Exploring the Application of Network Theory Techniques in Research Addressing Transportation Challenges: A Decadal Analysis

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1. Introduction

Network Theory (NT), often called Social Network Analysis (SNA), is a widely used methodology that helps researchers understand and visualize the connections that shape reality. SNA is not limited to social context and has been applied to various fields. For example, in public health, SNA helps track the spread of diseases, and in business, it assists in optimizing collaboration among organizations.

At its core, NT is about studying relationships using mathematical and visual tools to uncover hidden patterns, like who the key actors are, which groups exist, and where gaps or bottlenecks in communication or influence might exist. One key concept in NT is Nodes and Edges. Nodes represent the entities (people, organizations, words, etc.), and Edges represent their connections. By analysing these connections, NT can reveal the structure of a network, its density, and the roles different nodes play. Since the transportation world is built as a vast web of connections, from commuters using public transit to the flow of goods and information in a logistics network, NT can bring valuable insights to this complex system.

The aim of the study was to explore how theories and techniques associated with the methodology of network theory are applied to the transportation domain. Research articles published within the past ten years in transportation research journals were the focus of the study. Concepts from three distinct realms, namely (1) the network theory methodology realm, (2) the realm of transportation modes, and (3) the realm of transportation topics addressed in the transport sector, were examined in each study. The network analysis methodology was not only investigated in this work but also used to identify the various connections between these three realms. More specifically, the objective of this was twofold:

- Extracting scientific papers reflecting the current state of academic research at the intersection of transportation and network analysis.
- Identify anomalies or existing research gaps that integrate transportation and network analysis to propose new avenues for researchers in the field.

2. Extracting Relevant Articles

An SQL query was built and used in the SCOPUS (https://www.scopus.com/) database to extract relevant academic items and construct the study's dataset. The query asked for papers that:

(1) included in their title, abstract and/or keywords: “network theory" OR "Social Network Analysis," OR "Network Analysis Methodology".
(2) published in journals that have: “Transportation” OR “Transport” OR “Travel” in their names.
(3) In the years 2013-2023.

233 papers were returned as a table with their bibliographic fields, including Title, Author, Affiliation, Full Abstract, Publication Date, Journal Name, PDF link, and DOI. To ensure that all research papers related to transportation and networks, three sets of terms from transportation and network theory were defined, indicating that an article is relevant. An expert in network analysis created a group of 29 Network Analysis terms, and a transportation expert defined terms in a group of 27 Transport Topics (TT) terms and a set of 40 Transport Mode (TM) terms. Table 1 depicts the terms included in the three groups.

29 Network Analysis terms (NT)	**27 Transport Topics terms (TT)**	**40 Transport Modes terms (TM)**
Actor	Cargo	Airline
Betweenness	Cyber	Airport
Bridge	Deliveries	Autonomous
Broker	freight	Bicycle
Brokerage	Highway	Bike
Centrality	Intersection	Bike-sharing
Centroid	Junctions	Bus
Clique	Logistics	Cab
Cluster	Mode choice	Car
Cohesion	Movement behaviors	Commute (commuting)
Community	Policy	Demand responsive transport
Connectivity	Road	Electric vehicle
Degree	Safety	Electric transport
Density	Security	Escooter (E-scotter)
Diffusion	Social media	Flights
Edge	Street	Light rail
Ego	Traffic assignment	LRT
Eigenvector	Traffic control	Marine
Group	Traffic demand	Maritime
Homophily	Traffic flow	Metro

Link	Traffic management	Micro mobility
Multiplexity	Transportation planning	Multi-modal
Power law	Travel behaviour	Naval
Relationship	Travel Choice	Pedestrian (s)
Scale-free	Travel demand	Public transport
Small world	Urban mobility	Rail transit
SNA	Urban traffic	Railroad
Structural Hole		Railway
Triad		Ridesharing (Ride-sharing)
		Shared mobility
		Subway
		Taxi
		Train
		Urban rail
		Vehicle
		Walking

Table 1: Professional terms in the fields of Network Theory and Transportation

In Table 2 to Table 5, the NT terms are explained and also categorized by the level of network analysis they are associated with. It should be noted that some terms can be associated with more than one level, but this general classification clarifies the main concepts:

Name	**Description**
Actor	It is the basic element in the network. It can be an individual, object, or organization which connects to other elements (actors/nodes)
Edge, Link, Relationship	The connection between nodes usually indicts interaction between two nodes
Degree	Degree is the term used for the number of connections. It is a measure of the node's connectivity within the network. The degree of a graph is the maximum degree among its nodes.
SNA	Social Network Analysis – The methodology of exploring networks

Table 2: General terms associated with Network Theory

Name	Description
Centrality	The main character of a node in a network. There are more than 20 types of centralities.
Degree	Degree is a measure of the node's connectivity within the network based on the number of the node's connections. It is the most frequently used measure of centrality. Additionally, a degree of a graph is the maximum degree among its nodes.
Betweenness	An instance of Centrality. Measurement of the number of times a node lies on the shortest path between other nodes. It indicates the nodes' importance
Eigenvector	An instance of Centrality. Measures the transitive influence of nodes - A node is important if it is linked to other important nodes
Bridge	A relationship that connects a member (a broker) in a community with another member in a nearby community
Broker, Brokerage	A member of a community who connects it to other communities
Ego	The subnetwork of around one specific node (the ego) and its relations.

