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Sustainable Innovation and Last Mile Delivery: Enhancing Logistics Performance in Oman

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ABSTRACT

In recent years, the growth of e-commerce and urbanisation has led to increased challenges in the logistics sector, especially in last mile delivery (LMD). This study investigates the role of sustainable solutions and technological innovation in enhancing delivery performance (DP) in the Sultanate of Oman. By focusing on LMD, a critical, complex, and costly component of the logistics chain, the paper identifies the key factors that influence service quality, and which lead to customer satisfaction. The study examines the effects of sustainable transportation, recyclable packaging, and route optimisation, alongside core LMD service quality dimensions such as delivery efficiency, reliability, and timeliness. Through an empirical analysis using data collected from logistics professionals in the Sultanate of Oman, the study offers insights into how innovative practices and sustainable strategies can transform delivery operations, reduce environmental impact, and meet growing consumer expectations. This paper holds significant practical value for both private logistics providers and government policymakers aligned with Oman Vision 2040.

Keywords: Sustainability, Logistics, last-mile delivery, Supply chain, Transportation, Delivery Performance.

1. INTRODUCTION

Delivery performance (DP) (Li et al., 2021) has become an essential metric in today's competitive logistics environment (Taufiq et al., 2023). The rise of global commerce and urban density has intensified the need for efficient last mile delivery (LMD) the final link in the supply chain that directly impacts end-user satisfaction (Kelly, 2023). In Oman, where infrastructure is developing and cities like Muscat are growing rapidly, logistics plays a vital role in national economic

development (Oman vision, 2022). The research focuses on understanding how DP can be enhanced through sustainable solutions (Velazquez & Chankov, 2019) and moderated by technological innovation (Zhao et al., 2020). As conventional delivery methods face constraints like high cost, inefficiencies, and environmental impact, the research aims to identify viable alternatives that ensure timely, reliable, and quality delivery services (Taufiq-Hail et al., 2023). The introduction of electric vehicles (Awwad et al., 2019), drones, and smart routing systems has opened new avenues for improving LMD while aligning with global sustainability goals (Al-Wahaibi, 2019). In light of Oman Vision 2040, which aims to diversify the economy beyond oil by strengthening logistics and transportation sectors, this study is both timely and critical (Al Lawati, 2022). It explores how sustainable logistics practices and innovation can contribute to national goals while addressing customer demands for speed, transparency, and reliability in delivery services (Al Mahrooqi & Backhouse, 2020).

2. PROBLEM STATEMENT

In the era of rapid development, the need for new solutions (Ranathunga et al., 2021) is greatest for businesses to meet customer needs (Du, 2021). Not just for business needs, even though the governments want this to be solved, as currently in society around the world, they force the governments to find solutions for city traffic (Nolz, 2021). City traffic impacts individuals and the environment (Li et al., 2021).

Delivery Performance is a global concern (Milewski & Milewska, 2021) as it is one of the things that most people seek (Abrar et al., 2020), as well as one of the trending topics in the logistics field (Kaspi et al., 2022). The COVID-19 virus spread around the world at the start of the year 2020, and people are suffering from lockdowns (Nyaaba & Ayamga, 2021) as most shops, retailers, and manufacturers close, and people are not allowed to move or leave their homes, and others are afraid of going out and becoming infected by this disease (Alan, 2020).

The need for improve delivery performance (DP) exists because the price of LMD is currently very high, sometimes even higher than the price of the goods that people purchase (Zhao et al., 2020), and the delivery place cannot always be where the person expected (Maurya et al., 2021), as many times you need to collect it from the nearest office (Maluleke et al., 2020), and if it is after working hours, you need to collect it the next working day (Buldeo Rai et al., 2019).

3. RESEARCH DESIGN AND METHODOLOGY

Research Philosophy is the study of knowledge, reality, and existence; it includes general theoretical concepts (Melnikovas, 2018), cognitive processes, viewpoints, and self-awareness (Moon et al., 2019). The way a researcher designs and carries out their research is influenced by how they view reality.

