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Relational Differentiation in Green Last-Mile Delivery Networks: A Comparative Stakeholder Analysis Across Mission Cities

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Abstract

This study examines stakeholder network relations in implementing green last-mile delivery (GLMD) solutions through social network analysis (SNA) in a comparative study of two EU Mission cities: Wrocław and Rotterdam. Using the Stakeholder Network Relations Measurement framework, semi-structured interviews assessed dyadic ties across three weighted relational dimensions: strength, reciprocity, and proximity. Two-mode networks were analysed at both macro and micro levels using density, centralization, transitivity, and centrality indicators (degree, closeness, betweenness). Results reveal that both cities form dense, three-cluster networks, yet follow fundamentally different structural logics. Wrocław exhibits a moderately centralized, small-world configuration, driven by operational hubs (E-Customer, Transport Company), which favours efficient information diffusion. Rotterdam displays a more egalitarian, highly cohesive structure, anchored by institutional and knowledge actors (Local Government, Research Institutions), that emphasizes trust-based triadic closure. In both cities, Research Institutions emerge as key structural anchors bridging otherwise disconnected clusters, while peripheral actors—Industry Organizations and Shareholders—remain weakly integrated. The findings demonstrate that relational differentiation in GLMD networks is context-dependent and suggest that network governance strategies should balance diffusion efficiency with structural resilience while deliberately activating marginal stakeholders to strengthen collective decision-making capacity across Mission cities.

Keywords: last-mile delivery; stakeholder network relations; social network analysis; sustainable urban logistics; collaborative governance; Mission cities;

1 Introduction

Green last-mile delivery (GLMD) poses a critical challenge for sustainable city logistics, requiring coordinated action among diverse stakeholders, including public organizations (such as local authorities, universities), private organizations (such as shippers, receivers, courier/logistics companies, technology providers), NGOs, and society (such as customers and residents) (Kiba-Janiak, 2019). The complexity of implementing GLMD solutions in urban environments necessitates understanding not only who the stakeholders are, but how they relate to one another and what structural patterns characterize their collaborative networks (Kiba-Janiak et al., 2021). Urban consolidation centres, cargo bikes, electric vehicles, and parcel lockers represent key GLMD solutions, yet their successful deployment depends on multi-stakeholder alignment that extends beyond purely technical considerations (Björklund & Johansson, 2018; Macharis & Kin, 2017). Wiele badan podkreśla the crucial role of stakeholders in the effective implementation of solutions in the field of GLMD. It largely depends on the quality of the relationships and cooperation between stakeholders (Šemanjski & Gautama, 2019; Paddeu et al., 2024). Although there has been research into the varying expectations and behaviours of different stakeholder groups, there is a lack of research analysing relations in GLMD networks with the usage of social network analysis (SNA).

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This study examines stakeholder network relations in implementing GLMD solutions through social network analysis (SNA) of dyadic ties in two EU Mission cities: Wrocław and Rotterdam. Mission cities, designated under the EU Mission for Climate-Neutral and Smart Cities, represent urban areas committed to achieving climate neutrality by 2030, making them particularly relevant contexts for investigating how collaborative networks can drive sustainable logistics transformation. The selection of Wrocław and Rotterdam enables cross-national comparison between Central and Western European governance traditions. The research aims to: (i) identify the key characteristics of stakeholder relations in GLMD networks, (ii) analyse how relational dimensions vary across different stakeholder types, (iii) assess challenges and opportunities for enhancing collaboration, and (iv) derive strategic insights for accelerating sustainable urban logistics implementation.

The paper is organized as follows. Section 2 reviews the theoretical foundations underpinning stakeholder network analysis in urban logistics, drawing on stakeholder theory, collaborative governance frameworks, and social network analysis methodology. Section 3 describes the research methodology, including the five-stage analytical process and the relational dimensions framework. Section 4 presents the results at both macro and micro network levels. Section 5 discusses the implications of the comparative findings, and Section 6 offers conclusions and directions for future research.

2 Literature Review and Theoretical Framework

Stakeholder theory, originally developed by Freeman (1984), emphasizes identifying actors with legitimate interests in organizational outcomes and understanding the nature of their involvement. In the context of city logistics, stakeholder theory has evolved to address the multi-actor complexity in which public policy, commercial interests, and environmental concerns intersect (Lindholm & Behrends, 2012; Ballantyne et al., 2013). Mitchell et al. (1997) introduced stakeholder salience based on three attributes—power, legitimacy, and urgency—providing a framework for prioritizing stakeholder engagement. Rowley (1997) further advanced this perspective by proposing a network theory of stakeholder influences, recognizing that stakeholder behaviour emerges from relational patterns within the network rather than from individual characteristics alone.