Table 3: Node-level terms associated with Network Theory

Name	Description
Community, Group, Cluster, Clique	A set of nodes whose inner links are stronger than their outer links
Triad	A small group of three nodes and the relationships between them
Centroid	The center (central node) of a community
Homophily	The tendency of similar nodes (based on node attributes) to attach to each other
Structural Hole	It is the disconnected "area" (an "empty space between nodes) of the network between highly connected groups.

Table 4: Community-level terms associated with Network Theory

Name	Description
Cohesion, Connectivity	The degree to which nodes are directly connected to each other.
Density	The ratio between the actual connections in the network and the maximum number of possible connections
Power-law	A power-law degree distribution is where most nodes have very few relations while a few central nodes have a considerable number of relations
Scale Free Network	A network whose distribution of links follows a power law.

Small World Network	A network where most nodes are not neighbors of one another, and most nodes can be reached from every other by a small number of connections
Diffusion	The process by which a contagion (such as information, disease, meme) spreads through a network.
Multiplexity	A structural property of a network where more than one type of relationship exists between two nodes

Table 5: Network-level terms associated with Network Theory

The terms Node(s) and Topology were omitted from the final term list since they are commonly used in transportation research independent of Network Theory.

3. Building the Research Database

After importing 233 papers and their details from Scopus, a dataset was constructed, each row representing an article. The initial dataset underwent a mapping and filtering process outlined as follows:

a. Ninety-seven binary fields, as illustrated in Table 1, were added to each row (article), with each field corresponding to one of the terms in the three specified groups.
b. Only articles that incorporated at least one term from the NT group and at least one term from either the TT or TM groups were retained in the final dataset. This criterion was applied to ensure the dataset's suitability for analyzing the application of Network Theory techniques in transport-related research.

Following this filtering process, the final dataset comprised 160 academic articles (Appendix A). These articles were published within the past decade in journals related to transportation and were pertinent to both Network Theory and transportation research.

4. Encoding

After establishing the research database, each article that met the research criteria underwent a counting process. This process aimed to determine the number of terms falling into each of the three predefined categories (NT, TT, TM). An automated terms scan was executed in each article, resulting in a matrix. This matrix featured the 160 articles as rows and the terms, categorized into three groups, as columns.

In this matrix, the cells represented whether a specific term was present in a particular article. These cells operated as binary variables, taking on the value "1" if the corresponding term was found in the article. If a term appeared more than once in different sections of the article, the value in the matrix cell remained "1."

5. Modeling

Following the creation of the matrix, the research dataset containing the appearance of relevant terms in transportation articles was completed. This matrix can serve various methodological purposes, such as similarity analysis to calculate the similarity between different research articles.

The basic tool of NT, i.e., visualization of entities and connections between them, was used to enhance the understanding of the utilization of network-related terms in transportation research and to identify critical patterns and gaps in the application of network methodologies and techniques in transportation research.

A network (graph) consisting of all the terms and articles could be constructed through the matrix. The network comprises 160 articles, and 96 terms are featured in them. The possible connections between an article and a specific term are represented by the edges in the network, with the presence of an edge indicating that the term is used in the article. When there is no connection between an article and a term in the network, it signifies that the term is not included in that article. In the initial stage, a bipartite network was created, wherein nodes of the "article" type can only be linked to nodes of the "term" type and vice versa. In the subsequent stage, network projection was carried out by the researchers. This process transformed nodes of the "article" type into links between nodes of the "term" type and established a network consisting solely of terms. The connection between terms A and B denoted the number of articles in which both terms were present.

In this manner, a network of terms was fashioned, conveying the relationships between terms from the three categories defined at the outset of the research. The strength of the connections in this network signifies how frequently the terms co-occur in articles related to transportation research. This network serves as the focus of our study. Through it, the connections between terms are explored, and a network map of the mutual relationships between terms from the network domain and terms from the transportation domain is created. Social Network Analysis (SNA) tools were employed to examine the significance of nodes (terms) in the network, the communities that emerge in this network, and the overall structure of the network.

6. Results

Network maps are represented in the following section. Within these networks, the nodes represent terms from all three categories (Transportation-related terms, Network-related terms, and Terms related to topics transportation-associated-related terms). The weight of the link is highly significant since the strength signals on the frequency in which these terms are joined appear in the corpus of the academic transportation papers that were explored.

In the following network maps, the following graphical conventions are used: The nodes' dimensions reflect their Eigenvector Centrality, meaning their importance in the relevant network based on the significance of their connected neighbors. The thickness of the links and the intensity of their color indicate the frequency of occurrences where both terms are found in articles. The nodes are color-coded to denote their category: Orange nodes denote Network Theory (NT) terms, green nodes denote to the Transport Topics (TT) term and purple nodes denote Transport Modes (TM) terms. The visual algorithm used in the maps tends to allocate the nodes with the highest number of links in the heart of the network. In the network's periphery, the algorithm drew the nodes with minimum links to other nodes.

