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Assessing Carbon Footprint Reduction Strategies for Last-Mile Delivery in Emerging Economies: An INTERPRETIVE STRUCTURAL MODELLING (ISM) Approach

Israt Jahan Juthi, Nafisa Tabassum Prithy, Samia Islam Jonma,

Ahsanullah University of Science and Technology

ABSTRACT

In a world of urbanization and rapid e-commerce growth, we have increased the carbon footprint of last-mile delivery. Particularly in emerging economies, where a lack of regulatory frameworks and infrastructure deprivation play challenging roles. This study mainly addresses the need to show and execute effective carbon footprint reduction strategies in this context. To identify and analyze the interdependencies among the key strategies, most of which are given by experts for sustainable urban logistics, Interpretive Structural Modelling (ISM) has been utilized. The purpose of this study is to identify ten core strategies and to rank and evaluate them by using Interpretive Structural Modelling (ISM) to build a hierarchical model that visualizes their relationships. After analyzing, a clear hierarchical structure has been shown. Such as Public-Private Partnerships (PPPs) and the integration of Green Supply Chain Management (GSCM), which were found to be the primary drivers. These strategies create the essential policy and collaborative environment necessary for other strategies to succeed. Other strategies that can be called linkage strategies are load optimization, collaborative logistics, and parcel lockers. These strategies mainly serve a dual role by enabling advanced solutions and giving foundational support. Some solutions, including fleet electrification, micro-mobility, and urban micro-hubs, emerged as dependent strategies, as their

successful implementation relies heavily on the lower-level enablers. To conclude the study, policymakers and industry experts should categorize and prioritize efficiencies and strengthen the foundational structure before investing in any high-tech solutions. The purpose of this research study is to show the insights into different perspectives on how important green logistics are in developing nations, and for this, the contribution of various environmental, economic, and operational factors is important.

Keywords: Sustainable Supply Chain Logistics, E-Commerce, Carbon Emissions, Last-mile delivery

Introduction

1.1Background of the Study:

The process of delivering a product from a central location to the customer's door is referred to as “last-mile delivery”. This stage, which is often the most costly and time-consuming portion of the supply chain, is highly significant to customers (Org P A G E et al., 2024).

Last-mile delivery, the last stage in the supply chain where goods are delivered from a distribution center to the final customer, is recognized as the most resource-intensive and environmentally degrading portion of the supply chain. As the emerging growth of e-commerce continues, a continuous need for fast and agile delivery becomes an important factor. Because of this traffic congestion, fuel emissions have grown rapidly and magnifying the carbon footprint of urban local transport(Carbon Footprint Reduct Ion St Rat Egies, n.d.). This is even more acute in developing economies due to the deficiency of infrastructure, regulatory gaps, informal logistics operations, and the absence of technological integration. These economies tend to rely on vintage cars, lack good urban planning, and suffer from uneven environmental rule enforcement.

It is thus not only important but also complex to select and implement effective carbon footprint mitigation measures in last-mile delivery, as it requires an integrated approach towards understanding interlinked aspects such as technology adoption, policy environment, stakeholder coordination, and customer behavior(*PaperIJMEMS*, n.d.). Traditional approaches to reducing fleet electrification, route optimization, and alternative delivery modes are gaining popularity globally, but have not yet been well explored in developing economies (Islam et al., 2024). Economic, social, and logistical constraints significantly influence the viability and efficacy of such measures in these economies. Hence, there exists a critical need to examine these strategies in the socio-economic and infrastructural contexts of emerging markets.

To bridge this void, this research employs an Interpretive Structural Modelling (ISM) method, a widely applied qualitative approach used in identifying and examining the relationships between variables influencing complex problems. ISM helps organize a hierarchical structure that displays the direct and indirect relationships between the prominent factors involved (Attri et al., 2013). This modeling approach is most suitable for the key study since it accommodates the involvement of stakeholders and experts to rank and appraise strategies in terms of contextual convenience and feasibility.