In GLMD networks specifically, stakeholders encompass logistics operators seeking operational efficiency, public authorities pursuing sustainability goals, e-commerce platforms optimizing customer experience, technology providers developing green solutions, research institutions generating knowledge, and end-users whose preferences shape demand patterns (Kiba-Janiak et al., 2021). The diversity of stakeholder interests creates coordination challenges, as logistics operators may prioritize cost reduction while public authorities emphasize emissions mitigation and end-users value convenience and speed (Jagoda et al., 2023). Lindholm and Blinge (2014) highlighted that awareness gaps among local authority policy planners regarding sustainable freight transport further complicate multi-stakeholder coordination.

Collaborative governance frameworks provide theoretical foundations for understanding multi-stakeholder coordination in complex policy domains. Ansell and Gash (2008) identified key conditions for successful collaborative governance, including prior history of cooperation, power asymmetries, and institutional design. The Quadruple Helix model (Carayannis & Campbell, 2009) extends this perspective by emphasizing that innovation in sustainable urban systems emerges from interactions among four sectors: government, industry, academia, and civil society. Recent research emphasizes that collaborative governance success depends on relational factors including trust, reciprocity, and shared understanding (Kiba-Janiak et al., 2024). These relational dimensions are particularly relevant in GLMD contexts, where subsidized pilot projects must transition into financially sustainable operations through robust stakeholder partnerships (Kin et al., 2018).

Social network analysis (SNA) provides methodological tools to examine relational structures within stakeholder networks. SNA focuses on patterns of relationships rather than individual attributes (Wasserman & Faust, 1994), enabling researchers to identify central actors, brokerage positions, and structural vulnerabilities. Key relational dimensions include tie strength—where strong ties facilitate trust and resource exchange while weak ties enable access to novel information and bridge structural holes (Granovetter, 1973)—reciprocity, capturing mutual exchange patterns, and proximity encompassing cognitive, organizational, social, and institutional dimensions (Boschma, 2005). Mucowska (2024) developed a comprehensive framework for measuring stakeholder relations in GLMD networks, operationalizing these dimensions through weighted indicators that capture the multifaceted nature of inter-organizational ties.

3 Methodology

This study applied social network analysis (SNA) methodology to examine stakeholder relations involved in implementing GLMD solutions in selected Mission cities. The analytical process consisted of five consecutive stages commonly used in SNA literature (Abramek, 2021; Klimas, 2016): (i) identifying nodes and attributes within the network, (ii) collecting empirical data, (iii) constructing a two-mode relation matrix, (iv) analysing network structure, and (v) synthesizing findings and deriving conclusions.

Within this framework, the nodes were respondents representing 16 organisations engaged in last-mile delivery processes in Wrocław and Rotterdam, whereas the attributes were the stakeholder categories relevant to the implementation of green last-mile solutions: City Hall (UMW/UMR), Transport Companies (TC), E-commerce Platforms (ECM), Competitors (ME), Media, Research Institutions (SCN), Associations and Foundations (FOU), Equipment and Technology Providers (SUP), E-customers (E-CL), Industry Organizations (ORG), and Shareholders (SHR). Relationship formation was assessed through three relational dimensions—strength, reciprocity, and proximity—each comprising weighted elements derived from prior research (Mucowska, 2024) (Table 1).

In stage (ii), semi-structured interviews were conducted with selected last-mile delivery stakeholders in both cities in the years 2023-2024. Respondents evaluated relationships across the three weighted dimensions on a 1–5 scale (1 = low importance; 5 = critical). Missing responses were treated as the absence of a relationship. Based on collected data, a two-mode relation matrix $m \times n$ was constructed, where m are respondents (nodes) and n are stakeholder categories (attributes). The dimensional components were aggregated into a single variable on a 0–5 scale (0 = no relationship; 5 = critical relationship).

