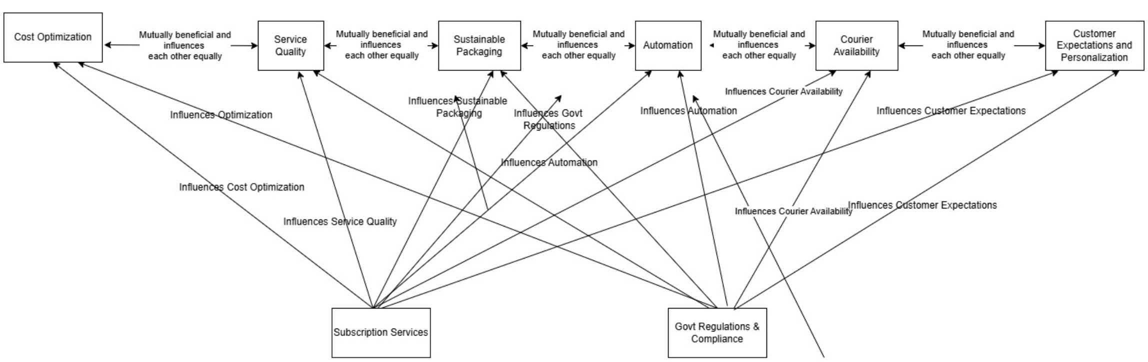

Figure 3.13: Final TISM Hierarchy

The final TISM hierarchy reflects the layered dependency structure, with F5 and F8 as root drivers influencing all other elements directly or indirectly. Notably, F5 (Subscription Services) emerges as a commercial innovation shaping user engagement and operational predictability, while F8 (Government Regulations) acts as a regulatory anchor, shaping compliance behavior and influencing long-term strategic alignment.

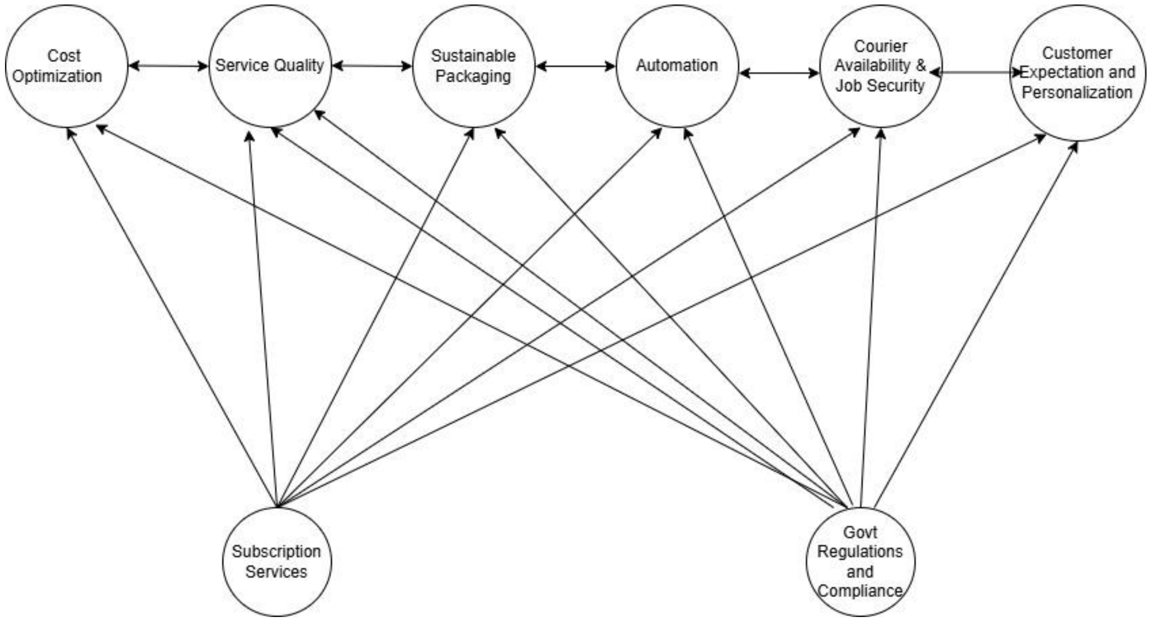

Figure 3.14 Diagraph of TISM

Step 6: MICMAC Analysis (Driving Power–Dependence Matrix)

The MICMAC analysis complements TISM by categorizing the identified factors based on two key metrics (Jena et al. 2017).:

13
34
Driving Power: The total number of elements a particular factor can influence (row-wise sum in the Final Reachability Matrix).

