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Application of Cognitive Logistic Networks for Route Optimization in Oman's Logistics Operations

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Abstract

Oman's transportation and logistics sector plays an important role in having a national economic diversification, which comes under the Oman Vision 2040. Hence, the sector faces challenges that are known as inefficient routing, scattered data systems, and reduced visibility in real-time operations. Considering these issues, this paper examines the potential of the proposed Cognitive Logistics Network (CLN) as a strategic system to improve route optimization and operational efficiency. Logistics frameworks that are designed to learn, evolve, and execute decisions on their own are created practically through a Cognitive Logistics Network, which incorporates artificial intelligence, data analytics, and integrated systems. Intending to identify the most efficient transportation routes, this paper examines how cognitive networking will respond to parameters such as traffic scenarios, delivery preferences, and environmental constraints. The research project focuses on how implementing a cognitive framework can boost collaboration, reduce delivery times, and improve resource utilization throughout transportation networks to completely transform the logistics sector. The findings illustrate how deploying CLNs enhances Oman's transportation network's sustainability, integration, and transparency. The study analyzes ways of adopting the Cognitive Logistic Network (CLN) to improve decision-making, sustainability, and competitive advantage in the field of logistics. In general, this research demonstrates how introducing a cognitive logistics system to modern logistics systems can increase operational resilience, enhance competitiveness, and reduce delivery times.

Keywords
Cognitive Logistics Network, Route Optimization, Sustainability, Oman Vision 2040, Operational Efficiency.

1. Introduction
The logistics sector is one of the significant supporting systems of the economy of the Sultanate of Oman. The supply chain globally is growing, which in turn is increasing the expectations of the customer, leading to the need for continuous improvement of the sector's efficiency and reliability. Under Vision 2040, the logistics sector in the Sultanate is a major pioneer in driving economic growth (Al-Qasimi et al., 2024). As the demands of the customers increase along with the handling volume, the requirement for a more efficient handling of logistics operations becomes vital, covering the process, highlighting the need for a much higher-end and intelligent, data-driven decision-making system having the ability to improve route selection, planning accuracy, and flow of documentation. Predictive analytics and deep learning techniques provide proactive logistics planning as well as improved decision-making (Puli

& Yasmeen, 2021). Management of the disruptions has become a critical focus in Oman's freight logistics because of the increasing operational uncertainties (Zainul Abideen, 2025). Logistics sector development has a very strong and positive impact on GDP growth, especially in developed economies where air freight and high-speed distribution systems are mainly used. The author Yan et al. (2023) suggests in their paper that high-quality development of logistics leads to higher progress in the economy and industrial growth.

1.1 Research Questions

RQ1: How can the implementation of the Cognitive Logistics Network (CLN) result in route optimization, increasing the efficiency of the operation in the logistics sector?
RQ2: To what extent can CLN shift logistics operations from reactive to predictive decision-making?