The purpose of this study is to find the factors that directly influence carbon emissions in last-mile delivery. The correlation between strategies collected from policymakers and industry experts plays a significant role in this study. Also, interpretive structural modeling creates a hierarchical structure after proper data analysis and compares the strategies.

This research can bridge the existing gap between current supply chain logistics challenges and sustainable supply chain logistics.

1.2 Research Objectives

This study aims to answer the environmental issue of last-mile delivery in emerging economies by ascertaining the significant drivers of emissions and how they can be minimized. In using Interpretive Structural Modelling (ISM), it analyzes the interconnection between the strategies. It endeavors to prioritize sustainable solutions and guide green logistics practices

1. To identify key strategies that contribute to carbon emissions in last-mile delivery in emerging economies.

2. Understanding & evaluating the strategies for reducing the emissions of carbon footprint in last-mile logistics.

3. To apply Interpretive Structural Modelling (ISM) to analyze and create relationships between the strategies.

4. To analyze the chosen strategies based on their impact and feasibility.

5. To provide practical recommendations for policymakers and industrial experts in the supply chain logistics market.

LITERATURE REVIEW

After a brief literature review that is relevant to our study, the key variables of this research study are these: carbon footprint reduction and strategies for last-mile delivery. Also, for supply chain logistics. Our research outcome will consider all these strategies as explanatory factors.

Since the 1990s, when e-commerce first gained popularity, there has been a constant debate about its effects on sustainability. Models of last-mile delivery that include pickup places offer an alternative to the more traditional ones that deliver products directly to clients' houses (Brown & Guiffrida, 2014). As an alternative, the delivery service may drop off products at a site where customers can pick them up, usually near their homes. These facilities are sometimes referred to as collection-and-delivery stations. Customers can self-collect packages from these sites (Niemeijer & Buijs, 2023).

In Bangladesh's changing urban environment, last-mile delivery, the last, vital stage in moving commodities from significant centers to end users, has long been beset by inefficiency and exorbitant costs (Org P A G E et al., 2024). The primary benefit for a delivery company of including pickup locations in its last-mile delivery operation is more efficient delivery routes. Consumers are choosing to go alone increasingly. The fewer times a delivery van needs to come to a customer's house to pick them up. Previous studies have shown that this leads to shorter delivery routes(Niemeijer & Buijs, 2023).

One of the biggest obstacles to reducing the consequences of climate change is lowering greenhouse gas (GHG) emissions from the transportation of commodities. Fossil fuels, which release greenhouse gases (GHGs), especially CO2, which contribute to climate change, are the primary source of electricity for road freight transportation(Raj et al., 2008). The transportation sector, which emits a growing quantity of GHG emissions, must reduce its GHG emissions by at least 60% to meet the EU's targets of 80% to 95% reduction in GHG emissions by 2050 (Halldórsson & Wehner, 2020).

The goal of sustainable supply chain management strategies, or SSCMPS, is to maintain environmental, social, and economic stability. Because sustainable supply chain practices and activities increase financial and operational performance while reducing the negative effects of firm operations on the environment and society, the stability and robustness of the industry linkage depend on the SSCMPS operating (Helal et al., 2024).

Because of its distinct delivery structure, the last mile is said to be one of the most expensive supply chain segments. Between 13 and 75 percent of the total cost of logistics can be attributed to last-mile expenses. These high percentages are the result of inefficiencies and poor environmental performance. The last-mile issues are especially prevalent when home deliveries require a signature to be accepted. There will surely be a significant failure rate if no delivery window is specified because the customer is "not at home." Because of this, it could take two or three presentations until the product is presented properly. A set delivery timeframe, however, will inevitably make routes less effective (Macharis & Melo, 2011). Previous studies have shown that using PLs might significantly reduce the overall costs and carbon emissions associated with last-mile delivery. Nonetheless, several studies indicate that most consumers favor using PLs near their homes; the farther they are from PLs, the less likely they are to plan to pick up themselves (Jiang et al., 2019).