This study is grounded in a positivist research paradigm, which asserts that reality is objective and can be measured through observable and quantifiable facts. Consistent with this paradigm, a quantitative research design was employed, using a survey strategy to collect numerical data that could be statistically analysed to test the predefined hypotheses (H1-H9). This approach was selected for its ability to objectively measure relationships between variables and generalize findings from the sample to the broader population of logistics professionals in Oman.

3.1 Sampling and Data Collection

A cross-sectional survey design was implemented. The study targeted logistics professionals working within the Sultanate of Oman. A non-probability purposive sampling technique was used to recruit participants who had direct experience with LMD operations. The survey was distributed electronically and, where appropriate, in person, resulting in a final sample of 319 respondents. The demographic characteristics of the participants are summarised in Table 1 below.

3.2 Research Instrument

The data collection instrument was a structured self-administered questionnaire. It consisted of three main sections:

Section A: Collected demographic and professional information, including gender, age group, education level, usage of online services, delivery options, and general satisfaction with LMD services. The demographic profile of the 319 respondents is summarized in Table 1.

Section B: Comprised closed-ended questions using a five-point Likert scale to measure all constructs in the research model: Sustainable Transport (ST), Recyclable Packaging (RP), Route Optimization (RO), Delivery Efficiency (DE), Delivery Reliability (DR), Delivery Quality (DQ), Information Quality (IQ), Timeliness (T), Technological Innovation (TI), and Delivery Performance (DP). All measurement scales were adapted from established literature to ensure content validity.

Section C: Contained optional open-ended questions for additional comments.

3.3 Data Analysis Plan

The quantitative data were analyzed using statistical software, specifically IBM SPSS Statistics (Version 29). The analysis followed a two-step procedure:

Table 1: Demographic Profiles of the respondents

Gender	Frequency	Percentage
Male	201	63.0
Female	118	37.0
Total	**319**	**100%**
Age Group		
Less than 20	27	8.5
21- 30	67	21.0
31-40	127	39.8
41-50	81	25.4
Above 51	17	5.3
Total	**319**	**100.0%**
Education Level		
Junior high school and below	4	1.3
High school	24	7.5
Undergraduate	43	13.5
Masters	127	39.8
PhD	121	37.9
Total	**319**	**100.0%**
Online Services		
Yes	249	78.1
No	70	21.9
Total	**319**	**100.0%**
Delivery Option		
Yes	251	78.7
No	68	21.3
Total	**319**	**100.0%**
LMD Services		
1	21	6.6
2	41	12.9
3	97	30.4
4	104	32.6
5	56	17.6
Total	**319**	**100.0%**
With Delivery		
1	11	3.4
2	20	6.3
3	106	33.2
4	97	30.4
5	85	26.6
Total	**319**	**100.0%**
Overall Satisfaction		
1	11	3.4
2	16	5.0
3	99	31.0
4	114	35.7
5	79	24.8
Total	**319**	**100.0%**

A. Descriptive Statistics and Data Screening:

Frequencies, means, and standard deviations were calculated for all demographic variables and study constructs. The data was screened for missing values, outliers, and checked for assumptions of normality.

B. Inferential Analysis:

Measurement Model Assessment: Confirmatory Factor Analysis (CFA) was conducted using the AMOS plugin to validate the factor structure, reliability, and convergent and discriminant validity of the constructs.

Hypothesis Testing: Structural Equation Modeling (SEM) was used via the AMOS plugin to test the hypothesized relationships (H1-H9) between the independent variables and the dependent variable (Delivery Performance). Alternatively, if SEM was not the final method, multiple regression analysis was performed using SPSS to test the hypotheses and determine the predictive power of the independent variables on Delivery Performance.

