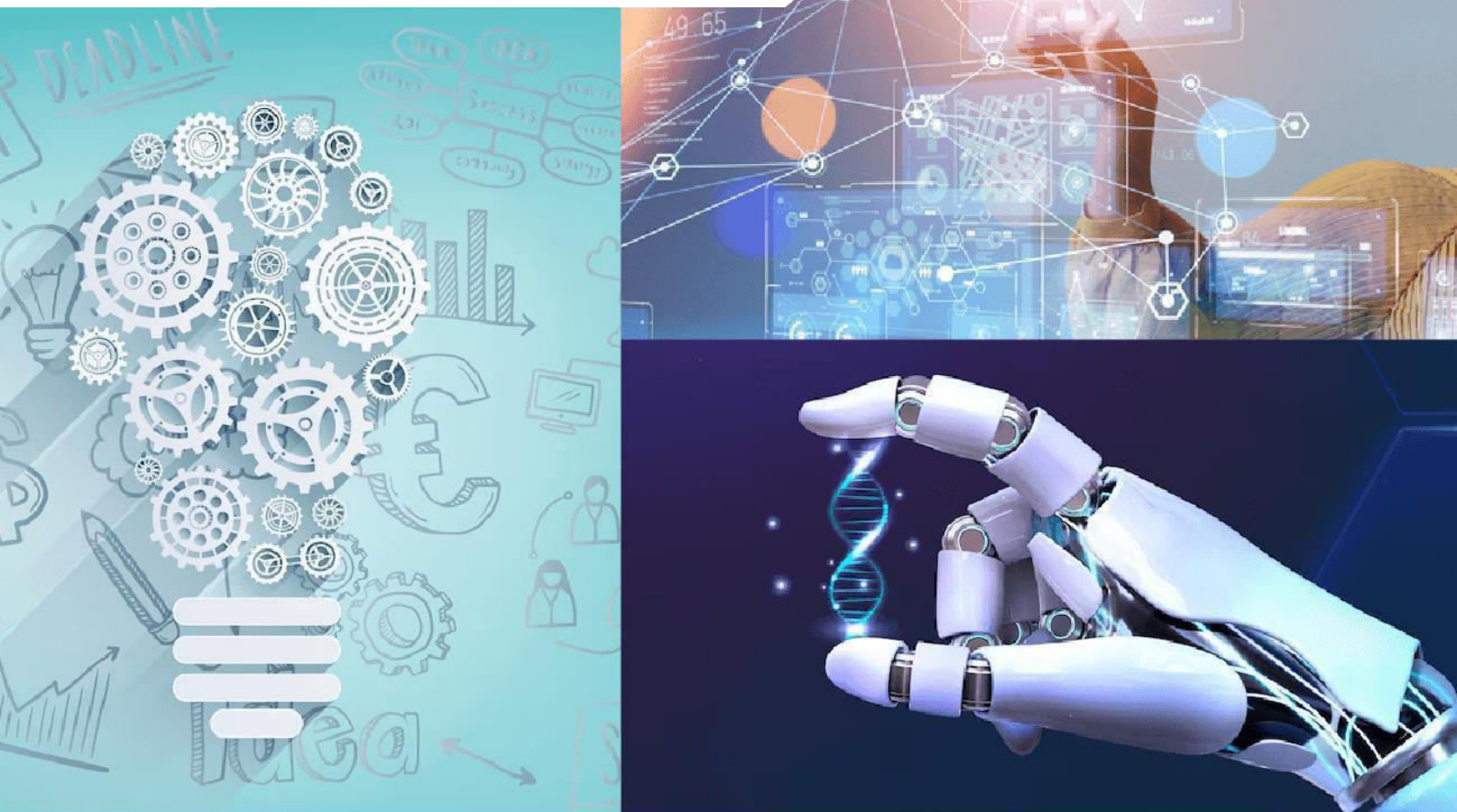




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Human-Centric Sustainable Last-Mile Delivery: A Hybrid AHP-VIKOR Framework for Evaluating Urban Logistics Alternatives