6.1. Analysis of the Network Theory terms

Looking at the overall network of terms, as presented in Figure 1, there are several apparent phenomena. Most of the NT terms are in the center of the network, indicating their strong co-appearance with other substantial nodes. However, the most prominent connections of these nodes are with other NT terms rather than with transport-related terms.

For better analysis of the most prominent NT terms, the network-analysis level characterizing each NT term is presented in **Figure 2**.

The dominance of the general terms in NT, circled in black, is not surprising. Seven of the eight terms related to the node-level appear in the overall network, all circled in blue. Centrality is a fundamental term in NT and Degree is its most common measure, thus their dominance is expected. Apparently, Betweenness is more commonly used as a measure of Centrality compared to Eigenvector.

Ego is not a very prominent term, indicating that in the studies surveyed, the relations of one specific node with other nodes in the analyzed network is not often explored. Bridge, Broker, and Brokerage, the three less-mentioned terms in the node-level, are significant when identifying communities within networks. This significance arises from brokers' critical role in connecting different communities within these networks.

Only four of the eight community-level terms (circled in green) appear in the overall term network. These terms are the synonyms Community, Group and Cluster, that represent the basic concept of this level. Apparently, the fourth synonym, “Clique”, is less popular.

The term Structural hole, which connects the community analysis to the network topology, is very rare. Moreover, while the terms Community, Cluster and Group describe the existence of closely related nodes, the terms Centroid and Triad, that are related to the analysis and the reasoning of group creation are missing.