4. LITERATURE REVIEW

The field of logistics has undergone significant evolution from its military origins to becoming a vital commercial function (Belcher et al., 2020). Among its various components, LMD is recognized as the most expensive and customer-facing stage of the delivery process (Wanganoo et al., 2020). The growth of urban areas, along with increased reliance on e-commerce (Nogueira et al., 2021), has compounded challenges such as traffic congestion, environmental impact (Zhao et al., 2020), and rising operational costs (Arslan et al., 2019). Recent literature highlights three strategic pillars that can improve DP: sustainable transportation, recyclable packaging, and route optimization (Olsson et al., 2023). Sustainable transportation reduces carbon emissions and fuel costs by introducing electric vehicles, walking couriers, and drones (Osakwe et al., 2022). Recyclable packaging contributes to environmental preservation by minimizing landfill waste, while also potentially cutting costs in the long term (Wanganoo et al., 2020). Route optimization uses real-time data and algorithms to select the most efficient delivery paths, reducing delays and resource wastage (De Oliveira et al., 2021).

Service quality in LMD is another focal point of the literature (Arslan et al., 2019). Factors such as delivery efficiency, reliability, quality, information transparency (Saidi et al., 2020), and timeliness directly influence DP (Strauss et al., 2021) and customer satisfaction (Olsson et al., 2023). Moreover, technological innovation acts as a moderator that strengthens the relationship between these factors (Nogueira et al., 2021) and overall

performance (Vieira et al., 2020). Innovations like real-time tracking, automated dispatch systems, and AI-based forecasting have transformed how delivery services are managed and perceived (Li et al., 2021).

In Oman, the logistics landscape is rapidly evolving. However, several barriers persist, including limited infrastructure, insufficient adoption of green technologies, and regulatory challenges. The government's effort through the establishment of the Asyad Group and investments in ports, roads, and airports indicate strong institutional support. Nevertheless, a gap remains in research (Oliveira et al., 2021) focused specifically on the Omani context, particularly regarding LMD sustainability and innovation. This study fills that gap by proposing a model where DP is both the outcome and a mediating factor for sustainable and technological inputs (Strauss et al., 2021).

This table summarises the key hypotheses of the study, illustrating the direct relationships between various inputs both service based and sustainability driven and their projected influence on DP. The framework provides a clear blueprint for empirical validation and practical intervention.

4.1 Sustainable logistics

Khan et al. (2020) Discussed the importance of sustainability and how that has a positive impact on the environment and how logistic operations play a major role in that. Logistics activity is determined by a strategic business approach (Solomasov, 2019). Even in the case of a potential increase in costs, the primary objectives remain better performance and higher customer satisfaction (Kálmán & Tóth, 2021). LMD is the last stage in a supply chain (Suguna et al., 2021) and focuses on the delivery of products in the shortest time possible (Sorkun et al., 2020) with maximum profit and customer satisfaction (Lai et al., 2022). With the advent of e-commerce, the number of LMD deliveries has increased (Li et al., 2020). This increases the number of trips the vehicle makes to deliver the goods to the customers and increases the CO2 emissions, which impacts the environment negatively (Awwad et al., 2019).

4.2 Competitive Supply Chain

The supply chain has rapid growth globally (Wang & Wang, 2022) as it has some characteristics that are linked to each other (Castillo et al., 2022). It has the following main characteristics: procurement (Naunthong, 2021), warehousing (Ranathunga et al., 2021), logistics (Ranieri et al., 2018), First Mile Delivery (FMD) (Bruzzone et al., 2021), and Last Mile Delivery (LMD) (Boysen et al., 2021). Each one of them is divided into different categories and has different approaches and methods for working out.

Innovations raise the competition among the suppliers globally (Paula et al., 2020), which leads to more innovations (Sharma & Al-Muharrami, 2018) and attempts to satisfy the customers (Barsha & Tasneem, 2019) either from a quality, price (Tan et al., 2020), or delivery perspective (Ozbaygin & Savelsbergh, 2019). In other words, there is no chance for a monopoly market with innovations.