Vaibhav Sabharwal, Mr. Ravi Kumar

Department of B.B.A.(Financial Investment Analysis), School of Open Learning, University of Delhi, India

Assistant Professor, Department of Financial Studies, School of Open Learning, University of Delhi, India

ABSTRACT: The rapid growth of e-commerce and quick-commerce services has transformed last-mile delivery into one of the most critical and complex components of urban logistics. While existing research primarily focuses on operational efficiency and environmental sustainability, limited attention has been given to integrating human-centric factors such as delivery partner safety, workload pressure, income stability, and worker well-being within structured decision-making frameworks. Furthermore, empirical evidence from the Indian urban logistics context remains relatively limited. To address these gaps, the present study evaluates sustainable and human-centric last-mile delivery alternatives using a hybrid Analytic Hierarchy Process (AHP) and VIKOR Multi-Criteria Decision-Making (MCDM) framework. Primary data were collected from 251 respondents, including e-commerce consumers, delivery partners, and logistics professionals. The AHP results identified Sustainability (0.303), Customer Satisfaction (0.230), and Worker Welfare (0.197) as the most important evaluation criteria. The VIKOR analysis ranked the Mixed Sustainable Delivery Model as the most preferred alternative, followed by Electric Bike Delivery and Parcel Locker Systems. The findings indicate that stakeholders increasingly favour balanced delivery models that integrate environmental sustainability, service reliability, operational efficiency, customer satisfaction, and worker welfare rather than purely speed-driven approaches. The study contributes to sustainable logistics literature by incorporating human-centric considerations within a structured MCDM framework and provides practical insights for developing resilient, sustainable, and socially responsible urban delivery systems.

KEYWORDS: Last-Mile Delivery, Human-Centric Logistics, Sustainable Urban Logistics, AHP-VIKOR, Multi-Criteria Decision Making

I. INTRODUCTION

The rapid growth of e-commerce and quick-commerce services has significantly transformed consumer purchasing behaviour and urban logistics systems across the world. Customers increasingly expect faster, more reliable, and more convenient delivery services, prompting logistics providers to redesign their distribution networks and delivery strategies. As a result, last-mile delivery, which refers to the final movement of goods from a distribution centre or fulfilment hub to the end customer, has emerged as one of the most critical and challenging stages of the supply chain (Gevaers et al. (2011)). Although it represents the shortest segment of the delivery journey, the last mile often accounts for a substantial proportion of total logistics costs and is associated with significant operational complexities, including traffic congestion, route fragmentation, failed delivery attempts, and increasing customer service expectations.

The growing volume of urban freight movements has also intensified concerns regarding environmental sustainability. Conventional delivery operations contribute to traffic congestion, greenhouse gas emissions, air pollution, and energy consumption in urban areas (Taniguchi et al. (2014)). Consequently, researchers and practitioners have increasingly explored alternative delivery solutions such as electric delivery vehicles, cargo bicycles, parcel locker systems, micro-distribution hubs, and crowdshipping networks to improve the sustainability of urban logistics operations (Melo & Baptista (2017); Morganti et al. (2014)). These alternatives seek to balance operational efficiency with environmental responsibility while addressing the growing demands of urban consumers. In recent years, attention has also shifted towards the human dimension of last-mile delivery systems. The rapid expansion of platform-based delivery services has increased reliance on gig-economy workers who frequently operate under strict delivery schedules and performance targets. Studies have highlighted concerns related to workload pressure, safety risks, job insecurity, physical fatigue, and income uncertainty among delivery personnel (Huws (2019); Schor (2020); Adams-Prassl (2021)).

