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"Navigating Last-Mile Delivery in Quetta, Pakistan: Sustainable Innovations for a Provincial Urban Hub"

M. Asif Khan: *MBA Experienced Marketing and Logistics Professional*
Saud Ul Taj: *Visiting Professor at Glasgow Caledonian University London*

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ABSTRACT

This research article explores the critical challenges and opportunities associated with last-mile delivery in Quetta, Pakistan, focusing on the impact of high fuel costs and inefficient infrastructure. Through an analysis of current logistics practices and firsthand experience in a pioneering logistics company, this study identifies key issues affecting delivery efficiency, including the lack of optimized routing, informal addressing systems, and poor road conditions. The research highlights the potential of emerging technologies, such as electric vehicles (EVs) and AI-driven route optimization tools, to mitigate these challenges and enhance operational efficiency. Additionally, it discusses the importance of supportive government policies and public-private partnerships in promoting sustainable logistics practices. The findings suggest that a coordinated approach integrating technology, sustainable practices, and collaboration among stakeholders is essential for transforming last-mile delivery in Quetta. This study contributes to the existing literature on logistics by providing actionable insights for policymakers, logistics providers, and researchers interested in improving urban delivery systems in developing regions.

1. Introduction

Definition of Last-Mile Delivery:

Last-mile delivery, the final stage of the supply chain where goods are transported from a distribution center to the customer's doorstep, plays a pivotal role in the logistics and e-commerce ecosystems. This phase is not only the most time-consuming and costly but also the most critical in shaping customer satisfaction. In Pakistan's city of Quetta, last-mile delivery faces distinct challenges due to the city's geographical location, underdeveloped infrastructure, and security concerns. Quetta, being a gateway to rural Balochistan and situated in a mountainous region, presents unique logistical obstacles such as difficult terrain, poor road conditions, and a lack of formal addressing systems.

Additionally, the growing demand for e-commerce services in the city, driven by increasing internet penetration and smartphone usage, has further emphasized the need for efficient last-mile delivery solutions. However, the expansion of last-mile delivery in Quetta is hindered by a combination of infrastructural inadequacies, traffic congestion, and high delivery costs. Despite these challenges, there is significant potential for growth and innovation in this space, particularly through the implementation of crowdsourced delivery models, technological advancements in route optimization, and sustainable delivery methods such as drones or electric vehicles. As businesses strive to meet customer expectations for faster and more reliable deliveries, addressing these challenges becomes critical not only for improving logistics efficiency but also for fostering e-commerce growth in the region. This research explores the importance of last-mile delivery in Quetta, identifies key challenges, and examines potential solutions to optimize this vital component of the logistics chain.

2. Problem Statement:

Limited Delivery Infrastructure:

Unlike bigger cities like Karachi or Lahore, Quetta has limited access to advanced logistics infrastructure like large warehouses, automated sorting centers, or sophisticated delivery fleets. This can result in longer delivery times and higher costs.

Objectives:

The objective of this research is to analyze the impact of limited delivery infrastructure on last-mile delivery efficiency in Quetta and to explore innovative solutions, such as technology-driven optimization, crowdsourced delivery models, and sustainable transportation methods, to overcome these infrastructural challenges and improve overall delivery performance in the city.

3. Literature Review

The study of last-mile delivery has gained considerable attention in recent years due to the rapid growth of e-commerce and the increasing complexity of urban logistics. While global research highlights key challenges such as traffic congestion, failed deliveries, and rising operational costs, the context of emerging markets, particularly cities like Quetta, remains underexplored. As a researcher with hands-on experience working in a pioneer logistics company in Quetta, I have observed firsthand the unique infrastructural, geographic, and logistical hurdles the city faces. This literature review seeks to synthesize global findings and contextualize them with insights from the local logistics landscape in Quetta.