Table 1. Relational dimensions used in the analysis

Relational attribute (weight)	Element (code)	Element weight within attribute	Total weight (Attribute × Element)
F1 Strength (0.42)	F1.1 Engagement in the relationship	0.36	0.1512
	F1.2 Trust in the relationship	0.36	0.1512
	F1.3 Knowledge exchange	0.28	0.1176
F2 Reciprocity (0.26)	F2.1 Degree of reciprocity	0.31	0.0806
	F2.2 Information exchange	0.43	0.1118
	F2.3 Formal agreements	0.26	0.0676
F3 Proximity (0.32)	F3.1 Cognitive dimension	0.21	0.0672
	F3.2 Organizational dimension	0.28	0.0896
	F3.3 Social dimension	0.28	0.0896
	F3.4 Institutional dimension	0.23	0.0736

Source: authors’ own elaboration.

With the matrix in place, step (iv) involved network analysis at both macro and micro levels. Macro-level analysis examined overall network properties, including density, degree centralization, average distance, transitivity/closure, and small-worldness. Micro-level analysis focused on individual node and attribute centrality measures: degree centrality (number of connections), 2-local centrality (neighbourhood quality), closeness centrality (accessibility), and betweenness centrality (brokerage potential). Step (v) involved deriving study conclusions through a comparative synthesis of findings across both cities.

4 Results

4.1 Comparative macro-level network structure

Figures 1 and 2 depict the two-mode networks for Wrocław and Rotterdam, respectively. Both networks consist of 10 nodes with comparable numbers of ties (44 for Wrocław, 43 for Rotterdam) and similar average degrees (4.4 and 4.3), indicating high collaborative activity in both cities.

The Wrocław network exhibits a density of 0.489, indicating that 48.9% of all possible relationships are present—a moderately high value typical of small, intensively cooperating networks and suggesting neither fragmentation nor significant isolation of actors. The degree of centralization of 0.389 suggests a partially centralized structure with an informal core of actors with more connections, yet not extremely hierarchical. The structure indicates no dominance of a single super-node; instead, the network displays a core cluster rather than a rigid hierarchy.

The average distance of 1.644 means that each node is separated from any other node by slightly more than 1.5 steps, indicating relatively short paths and a high potential for information, resource, and influence flows across the network. The transitivity/closure measure of 0.539 indicates a tendency toward triadic structures, with coalition structures and shared ties enhancing the cohesion of communication channels. Notably, Wrocław displays small-world characteristics (Small Worldness = 1.117), combining high clustering with short path lengths—an optimal

configuration for the flow of information and innovation. Overall, the Wrocław network functions as a single integrated organism: collaboration is based more on partnership than on unilateral dominance, information diffusion is highly efficient, and moderate centralization ensures a balance between efficiency and resilience.

The Rotterdam network shows a density of 0.478, comparable to Wrocław but with a notably different structural profile. Degree centralization (0.306) is lower, indicating a more egalitarian configuration where ties are distributed more evenly across actors, and the network functions more as a flat collaborative structure than a core-periphery system. The average distance of 1.157 is remarkably low, suggesting that almost every node is reachable from any other in just over one step—characteristic of compact, cohesive networks where relational proximity is extremely high. Such short paths imply strong potential for rapid information diffusion, efficient resource exchange, and a high level of communicative cohesion.