According to research, 73% of customers had delivery issues. Poor address quality may be the cause of these failures, which could have an impact on delivery profitability. Localizing the address field has various advantages for global companies and retailers. Each country has a different format for addresses. By soothing customers and making it easier for delivery staff to see the address label, localizing the address fields at checkout lowers the likelihood of delivery issues. Local checkouts and trustworthy suppliers that can handle and lessen these problems are essential for retailers. Traditional forms of transportation, such as motorbikes and cycle rickshaws, are quick but environmentally harmful. This calls into question how last-mile delivery operations affect the environment (Islam et al., 2024).

ISM is defined as a process that aids individuals in better understanding their beliefs and identifying their areas of ignorance. Its most important function is organizational. The ISM process transforms vague and poorly stated mental models of systems into unique and unambiguous models(*Evaluating_Sustainable_Last-Mile_Delivery_LMD_in_B2C_E-Commerce_Using_Two-Stage_Fuzzy_MCDM_Approach_A_Case_Study_From_Vietnam*, n.d.). ISM starts with the identification of aspects that are relevant to the problem or issue before moving on to a group problem-solving technique. After that, a context-relevant subordinate relation is chosen. Pairwise variable comparison is used to build a structural self-interaction matrix (SSIM) following the determination of the element set and contextual relationship(Attri et al., 2013).

2.1 Research Scope & Limitations

In our research challenge, we focus on prioritizing the strategies that are directly given by policymakers and industry experts. Here are the factors we considered:

Our research study focuses on the emerging economies of our country, where supply chain logistics played the most vital role, which includes roads, rules, and technology.

Our main purpose is to provide solutions for reducing carbon emissions in the last-mile delivery. For this solution, we use Interpretive Structural Modelling (ISM).

Limitations

Our research only focused on experts' advice. But a vast majority of ideas can be implemented to connect all the dots to get the best results.

Our method is great for showing which strategies influence others, but it doesn't tell us *how much* one thing affects another

METHODOLOGY

Interpretive Structural Modelling (ISM) is a methodology used to identify and summarize relationships among specific variables, elements or factors that define a complex problem or systematic way, particularly when dealing with ill-structured problems of human judgment. ISM is the procedure for identifying the significant factors about an issue, establishing the contextual relationships among them, and developing a hierarchical model to exhibit relationships. The model enables the stakeholders to visualize which factors are independent, which are dependent, and how they influence each other. It is particularly useful in fields such as strategic planning, policy development, management, and systems engineering. To explore the interdependence among carbon-footprint reduction strategies for last-mile delivery in emerging economies, this study uses Interpretive Structural Modeling (ISM). ISM is a well-established multi-criteria decision-making (MCDM) method that converts qualitative judgments into a structured model, revealing both direct and transitive relationships among strategies. This approach is especially apt for last-mile delivery, where interventions are interrelated and their effectiveness depends on sequencing and mutual influence. Applying ISM identifies the most influential driving strategies and uncovers dependent strategies that emerge as outcomes. The analysis is implemented with the SmartISM platform, which supports matrix development, transitivity checks, level partitioning, and the construction of the hierarchical model.

Symbols to define relationships:

V → row variable influences corresponding column variable
A → row variable is influenced by corresponding column variable
X → row and correspnding column variable infulence each other
O → row and correspnding column variable have no relationship

