Modelling Structural Linkages Among Last Mile Logistics Barriers: Interpretive Structuring Modelling (ISM) Approach

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ABSTRACT

The present study recognises and analyses the barriers hindering implementation of sustainable practices in last mile logistics (LML) using Interpretive Structural Modelling (ISM). The review of literature and interviews with experts result in five barriers namely, user resistance, budgetary limitations, political and legal obstacles, infrastructure constraints and technical difficulties. The model reveals that user resistance serves as the primary driver among the barriers, followed by budgetary limitations and legal obstacles, which share equal significance. Infrastructure constraints came next in the hierarchy. Followed by ISM, the barriers were subjected to MICMAC analysis which classified them into linkage, autonomous, dependent and driver barriers. User resistance is the driver barrier whose presence leads to other barriers in the model, whereas, constraints due to infrastructure and technical difficulties are the dependent barriers. The result of the analysis from this study offers valuable guidance for industry stakeholders and policymakers alike, emphasizing the importance of strategic interventions aimed at overcoming these barriers.

Keywords: last mile logistics, sustainability, Interpretive Structural Modelling (ISM), MICMAC, barriers

1 Introduction

Urbanization and increasing demands for goods pose significant challenges for sustainability in the logistics industry. While the rapid pace of urbanisation provides for urban progress and reliable goods provision, it results in escalating traffic, space limitations, and varied customer demands [1]. Urban residents also have higher expectations for quick and frequent deliveries, increasing the volume and frequency of last mile logistics, thereby deteriorating sustainability initiatives. The last mile logistics (LML) is the final leg of the supply chain (from distribution to end consumer) which often involves numerous short and frequent steps. The pressing concerns of carbon emission and keeping the global temperatures within control, businesses across the globe are taking measures to drive sustainability in last mile logistics. In India, Flipkart and Bajaj Auto have signed MoU for fostering adoption of EVs in the LML ensuring greener deliveries via 1000 technologically advanced electric three wheeler cargo vehicles [2]. Aramex, global logistics leader, has also started integrating e-bikes into its UAE delivery operations with an ambitious target of converting 98% of its fleet to electric vehicles by 2030 [3]. Despite the requirement and the advantages brought by sustainability initiatives in LML, companies face considerable barriers in its implementation. Often companies face the trade off between reducing green-house gas emissions and adjusting delivery capacity, high initial investments, lack of infrastructure, payments of workers, to name a few [4]. It is vital that managers identify barriers contextual to the supply chain while also analysing their interaction for better resource allocation and business outcomes. The present study aims to identify the barriers for a case supply chain and unravel the hierarchical relationships among these barriers by employing Interpretive Structural Modelling (ISM). ISM provides the significant driver and the dependent barriers which help managers in better resource allocation thereby, paving the way for the adoption of sustainable last-mile logistics practices. The study

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offers insights on taking informed decisions on these barriers thereby helping in implementation of strategies.

2 Literature Review

The term last mile originally found its usage in the realm of telecommunications, referring to the final segment of a telecommunication network [5]. However, in the context of goods supply chain and logistics, last mile logistics (LML) represents the conclusive phase of the supply chain journey, representing the closing link between businesses and their customers [6]. At present, companies deploy third party logistics (3PLs) such as FedEx, DHL, Delhivery, Shiprocket etc., to ship products to end customers. LML is categorised into 5 modes: reception box, collection point, post office, attended home delivery, and unattended home delivery [7].

2.1 Barriers to Sustainability initiatives in Last Mile Logistics

The share of GHG emission in LML increases as the proportion of failed first time delivery increases. CO2 from the second time delivery per drop increases between 9% and 75% [8]. Some of the ways in which the failed first-time delivery can be prevented include use of Reception Box (RB), Collection and Delivery Points (CDPs) and Unattended Home Delivery (UAHD). This is one instance of many barriers that the companies are presented with. Table 1 tabulates these barriers in different country contexts along with the research methods used for their identification.