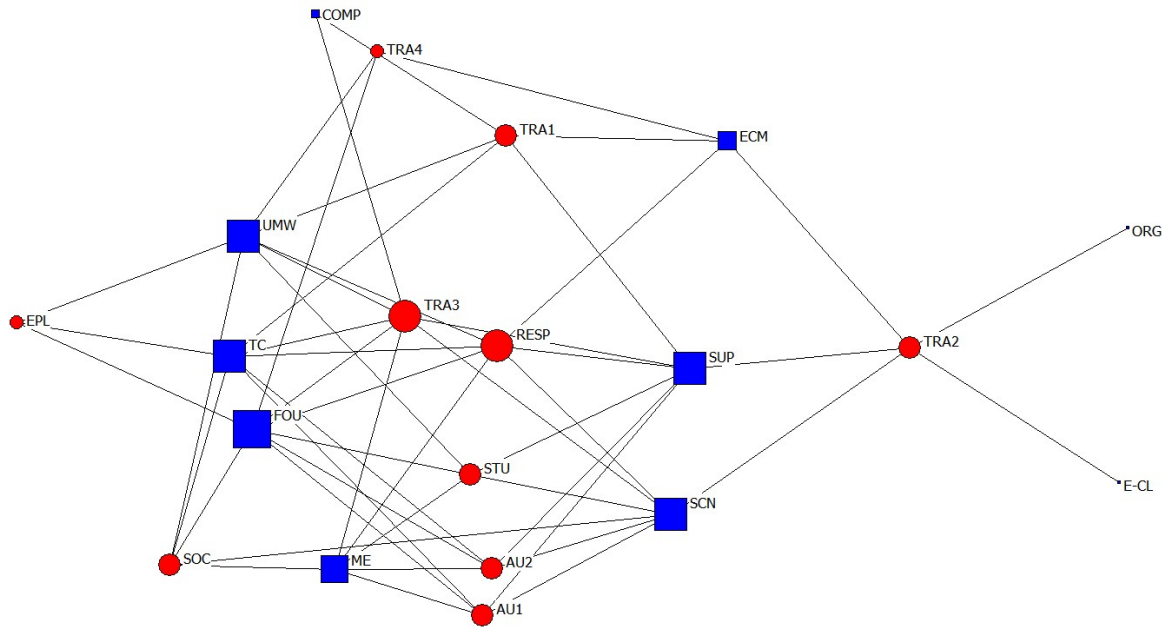


Figure 1. Macro-level network visualization for Wrocław

Legend: SOC — Associations and Foundations, TRA1 — Transport Company 1, AU1 — Local Government Unit 1, TRA2 — Transport Company 2, RESP — E-client, STU — Equipment Suppliers, TRA3 — Transport Company 3, AU2 — Local Government Unit 2, TRA4 — Transport Company 4, EPL — E-platforms, UMW — Wrocław City Hall, TC — Transport Companies, ECM — E-commerce Platforms, COMP — Competitors, ME — Media, SCN — Research Institutions, FOU — Associations and Foundations, SUP — Equipment and Technology Providers, E-CL — E-customers, ORG — Industry Organizations, SHR — Shareholders.

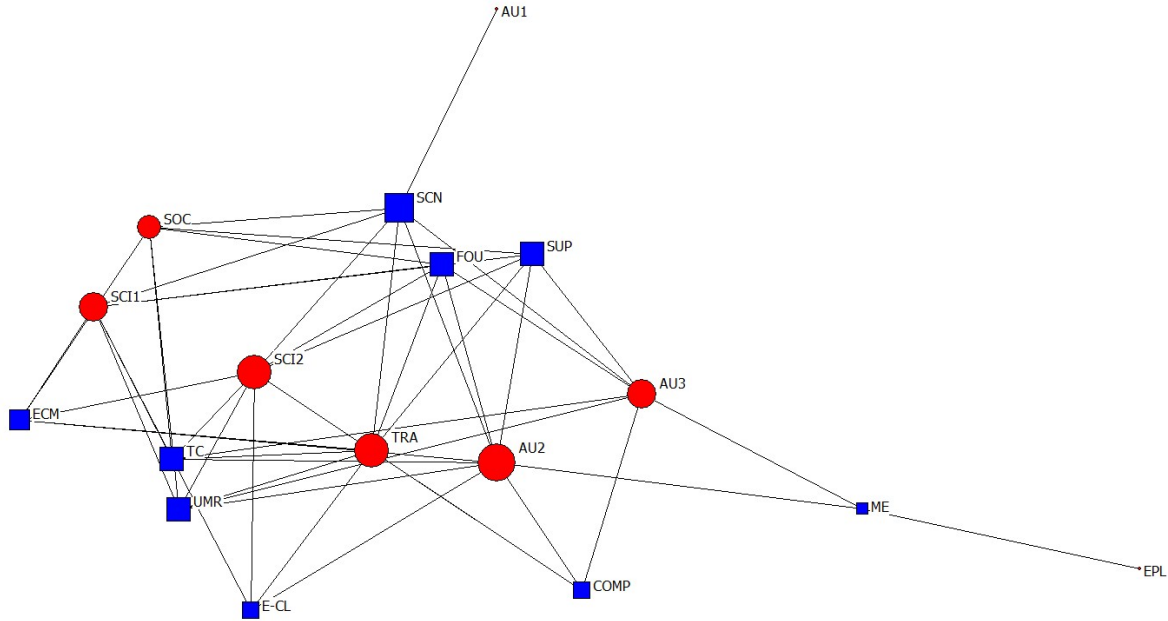


Figure 2. Macro-level network visualization for Rotterdam

Legend: SOC — Associations and Foundations, TRA — Transport Company, AU1 — Local Government Unit 1, SCI1 — Research Institution 1, RESP — E-client, STU — Equipment Suppliers, AU2 — Local Government Unit 2, AU3 — Local Government Unit 3, EPL — E-platforms, SCI2 — Research Institution 2, UMR — Rotterdam City Hall, TC — Transport Companies, ECM — E-commerce Platforms, COMP — Competitors, ME — Media, SCN — Research Institutions, FOU — Associations and Foundations, SUP — Equipment and Technology Providers, E-CL — E-customers, ORG — Industry Organizations, SHR — Shareholders.