Despite the growing recognition of these issues, human-centric factors are often underrepresented in formal evaluation frameworks used to assess delivery alternatives. Most existing studies primarily focus on economic efficiency, delivery speed, and environmental performance, while worker well-being and social sustainability receive comparatively limited consideration (Simić et al. (2021); Wang et al. (2023)). Another limitation in the existing literature is the relatively limited empirical evidence from the Indian urban logistics context. A large proportion of research on sustainable last-mile delivery has been conducted in European and North American cities, where infrastructure conditions, regulatory frameworks, and consumer behaviour differ significantly from those observed in Indian cities. Rapid urbanisation, high population density, mixed traffic conditions, and the growing popularity of quick-commerce services create unique challenges for sustainable last-mile delivery in India. Therefore, there is a need for context-specific research that evaluates delivery alternatives while considering economic, environmental, operational, and human-centric dimensions simultaneously.

To address these gaps, the present study investigates sustainable and human-centric last-mile delivery alternatives using a hybrid Analytic Hierarchy Process (AHP) and VIKOR Multi-Criteria Decision-Making (MCDM) framework. Primary data were collected from 251 respondents comprising e-commerce consumers, delivery partners, and logistics professionals. By incorporating multiple stakeholder perspectives, the study seeks to identify delivery alternatives that best balance sustainability, service quality, operational feasibility, customer satisfaction, and worker welfare. The study contributes to the existing literature in three important ways. First, it integrates human-centric factors into the evaluation of last-mile delivery alternatives alongside economic and environmental considerations. Second, it provides empirical evidence from the Indian urban logistics context, which remains relatively underexplored in existing research. Third, it demonstrates the application of a hybrid AHP-VIKOR framework as a structured decision-support tool for evaluating complex logistics alternatives. The findings of the study are expected to provide useful insights for logistics firms, policymakers, urban planners, and researchers seeking to develop more sustainable, resilient, and socially responsible last-mile delivery systems.

II. LITERATURE REVIEW

Last-mile delivery (LMD) has become a central topic in logistics and supply chain research due to the rapid growth of e-commerce and increasing customer expectations for faster and more reliable deliveries. The last mile represents the final stage of the logistics process, where goods are transported from a distribution centre or local fulfilment hub to the end customer. Although it covers a relatively short geographical distance, this stage is often regarded as the most complex, expensive, and operationally challenging component of the supply chain (Gevaers, Van de Voorde & Vanelander (2011)). Researchers have identified factors such as fragmented delivery routes, traffic congestion, failed delivery attempts, labour intensity, and increasing service expectations as major contributors to the complexity of last-mile operations. The rapid expansion of urban e-commerce has further intensified pressure on logistics networks. Allen, Thorne and Browne (2018) observed that growing demand for home deliveries and same-day fulfilment services has increased delivery frequency within urban areas, creating additional congestion and operational challenges. Similarly, Mangiaracina, Perego, Seghezzi and Tumino (2019) highlighted that changing consumer expectations have encouraged logistics providers to invest in innovative fulfilment strategies, including micro-fulfilment centres, decentralised distribution networks, and flexible delivery fleets. These developments have transformed last-mile delivery from a purely operational activity into a strategic component of supply chain competitiveness.

A significant stream of literature focuses on sustainability within urban logistics systems. Traditional delivery operations contribute substantially to greenhouse gas emissions, traffic congestion, air pollution, and energy consumption in urban environments (Taniguchi & Thompson (2014)). Consequently, researchers have explored a variety of sustainable delivery alternatives aimed at reducing the environmental footprint of freight transport. Electric delivery vehicles have emerged as one of the most widely studied alternatives due to their potential to reduce emissions and noise pollution. Pelletier, Jabali and Laporte (2018) reported that electric delivery fleets can significantly improve environmental performance, although challenges related to charging infrastructure, battery capacity, and investment costs remain important considerations. Cargo bicycles and e-cargo bikes have also attracted considerable attention as environmentally friendly delivery solutions. Melo and Baptista (2017) demonstrated that cargo bicycles can perform efficiently in dense urban areas, particularly when integrated with micro-distribution hubs. Likewise, Gruber, Kihm and Lenz (2014) found that cargo bike deliveries can reduce fuel consumption and traffic congestion while maintaining service effectiveness for lightweight parcels. Parcel locker systems and collection points have been proposed as additional mechanisms for improving delivery efficiency and reducing repeated delivery attempts. Morganti, Dablan and Fortin (2014) observed that parcel locker networks can reduce vehicle travel distances and enhance delivery success rates, thereby contributing to both operational and environmental benefits.