Table 1: *List of barriers to sustainability identified across the world in various sectors:*

Reference	Research Methods	Identified Barriers	Country	Industry
[9]	Semi Structured Expert Interviews, Qualitative Content Analysis	User Resistance Barriers, Financial Barriers, Political and Legislative Barriers, Infrastructural Barriers, Technical and Technological Barriers	Germany, France, Sweden, Austria	Urban Logistics
[10]	ISM and MCDM	Improper or Lack of packaging, Improper handling of packed produce while loading and unloading the F&V, Non availability of refrigerated vehicles, Poor stowage, Bad condition of roads	India	F&V supply chains
[11]	Systematic literature review	Technological, infrastructural, LML system and management, and logistic cost related challenges	General perspective	Urban freight LML
[12]	Expert interviews	lack of strong leadership, resources, and policy tools, technological challenges, costs,	North America	Urban freight LML

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Reference	Research Methods	Identified Barriers	Country	Industry
		workforce, disaggregated nature of the urban freight "system"		
[13]	Route optimisation	Technological challenges	General perspective	Urban freight LML
[14]	Systematic literature review	Technological developments, crowd shipping, government policy making	General perspective	Cargo shipments

Many obstacles to sustainability in last-mile logistics are found in the literature, including user resistance, budgetary limitations, political and legal obstacles, infrastructure constraints, and technical difficulties in several nations, including Germany, France, Sweden, Austria, North America and India. These include technological challenges, disaggregated nature, infrastructural challenges, user resistance to name a few. These analyses have been performed while giving a general perspective across cargo LML, urban logistics, food and vegetable supply chains.

2.2 Research Objectives

A notable research gap exists in the application of the Interpretive Structural Modelling (ISM) framework, particularly within the realm of sustainability in last mile logistics. Although the literature study identifies several barriers using qualitative methods like expert interviews and content analysis, there is not much research using ISM to thoroughly examine the hierarchical links between these barriers. Research projects including ISM would provide a systematic framework for determining the major factors impacting sustainability in last-mile delivery operations. The present study, hence, is undertaken to fulfil these gaps with the objective to utilize the Interpretive Structural Modelling (ISM) framework to analyse hierarchical relationships among barriers hindering sustainability in last mile logistics.

3 Research Methodology

The Research Methodology for this study consists of three critical components. Initially, a comprehensive compilation of barriers related to sustainability in last mile logistics (LML) is conducted, providing an in-depth understanding of the challenges within this domain. Subsequently, Interpretive Structural Modelling is applied to the present problem. A Structural Self Interaction Matrix (SSIM) will be developed to quantitatively evaluate and measure the sustainability performance of LML practices, followed by an initial Reachability Matrix. SSIM will be constructed to map out the relationships and interactions among various sustainability indicators and their impacts within LML. The reachability matrix identifies the reachability, antecedent and intersection sets which are further level partitioned to develop the structural model. Additionally, the methodology involves the utilization of MICMAC analysis post ISM, enabling further insights into the driving and dependent factors within the structural model.

4 Findings and Discussions

Based on the Interpretive Structural Modelling (ISM) and MICMAC analysis, the present section elaborates on its findings. Section 4.1 elaborates upon the findings of the literature review giving the names and explanation about the barriers, followed by section 4.2 which gives the ISM model comprising of Structural Self Interaction Matrix, reachability matrix and level partitioning. Section 4.3, lastly provides the MICMAC grid classifying the barriers into four categories.

4.1 Barriers to sustainability in LML

The barriers obtained after discussions with experts include User Resistance (UR), Budgetary Limitations (BL), Political and Legal Obstacles (PO), Infrastructure Constraints (IC) and Technical Difficulties (TD). User resistance refers to the reluctance or opposition from end-users towards adopting sustainable practices and delivery options in LML. Budgetary limitations refer to constraints related to financial resources for implementing sustainable initiatives. Political and legal obstacles encompass regulatory challenges and governmental policies that affect sustainable LML. Infrastructure constraints are the limitations in infrastructure that hinder the implementation of sustainable last mile practices in LML and Technical difficulties refer to challenges associated with the adoption and integration of technology for sustainable last mile operations in LML.

4.2 Interpretive Structural Modelling

Interpretive Structural Modelling (ISM) [15] framework will be developed using the knowledge gained from this wide variety of barriers. This framework will provide an organized strategy for identifying the challenges involved in attaining sustainable last mile logistics

4.2.1 Structural Self Interaction Matrix (SSIM)

A contextual relationship of influence was selected, and four symbols were employed to signify the direction of the relationship between any two barriers (i and j) as shown in Table 2.

Table 2*: Notation for pair-wise comparison between barriers*

Symbol	Description
V	i influences j, not vice versa
A	j influences i, not vice versa
X	i and j influence each other
O	i and j are unrelated

The Structured Self Interaction Matrix (SSIM) (Table 3) is then constructed based on the ratings provided by experts regarding the strength and direction of relationships between pairs of barriers to sustainable practices in Last Mile Logistics (LML).