Note: red circles denote nodes (respondents); blue squares denote attributes (stakeholder categories). Symbol size represents degree centrality. Visualization prepared in NetDraw

Source: authors' own elaboration.

Rotterdam's transitivity/closure (0.846) substantially exceeds Wrocław's (0.539), indicating a strong tendency toward triadic relationships. If two nodes are connected to a third node, they are also likely to be connected to each other. High closure strengthens trust, enhances collective action, and reflects mature network structures with dense subclusters. However, the Small Worldness value of 0 indicates that Rotterdam's network lacks small-world characteristics despite its high clustering, suggesting a structural logic oriented toward local bonding rather than global bridging.

Overall, both networks function as integrated systems without isolated entities. Wrocław's structure supports efficient information diffusion through its small-world configuration, while Rotterdam's compact, cohesive architecture facilitates rapid coordination through extremely short paths and strong local bonding. The key structural divergence—centralization versus egalitarianism—carries important implications for how green logistics innovations propagate through each network.

With the macro-network analysis for Wrocław and Rotterdam complete, it is possible to proceed to the micro-network analysis, examining individual nodes and attributes through degree, 2-local, closeness, and betweenness centrality measures. This disaggregated perspective reveals the specific actors and stakeholder categories that drive connectivity, broker information flows, and occupy structurally vulnerable positions within each network.

4.2 Comparative micro-level attribute analysis

At the micro level, the two cities reveal distinct patterns of actor centrality and brokerage. In Wrocław, the highest degree values were recorded for E-Customer (RESP) and Transport Company 3 (TRA3, both 0.636), confirming these entities as the most active operational hubs. Both nodes also demonstrate high closeness values (0.725), meaning they are the best-positioned nodes in terms of accessibility—they can reach or be reached by any other actor with the fewest intermediary steps. Transport Company 2 (TRA2) emerges as the primary broker (betweenness 0.205), linking otherwise disconnected network segments—a strategically powerful but structurally vulnerable position.

The scatter plot analysis for Wrocław nodes reveals a clear structural differentiation. E-Customer (RESP) and Transport Company 3 (TRA3) emerge as the strongest hubs, demonstrating very good accessibility and high 2-local centrality, albeit with moderate brokerage. The middle group, including Associations and Foundations (SOC), Equipment Suppliers (STU), and Local Government Units (AU1, AU2)—operates stably but forms weaker connections, with slightly higher betweenness observed for Transport Company 1 (TRA1). The periphery consists of E-Platform (EPL) and Transport Company 4 (TRA4), which exhibit minimal centrality across all measures.

In Rotterdam, Local Government Unit 2 (AU2) dominates with the highest degree (0.818) and closeness centrality (0.674), serving as the primary broker (betweenness 0.134) and having the best accessibility across the entire network. Transport Company (TRA) and Research Institution 2 (SCI2, both 0.727) follow as secondary hubs. This contrast highlights Wrocław’s operational-actor dominance versus Rotterdam’s institutional-actor anchoring—a fundamental difference reflecting distinct governance traditions and stakeholder engagement patterns in the two cities.

Among attributes, both cities share Research Institutions (SCN) as a structurally central category. In Wrocław, Associations and Foundations (FOU) lead in degree centrality (0.800), followed by SCN, Equipment and Technology Providers (SUP), City Hall (UMW), and Transport Companies (TC), all at 0.700. These stakeholders have the most connections to nodes, forming the core of stakeholders with strong exposure in the network. The 2-local centrality measure, which captures attribute strength through the quality of neighbours, distinguishes FOU (0.364) and SUP together with SCN (both 0.355) as the most embedded attributes. The closeness measure indicates that SCN and SUP (both 0.750), as well as FOU (0.714), are the most central in terms of distance—these stakeholders can be reached the fastest across the entire two-mode network. SUP (betweenness 0.131) and SCN (0.127) serve as critical information brokers, controlling flows between various nodes and connecting areas that would otherwise be more fragmented. From the perspective of closing structural holes, Equipment and Technology Providers and Research Institutions act as connectors between different organizational spheres. Shareholders (SHR) are so distant that they are de facto unreachable within the Wrocław network.