	entation of fleet electrification and alternative fuel vehicles (AFVs) is being carried out.	e of advanced route optimization and fleet management software is being adopted.	stablishment of urban micro-hubs and consolidation centers is being undertaken.	The promotion of multimodal transport for the first-mile is being supported.	adoption of non-motorized and micro-mobility solutions is being encouraged.	installation of parcel lockers and centralized collection points is being expanded.	The optimization of vehicle load and capacity utilization is being pursued.	loyment of collaborative logistics and crowdsourcing platforms is being facilitated.	integration of green supply chain management (GSCM) is being implemented.	pment of infrastructure through public-private partnerships (PPPs) is being promoted
The implementation of fleet electrification and alternative fuel vehicles (AFVs) is being carried out.		V	V	V	V	V	V	V	V	V
The use of advanced route optimization and fleet management software is being adopted.			V	V	V	V	V	V	V	V
The establishment of urban micro-hubs and consolidation centers is being undertaken.				V	V	V	V	V	V	V
The promotion of multimodal transport for the first-mile is being supported.					V	V	V	V	V	V
The adoption of non-motorized and micro-mobility solutions is being encouraged.						V	V	V	V	V
The installation of parcel lockers and centralized collection points is being expanded.							V	V	V	V
The optimization of vehicle load and capacity utilization is being pursued.								V	V	V
The deployment of collaborative logistics and crowdsourcing platforms is being facilitated.									V	V
The integration of green supply chain management (GSCM) is being implemented.										V
The development of infrastructure through public-private partnerships (PPPs) is being promoted										

Ten strategies were selected from the literature and practitioner insights, including integration of Green Supply Chain Management (GSCM), fleet electrification and alternative fuel vehicles (AFVs), route optimization, establishment of urban micro-hubs, multimodal transport promotion, micro-mobility, parcel lockers, load optimization, collaborative logistics, and public–private partnerships (PPPs). These strategies formed the initial input set for ISM analysis.

Structural Self-Interaction Matrix (SSIM)

Variables	1	2	3	4	5	6	7	8	9	10
The implementation of fleet electrification and alternative fuel vehicles (AFVs) is being carried out.		V	V	V	V	V	V	V	V	V
The use of advanced route optimization and fleet management software is being adopted.			V	V	V	V	V	V	V	V
The establishment of urban micro-hubs and consolidation centers is being undertaken.				V	V	V	V	V	V	V
The promotion of multimodal transport for the first-mile is being supported.					V	V	V	V	V	V
The adoption of non-motorized and micro-mobility solutions is being encouraged.						V	V	V	V	V
The installation of parcel lockers and centralized collection points is being expanded.							V	V	V	V
The optimization of vehicle load and capacity utilization is being pursued.								V	V	V
The deployment of collaborative logistics and crowdsourcing platforms is being facilitated.									V	V
The integration of green supply chain management (GSCM) is being implemented.										V
The development of infrastructure through public-private partnerships (PPPs) is being promoted										

Fig 3.1 Structural Self-Interation Matrix (SSIM)

Pairwise relationships between strategies were elicited using four symbols: V (strategy i influences j), A (strategy j influences i), X (mutual influence), and O (no relation). SSIM captures qualitative expert judgments and serves as the foundation of the model.

Final Reachability Matrix(FRM)

Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
The implementation of fleet electrification and alternative fuel vehicles (AFVs) is being carried out.	1	1	1	1	1	1	1	1	1	1	10
The use of advanced route optimization and fleet management software is being adopted.	0	1	1	1	1	1	1	1	1	1	9
The establishment of urban micro-hubs and consolidation centers is being undertaken.	0	0	1	1	1	1	1	1	1	1	8
The promotion of multimodal transport for the first-mile is being supported.	0	0	0	1	1	1	1	1	1	1	7
The adoption of non-motorized and micro-mobility solutions is being encouraged.	0	0	0	0	1	1	1	1	1	1	6
The installation of parcel lockers and centralized collection points is being expanded.	0	0	0	0	0	1	1	1	1	1	5
The optimization of vehicle load and capacity utilization is being pursued.	0	0	0	0	0	0	1	1	1	1	4
The deployment of collaborative logistics and crowdsourcing platforms is being facilitated.	0	0	0	0	0	0	0	1	1	1	3
The integration of green supply chain management (GSCM) is being implemented.	0	0	0	0	0	0	0	0	1	1	2
The development of infrastructure through public-private partnerships (PPPs) is being promoted	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	1	2	3	4	5	6	7	8	9	10	

Fig 3.2 Final Reachability Matrix (FRM)

The SSIM was translated into a binary adjacency matrix by applying standardized coding rules. Each V, A, X or O was converted to 1s and 0s to reflect directional influence, with diagonals set to unity to ensure self-reachability.