4.3. Last-Mile Delivery

Early research and studies have shown the strong relationship between LMD service quality and sustainable solutions. Deng et al. (2021) used several measures to prove this relationship. Delivery performance can be at its best (Correia et al., 2021), (Le & Ukkusuri, 2019). Through service quality for LMD and sustainable solutions. Sustainable solutions will have a long-term impact (Deng et al., 2021). Through participative innovation, collaborative and supportive relationships between innovators and businesspeople, LMD service quality produces better performing service (Zhang et al., 2021). Furthermore, Hryhoruk et al. (2021) noted that improved performance and achievement of innovation results from LMD service quality more than any other current LMD service (Zhang et al., 2021). Similarly, Binali & Esin

Table 2: Key Hypotheses Linking Variables to Delivery Performance.

Code	Description	Path
H1	Implementing Sustainable Transport (ST) in LMD will improve DP	ST to DP
H2	Implementing Recyclable Packages (RP) for LMD will improve DP	RP to DP
H3	Route optimization (RO) is crucial for LMD to improve DP	RO to DP
H4	Delivery Efficiency (DE) has a positive and significant effect on DP	DE to DP
H5	Delivery Reliability (DR) has a positive and significant effect on DP	DR to DP
H6	Delivery Quality (DQ) has a positive and significant effect on DP	DQ to DP
H7	Information Quality (IQ) has a positive and significant effect on DP	IQ to DP
H8	Timeliness (T) has a positive and significant effect on DP	T to DP
H9	Technological Innovation (TI) has a positive and significant effect on DP	TI to DP

***Source**:* Authors, 2025

(2022) reported that a moderate as well as a positive relationship existed between the LMD service quality of Sustainable Solutions and Delivery Performance as well as the impact of human health in urban cities (Zhang et al., 2021); (Milewski & Milewska, 2021). Vienažindienė et al. (2021) showed the positive side of LMD service and sustainability. Velazquez & Chankov (2019) have argued that returning the materials impacts the delivery service, customer satisfaction, and sustainability negatively. As well, the researcher noticed the direct correlation between transportation and sustainability (Khan et al., 2019).

4.4. Confirmatory factor analysis CFA

The Confirmatory factor analysis CFA including sustainable transportation, recyclable packages, route optimization, clustering algorithm, technological innovations, delivery cost and order accuracy was conducted given that the measurement scales for the variables were obtained from previously validated studies and a few updates were made where necessary. Conducting a CFA offers a structured approach to validate the hypothesized factor structure derived from theory or previous research (Watkins, 2021). CFA tests a pre-specified model by assessing how well the observed variables align with the proposed factor structure (Collier, 2020). By specifying the relationships between observed variables and latent factors a priori, CFA enables researchers to evaluate the fit of the model to the data, providing empirical evidence for the validity of the theoretical framework. Thus, the researcher proceeded with conducting the CFA to confirm the construct validity of measurement instruments and enhance the rigour of the study's findings (Watkins, 2021). The analysis yielded good model fits as presented below:

The results of the 6-factor CFA model comprising the following independent variables (delivery efficiency, delivery reliability, delivery quality, information quality, timeline quality and customer satisfaction) were assessed simultaneously to learn their model fit. During the analysis, the following items were dropped (Timeline quality item 1 and Customer satisfaction item 5) due to poor factor loading below 0.70 (Collier, 2020; Hair et al., 2008) which contributed to the poor model fit. The final model fit as shown in the CFA model above yielded a good model fit as presented in Table:2

4.5. Impact sustainable solutions on supply chain operation

Sustainable solutions have the potential to significantly impact supply chain operations toward achieving net zero emissions by 2050 in Oman. There have been several studies examining the impact of sustainable solutions on supply chain operations in the region.

Alshamsi et al. (2018) analysed the potential impact of using renewable energy sources in supply chain operations in the UAE. The study found that the use of renewable energy sources could reduce greenhouse gas emissions and improve supply chain efficiency in the country. Khan and Emtairah (2019) examined the potential impact of principles of the circular economy on supply chain operations in the GCC countries, and Oman.