Alongside environmental sustainability, researchers have increasingly recognised the importance of social sustainability and human-centric logistics. The emergence of platform-based delivery systems and gig-economy business models has created new opportunities for flexible employment while simultaneously raising concerns regarding working conditions and worker welfare. Huws (2019) argued that platform-based logistics systems often rely on algorithmic management practices that can increase workload pressures and reduce job security. Similarly, Schor (2020) highlighted issues related to income uncertainty, performance monitoring, and work intensification within gig-economy delivery platforms. Adams-Prassl (2021) further noted that delivery personnel frequently face safety risks, long working hours, and limited employment protections.

Recent empirical studies have strengthened the argument for incorporating human-centric considerations into logistics planning. Apouey et al. (2022) found that delivery workers often experience significant physical fatigue and psychological stress due to strict delivery schedules and performance targets. Seetharaman et al. (2021) found that delivery workers frequently develop peer worker networks to cope with social isolation, share information, and address work-related challenges encountered during platform-based delivery work. These findings suggest that worker well-being represents an essential dimension of sustainable logistics that should be considered alongside economic and environmental objectives. To evaluate the growing number of delivery alternatives and sustainability criteria, researchers have increasingly adopted Multi-Criteria Decision-Making (MCDM) approaches. The Analytic Hierarchy Process (AHP), developed by Saaty (1980), is widely used to determine the relative importance of evaluation criteria through pairwise comparisons. Similarly, the VIKOR method proposed by Opricovic (1998) facilitates the ranking of alternatives by identifying compromise solutions that best satisfy multiple decision criteria. Hybrid MCDM approaches have gained popularity because they enable simultaneous consideration of economic, environmental, operational, and social factors. Krstić et al. (2021) demonstrated the effectiveness of integrated MCDM models for evaluating urban logistics alternatives, while Wang et al. (2023) applied fuzzy MCDM techniques to compare delivery technologies including electric vehicles, cargo bicycles, drones, and autonomous delivery systems.

Despite significant advancements in the literature, several important gaps remain. Many studies continue to prioritise environmental performance and operational efficiency while giving comparatively less attention to delivery worker well-being and human-centric sustainability indicators. Furthermore, a substantial proportion of existing research has been conducted in European and North American urban contexts, limiting the applicability of findings to rapidly growing logistics markets such as India. The integration of multiple stakeholder perspectives, including customers, delivery personnel, and logistics professionals, also remains relatively limited within existing decision-making frameworks. These limitations highlight the need for a more comprehensive evaluation approach that simultaneously incorporates economic efficiency, environmental sustainability, operational feasibility, customer expectations, and worker welfare. Accordingly, the present study adopts a hybrid AHP-VIKOR framework to evaluate sustainable and human-centric last-mile delivery alternatives using primary stakeholder data collected from the Indian urban logistics context.

III. METHODOLOGY / APPROACH

The present study adopts a quantitative research approach to evaluate sustainable and human-centric last-mile delivery alternatives in the context of urban logistics. The study combines primary stakeholder data with a hybrid Multi-Criteria Decision-Making (MCDM) framework consisting of the Analytic Hierarchy Process (AHP) and the VIKOR method. This integrated approach enables the evaluation of delivery alternatives across multiple economic, environmental, operational, and human-centric criteria.