Global Perspectives on Last-Mile Delivery Challenges:

Several studies have highlighted that the last-mile segment can account for up to 53% of total shipping costs (Gevaers et al., 2014). Urban congestion, fuel inefficiency, and increasing consumer demand for faster deliveries are critical challenges identified across major cities globally (Esper et al., 2003). The rise of e-commerce has further exacerbated these issues,

Corresponding Author's Email: saud.taj@london.aru.ac.uk

placing additional pressure on logistics providers to streamline their last-mile delivery operations. Various solutions have been proposed, including the use of optimization algorithms for route planning (Lin et al., 2016), the integration of technology in fleet management (Johnson C McCormick, 2019), and the adoption of green logistics methods like electric vehicles and bicycles (Janjevic C Ndiaye, 2014). However, most of this research has focused on developed economies, where robust infrastructure, advanced logistics networks, and supportive regulatory frameworks are present. In contrast, cities in developing nations, such as Quetta, face more fundamental challenges that make the direct application of these solutions difficult.

Last-Mile Delivery in Emerging Markets:

In emerging markets, last-mile delivery issues are often exacerbated by inadequate infrastructure, informal address systems, and limited use of advanced logistics technology. Research in cities like Nairobi, Kenya, and Dhaka, Bangladesh, indicates that logistics companies in such regions often rely on manual processes, resulting in inefficiencies and higher operational costs (Munoz C Dittmar, 2020). Similarly, studies in South Asia reveal that limited warehousing and distribution networks significantly hinder last-mile efficiency, contributing to delays and increased fuel costs (Das C Bhatnagar, 2021). These findings

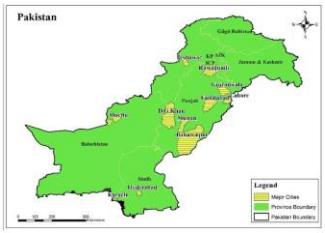
resonate with the challenges experienced in Quetta, where logistics companies struggle with inconsistent road conditions, lack of standardized addresses, and constrained access to technology.

The Quetta Context: Observations from the Field:

From my direct experience working with a pioneer logistics company in Quetta, I have witnessed the interplay of these global trends within the city's unique context. Quetta's geographic location—surrounded by mountainous terrain—coupled with poor road infrastructure, exacerbates the complexity of delivering goods, particularly in rural and suburban areas. The city's growth as an e-commerce hub has outpaced the development of its delivery infrastructure, creating bottlenecks in logistics operations. Quetta's informal address system is another significant issue, requiring drivers to frequently rely on customer calls for precise directions, resulting in longer delivery times and increased operational costs. This aligns with findings from global research in cities with similar infrastructural limitations, where lack of formal address systems can lead to delivery delays and higher rates of failed deliveries (Gonzalez-Feliu et al., 2017). Moreover, the limited number of warehousing and distribution hubs in the city further strains last-mile operations. Unlike larger urban centers like Karachi or Lahore, Quetta lacks the sophisticated logistics infrastructure necessary to efficiently manage the growing volume of e-commerce deliveries. Without adequate distribution networks, last-mile delivery companies in Quetta are forced to operate with higher transportation costs and lower delivery efficiency.

Potential Solutions in Quetta: Learning from Global Models:

Despite the challenges, there are potential strategies to improve last-mile delivery in Quetta, drawing from both global research and local



knowledge.

For example, (crowdsourced delivery models)—which have been successfully implemented in cities like São Paulo, Brazil (Zanoni C Zavanella, 2020)—could be adapted for Quetta's local context. By utilizing local drivers with in-depth knowledge of the city's informal address system, logistics companies can reduce costs and improve delivery speed. In addition, 'technology-driven solutions such as mobile apps and GPS-based routing

Corresponding Author's Email: saud.taj@london.aru.ac.uk

systems could address the challenge of inconsistent addresses, as they have in other developing urban areas. Global research suggests that adopting real-time tracking and dynamic route optimization can improve last-mile delivery efficiency by up to 30% (McKinnon et al., 2015). While such technologies are not yet widely used in Quetta, they represent a promising avenue for improvement, especially as smartphone penetration increases in the region. Furthermore, 'sustainable delivery models' including the use of electric bikes and small electric vehicles, can mitigate the rising fuel costs and environmental impact of last-mile delivery. Research conducted in European cities has shown that switching to electric vehicles for short-distance deliveries significantly reduces carbon emissions and operating expenses (Cherrett et al., 2017). Given Quetta's moderate traffic levels and relatively short delivery distances within the city, this approach could be a feasible solution to both reduce costs and contribute to greener logistics practices. In conclusion, while last-mile delivery research has largely focused on developed

economies, the challenges faced by cities like Quetta align with those observed in other emerging markets. Drawing from global studies and local insights from my experience in the logistics sector, it is clear that solutions such as crowdsourced models, technology integration, and sustainable transportation methods hold promise for improving last-mileefficiency in Quetta. Addressing the city's limited delivery infrastructure requires not only adapting global best practices but also tailoring them to the specific geographical, economic, and infrastructural realities of the region. This literature review provides a foundation for exploring these potential strategies in greater detail throughout this research.