2. Literature Review

Logistics development involves an integrated idea with effective integration and supervision of many transportation parts, which defines the economic outcomes of the nation. Sukati et al. (2022) analyze the effect of logistics sector integration on economic growth in the Sultanate of Oman, offering logistics as a significant means of competitive edge in a global market. Abideen (2025) shows targeted research on the disruption management across Oman's freight logistics sector, highlighting the simulation-based frameworks for addressing the challenges. In the logistics sector, the implementation of the Cognitive Logistics Network (CLN) is an advancement that can incorporate simulation outputs for real-time route adaptations. Under the 2040 Vision, Al Abbadi et al. (2021) researched the position of Logistics and Supply Chain Management (LSCM) as one of the significant pillars for economic diversification in Oman under the 2040 Vision. In adopting the technological implementation in improving the efficiency and optimization of the route, documentation and overall logistics operations, the CLN framework aligns with algorithms such as Genetic Algorithm and Ant Colony Optimization. The hybrid method of choosing both the algorithm for the implementation stands as important in addressing modern demands in the operations for cost reduction, error-free, time saving and resource utilization (Gupta et al. (2024). The amalgamation of logistics development strategies with Oman Vision 2040 is essential for boosting national supply chain competitiveness (Rahman et al., 2021). Sectoral reforms in logistics have a significant role in reaching Oman Vision 2040 economic objectives (Sanni, 2025).According to Smith & Nguyen, 2021, advances in electric powertrain systems support the transition toward energy-efficient and intelligent transportation solutions. In the study of Bolotbekova et al. (2025), the author presents the practical application of Genetic Algorithm (GA) for tourist trip route integration with the public bus transit in Konya, Turkey, this addresses the intricate issues of route planning this shows how the algorithm can iteratively refine the routes based on their previous data. In the study of Rismanto and Judijanto (2023), the authors highlight the importance of dynamic real-time optimization in the logistics sector powered by AI and real-time data, which can reduce delays, monitor traffic, reduce costs, and increase delivery performance. In his study, Tyagi et al. (2022) provide a technical analysis of complicated routing algorithms, primarily bioinspired approaches, which include particle swarm optimization, genetic algorithms, and an ant colony computation, known to be highly efficient at identifying effective routes in rapidly changing and uncertain conditions. Comparative studies on vehicle routing algorithms highlight the efficiency of bio-inspired optimization techniques under smart city applications (Nha et al., 2012). Artificial intelligence has shown strong potential in improving defect detection and decision support systems throughout industrial applications (Li & Chen, 2023). The multi-phase framework for the system addressed in the study conducted by Beed et al. (2020), a hybrid metaheuristic algorithm, aligns with the cognitive principles of exploration and exploitation by giving integration to the CLN for better adaptability in the Omani transport route optimization. Oman's logistics sector continues to face structural and operational challenges alongside emerging digital transformation trends (Magd & Ruzive, 2021). In the paper of authors, Gafiatullin and Mukhanova (2025), they give an explicit understanding of the reshaping of logistics operations using machine learning (ML) and cognitive systems. Showcasing that modern logistics highly rely on algorithms with the capacity of real-time data processing, allowing companies for the optimization of delivery routes, demand forecasting, and automate repetitive operations. The use of the proposed Cognitive Logistics Network framework is highly significant in the logistics industry. Boute and Udenio (2021) presented AI as a profound but beneficial instrument within logistics decision-making, underlining how algorithms could assist human planners instead of replacing their place in the organization. The significance they place on algorithmic optimization and IoT-facilitated real-time data remains in accordance to the essential requirements of modern digital logistics networks. However, the literature papers give a noticeable gap in the application of the CLN-based framework, giving basic operational support.

3. Methods

This study employed a quantitative method for data collection. In the quantitative approach, the secondary data source was in the form of insights from existing literature on the topic and related. Primary sources of data were collected as in the form of questionnaires distributed, and data was collected as in the form of a case-study based on a logistics organization operating in Oman. The questionnaire was designed to capture operational challenges, routing inefficiencies, delay factors, and perceptions regarding the adoption of intelligent routing and Cognitive Logistics Network (CLN) systems. The research paper follows a case-informed approach while maintaining a sector-level analytical focus to enhance the generalizability of the findings.

3.1 Analysis

This study analyzes the data for this project using the quantitative statistical analysis that opens a complex understanding of the work of operations and the thoughts of the employees within the organization. Descriptive Statistics is used to summarize the collected dataset and understand the overall trends. This method measures the mean, median, mode, and standard deviation, which will be applied in the group sections of the dataset. The inferential statistics is used for comparing the set of groups in the collected dataset.

4. Data Collection and Analysis

4.1 Freight Documentation Issues in Daily Operations at the Organization

The respondents were asked about the existing route management and operational activities, and what is the frequency of freight documentation issues is, with the options “very often”, “sometimes”, “rarely”, and “never”. The results are analysed in the following form tables (Table 1- Table 2) and descriptive analysis inference.

Table 1. Frequency Distribution Table

Options	Code	Frequency	Percentage
Very Often	4	4	36.40%
Sometimes	3	4	36.40%
Rarely	2	2	18.20%
Never	1	1	9.10%

Table 2. Descriptive Statistics

Statistics	Value
Mean	3.09
Median	3
Mode	4
SD	0.83

Inference of the Descriptive analysis

The results show a mean of 3.09, showing employees deal with the freight documentation issues "sometimes" and "very often". This indicates that the higher shortcomings happening in the operations is due to the freight documentation issues, showing a need for implementing automation in the operation or digital freight systems to reduce manual intervention.