A. Research Design and Data Collection

Primary data were collected through a structured questionnaire designed to capture stakeholder perceptions regarding last-mile delivery systems. The questionnaire was developed after an extensive review of literature related to sustainable logistics, urban freight transport, delivery worker welfare, and multi-criteria decision-making models. Google Forms was used as the survey platform due to its accessibility and ease of response collection. The study targeted three major stakeholder groups within the last-mile delivery ecosystem:

1. E-commerce consumers
2. Delivery partners
3. Logistics and supply chain professionals

A total of 251 valid responses were collected and used for analysis. The final sample consisted of 126 e-commerce consumers, 60 delivery partners, and 64 logistics and supply chain professionals. The inclusion of multiple stakeholder groups ensured that the evaluation framework incorporated diverse perspectives regarding customer expectations, operational realities, sustainability concerns, and workforce well-being. The study employed non-probability convenience and purposive sampling techniques to reach relevant stakeholder groups.

B. Reliability Assessment

To examine the internal consistency of the survey instrument, reliability analysis was conducted using Cronbach's Alpha. The obtained Cronbach's Alpha value was 0.748, indicating acceptable reliability and demonstrating that the questionnaire items were suitable for further statistical analysis. The reliability coefficient exceeded the commonly accepted threshold of 0.70 suggested by Nunnally (1978), confirming the consistency of the collected responses.

C. Statistical Analysis

Several statistical techniques were employed to analyse stakeholder responses and identify significant relationships among the study variables.

Correlation Analysis

Pearson correlation analysis was used to examine relationships among variables related to workload, working conditions, income stability, flexibility of working hours, and delivery pressure. The analysis helped identify the extent to which operational and human-centric factors are associated with delivery partner experiences.

One-Way ANOVA

A One-Way Analysis of Variance (ANOVA) was conducted to determine whether significant differences existed in working condition satisfaction across different levels of pressure associated with speed-oriented delivery branding and delivery expectations.

Multiple Linear Regression

Multiple linear regression analysis was performed to identify factors influencing delivery partner satisfaction. Variables such as workload per shift, income stability, flexibility of working hours, break availability, and delivery pressure were included as independent variables to evaluate their impact on overall working condition satisfaction.

D. AHP Framework

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), was applied to determine the relative importance of evaluation criteria. Based on stakeholder responses and literature findings, six major criteria were considered:

- Sustainability
- Customer Satisfaction
- Worker Welfare
- Reliability
- Delivery Speed
- Cost Efficiency

Pairwise comparison matrices were constructed, and criterion weights were calculated. Consistency testing was performed to ensure the reliability of judgments. The calculated Consistency Ratio (CR) was 0.035, which is below the acceptable threshold of 0.10, indicating satisfactory consistency.

E. VIKOR Framework

Following the determination of criterion weights through AHP, the VIKOR method proposed by Opricovic (1998) was employed to rank alternative delivery models. The alternatives evaluated in the study included:

- Mixed Sustainable Delivery Model
- Electric Bike Delivery
- Parcel Locker System
- Crowdshipping
- Drone-Based Delivery
- Petrol Bike Delivery

The VIKOR methodology identifies compromise solutions by considering both group utility and individual regret measures, thereby facilitating balanced decision-making under multiple conflicting criteria.

F. Research Framework

The overall research framework consists of three stages. First, stakeholder perceptions were collected through a structured survey. Second, statistical analyses were conducted to identify significant relationships and validate stakeholder concerns regarding sustainability and worker welfare. Finally, the AHP-VIKOR framework was applied to prioritise evaluation criteria and rank alternative delivery systems. This integrated approach enabled a comprehensive assessment of sustainable and human-centric last-mile delivery alternatives within the Indian urban logistics context.

IV. RESULTS & DISCUSSION**A. Respondent Profile**

The study utilised 251 valid responses collected from three key stakeholder groups involved in the last-mile delivery ecosystem. The sample comprised 126 e-commerce consumers, 60 delivery partners, and 64 logistics and supply chain professionals. The inclusion of multiple stakeholder groups enabled the study to capture diverse perspectives related to customer expectations, operational realities, sustainability concerns, and worker welfare. Such a multi-stakeholder approach provides a comprehensive understanding of the factors influencing sustainable last-mile delivery systems.