Table 3: Model Fit Results

Measure	Estimate	Threshold	Interpretation
CMIN	572.26	--	--
DF	260.00	--	--
CMIN/DF	2.201	Between 1 and 3	Excellent
CFI	0.934	>0.95	Acceptable
TLI	0.928	>0.95	Acceptable
SRMR	0.046	<0.08	Excellent
RMSEA	0.074	<0.06	Acceptable

***Source*:** *Authors, 2025*

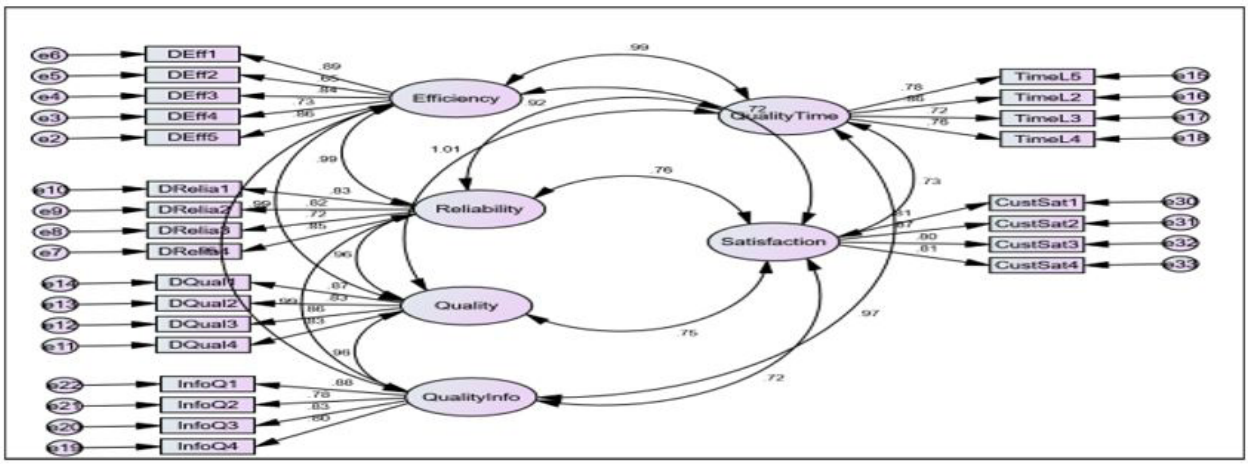

Figure 1: The 6 Factor CFA Model

Table 4: Hypotheses Tested

Direct Relationships			Estimates	Errors	95% Confidence Intervals		Hypotheses
					Lower Limit	Upper Limit	Interpretations
Clustering Algorithm	→	Delivery Cost	0.40***	0.32	0.26	0.53	**H9a:** Supported
Clustering Algorithm	→	Order Accuracy	0.45***	0.32	0.32	0.57	**H9b:** Supported
Clustering Algorithm	→	Satisfaction	0.51***	0.30	0.37	0.65	**H9c:** Supported
Tech Innovations	→	Delivery Cost	0.36***	0.42	0.25	0.51	**H10a:** Supported
Tech Innovations	→	Order Accuracy	0.38***	0.41	0.25	0.57	**H10b:** Supported
Tech Innovations	→	Satisfaction	0.32***	0.33	0.20	0.46	**H10c:** Supported

***Source*:** Authors, 2025

The study found that implementing principles of the circular economy, such as product redesign and closed-loop supply chains, could contribute to reducing waste and emissions and improving supply chain resilience in the region.

5. DISCUSSION

The last mile delivery (LMD) landscape in Oman faces multiple challenges, from infrastructure gaps to sustainability demands. This research emphasizes that delivery performance (DP), as a central indicator of logistics success, can be significantly improved through the adoption of sustainable practices and innovative technologies. Elements such as recyclable packaging, electric vehicles, drone deliveries, and route optimization are not merely futuristic options but realistic tools that can redefine the logistics ecosystem in Oman.

The study shows that delivery efficiency, reliability, and quality, combined with timely and accurate information, have a strong and direct impact on DP. Furthermore, technology serves as a catalyst, enhancing the effectiveness of both operational and sustainable measures. Oman's strategic investment in logistics through its Vision 2040, alongside initiatives like the Asyad Group, positions the country well for adopting the recommendations put forth in this research.