4.2 Frequency of Delivery Delays Experienced by Drivers

The respondents were asked about the frequency of delivery delays experienced by drivers with the options, “very often”, “sometimes”, “rarely”, “never”. The following table describes the collected data clearly, and the inference is given below in Table 3, Table 4.

Table 3. Frequency Distribution Table

Options	Code	Frequency	Percentage
Very Often	4	1	9.10%
Sometimes	3	6	54.50%
Rarely	2	3	27.30%
Never	1	1	9.10%

Table 4. Descriptive Statistics

Statistics	Value
Mean	2.73
Median	3
Mode	3
SD	0.79

Inference of the Descriptive analysis

The results give a mean of "2.73", indicating that the drivers face delays between "rarely" and "sometimes", which leans towards "sometimes". This indicates that while some drivers rarely or never face delays, there are drivers who experience delays more often.

4.3 Key Factors Contributing to Delivery Delays

The respondents were asked to rank the main reasons among the options that cause delivery delays on a scale of 1 (biggest cause) to 5 (smallest cause) (Table 5).

Table 5. Frequency Distribution Table

Reasons for Delay	Mean	Median	Mode	Standard Deviation	Rank Counts (1-5)
Traffic congestion	2.27	2	1,3	1.27	1:4, 2:2, 3:4, 4:0, 5:1
Wrong route selection	2.73	3	2,3	1.27	1:2, 2:3, 3:3, 4:2, 5:1
Vehicle or mechanical issues	3	3	2,3,4	1.18	1:1, 2:3, 3:3, 4:3, 5:1
Customer side delay	2.36	2	2	1.43	1:3, 2:5, 3:1, 4:0, 5:2
Waiting for document approval	3	3	3	1.34	1:2, 2:1, 3:5, 4:1, 5:2

4.4 Perceived Impact of Integrating Transport Routing within the Freight Management System

The respondents were asked to rank whether integrating the transport routing in the freight system decreases the delays. The options are formed, and the results are accepted (Table 6. Table 7).

Table 6. Frequency Distribution Table

Options	Code	Frequency	Percentage
Yes	1	10	90.90%
No	0	1	9.10%

Table 7. Descriptive Statistics

Statistic	Value
Mean	0.91
Median	1
Mode	1 (Yes)
SD	0.29

Inference of the Descriptive Analysis

The results of the question highlight the strong and consistent positive attitude of the respondents regarding the integration of the transport routing system.

4.5 Perceived Usefulness of Automated Route Recommendation Systems

The respondents were asked about the usefulness of a system automatically suggesting the best routes, and provided with options "not useful", "somewhat useful", and "very useful" (Table 8, Table 9).

Table 8. Frequency Distribution Table

Options	Code	Frequency	Percentage
Not useful	1	0	0.00%
Somewhat useful	2	4	36.40%
Very useful	3	7	63.60%

Table 9. Descriptive Statistics

Options	Code	Frequency	Percentage
Not useful	1	0	0.00%
Somewhat useful	2	4	36.40%
Very useful	3	7	63.60%

Inference of the Descriptive analysis

This result reveals a strong positive perception among the employees regarding the usefulness of an automated system that can suggest the best transport routes. The mean is 2.64, which is closer towards the higher end of the scale, showing an inclination towards the response option "Very useful".

4.6 Expected Benefits of Cognitive Logistics Network (CLN) Implementation

The respondents were asked about their opinion on the benefits of a CLA, with four options, "less delays", "faster routing", "fewer errors in documentation", and "all of them" (Table 10, Table 11).

Table 10. Frequency Distribution Table

Options	Code	Frequency	Percentage
Less delays	1	1	9.10%
Faster routing	2	3	27.30%
Fewer errors in documentation	3	0	0.00%
All of the above	4	7	63.60%

Table 11. Descriptive Statistics

Statistics	Value
Mean	3.27
Median	4
Mode	4
SD	1.01

Inference of Descriptive Analysis

From the obtained results, we get a mean of 3.27, indicating that most of the employees believe that the Implementation of the Cognitive Logistics Network (CLN) can bring broad improvements.

5. Summary of improvements and recommendations

5.1 Improve

Process improvement through the implementation of the Cognitive Logistics Network System integrated with AI agents and algorithm. The following table proposes the set of AI agents that will be integrated in the CLN framework addressing the operational problems and inefficiencies (Table 12).