Table 1: Stakeholder Distribution

Respondent Category	Frequency	Percentage (%)
E-commerce Consumers	126	50.2
Delivery Partners	60	23.9
Logistics Professionals	64	25.5
Total	250*	100

*Percentages are rounded; total responses analysed = 251.

The respondent profile demonstrates balanced representation across the major stakeholder groups involved in urban last-mile delivery operations.

B. Reliability Analysis

The reliability of the questionnaire was assessed using Cronbach's Alpha to evaluate internal consistency among survey items

Table 2: Reliability Statistics

Measure	Value
Cronbach's Alpha	0.748
Number of Items	11

The obtained Cronbach's Alpha value of 0.748 exceeds the recommended threshold of 0.70 (Nunnally, 1978), indicating acceptable reliability and consistency of the survey instrument. Therefore, the collected responses were considered suitable for further statistical analysis.

C. Delivery Partner Findings

The responses obtained from delivery partners reveal several important human-centric concerns associated with last-mile delivery operations.

Table 3: Key Delivery Partner Findings

Variable	Major Response
Average Deliveries per Day	10–20 deliveries (40%)
Workers Reporting Heavy Workload	53.3%
Workers Reporting Frequent Stress	70.0%
Workers Experiencing Significant Fatigue	60.0%
Workers Supporting Restrictions on Ultra-Fast Delivery Branding	55.0%
Workers Reporting Pressure from Speed-Focused Branding	55.0%

The findings indicate that delivery personnel frequently experience workload pressure, physical fatigue, and operational stress. Tight delivery schedules, traffic congestion, and performance expectations emerged as major contributors to workplace strain. These observations are consistent with studies by Huws (2019), Schor (2020), and Apouey et al. (2022), which highlight the challenges faced by gig-economy delivery workers.

D. Customer Perspectives

Customer responses demonstrate increasing awareness of sustainability and worker welfare issues within urban delivery systems.

Table 4: Key Customer Findings

Variable	Result
Support for Sustainable Delivery Options	35.2%
Support for Cargo Bikes/E-Bikes	55.5%
Willingness to Accept Additional Delivery Time for Sustainability	76.2%
Concern Regarding Unsafe Driving Behaviour	38.1%
Preference for Realistic Delivery Commitments	57.1%

The results indicate that customers value reliability, worker safety, and environmental responsibility alongside delivery speed. A substantial majority of respondents expressed willingness to accept slightly longer delivery times in exchange for more sustainable delivery services, supporting findings reported by Punel and Stathopoulos (2017) and Yuen, Wang and Wong (2018).

E. Logistics Professional Perspectives

Logistics and supply chain professionals identified traffic congestion, rising operational costs, and workforce-related challenges as major barriers affecting delivery performance.

Table 5: Key Professional Findings

Variable	Result
Traffic Congestion as Major Challenge	53.1%
Sustainability-Driven Future Models	28.1%
Support for Balanced Delivery Strategies	42.2%
Support for Structured MCDM Models	65.6%
Electric Vehicles as Preferred Sustainable Alternative	42.2%

The findings suggest that industry professionals increasingly recognise the importance of balancing efficiency, sustainability, and worker welfare when designing future delivery systems.

F. Correlation Analysis

Pearson correlation analysis was conducted to examine relationships among variables associated with delivery partner working conditions.

Table 6: Significant Correlation Results

Variables	Correlation Coefficient (r)
Flexibility of Working Hours – Income Stability	0.670
Workload Per Shift – Income Stability	0.481
Workload Per Shift – Break Availability	0.408
Workload Per Shift – Speed Pressure	0.451

The strongest positive relationship was observed between flexibility of working hours and income stability ($r = 0.670$), indicating that greater flexibility is associated with improved perceptions of income security. Positive relationships were also observed between workload and delivery pressure, suggesting that increasing workloads contribute to higher operational stress levels.