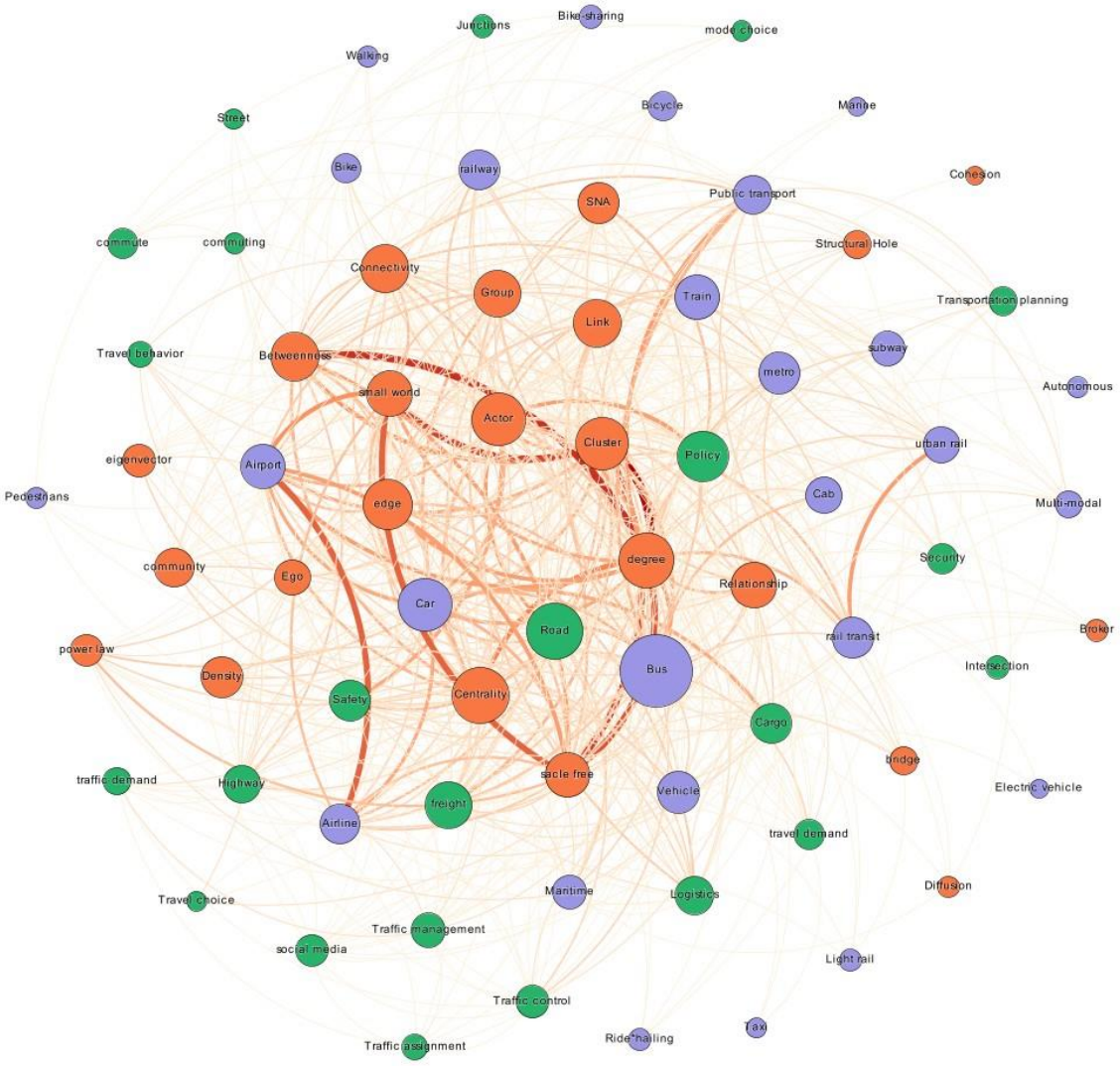

Figure 1 – The entire network of terms

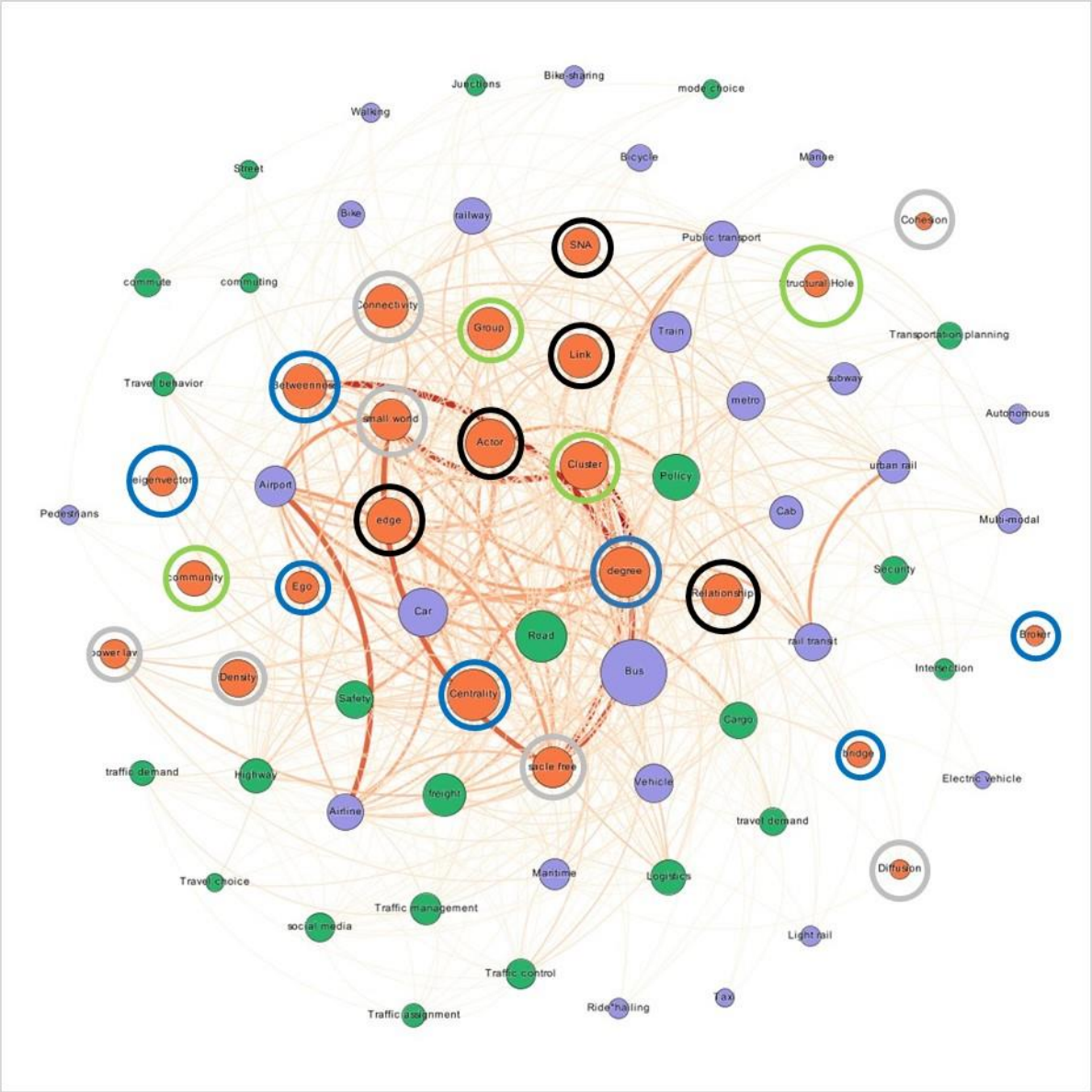

Figure 2 – The entire network of terms categorized by the network-analysis level they are associated with (see Table 2, Table 3, Table 4 and Table 5). Black circles indicate general terms, blue circles indicate node-level analysis, green circles indicate community-level analysis and grey circles indicate network-level analysis

Connectivity, the most noticeable concept of a network, is the most dominant of all network-level terms (circled in grey) that appear in the network of terms. Its synonym, Cohesion, is also used, but to a much lesser extent. Apart from the term Multiplexity, all other seven network-level terms appear in the network. The term Small-world is noticeable, indicating that the concept of Connectivity is further explored by investigating certain topology where the network is connected through a small number of nodes. Scale free, a concept that describes network's topology and is closely related to Power Law, is prominent as well. It should also be noted that it is strongly linked to the term Bus and also, although to a lesser degree, to the term Airline.