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, 5, 6, 7, 8, 9, 10,	1,	1,	
2	2, 3, 4, 5, 6, 7, 8, 9, 10,	1, 2,	2,	
3	3, 4, 5, 6, 7, 8, 9, 10,	1, 2, 3,	3,	
4	4, 5, 6, 7, 8, 9, 10,	1, 2, 3, 4,	4,	
5	5, 6, 7, 8, 9, 10,	1, 2, 3, 4, 5,	5,	
6	6, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6,	6,	
7	7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 7,	7,	
8	8, 9, 10,	1, 2, 3, 4, 5, 6, 7, 8,	8,	
9	9, 10,	1, 2, 3, 4, 5, 6, 7, 8, 9,	9,	
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	10,	1
1 2 3 4 5 6 7 8 9 10				

Fig 3.3 Level Partitioning Iterations

Using the transitivity rule ("if strategy A influences B and B influences C, then A influences C"), the initial reachability matrix was expanded to include both direct and indirect influences. This procedure generated the final reachability matrix, which comprehensively represents system-wide interdependence.

Level Partitioning(LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1,	1,	1,	10
2	2,	1, 2,	2,	9
3	3,	1, 2, 3,	3,	8
4	4,	1, 2, 3, 4,	4,	7
5	5,	1, 2, 3, 4, 5,	5,	6
6	6,	1, 2, 3, 4, 5, 6,	6,	5
7	7,	1, 2, 3, 4, 5, 6, 7,	7,	4
8	8,	1, 2, 3, 4, 5, 6, 7, 8,	8,	3
9	9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	9,	2
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	10,	1

Fig 3.4 Level Partitioning (LP)

For each strategy, reachability and antecedent sets were determined from the final matrix. A strategy was assigned to the highest level if its reachability set equaled its intersection set. The process was iteratively applied until all strategies were stratified into distinct hierarchical levels.

Reduced Conical Matrix(CM)

Variables	10	9	8	7	6	5	4	3	2	1	Driving Power	Level
The development of infrastructure through public-private partnerships (PPPs) is being promoted	1	0	0	0	0	0	0	0	0	0	1	1
The integration of green supply chain management (GSCM) is being implemented.	1	1	0	0	0	0	0	0	0	0	2	2
The deployment of collaborative logistics and crowdsourcing platforms is being facilitated.	0	1	1	0	0	0	0	0	0	0	3	3
The optimization of vehicle load and capacity utilization is being pursued.	0	0	1	1	0	0	0	0	0	0	4	4
The installation of parcel lockers and centralized collection points is being expanded.	0	0	0	1	1	0	0	0	0	0	5	5
The adoption of non-motorized and micro-mobility solutions is being encouraged.	0	0	0	0	1	1	0	0	0	0	6	6
The promotion of multimodal transport for the first-mile is being supported.	0	0	0	0	0	1	1	0	0	0	7	7
The establishment of urban micro-hubs and consolidation centers is being undertaken.	0	0	0	0	0	0	1	1	0	0	8	8
The use of advanced route optimization and fleet management software is being adopted.	0	0	0	0	0	0	0	1	1	0	9	9
The implementation of fleet electrification and alternative fuel vehicles (AFVs) is being carried out.	0	0	0	0	0	0	0	0	1	1	10	10
Dependence Power	10	9	8	7	6	5	4	3	2	1		
Level	1	2	3	4	5	6	7	8	9	10		

Fig 3.5 Reduced Conical Matrix(CM)