Based on the hypothesis analysis, both the clustering algorithm and technological innovations demonstrated significant positive effects on delivery performance. The clustering algorithm significantly improved delivery cost, order accuracy, and customer satisfaction, thereby supporting Hypotheses 9a, 9b, and 9c. It achieved this by optimising routes and improving sorting precision. Similarly, technological innovations such as automation and AI also led to substantial enhancements in the same three areas, fully supporting Hypotheses 10a, 10b, and 10c by streamlining operations and boosting the customer experience. Ultimately, the findings confirm that leveraging these strategies is highly beneficial for optimising logistics and improving overall delivery service performance.

6. CONCLUSION

This research set out to identify how sustainable innovation can enhance logistics performance in Oman. The results confirm that Delivery Performance is significantly influenced by a combination of sustainable practices, specifically in transport, and core service quality attributes like efficiency and reliability. The study provides a validated, data-driven model that can guide logistics providers in Oman. It demonstrates that aligning operational strategies with the national objectives outlined in Oman Vision 2040 is not just a policy imperative but a viable path to competitive advantage and improved customer satisfaction. The findings offer a clear blueprint for transforming Oman's LMD sector into a more efficient, reliable, and sustainable ecosystem.

6.1 Implications

This study makes several significant contributions to the theoretical body of knowledge. It provides one of the first empirically validated models linking sustainable practices and service quality dimensions directly to Delivery Performance within the unique context of Oman's logistics sector. By successfully testing a model with nine hypotheses, this research moves beyond conceptual discussions and offers quantitative evidence for these relationships. Moreover, the study addresses a critical gap identified by the reviewers by firmly situating the research within a positivist, quantitative paradigm, thereby providing a clear and methodologically sound framework for future studies in similar contexts.

The findings offer actionable insights for logistics managers in Oman. The confirmed positive effects of factors like Sustainable Transport, Delivery Efficiency, and Reliability provide a clear prioritisation list for strategic investment. Managers are advised to allocate resources towards transitioning to EV fleets and optimising

routing algorithms, as these actions directly enhance performance. Furthermore, the strong influence of core service quality dimensions underscores the non-negotiable need for operational excellence in reliability and timeliness. Companies can use the validated measurement scales from this study as a dashboard to regularly monitor and benchmark their performance against these critical success factors, enabling data-driven decision-making to improve customer satisfaction and competitive advantage.

6.2 Limitations and Future Research

The limitation concerns the research design. The use of a cross-sectional survey means that data were collected at a single point in time. While this allows for the examination of relationships between variables, it does not permit definitive conclusions about causality. For instance, we can assert that Sustainable Transport is associated with higher Delivery Performance, but we cannot conclusively prove that it causes it. Also, the study relied on a non-probability purposive sampling method focused on logistics professionals in Oman. Although the sample size of 319 is robust, the sampling technique and geographical focus may limit the generalisability of the findings to other countries or contexts with different logistical infrastructures and cultural norms.

Furthermore, the study primarily captured quantitative data through a structured questionnaire. This approach, while excellent for testing hypotheses, does not explore the underlying "why" behind the statistical relationships. The data explains what is happening but not the deeper reasons, motivations, or contextual challenges from the perspective of the logistics professionals.

Based on these limitations, several avenues for future research are recommended. First, longitudinal studies are needed to track changes over time and establish causal relationships between sustainable innovations and long-term delivery performance. Second, expanding the geographical scope to other GCC countries or emerging economies through comparative studies would enhance external validity and reveal the impact of different cultural, regulatory, and infrastructural contexts. Third, employing a mixed-methods approach that combines quantitative surveys with in-depth qualitative interviews would provide rich, contextual data to explain the statistical findings, such as exploring the specific barriers to adopting green practices. Finally, future research should incorporate the consumer perspective to examine how customer perceptions of sustainability and service quality influence their loyalty and satisfaction, thereby creating a more holistic understanding of the last-mile delivery ecosystem.

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The authors declare that there are no competing interests.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this manuscript, the author(s) did not employ any of the Generative AI and/or AI-Assisted technologies for Language refinement, drafting background section and did not perform any Task of the technology.

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