Diffusion, a term that can be used for analyzing the phenomenon of the dispersion of traffic throughout the road network, is minimally depicted. The term Multiplexity, often related to the co-existence of several networks that might or might not interact, is entirely absent.

6.2. Analysis of the Transportation Topic terms

When examining Figure 1 in the context of the Transportation Topics (TT) terms, it is evident that among the classical transportation's research areas, Transportation planning, Travel behavior, Safety, Traffic Management and Control and Logistics, Safety and Logistics/ Freight are the most dominant topics. Safety is mainly linked to the NT concept of Actor but also to Community and Centrality and Freight is evidently linked to the concepts of Power law and Scale free. Policy is also conspicuous in the overall network, mainly directly linked to Actor and SNA. Lastly, the terms Road alongside the term Highway are dominant in the network, which is unsurprising given their role in the transportation network.

6.3. Analysis of the Transportation Modes terms

Among the Transportation Modes (TM) terms, marked in purple in Figure 1, two main phenomena stand out. The first is that air transport is noticeable and, in the context of land transportation, public transport (PT) and motorized modes are clearly dominant. Various terms addressing bike riding, i.e., Bike, Bicycle and Bike-sharing, indicate that some use of Network Theory is applied to this mode of transportation, and the most prominent NT terms associated with it is Connectivity. Walking, on the other hand, was hardly found in the investigated articles (while also considering Pedestrians as an alternative term). E-scooters and the term Micro-mobility have not appeared in any of the studies explored.

For a closer investigation of PT modes and their association with other terms, Figure 3 presents a sub-network around the PT-related TM terms: Public transport, Bus, Train, Rail transit, Urban rail, Subway, Metro, and Multimodal. 22 of the 23 NT terms that appear in Figure 1 also appear in Figure 3, however the dominance of the various NT terms in Figure 3 is more balanced than in Figure 1. Moreover, the vast majority of TT terms are also apparent in the PT-related network of terms, including non-trivial relationships, such as the one between Bus and Freight.