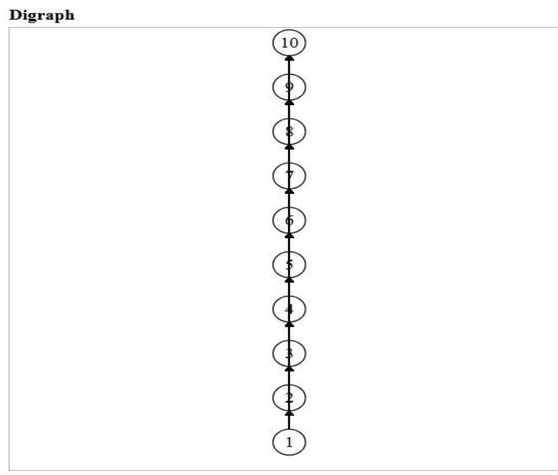

Fig 3.5 Digraph

The stratified strategies were graphically represented in a directed hierarchical model. Lower-level strategies reflect foundational drivers with strong influence, while higher-level strategies are more dependent outcomes. The resulting digraph was used for structural interpretation.

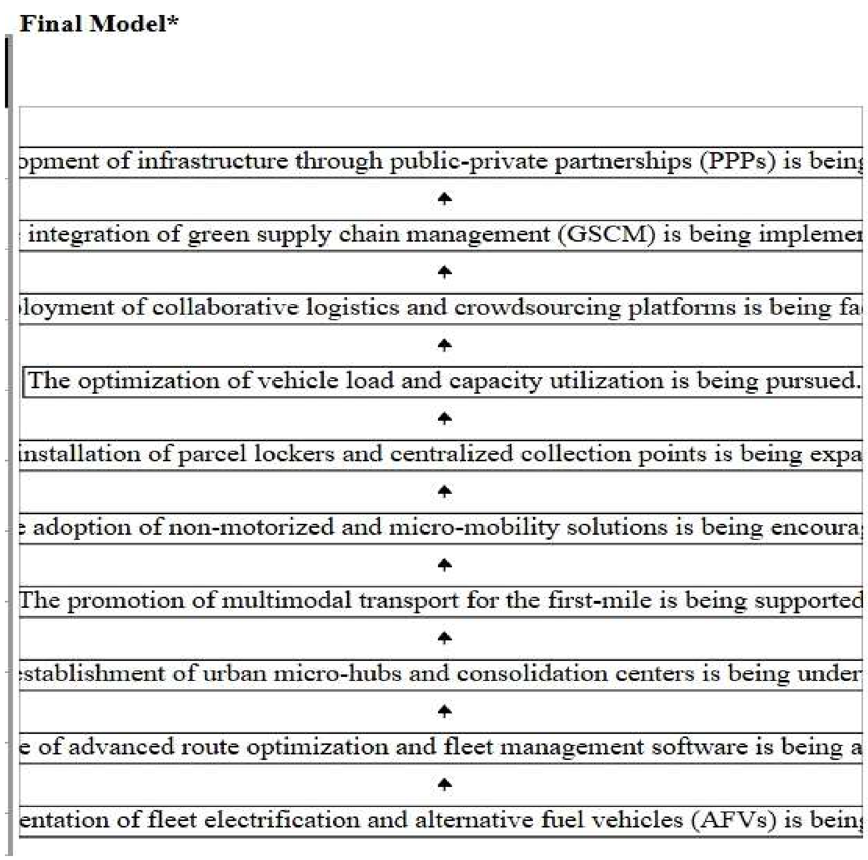

Fig 3.6 Final Model

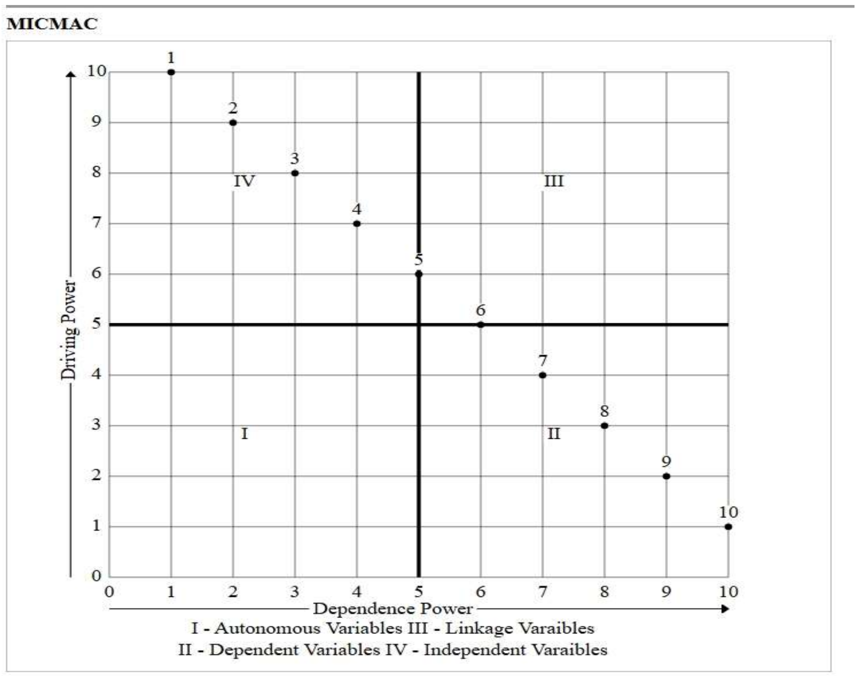

Fig 3.7 MICMAC

Finally, driving power (row sums) and dependence power (column sums) were calculated from the final reachability matrix. These measures positioned strategies within four clusters autonomous, dependent, linkage and driving offering further insight into their systemic role.

For instance, joint logistics promotes collaborative assets and reduces empty miles, while parcel locker networks and load optimization maximize operational efficiency and directly result in emission reduction gains. Since they occur at intermediary levels, it substantiates their bridging function between policy-driven enablers and technology-dependent solutions.

With increased levels of hierarchy, the adoption measures such as micro-mobility, multimodal first-mile promotion, and urban micro-hubs constituteThese were also termed linkage strategies, given their dual purpose of not only initiating follow-on action, but also being influenced by foundation enablers.

measures increasingly became dependent determinants. Such measures, while significantly decreasing carbon intensity, proved to be heavily reliant upon effectiveness in enforcement of both mid-level operation optimizations and governance regimes. For example, promotion of non-motorized transport or cargo bikes requires adequate infrastructure and logistic planning assistance for scalability. Similarly, micro-hubs and multimodality require network design investments and cooperative transport systems in advance.

Finally, the highest level is fleet electrification and conversion to alternative fuel vehicles (AFVs) as the most reliant strategy. As well documented as its ability to conserve emissions—77% in some empirical studies—is, implementation relies on availability of infrastructure (e.g., charging stations), economic incentives, and simultaneous adoption of lower-level alternatives. The initial introduction of EVs and AFVs shows that while they are a large technology solution, they must not be introduced in isolation and must be supported by underpinning systemic and operational.

Hierarchical relationships were maintained by the MICMAC analysis in clustering strategies into clusters of driving and dependence power. PPPs and GSCM were clustered in the independent cluster because they have a base and high-driving character. Operations efficiency strategies like load optimization, parcel lockers, and collaborative logistics were classified in the linkage cluster because they are enablers-driven and are required in facilitating higher-level strategies. Conversely, consumer-centric and technology-driven strategies such as fleet electrification, micro-mobility, multimodal promotion, and micro-hubs were classified in the dependent category, since they concurred with their system dependency and linkage approaches. Interestingly, no autonomous strategy was present, which is a proof of how highly interdependent carbon-reduction interventions for last-mile delivery are.