4. Current Trends in Last-Mile Delivery:

- Technology in Delivery: Discuss emerging technologies like:
- Drones: Highlight how drones are revolutionizing rural and urban deliveries.
- Autonomous Vehicles: Cover self-driving vehicles in urban settings.
- Robotics: Delivery robots for short-distance or building-specific deliveries.
- Crowdsourced Delivery: Use of gig economy drivers and third-party logistics platforms (e.g., Uber, Local Small service providers).
- Sustainability: Eco-friendly solutions like electric vehicles (EVs) or bikes for short-range deliveries.

4,a. Case Studies

- Amazon: Pioneering Drone Deliveries and Advanced Automation

Innovation: Amazon has been at the forefront of last-mile delivery innovation, particularly through its Prime Air program, which aims to deliver packages using drones. The company has also invested heavily in automated warehouses and robotic sorting centers, streamlining the fulfillment process and reducing delivery times.

Impact: Amazon's investments in AI-powered delivery algorithms, same-day delivery, and its own logistics fleet have transformed the speed and efficiency of last-mile delivery. Their local delivery hubs, combined with their innovative use of technology, allow Amazon to

offer next-day and two-hour deliveries in major cities.

Future Plans: Amazon is testing autonomous delivery robots called Scout and continues to push the boundaries of contactless, fast, and sustainable deliveries.

- Alibaba: Smart Logistics and Network Collaboration

Innovation: Alibaba's logistics arm, Cainiao, has integrated big data and IoT (Internet of Things) to create a smart logistics network that optimizes last-mile delivery. Cainiao's use of data-driven route optimization and real-time tracking enhances delivery precision and reduces delays.

Impact: Through partnerships with local couriers and extensive use of AI-based platforms,

Alibaba has managed to reduce delivery times across China's vast geography, even

reaching remote rural areas. Cainiao's system also incorporates parcel locker networks, making last-mile deliveries more convenient for customers who may not be at home.

Corresponding Author's Email: saud.taj@london.aru.ac.uk

Future Plans: Alibaba is pushing for more green logistics solutions, such as electric delivery vehicles and sustainable packaging to reduce environmental impact.

- Walmart: Hybrid Models and In-Store Pickup Innovations

Innovation: Walmart has developed a hybrid last-mile delivery model that integrates in- store pickups, curbside deliveries, and third-party delivery services. Walmart's Walmart+ membership service includes free same-day delivery, utilizing its vast network of stores as distribution hubs.

Impact: Walmart leverages its extensive physical store network to offer faster and cheaper last-mile solutions by transforming stores into micro-fulfillment centers. In addition,

Walmart is testing autonomous vehicles for grocery deliveries and drone technology to further enhance its delivery capabilities.

Future Plans: Walmart plans to expand its use of AI and machines, learning for predictive demand and route optimization to make deliveries faster and more efficient, especially for perishable goods.

5. Challenges:

- Cost Efficiency: Last-mile delivery is the most expensive part of the delivery chain.
- Customer Expectations: Same-day or next-day delivery expectations.
- Traffic and Urbanization: Congestion in cities affecting delivery times.

Failed Deliveries: Difficulty in completing the delivery when the customer is unavailable.

Opportunities:

Technological Advancements: AI, IoT (Internet of Things), blockchain, and big data for optimizing routes and delivery times.

New Business Models: Subscription-based delivery, collaborative shipping (crowd logistics).

Sustainability Focus : The rise of green logistics and eco-friendly transport options.

6. Methodology: Real-Time Functional Job Approach:

This research utilizes a real-time functional job approach, incorporating hands-on experience and data-driven analysis to explore last-mile delivery challenges in Quetta. Key steps include:

I. Field Observation and Participation : As an active participant in a pioneer logistics company, I engaged directly in daily operations such as route planning, warehouse management, and delivery processes. Shadowing drivers and interacting with customers provided real-time insights into the challenges posed by poor infrastructure, traffic, and informal addressing systems.