Dependence Power: The total number of elements that influence a particular factor (column-wise sum in the Final Reachability Matrix).

This classification helps in understanding the strategic positioning of each factor in terms of its influence and vulnerability and is crucial for decision-making in complex systems like last-mile food delivery.

Table 3.14: Driving and Dependence Power

Factor Code	Factor Name	Driving Power	Dependence Power
F1	Cost Optimization	6	8
F2	Service Quality	6	8
F3	Sustainable Packaging	6	8
F4	Automation	6	8
F5	Subscription Services	7	1
F6	Courier Availability	6	8
F7	Customer Expectations	6	8
F8	Government Regulations	7	1

Classification of Factors Based on MICMAC Quadrants

Based on the Driving and Dependence Powers, the factors are plotted into four categories/quadrants:

MICMAC

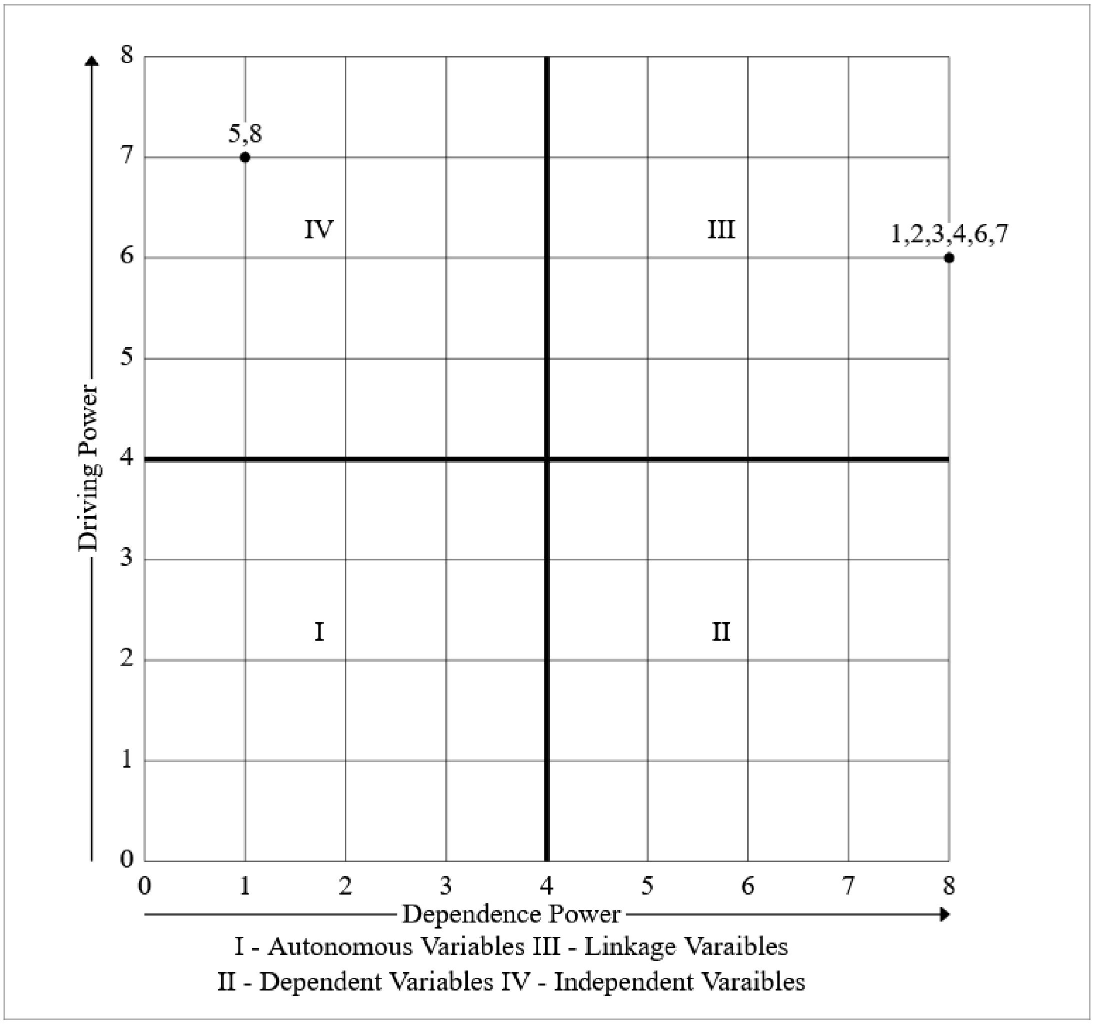

Figure 3.15: MICMAC Quadrants

1. Autonomous Factors (Low Driving, Low Dependence):
   These are factors that possess weak driving force and weak dependence. They are somewhat insulated from the system, exert little influence on other factors, and do not influence them significantly. They can be deemed as less vital in the structural model.
   No factors fall into this category in our study, indicating all factors are either influential or influenced.