DISCUSSION

Hierarchical ranking indicates that the system-level enablers formulate the groundwork for implementing sustainable last-mile delivery in emerging economies. Institutional drivers towards the lower side of the model, such as Public–Private Partnerships (PPPs) and the incorporation of Green Supply Chain Management (GSCM), were found to be the most effective strategies. Their coincidence places stark into context the fact that sustainability-oriented long-term carbon reduction measures are not going to be initiated without supportive policy frameworks, collective investment pacts, and supply chain processes that seek out sustainability. These provide the enablings environment on which other measures can be developed and initiated in a suitable way.

The evaluation also suggests linkage strategies like truck load optimization, parcel locker installations, and collaborative logistics have a bridging effect. These interventions bridge high-level technology-oriented solutions with the drivers in the system. Through optimization of operations and resource utilization, linkage strategies push policy and governance enablement bottom-up to the ground into tangible carbon savings. For instance, load optimization has a direct impact on vehicle mileage payback, whereas collaborative logistics facilitates mutual sharing of resources and creation of synergy that leads to improved effectiveness of enablers' and dependent strategies.

Dependent indicators such as top-of-the-hierarchy fleet electrification, multimodal freight transport, and top-of-the-hierarchy micro-mobility are strong but highly dependent indicators. The reason is that these measurements, however much robust abatement they shall experience, will never be able to do so by themselves. Electric vehicle adoption, for instance, depends on provision of charging infrastructure, provision of financial incentive, and provision of supply logistics streams. Consequently, micro-mobility and multimodal transport depend on safe infrastructure, civic uptake, and coordination with current logistics flows.

Collectively, the research validates the wisdom of approaching the sequence in reducing carbon from last-mile delivery. The emerging nations must first become policy and infrastructure ready as a pre-requisite, then develop operational competence, and then only shift to advanced technology interventions. In the absence of a step-by-step process, investments in high-cost interventions such as electric vehicle fleets can become second-best or wasteful. As such, the ISM model offers not just a theoretical model but a practical road map for decision-makers to co-coordinate policy, strategy, and resources so that they are able to achieve sustainable logistics systems.

CONCLUSION

The study employed Interpretive Structural Modelling (ISM) in examining interdependencies among ten carbon-reduction interventions for last-mile delivery in emerging economies. Hierarchical modelling established Public–Private Partnerships (PPPs) and Green Supply Chain Management (GSCM) integration to be at levels of primary influence as systemic drivers. Those interventions define the enabling environment through which other interventions can well be developed and scaled. Intermediate-range facilitators such as vehicle loading optimization, cooperative logistics platforms, and parcel lockers were positioned as linkage strategies bridging institutional assistance and more advanced technological solutions. Their positioning recognizes the two functions that they address both enjoying policy-driven frameworks and providing efficiency benefits directly that reduce emissions.

At very high levels, unconventional measures such as micro-mobility adoption, multimodal transport integration, city micro-hubs, and the electrification of fleets were looked at as dependent measures. While high carbon abatement potential exists for the measure's electric fleets by up to 77% and cargo cycles by 96–98% compared to conventional vans their effectiveness is highly reliant on infrastructure availability, financing, as well as effective operating coordination.

In general, the findings reaffirm that a green last-mile delivery process must be phased. Policymakers must establish governance structures, infrastructure, and partnerships beforehand, optimize operations afterwards, and only then turn to technology-based solutions. Practitioners are provided with the findings as an operations guide towards eliminating short-run operations-driven returns and long-run sustainability needs. Through this staged progression, these nascent economies reduce carbon footprint based on logistics but also set solid delivery channels that can be modified to suit shifting needs.

Future research can complement the present research by empirically validating the ISM technique through case studies or integration with other methods such as fuzzy MICMAC or DEMATEL to deal with uncertainty and quantify associations. These extensions will provide more meaningful results and still help decision-makers develop effective, context-relevant carbon decreasing strategies for last-mile delivery.

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