II. Data Collection through Technology : GPS tracking and route optimization tools were used to gather quantitative data on delivery times, route efficiency, and failed deliveries, identifying operational bottlenecks specific to Quetta.

III. Surveys and Interviews : Interviews with logistics staff—drivers, managers, and customer service—highlighted key challenges and the level of technology adoption in local operations.

IV. Case Study Comparison : Analyzing global e-commerce giants like Amazon, Alibaba, and Walmart provided benchmarks for adapting solutions such as crowdsourced delivery and AI-based optimization to Quetta's context.

V. Pilot Implementation: Small-scale trials of proposed solutions, such as crowdsourced delivery and route optimization tools, were conducted to assess their impact on reducing delivery times and improving efficiency.

VI. Evaluation: Results from the pilots were evaluated using feedback from staff and customers, as well as quantitative improvements in delivery speed and success rates, to refine solutions for Quetta's last-mile

Corresponding Author's Email: saud.taj@london.aru.ac.uk

delivery.

This approach blends practical experience with technology and global comparisons to address Quetta's last-mile delivery challenges effectively.

7. Results and Discussion:

Potential Solutions and Recommendations:

Given the significant impact of high fuel costs on last-mile delivery in Quetta, several solutions can be explored to optimize route management and reduce operational expenses. Key recommendations include:

a) Adoption of Electric-Powered Vehicles (EVs):

A shift to electric-powered vehicles , such as electric bikes or small electric delivery vans , offers a sustainable solution to reduce fuel dependency. EVs are particularly suited for short-range deliveries in urban areas like Quetta, where delivery distances are generally manageable. The use of electric vehicles could significantly cut fuel costs, lower carbon emissions, and reduce overall operational expenses, making deliveries more cost-effective and environmentally friendly.

b) Crowd-sourced Delivery Models:

Engaging local delivery drivers who are familiar with Quetta's informal addressing system and terrain could enhance route efficiency. Crowdsourcing not only reduces the need for large delivery fleets but also taps into local knowledge to optimize routes, cutting down delivery times and fuel consumption.

c) Implementation of Route Optimization Tools:

Introducing the AI-powered route optimization tools can streamline delivery operations by identifying the shortest and most efficient delivery paths. These tools can minimize time on the road, reduce fuel consumption, and lower operational costs. Pairing route optimization with electric vehicles would further amplify cost savings.

In summary, adopting electric-powered vehicles alongside route optimization technologies presents a viable solution to manage fuel costs and improve delivery efficiency in Quetta. These recommendations would not only reduce operational expenses but also contribute to more sustainable last-mile logistics.

8. Future Trends and Recommendations

As the logistics industry in Quetta navigates the challenges of high fuel costs and inefficient last-mile delivery, several future trends can be anticipated, aligned with three key areas: Emerging technologies ,Policy Recommendations , and Business Strategies

Emerging Technologies

Electric Vehicles (EVs) and Sustainable Delivery Solutions: The rise of electric-powered vehicles is poised to redefine last-mile delivery in Quetta. EVs offer a cost-effective, fuel- saving alternative for logistics companies, particularly as global advancements in battery technology reduce upfront costs and extend vehicle range. Drones and autonomous delivery robots may also become viable solutions for hard-to-reach areas or congested urban zones, further reducing operational expenses.

AI-Powered Route Optimization: The integration of AI-driven tool sand machine learning algorithms will optimize delivery routes in real-time, minimizing fuel consumption and enhancing delivery speed. In Quetta, where informal addressing and poor infrastructure present challenges, AI-powered systems can significantly reduce delays and improve route efficiency.

Smart Warehousing: Automation and IoT (Internet of Things)in warehousing will streamline order fulfillment and inventory management, further cutting down delivery lead times. These technologies can help reduce bottlenecks and inefficiencies that contribute to high operational costs.