2. Dependent Factors (Low Driving, High Dependence):
   These are high dependence and low driving power. These factors have considerable influence from other factors but have little effect on their own. They usually manifest at the bottom of the hierarchy in structural models.
   No factors fall into this category in our study, indicating all factors are either influential or influenced.

3. Linkage Factors (High Driving, High Dependence):
   They have high driving power and high dependence. Both are influential and sensitive to the changes in other factors. Due to their dual nature, they tend to be unstable and need to be managed very carefully because their changes can have cascading effects across the system.

   F1 (Cost optimization)
   F2 (Service Quality)
   F3 (Sustainable packaging)
   F4 (Automation)
   F6 (Subscription Services)
   F7 (Courier Availability)

4. Independent/Driving Factors (High Driving, Low Dependence):
   These have high driving power but low dependence. They have strong influence on other factors but are themselves less influenced by them. These are the most strategic and key factors within the system and tend to be the building blocks in interpretive models.

   F5 (Subscription Services)
   F8 (Government Regulations)

   Subscription Services (F5) influence customer retention models and expectations, while Government Regulations (F8) exert systemic pressure through compliance mandates.

CHAPTER 4

RESULT AND DISCUSSION

This study employed Total Interpretive Structural Modeling (TISM) to identify and analyze the critical factors influencing last-mile food delivery optimization. The methodology yielded six interrelated key factors:

- F1: Cost Optimization
- F2: Service Quality
- F3: Sustainable Packaging
- F4: Automation
- F5: Subscription Services
- F6: Courier Availability
- F7: Customer Expectations
- F8: Government Regulations

4.1 Result

The Total Interpretive Structural Modeling (TISM) methodology was applied to identify and structurally analyze the key factors influencing consumer preferences and operational strategies in the context of last-mile food delivery. Through a multi-step process involving factor identification, pairwise comparisons, structural self-interaction matrix formulation, reachability analysis, level partitioning, and MICMAC analysis, a comprehensive interpretive framework was developed.

Factor Identification and Initial Structuring

Eight critical factors were initially identified through literature review and domain understanding. These included: Cost Optimization (F1), Service Quality (F2), Sustainable Packaging (F3), Automation (F4), Subscription Services (F5), Courier Availability & Job Security (F6), Customer Expectations & Personalization (F7), and Government Regulations & Compliance (F8). These elements encompass both operational dimensions and consumer-centric considerations, ensuring a holistic representation of the food delivery ecosystem.

Pairwise Comparisons and Interpretive Logic

Each factor was examined in pairwise relation with the others to determine directional influence and underlying logical rationale. The interpretive logic helped to uncover not just whether a factor influenced another, but *why* it did so—adding depth to the structural analysis. For instance, Automation (F4) was seen to influence Service Quality (F2) and Cost Optimization (F1), due to its role in route planning, real-time tracking, and operational efficiency. Similarly, Subscription Services (F5) impacted Customer Expectations (F7) and Courier Availability (F6) by altering demand patterns and revenue predictability.

The qualitative pairwise relationships were captured in the SSIM using symbolic representations (V, A, X, O), which were then converted into binary format to derive the Initial Reachability Matrix. The transitivity check was performed to ensure consistency and derive the Final Reachability Matrix. This matrix served as a foundation for further hierarchical modeling and power-dependence analysis.

Level partitioning was executed iteratively to classify factors into hierarchical layers. In 58 the first iteration, five factors—F1, F2, F3, F4, and F6—were found to have their Reachability Sets equal to their Intersection Sets, assigning them to Level I of the hierarchy. These factors represent the most responsive or influenced components in the system.

In the second iteration, Subscription Services (F5) and Government Regulations (F8) were identified as Level II drivers—indicating their foundational and strategic roles in shaping the structure of the food delivery landscape.

The final TISM hierarchy reflects the layered dependency structure, with F5 and F8 as root drivers influencing all other elements directly or indirectly. Notably, F5 (Subscription Services) emerges as a commercial innovation shaping user engagement and operational predictability, while F8 (Government Regulations) acts as a regulatory anchor, shaping compliance behavior and influencing long-term strategic alignment.