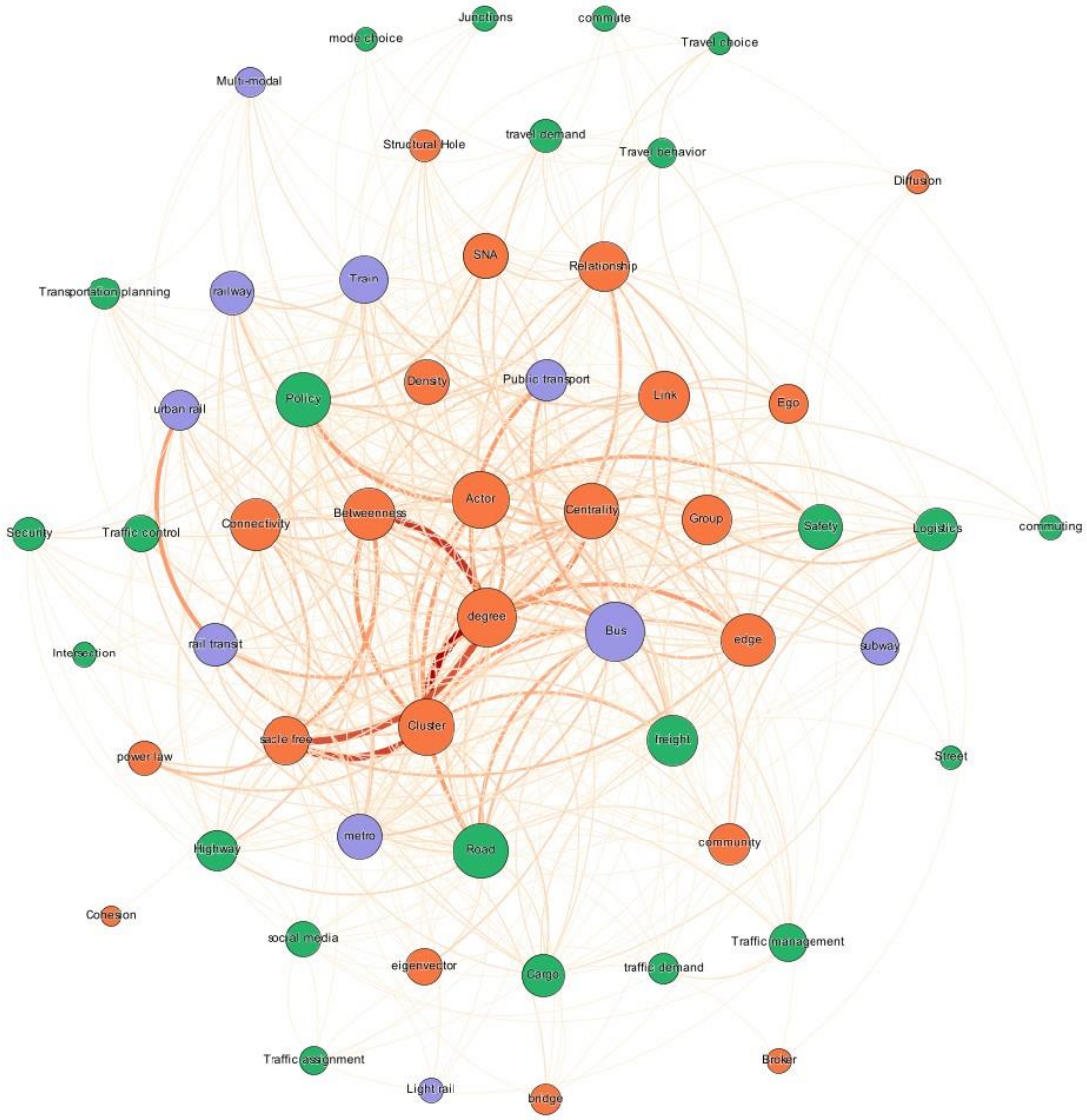

Figure 3 – The terms' network associated with various public transport modes

7. Conclusions

This study investigates the utilization of Network Theory (NT) in research studies addressing various transportation challenges over the past decade. The results reveal a relatively limited application of Network Theory to transportation-related topics, with only 160 identified scientific articles using NT as the methodology. In comparison, a similar search focusing on Deep Learning in transportation journals alone yielded more than 550 articles.

A network analysis of NT, Transportation Topics (TT), and Transportation Modes (TM) terms uncovers notable trends and relationships. As anticipated, the core NT concepts stand out

prominently in this category. However, more intricate concepts associated with network analysis are either sparse or entirely missing.

Ego, a concept often used with respect to the node-level of network analysis, is not a very prominent term, indicating that in the studies surveyed, the relations of one specific node with other nodes in the analyzed network is not often explored. Diffusion, a concept that can be used for analyzing the phenomenon of the dispersion over time of traffic throughout the road network, was found as insignificant in the network of terms. The scarcity of the terms Bridge and Broker suggests that the exploration of communities' dynamics and their complex interactions within transportation networks are limited. Last but not least, the absence of the term Multiplexity indicates a missed opportunity to explore the coexistence of multiple networks in transportation studies (Multimodality).

As for the TT, Safety and Logistics/Freight emerge as dominant topics alongside Policy, which is a term associated with many transportation problems. The dominance of Road and Highway correlates with the dominance of motorized TM. Among the various TM, bike seem to be investigated to a moderate degree, while Walking is rarely addressed when applying NT techniques. In the examination of public transport modes, it was discovered that nearly all NT terms remain applicable, demonstrating the widespread utilization of NT concepts in the realm of public transportation.

Several additional observations regarding the correlation between transportation and NT terms warrant attention. The most noticeable connections between TT and NT primarily involve general NT terms like Actor and Community, which is expected. However, the limited strong links between TT and more specific NT terms underscore the diverse application of network theory techniques within the transportation field. Notably, the evident association between logistics-related terms and Scale-free and Power Law stands out in this regard. Another noteworthy finding is the preference for Betweenness over Eigenvector as a Centrality measure in the analysis of NT and transportation terms. Further investigation is needed to understand the reasons behind these phenomena.

Appendix A – 160 transportation-related research articles in which Network Theory was applied

Authors	Title	Year	Source title
Zhang H.; Zhang T.	Cascading failures analysis of urban subway network based on CML	2013	Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)
Woo S.-H.; Kang D.-J.; Martin S.	Seaport Research: An Analysis of Research Collaboration using Social Network Analysis	2013	Transport Reviews
Lin J.; Ban Y.	Complex Network Topology of Transportation Systems	2013	Transport Reviews
Deng Y.; Li Q.; Lu Y.; Song L.	Analysis of site selection for metro emergency stations in network operation	2013	Advances in Transportation Studies
Van der Lugt L.; Dooms M.; Parola F.	Strategy making by hybrid organizations: The case of the port authority	2013	Research in Transportation Business and Management
Wang X.; Niu S.; Liu J.; Gao J.	Structural characteristics comparisons between the provincial expressway network and the trunk highway network in China	2014	CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems - Proceedings of the 14th COTA International Conference of Transportation Professionals
Wang X.; Niu S.; Gao J.; Zhang J.	A study on the highway network key segments identifying method based on the structural characteristics	2014	CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems - Proceedings of the 14th COTA International Conference of Transportation Professionals