I. Policy Recommendations

Government Incentives for Green Logistics : To promote the adoption of electric vehicles and sustainable delivery models , local and national governments should

Corresponding Author's Email: saud.taj@london.aru.ac.uk

offer tax incentives and subsidies businesses investing in EV fleets and charging infrastructure. Policies could also support the development of public EV charging station to ease the transition for logistics providers. Infrastructure Development: There is a need for government initiatives to improve
Quetta's road infrastructure and address systems, making it easier for logistics companies to navigate the city efficiently. Public-private partnerships could be established to fund the development of digital addressing systems, which would reduce the challenges of informal housing and unmarked locations.
Regulatory Support for Emerging Technologies : Governments should establish clear regulations that support the integration of emerging technologies like drones,
autonomous delivery vehicles, and electric scooters in the logistics sector. This includes developing airspace regulations for drones and providing legal frameworks for autonomous vehicles to operate in urban areas.
ll. Business Strategies
Diversification into Sustainable Delivery : Logistics companies in Quetta should explore investing in electric-powered delivery fleets and alternative transport methods such as electric bikes for short-range deliveries. These sustainable options not only reduce fuel costs but also align with global trends toward eco-friendly business practices, improving both cost efficiency and brand reputation.
Adoption of Crowdsourced Delivery Models : To optimize last-mile delivery, companies can implement crowdsourced delivery systems , employing local drivers familiar with
Quetta's unique terrain and informal addresses. This strategy allows for more flexible, cost-efficient delivery services, particularly for smaller, local businesses that may not have large delivery fleets.
Leverage Technology for Customer Engagement: By adopting real-time tracking systems and automated customer communication , businesses can provide customers with accurate delivery times and minimize failed delivery attempts. This enhances customer satisfaction and operational efficiency, reducing the need for costly redelivery efforts. This research highlights the significant challenges posed by high fuel costs and inefficient last-mile delivery systems in Quetta, as well as the potential for emerging technologies and innovative business strategies to address these issues. Through hands-on experience in
the logistics sector, it became clear that fuel consumption, poor infrastructure, and informal addressing systems are critical factors driving up operational costs in last-mile delivery. As part of this research, the author engaged in several meetings with government officials and professional bodies in Quetta to discuss these challenges and explore potential solutions. These discussions emphasized the need for policy support to encourage the adoption of electric vehicles (EVs), as well as infrastructure improvements to ease delivery operations. Key stakeholders expressed interest in public-private partnerships that could help fund the development of a digital addressing system and promote sustainable logistics practices. In light of these conversations, the research concludes that a coordinated approach involving technology adoption, government incentives , and business model innovation is essential for transforming last-mile delivery in Quetta. By embracing electric-powered vehicles, AI-driven route optimization, and crowdsourced delivery models, logistics providers can reduce fuel dependency, cut costs, and improve delivery efficiency. The support and collaboration of local authorities will be instrumental in driving these changes and fostering a more sustainable and cost-effective logistics ecosystem in Quetta.

G. Conclusion

This research has explored the critical challenges and opportunities within Quetta's last- mile delivery ecosystem, with a particular focus on the impact of high fuel costs and

Corresponding Author's Email: saud.taj@london.aru.ac.uk

infrastructural inefficiencies. Through hands-on experience in logistics operations, real- time data collection, and analysis of global best practices, it has become evident that high fuel costs significantly hinder the profitability and efficiency of last-mile deliveries in Quetta. The absence of optimized routing, poor road conditions, and informal addressing systems further exacerbate these issues. Emerging technologies such as electric vehicles (EVs) , AI-powered route optimization , and crowdsourced delivery models offer promising solutions to these challenges. EVs, in particular, can reduce fuel dependency and operational costs while contributing to sustainable logistics practices. The application of AI to streamline route planning and real- time tracking can minimize delays and inefficiencies, making last-mile delivery more cost- effective and customer-friendly. Several meetings between the author and government officials and professional bodies in Quetta have confirmed that addressing these challenges requires coordinated action. Policy support in the form of incentives for EV adoption ,investment in infrastructure improvements , and regulations that support technological innovations is crucial. Public-private partnerships could play a significant role in funding key initiatives such as EV charging infrastructure and the development of digital address systems to ease delivery operations. Ultimately, the future of last-mile delivery in Quetta lies in the integration of technology , sustainable practices , and government collaboration . By embracing electric vehicles, advanced routing tools, and innovative business models, logistics providers can reduce costs, improve delivery efficiency, and pave the way for a more sustainable and effective logistics system in Quetta.

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Corresponding Author's Email: saud.taj@london.aru.ac.uk