G. One-Way ANOVA

A One-Way Analysis of Variance (ANOVA) was performed to examine whether working condition satisfaction differed significantly across groups experiencing varying levels of delivery pressure.

Table 7: ANOVA Results

Statistic	Value
F-value	1.893
p-value	0.125

Since the p-value exceeds the 0.05 significance level, the results indicate that no statistically significant differences exist in working condition satisfaction across the analysed pressure categories.

H. Multiple Regression Analysis

A multiple linear regression model was estimated to identify factors influencing delivery partner satisfaction.

Table 8: Regression Model Summary

Statistic	Value
R ²	0.152
Adjusted R ²	0.073
F-value	1.932
Significance	0.104

Table 9: Significant Predictors

Variable	p-value
Workload Per Shift	0.016
Income Stability	0.039
Flexibility of Working Hours	0.019

The results indicate that workload per shift, income stability, and flexibility of working hours significantly influence delivery partner satisfaction. These findings reinforce the importance of incorporating human-centric considerations into sustainable logistics planning.

I. AHP Results

The Analytic Hierarchy Process (AHP) was applied to determine the relative importance of evaluation criteria.

Table 10: AHP Criteria Weights

Criterion	Weight
Sustainability	0.303
Customer Satisfaction	0.230
Worker Welfare	0.197
Reliability	0.126
Delivery Speed	0.082
Cost Efficiency	0.062

Table 11: Consistency Test

Measure	Value
Consistency Ratio (CR)	0.035

The Consistency Ratio is well below the acceptable threshold of 0.10, indicating satisfactory consistency in the pairwise comparisons. Sustainability emerged as the most important evaluation criterion, followed by customer satisfaction and worker welfare.

J. VIKOR Ranking Results

The VIKOR method was employed to rank alternative delivery models based on the weighted criteria obtained from the AHP analysis.

Table 12: Final VIKOR Rankings

Rank	Alternative
1	Mixed Sustainable Delivery Model
2	Electric Bike Delivery
3	Parcel Locker System
4	Crowdshipping
5	Drone-Based Delivery
6	Petrol Bike Delivery

The results indicate that integrated sustainable delivery systems provide the most balanced solution when economic, environmental, operational, and human-centric criteria are simultaneously considered.

Table 13: Summary of Statistical Findings

Analysis	Key Result	Interpretation
Cronbach Alpha	0.748	Acceptable reliability
Correlation	$r = 0.670$	Strong positive relationship
ANOVA	$p = 0.125$	No significant difference
Regression	$R^2 = 0.152$	Moderate explanatory power
AHP	CR = 0.035	Consistent judgments
VIKOR	Rank 1 obtained	Best compromise solution identified

V. DISCUSSION

The findings reveal a clear shift away from purely speed-driven delivery models towards more balanced and sustainable approaches. Across all stakeholder groups, concerns regarding worker welfare, environmental sustainability, service reliability, and operational resilience emerged as significant considerations. Delivery partners reported substantial fatigue and stress associated with speed-oriented delivery systems, which is consistent with previous studies highlighting the physical and psychological pressures experienced by gig-economy workers (Huws (2019); Schor (2020); Apouey et al. (2022)).

Customer responses indicate growing awareness of sustainability and worker welfare issues. A large proportion of respondents expressed willingness to accept slightly longer delivery times in exchange for safer and more environmentally responsible delivery services. These findings support earlier research suggesting that consumers increasingly value sustainability when it does not significantly compromise convenience or service quality. The perspectives of logistics professionals further reinforce the importance of balancing operational efficiency with sustainability objectives. Traffic congestion emerged as the most significant operational challenge, reflecting observations regarding the growing complexity of urban freight transport. Furthermore, the strong support for structured MCDM approaches demonstrates increasing industry recognition that last-mile delivery decisions involve multiple and often conflicting objectives.