In Rotterdam, SCN leads in degree (0.700), neighbourhood strength, and brokerage (0.108), while Rotterdam City Hall (UMR), TC, FOU, and SUP each score 0.600, forming a compact cluster of highly influential attributes that constitute the network’s functional backbone. Closeness values confirm SCN (0.652) as the most accessible attribute, reflecting its strategic integration. Media (ME) plays a noteworthy bridging role (betweenness 0.085) despite lower degree values, facilitating communication between specific relational clusters that would otherwise remain more separated. In both cities, Industry Organizations (ORG) and Shareholders (SHR) remain structurally isolated at the network periphery, positioned without functional integration, indicating that these stakeholder categories have yet to be effectively incorporated into GLMD collaborative arrangements.

5 Discussion

The comparative analysis reveals that Wrocław and Rotterdam represent two distinct archetypes of GLMD stakeholder networks. Both networks display three-cluster architectures comprising a high-capacity core, a bridging meso-layer, and a peripheral cluster, yet their compositions and structural logics differ substantially (Table 2).

Wrocław’s core cluster centres on E-Customer (RESP) and Transport Company 3 (TRA3) among nodes, with SUP, SCN, and FOU as core attributes, reflecting an operational-technological network structure. The Wrocław network exhibits a three-cluster architecture in which the first cluster comprises the densely connected core, the second encompasses bridging attributes (UMW, TC, ME) that maintain broad ties with lower brokerage, and the third contains peripheral nodes (TRA4, EPL) and attributes (E-CL, ORG, SHR) with low involvement and limited structural impact.

Table 2. Comparison of Wrocław and Rotterdam networks

Cluster	Wrocław	Rotterdam
Cluster 1: core	Nodes: RESP, TRA3. Attributes: SUP, SCN, FOU → dense, high diffusion potential and brokerage.	Nodes: AU2, TRA, SCI2. Attributes: SCN, UMR, TC, FOU, SUP → compact, accessible backbone, while AU2 and SCN provide brokerage.
Cluster 2: bridging / meso	Attributes: UMW, TC, ME → broad ties, lower brokerage.	Nodes: AU3, SCII. Attributes: ME, ECM → secondary connectors, while ME bridges despite lower degree.
Cluster 3: periphery	Nodes: TRA4, EPL. Attributes: E-CL, ORG, SHR → low centrality and integration.	Nodes: RESP, STU, EPL. Attributes: ORG, SHR (E-CL near periphery) → marginal involvement and minimal brokerage.
Overall node-layer profile	Operational hubs (RESP, TRA3) drive activity, single-broker risk (TRA2).	Institutional node (AU2) anchors connectivity, multiple secondary bridges, clear periphery.

Overall attribute-layer profile	Knowledge/technology-based core (SCN, SUP) with FOU as a strong hub.	Institutional-knowledge core (SCN with brokerage, UMR/TC/FOU/SUP with broad reach).
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Source: authors' own elaboration.

Rotterdam's core features AU2, TRA, and SCI2 among nodes, with SCN, UMR, TC, FOU, and SUP as attributes, indicating an institutional-knowledge anchoring pattern. The Rotterdam three-cluster structure positions AU3 and SCI1 as secondary connectors in the meso-layer alongside ME and ECM, while RESP, STU, and EPL occupy the periphery alongside ORG and SHR. Notably, E-Customer (RESP)—a core actor in Wrocław—is peripheral in Rotterdam, highlighting how the same stakeholder type can occupy fundamentally different structural positions depending on local governance arrangements and engagement traditions.

A noteworthy finding concerns the structural position of E-Customer (RESP), which occupies a core position in Wrocław but is peripheral in Rotterdam. This divergence illustrates how identical stakeholder types can assume fundamentally different structural roles depending on local governance arrangements, institutional traditions, and the specific configuration of engagement practices. Similarly, the role of Media (ME) differs between the two cities: in Rotterdam, ME serves as an important bridging attribute connecting otherwise separate clusters, while in Wrocław its bridging function is more limited. These observations underscore the context-dependent nature of stakeholder network structures and caution against applying universal governance templates across different urban settings.