Authors	Title	Year	Source title
Zhang J.; Ren J.; Wu C.	Modeling air traffic controllers' decision making processes with relational complexity network	2014	2014 17th IEEE International Conference on Intelligent Transportation Systems, ITSC 2014
Wang J.-E.; Mo H.-H.	Complex evolution process of China's air transport network	2014	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Zary B.; Bandeira R.; Campos V.	The contribution of scientific productions at the beginning of the third millennium (2001 - 2014) for humanitarian logistics: A bibliometric analysis	2014	Transportation Research Procedia
Yue Y.; Lan T.; Yeh A.G.O.; Li Q.-Q.	Zooming into individuals to understand the collective: A review of trajectory-based travel behaviour studies	2014	Travel Behaviour and Society
Wang J.; Wang X.	Research of container shipping network degrees distribution based on the k-shell decomposition	2014	Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)
Kowald M.; Axhausen K.W.	Surveying data on connected personal networks	2014	Travel Behaviour and Society
Zhang Y.; Li W.; Qin Y.; Zhang Y.	Synthetic matrix representation method research on urban road networks	2014	CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems - Proceedings of the 14th COTA International Conference of Transportation Professionals

Authors	Title	Year	Source title
Bakht M.N.; El-Diraby T.E.	Hidden social networks that drive online public involvement in infrastructure construction : Case study of light rail transit projects in North America	2014	Transportation Research Record
Zhang X.; Li W.; Deng J.; Wang T.	Research on hub node identification of the public transport network of guilin based on complex network theory	2014	CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems - Proceedings of the 14th COTA International Conference of Transportation Professionals
Pike S.	Travel mode choice and social and spatial reference groups	2014	Transportation Research Record
Zhao Q.-Y.; Cao J.-X.; Chen L.-H.	Integration and optimization of quay cranes and trucks at container terminals	2014	CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems - Proceedings of the 14th COTA International Conference of Transportation Professionals
Niu S.-Y.; Li B.; Niu W.-J.; Zhang J.-S.; Liu W.-F.	Evaluation of Highway Network Node Importance via Node Benefit Function and Weighted Node Betweenness	2015	CICTP 2015 - Efficient, Safe, and Green Multimodal Transportation - Proceedings of the 15th COTA International Conference of Transportation Professionals
Zhang Y.; Lu Y.; Lu G.; Wang Y.	Beijing Subway Network Connectivity Reliability Analysis Based on Complex Network	2015	CICTP 2015 - Efficient, Safe, and Green Multimodal Transportation - Proceedings of the 15th COTA International Conference of Transportation Professionals
Hwang H.; Park J.; Kwon C.; Friedman K.;	The ties that bind: Bi-national trade implications of the US and Canada using bi-	2015	Research in Transportation Business and Management

Authors	Title	Year	Source title
Attard N.; Chang S.H.; Wells S.	national freight movement network via border crossings		
Kim A.; Lu J.	A Study on the Effects of Network Centrality and Efficiency on the Throughput of Korean and Chinese Container Ports	2015	ICTE 2015 - Proceedings of the 5th International Conference on Transportation Engineering
Joubert J.W.; Meintjes S.	Computational considerations in building inter-firm networks	2015	Transportation
Cook A.; Blom H.A.P.; Lillo F.; Mantegna R.N.; Miccichè S.; Rivas D.; Vázquez R.; Zanin M.	Applying complexity science to air traffic management	2015	Journal of Air Transport Management
Zheng L.; Wang S.; Wang W.; Ding T.	Study on the identification method of hub node in urban road network	2015	Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)
Wei Z.-L.; Gan Y.-J.; Zhao P.	Characteristic research of urban complex traffic network	2015	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Sun H.; Zhang Y.; Wang Y.; Li L.; Sheng Y.	A social stakeholder support assessment of low-carbon transport policy based on multi-actor multi-criteria analysis: The case of Tianjin	2015	Transport Policy

Authors	Title	Year	Source title
Jia H.-F.; Han J.-Q.; Li Y.-X.	Reliability Analysis of a Typical Road Network Based on the Complex Network Theory	2016	CICTP 2016 - Green and Multimodal Transportation and Logistics - Proceedings of the 16th COTA International Conference of Transportation Professionals
He B.-H.; Liu Y.; He Y.; Li Z.-H.	Theories and confirmed model of household's activity-travel behavior based on social network	2016	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Zhang H.-H.; Liao Z.-H.; Zhang Q.-Q.; Zhang X.-Y.	Impact of adjusting airspace structure on arrival traffic flow in terminal area	2016	Jiaotong Yunshu Gongcheng Xuebao/Journal of Traffic and Transportation Engineering
Belkoura S.; Cook A.; Peña J.M.; Zanin M.	On the multi-dimensionality and sampling of air transport networks	2016	Transportation Research Part E: Logistics and Transportation Review
Editorial Department of China Journal of Highway and Transport	Review on China's traffic engineering research progress: 2016	2016	Zhongguo Gonglu Xuebao/China Journal of Highway and Transport
Xu L.; Liu X.	The characteristic analysis of transit network in small cities based on the complex network theory	2016	Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)
Feng H.-F.; Li C.-H.; Wang R.	Vulnerability study for public transport network of valley city: Case of Lanzhou	2016	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology

Authors	Title	Year	Source title
Xu P.; Shao C.	A RLP modeling and complexity analysis on urban transit network	2016	Wuhan Ligong Daxue Xuebao (Jiaotong Kexue Yu Gongcheng Ban)/Journal of Wuhan University of Technology (Transportation Science and Engineering)
Rubinstein S.; Martin-Rios C.; Erhardt N.; Hoffer Gittell J.; George V.P.	Organizational responses to uncertainty in the airline industry: Changes in patterns of communication networks	2016	Journal of Air Transport Management
Kowald M.; Axhausen K.W.	Social networks and travel behaviour	2016	Social Networks and Travel Behaviour
Ribeiro Santos C.C.; Do Vale Cunha M.; Borges de Barros Pereira H.	A comparative analysis of brazilian maritime transport by cabotage between 2010 and 2015 using network theory	2016	Maritime Transportation and Harvesting of Sea Resources
Jiang Y.; Yao B.; Wang L.; Feng T.; Kong L.	Evolution trends of the network structure of Spring Airlines in China: A temporal and spatial analysis	2017	Journal of Air Transport Management
Wanke P.; Falcão B.B.	Cargo allocation in Brazilian ports: An analysis through fuzzy logic and social networks	2017	Journal of Transport Geography
Boulmakoul B.; Besri Z.; Karim L.;	Combinatorial connectivity and spectral graph analytics for urban public transportation system	2017	Transportation Research Procedia

Authors	Title	Year	Source title
Boulmakoul A.; Lbath A.			
Wang Y.; Han B.-M.; Zhang Q.; Lu K.	China high-speed railway transportation network reconfiguration based on complex network theory	2017	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Xing Y.; Lu J.; Chen S.; Dissanayake S.	Vulnerability analysis of urban rail transit based on complex network theory: a case study of Shanghai Metro	2017	Public Transport
Feng J.; Xu Q.; Li X.-M.; Yang Y.-Z.	Complex Network Study on Urban Rail Transit Systems	2017	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Calatayud A.; Mangan J.; Palacin R.	Connectivity to international markets: A multi-layered network approach	2017	Journal of Transport Geography
Wang Q.-Z.; Si B.-F.	Urban Multi-modal Traffic Assignment Model and Algorithm under Transfer Constrain	2017	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Sun X.; Wandelt S.; Linke F.	On the topology of air navigation route systems	2017	Proceedings of the Institution of Civil Engineers: Transport
Zou X.; Yue W.L.	A Bayesian Network Approach to Causation Analysis of Road Accidents Using Netica	2017	Journal of Advanced Transportation

Authors	Title	Year	Source title
WANG J.J.; YAU S.	Case studies on transport infrastructure projects in belt and road initiative: An actor network theory perspective	2018	Journal of Transport Geography
Bringmann K.; De Langhe K.; Kupfer F.; Sys C.; Van de Voorde E.; Vanelslander T.	Cooperation between airports: A focus on the financial intertwinement of European airport operators	2018	Journal of Air Transport Management
Parajuli J.; Haynes K.E.	Transportation network analysis in Nepal: a step toward critical infrastructure protection	2018	Journal of Transportation Security
Li W.; Zheng S.; Lu Y.	The Analysis of Urban Traffic Accidents Based on Bayesian Network	2018	CICTP 2017: Transportation Reform and Change - Equity, Inclusiveness, Sharing, and Innovation - Proceedings of the 17th COTA International Conference of Transportation Professionals
He Z.-G.; Yang X.-L.; Jia Y.-L.	Construction of Intermodality Streamline Network Matching Based on the"Carrier Broker";	2018	Jiaotong Yunshu Xitong Gongcheng Yu Xinxi/Journal of Transportation Systems Engineering and Information Technology
Zhao L.; Zhao Y.; Hu Q.; Li H.; Stoeter J.	Evaluation of consolidation center cargo capacity and loctions for China railway express	2018	Transportation Research Part E: Logistics and Transportation Review
El-adaway I.H.; Abotaleb I.; Vechan E.	Identifying the most critical transportation intersections using social network analysis	2018	Transportation Planning and Technology

Authors	Title	Year	Source title
Luo Q.; Yang Y.; Mo Y.; Li W.; Zhang X.	Research on Structural Vulnerability of Shenzhen Metro Network Based on Complex Network Theory	2018	2018 3rd IEEE International Conference on Intelligent Transportation Engineering, ICITE 2018
Fabianski C.	Partnering for quality and performance: A standpoint for enhanced services	2018	Research in Transportation Economics
Sun L.; Huang Y.; Chen Y.; Yao L.	Vulnerability assessment of urban rail transit based on multi-static weighted method in Beijing, China	2018	Transportation Research Part A: Policy and Practice
Çavdar A.B.; Ferhatosmanoğlu N.	Airline customer lifetime value estimation using data analytics supported by social network information	2018	Journal of Air Transport Management
Zijlstra T.; Vanoutrive T.	The employee mobility budget: Aligning sustainable transportation with human resource management?	2018	Transportation Research Part D: Transport and Environment
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