Table 3: *Structural Self Interaction Matrix*

	UR	**BL**	**PO**	**IC**	**TD**
UR	-	V	V	V	V
BL		-	X	V	V
PO			-	V	V
IC				-	V
TD					-

4.2.2 Reachability Matrix

The initial reachability matrix (RM) is obtained from the SSIM by converting the notations into binary form using the rules given in Table 4. The matrix is checked for transitive relations to obtain the final reachability matrix. There is an existence of transitive link between three variables A, B and C if A Influences B, B

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influences C and C influences A. In the present scenario, there are no transitive link, therefore, the initial and final reachability matrix are same. The next step is to develop the structural digraph through level partitioning. Table 5 displays the Reachability Matrix for the barriers by following the specified rules.

Table 4 *Notation for conversion to binary form*

SSIM Symbol	Reachability Matrix (i,j)	Reachability Matrix (j,i)
V	1	0
A	0	1
X	1	1
O	0	0

Table 5: *Reachability Matrix after incorporating transitive links*

	UR	BL	PO	IC	TD
UR	1	1	1	1	1
BL	0	1	1	1	1
PO	0	1	1	1	1
IC	0	0	0	1	1
TD	0	0	0	0	1

4.2.3 Level partitioning and final structural model

The reachability and antecedent set are identified for each sustainability barrier along with the intersection set. The reachability set for a given element i consists of all elements that can be reached from i directly or indirectly. The antecedent set for a given element j consists of all elements that reach to j directly or indirectly. Intersection set includes the common elements from antecedent and reachability set. All barriers having same elements in the reachability and the intersection sets are assigned as the top level element in the ISM hierarchy. Similarly, levels are identified for other barriers by duplication of this process. Once the level was identified for a barrier, it was discarded from the list of remaining barriers. Table 6 depicts the reachability, antecedent and intersection set along with the levels.

Table 6: *reachability, antecedent and intersection set and level partitioning*

Layout	Reachability Set	Antecedent Set	Intersection Set	Level partitioning
UR	1,2,3,4,5	1	1	IV
BL	2,3,4,5	1,2,3	2,3	III
PO	2,3,4,5	1,2,3	2,3	III
IC	4.5	1,2,3,4	4	II
TD	5	1,2,3,4,5	5	I

Based on the level partitioning, the structural model is depicted in Figure 1.

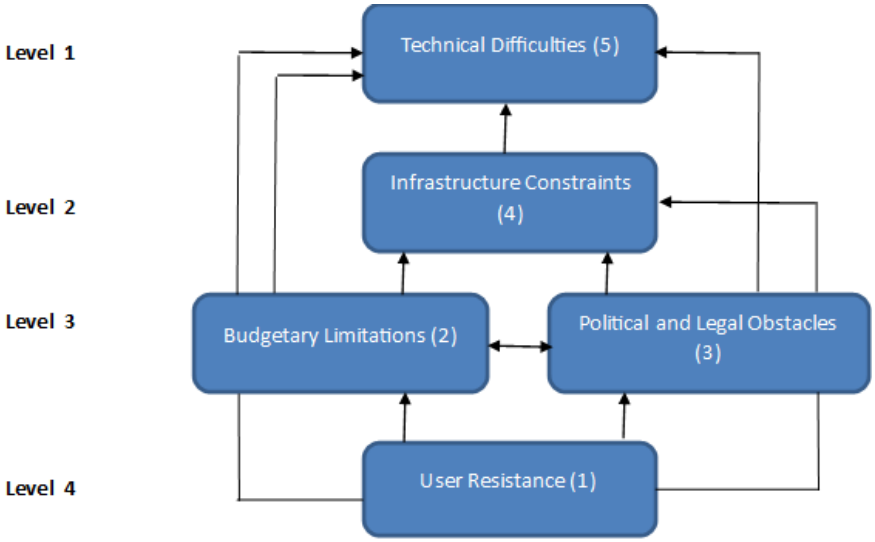

Figure 1: Hierarchical model of the barriers

4.2.4 MICMAC Analysis

MICMAC stands for Matrix of Cross-Impact Multiplications Applied to Classification which classifies the elements in the system based on the strength of their dependence and driving power. In the context of sustainability in Last Mile Logistics (LML), the MICMAC analysis helps identify key factors that exert significant influence and those that are more influenced by other factors. The driving power and dependence of each element is calculated (Table 7). It is followed by plotting these values on a graph and classifying them into four categories namely, autonomous, independent (or drivers), dependent and linkage variables (Figure 2).