The critical difference between the two networks lies in the trade-off between diffusion efficiency and resilience. Wrocław presents a moderately centralized, small-world configuration in which operational hubs and a strong knowledge-technology attribute layer drive connectivity, while reliance on a single key broker (TRA2) creates structural vulnerability. Rotterdam's network is more egalitarian, highly triadic, and extremely cohesive, with institutional and knowledge actors at the core and Media playing a bridging role despite lower degree centrality. Wrocław's small-world properties enhance global information flow but create broker-dependency risks, while Rotterdam's strong triadic closure enhances trust and local cohesion but may reduce system-level path efficiency.

In both cities, several stakeholder groups remain disconnected or weakly connected, particularly Industry Organizations (ORG) and Shareholders (SHR), limiting representativeness and formalization capacity within GLMD governance. These stakeholders' absence from the network core restricts the diversity of knowledge inputs and may reduce the legitimacy of collective decision-making processes. Activating peripheral stakeholders should therefore be a shared strategic priority to enhance knowledge diversity, network scalability, and the overall governance capacity for green logistics transformation.

In practical terms, Wrocław should implement backup relational pathways beyond TRA2 (e.g., RESP–SCN, TRA3–UMW, SUP–FOU) and formalize cooperation within its core via memoranda of understanding and shared data standards. Rotterdam, on the other hand, should diversify brokerage around AU2 by strengthening links such as AU2–RESP, SCN–EPL, and ME–ORG/SHR, while creating integration channels for currently peripheral actors. These steps would improve resilience and broaden the capacity of both networks to implement sustainable last-mile delivery solutions in line with GLMD and Mission city objectives.

6 Conclusions

This study demonstrates that dense and cohesive GLMD stakeholder networks can exhibit fundamentally different structural logics. Wrocław's network is more centralized, with a clearly identifiable operational core dominated by E-Customer and Transport Company 3. In contrast, Rotterdam's network distributes relational activity more evenly, with Local Government Unit 2 and Research Institutions serving as anchors for coordination. Brokerage concentration in single nodes creates vulnerability in both cities, though more acutely in Wrocław where Transport Company 2 serves as the dominant intermediary. The three-cluster structures observed in both networks—comprising a high-capacity core, a bridging layer, and a peripheral cluster—suggest that this architecture may be a general feature of GLMD governance networks in Mission cities.

Three overarching implications emerge for GLMD network design and governance. First, effective network design requires balancing diffusion efficiency with structural resilience. Wrocław's small-world configuration enhances information flow but demands redundant brokerage pathways to mitigate dependency on single intermediaries. Rotterdam's triadic closure strengthens trust and local cooperation but requires additional inter-cluster bridges for system-level integration and innovation diffusion. Policymakers and network designers should therefore pursue hybrid strategies that combine the strengths of both archetypes.

Second, Research Institutions (SCN) consistently act as structural anchors in both cities, underscoring their crucial role as coordinators, knowledge brokers, and integrators in GLMD networks. This finding suggests that policymakers should treat research institutions as active stewards of data governance and network coordination rather than passive advisors. Their bridging position enables them to connect otherwise disconnected actors and facilitate the translation of academic knowledge into practical logistics solutions.

Third, peripheral actors—particularly Industry Organizations and Shareholders—require deliberate activation in both networks, as their current marginal involvement restricts the diffusion of sustainable last-mile solutions and limits the legitimacy of collective decision-making structures. Targeted engagement strategies, such as stakeholder roundtables and shared data platforms, could help integrate these actors into the network core and enhance the overall governance capacity for green logistics transformation.

From a methodical perspective, this study demonstrates the value of combining macro-level and micro-level SNA indicators to reveal both systemic properties and actor-specific positioning within GLMD stakeholder networks. The use of weighted relational dimensions—strength, reciprocity, and proximity—provides a more nuanced assessment of stakeholder ties than binary connection matrices, capturing the multifaceted nature of inter-organizational relationships in sustainable urban logistics.

Future research should extend this comparative framework to additional Mission cities across different European governance traditions and longitudinally track how network structures evolve as GLMD initiatives mature. Integrating qualitative network narratives with quantitative SNA measures would further enrich the understanding of relational dynamics in sustainable urban logistics governance. Additionally, investigating the role of digital platforms and data-sharing ecosystems in reshaping stakeholder network topologies represents a promising avenue for advancing both theory and practice. The limitations of this study—including the cross-sectional nature of the analysis and the relatively small network sizes—should be addressed through longitudinal designs and expanded sampling strategies in future work.

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