MICMAC Analysis: Driving vs Dependence Power

10 The MICMAC (Matrice d’Impacts Croisés Multiplication Appliquée à un Classement) analysis was conducted to categorize the factors based on their driving power (total number of elements influenced) and dependence power (total number of elements influencing them).

Key Findings from MICMAC:

No factors were classified as Autonomous or Dependent, which suggests a tightly coupled system where all factors are either influenced or exert influence.

Linkage Factors (high driving and high dependence) included F1, F2, F3, F4, F6, and F7. These factors are highly interactive and sensitive to systemic shifts, and any changes in them could lead to ripple effects across the food delivery model. They represent both consumer-facing and operationally significant domains.

Independent/Driving Factors were F5 (Subscription Services) and F8 (Government Regulations). These elements exhibit high strategic importance due to their strong driving power and minimal susceptibility to influence, indicating their role as policy-level and structural levers in the system.

4.2. Discussion

The TISM and MICMAC analyses provide critical insights for practitioners and policymakers in the last-mile food delivery sector:

Subscription Services (F5) must be strategically designed, as they have cascading effects on customer engagement, pricing strategies, and delivery operations.

55 Government Regulations (F8) play a pivotal role in shaping ethical, legal, and sustainable operations, especially in matters of gig worker welfare, food safety, and environmental compliance.

Operational factors like Automation (F4) and Sustainable Packaging (F3) require careful integration with service quality initiatives, as they are highly interdependent and customer-facing.

Stakeholders must prioritize Courier Availability (F6) and Customer Expectations (F7) through proactive workforce management and personalization features to ensure long-term service competitiveness.

Overall, the structural model derived from TISM, coupled with MICMAC categorization, highlights the need for a balanced strategy that accounts for both technological innovation and regulatory adherence while aligning with evolving customer expectations.

CHAPTER 5

CONCLUSION, LIMITATION AND FUTURE SCOPE

5.1. Conclusion

This study utilized the Total Interpretive Structural Modeling (TISM) approach integrated with MICMAC analysis to explore and structure the key factors influencing last-mile food delivery logistics. Through a methodical examination of interrelationships and contextual dependencies among eight critical factors, the research successfully established a hierarchical model that reveals the system's internal dynamics.

The final TISM hierarchy demonstrated that Subscription Services (F5) and Government Regulations (F8) act as the primary driving forces in the last-mile delivery ecosystem. These two factors influence nearly all others, highlighting their foundational role in shaping operational and consumer-related outcomes. On the other end, factors such as Cost Optimization (F1), Service Quality (F2), Sustainable Packaging (F3), Automation (F4), Courier Availability (F6), and Customer Expectations (F7) were identified as linkage factors—highly influential yet also highly dependent—indicating their dynamic and sensitive nature within the system.

The MICMAC analysis reinforced these insights by categorizing the factors into strategic quadrants based on their driving and dependence powers. The absence of any autonomous or purely dependent factors reveals a tightly integrated and interdependent system, where each factor plays a vital role in influencing outcomes or being shaped by others.

Together, the TISM and MICMAC frameworks provide a robust decision-support structure for stakeholders in the food delivery sector, helping them identify leverage points and design interventions that can improve efficiency, sustainability, and customer satisfaction

5.2. Limitations of the Study

Despite offering a structured and insightful framework, the study is subject to several limitations:

53 Expert Bias: The pairwise comparisons and interpretive logic are based on expert opinions, which might be influenced by personal bias or limited knowledge scope.

Static Model: TISM provides a static representation of relationships and may not capture real-time or dynamic changes occurring in fast-evolving logistics ecosystems.

47 Limited Sample Size: The model was constructed based on a limited number of factors and inputs, which may not fully encapsulate the complexity of last-mile delivery logistics.

Exclusion of External Variables: Factors like fuel price volatility, macroeconomic conditions, or global supply chain disruptions were not considered, though they may significantly impact operations.

Regional Context: The model primarily reflects conditions in specific markets and may not be universally applicable without contextual adjustments.

5.3. Future Scope

32 The findings of this study open several avenues for future exploration:

Incorporation of Industry 4.0 Enablers: Future studies could incorporate emerging technologies like IoT, blockchain, and drones into the model to evaluate their potential impact on last-mile food logistics.

Dynamic Modeling with Fuzzy-TISM or ISM-DEMATEL: To address uncertainty and vagueness in expert judgments, advanced modeling approaches such as Fuzzy TISM or ISM-DEMATEL hybrid models can be employed.

Geographical and Cultural Variations: This model can be expanded to include cross-regional data

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