Table 7: reachability, antecedent and intersection set and level partitioning

Barriers	**1**	**2**	**3**	**4**	**5**	**Driver Power**
	UR	BL	PO	IC	TD	
UR	1	1	1	1	1	5
BL	0	1	1	1	1	4
PO	0	1	1	1	1	4
IC	0	0	0	1	1	2
TD	0	0	0	0	1	1
Dependence	1	3	3	4	5	16/16

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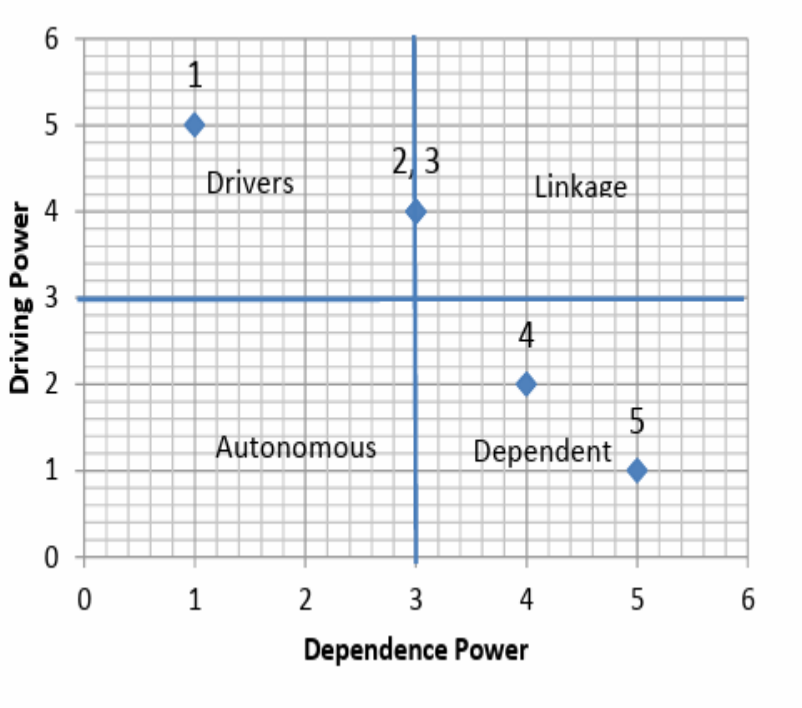

Figure 2: MICMAC Analysis

The barriers were classified into four clusters based on their characteristics and relationships. No barrier was classified into Autonomous Cluster. It suggests that none exhibited weak driving power and weak dependence, indicating a relative disconnection from the system. Dependent Cluster comprises of User Resistance and Technical Difficulties due to their limited driving power but significant dependence on other factors. Addressing these barriers effectively requires resolving other related obstacles beforehand. No barrier was categorized into the Linkage Cluster. This cluster implies strong driving power and significant dependence, rendering them unstable with considerable impacts on other factors in the system. Finally, Independent/Driver Cluster include Budgetary Limitations, Infrastructure Constraints, and Political and Legal Obstacles. These barriers exhibit strong driving power but weak dependence, suggesting their influential role as independent drivers within the system. Eliminating these barriers would likely lead to the removal of other barriers.

5 Conclusions, Limitations and Future Directions for Research

The present study is a comprehensive investigation into the barriers hindering the adoption of sustainable practices in Last Mile Logistics (LML). Discussions with experts representing academia and industry resulted in identification of five key barriers namely, user resistance, budgetary limitations, legal obstacles, infrastructure constraints and technical difficulties. These barriers collectively represent the multifaceted challenges inherent in transitioning towards sustainable practices in LML. The application of Interpretive Structural Modelling (ISM) framework gives an interpretation of the complex interactions among these barriers, thereby, providing a nuanced understanding of their interdependencies. The model suggests that Budgetary Limitations, Infrastructure Constraints, and Political and Legal Obstacles exert significant influence but weak dependence, suggesting their resolution could mitigate other barriers. User Resistance and Technical Difficulties were identified as dependent barriers implying that other barriers have poses influence on them. The absence of barriers in the autonomous cluster underscores the interconnected nature of LML sustainability challenges.

The study attempts to enhance the understanding of the barriers affecting sustainability initiatives in Last Mile Logistics (LML) and lays the groundwork for future research and policy measures designed to advance sustainability within the logistics and supply chain sector. By addressing these barriers collaboratively, stakeholders can work towards building more resilient, environmentally responsible, and efficient Last Mile Logistics systems, ultimately contributing to broader sustainability objectives. Despite efforts to comprehensively review available sources, the absence of primary data sources and industry-specific insights could have restricted the scope of the understanding of barriers to sustainability in Last Mile Logistics (LML). Finally, methodological constraints inherent in Interpretive Structural Modelling (ISM) and MICMAC analyses creeping in due to expert opinions, may have impacted the accuracy and reliability of the results.

6 Declarations

6.1 Competing Interests

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

6.2 Publisher's Note

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