The AHP results indicate that sustainability (0.303), customer satisfaction (0.230), and worker welfare (0.197) are the three most important evaluation criteria. This finding suggests that contemporary logistics decision-making extends beyond traditional cost and speed considerations. The relatively high weight assigned to worker welfare provides empirical support for integrating human-centric factors into last-mile delivery evaluation frameworks. Similarly, the VIKOR rankings reveal that the Mixed Sustainable Delivery Model and Electric Bike Delivery outperform conventional delivery alternatives when assessed across multiple criteria. These findings align with previous studies highlighting the environmental and operational advantages of integrated sustainable delivery systems (Melo & Baptista (2017); Krstić et al., (2021); Wang et al. (2023)). Overall, the results suggest that future urban logistics systems should prioritise balanced performance across economic, environmental, operational, and social dimensions. The integration of stakeholder perspectives, statistical analysis, and MCDM techniques demonstrates that sustainable and human-centric delivery models offer a more comprehensive solution than approaches focused exclusively on delivery speed. These findings provide practical implications for logistics firms, policymakers, and urban planners seeking to develop resilient and socially responsible last-mile delivery systems.

VI. CONCLUSION

The rapid growth of e-commerce and quick-commerce has increased the strategic importance of last-mile delivery while simultaneously raising concerns regarding environmental sustainability, urban congestion, worker welfare, and service reliability. In response to these challenges, the present study evaluated sustainable and human-centric last-mile delivery alternatives through a hybrid Analytic Hierarchy Process (AHP) and VIKOR Multi-Criteria Decision-Making (MCDM) framework. The study was based on primary data collected from 251 respondents comprising e-commerce consumers, delivery partners, and logistics professionals. The inclusion of multiple stakeholder groups enabled a comprehensive evaluation of economic, environmental, operational, and social dimensions of last-mile delivery systems. The findings revealed that stakeholders increasingly favour balanced delivery ecosystems that extend beyond traditional measures of speed and cost efficiency. The AHP results identified Sustainability (0.303) as the most

important evaluation criterion, followed by Customer Satisfaction (0.230) and Worker Welfare (0.197). Reliability (0.126), Delivery Speed (0.082), and Cost Efficiency (0.062) received comparatively lower weights, indicating a clear shift towards sustainability-oriented and human-centric delivery priorities. Survey findings further highlighted concerns regarding workload pressure, fatigue, delivery deadlines, and safety risks among delivery partners, while customers demonstrated growing support for environmentally responsible delivery practices provided that service quality and reliability are maintained. The VIKOR analysis ranked the Mixed Sustainable Delivery Model as the most preferred alternative, followed by Electric Bike Delivery and Parcel Locker Systems. These results suggest that integrated delivery systems combining sustainable mobility, technology-enabled coordination, operational efficiency, and workforce-oriented management practices offer the most balanced solution for future urban logistics environments. In contrast, conventional delivery approaches performed less favourably when evaluated across multiple sustainability and human-centric criteria.

From a theoretical perspective, the study contributes to the sustainable logistics literature by integrating worker welfare and stakeholder perspectives within a structured MCDM framework. It also provides empirical evidence from the Indian urban logistics context, where research on sustainable and human-centric last-mile delivery remains limited. From a practical perspective, the findings offer valuable guidance for logistics firms, policymakers, and urban planners seeking to design delivery systems that balance efficiency, sustainability, customer value, and workforce well-being. The study is subject to certain limitations, including its reliance on stakeholder perceptions from a specific sample and the evaluation of a selected set of delivery alternatives and criteria. Future research may incorporate larger and more geographically diverse samples, additional delivery technologies, real-time operational data, and advanced analytical approaches to further strengthen decision-making in sustainable urban logistics. Overall, the study concludes that the future of urban last-mile delivery lies in the adoption of balanced, sustainable, and human-centric logistics systems. By integrating economic efficiency, environmental responsibility, operational effectiveness, customer satisfaction, and worker welfare within an AHP–VIKOR framework, the research provides a comprehensive approach for evaluating and improving last-mile delivery alternatives in rapidly evolving urban logistics environments.

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