Table 12. Descriptive Statistics AI Agents using ACO & GA in the CLN Framework

AI Agent	Algorithm Used	Why does this fit perfectly
Route Optimization Agent (Based on Goal)	ACO	This algorithm is perfect here as it is ideal for the shortest path, dynamic routing, and congestion-aware selection of route.
Cost-Service Trade-off Agent (Based on Utility)	GA	GA handles multiple objective optimization, like cost, time, fuel, etc.

Prescriptive Decision Agent	ACO + GA (Hybrid)	Route options generated by ACO, optimal solutions under constraints are chosen by GA.
Learning & Prediction Agent	GA (parameter tuning)	GA optimizes model parameters and over time decision rules.
Multi-Agent Coordination Agent	GA	GA helps in finding optimal global solutions across the fleet, as well as in documentation.

Interpretation of Table 12
The Table provides how the specific AI agents within the CLN leverage optimization algorithms such as Ant Colony Optimization (ACO), Genetic Algorithm (GA), and their hybrid combination. In the quantitative analysis of the responses, there is a broad consensus among the employees on the significance of integrating a routing system and automated route recommendations, in support of this allocation.

5.2 Impact of Implementing the Cognitive Logistics Network in the logistics sector.

The implementation of a Cognitive Logistics Network (CLN) gives an important positive impact on logistics operations by enabling a shift from manual and reactive routing practices to predictive and data-driven decision-making. According to these findings of the questionnaire analysis, CLN adoption is expected to improve route optimization, reduce delays in delivery, and improve the overall operational efficiency through real-time data integration and intelligent route suggestions. The use of optimization algorithms such as Genetic Algorithms (GA) and hybrid GA–Ant Colony Optimization (GA+ACO) supports dynamic route planning by considering traffic conditions, delivery priorities, and operational constraints. Additionally, CLN aligns the improved coordination between drivers, planners, and management, leading to better resource utilization, reduced fuel consumption, and increased service reliability. At a sectoral level, the adoption of CLN aligns with Oman's logistics modernization goals by promoting digital transformation, operational resilience, and sustainable transport practices.

According to Zhang et al., 2023, Digital logistics significantly enhances operational efficiency and system responsiveness in complex economic environments. As the Cognitive Logistics Network is implemented in the logistics sector for route optimization and documentation processes, it overall increases operational efficiency. Table 13 shows the alignment of the AI Agents with the goals of Oman Vision 2040 Goal (Table 13).

Table 13. Alignment with Oman Vision 2040

Oman Vision 2040 Goal	Algorithm Contribution
Digitalization & Smart logistics	ACO & GA powered AI agents
Competitiveness & Cost Efficiency	GA-based optimization
Intelligent transport systems	ACO-based routing
Sustainability	Fuel- and emission-aware optimization

This synchronization of the proposed Cognitive Logistics Network (CLN) framework and Oman Vision 2040 supports national logistics development goals, along with resolving the internal issues, as in the course of the research.

5.3 Limitations

Despite the positive findings, this study is subject to some limitations. The analysis is completely dependent on questionnaire data collected from employees of a single medium-sized logistics organization operating in Oman, which may limit the generalizability of the results found from the collected data across the broader logistics sector. The sample size, while adequate for exploratory analysis, may not fully capture variations in operational complexity across different logistics firms or regions. Furthermore, the study focuses primarily on the conceptual and analytical evaluation of CLN implementation rather than real-time experimental deployment. External factors such as fluctuating traffic conditions, third-party service providers, and system interoperability challenges were not examined in depth. Future research could address these limitations by incorporating larger multi-company datasets and real-time operational testing.

6. Conclusion

The findings from the analysis of the data have explicitly shown that inefficiencies in route optimization and issues related to documentation at the organization are not isolated operational issues, whereas systemic bottlenecks need to be addressed by implementing an intelligent, integrated solution. The analysis of the collected data confirms the requirement of a Cognitive Logistics Network (CLN) combining the AI agents, monitoring in real-time, and algorithms for optimization of algorithms to support data-driven routing and operational decision-making. The addressed challenges in the route selection, delivery delays, and the inefficiencies in coordination are all directly considered in the proposed CLN framework, which is backed by the Genetic Algorithm (GA) and Ant Colony Optimization (ACO).

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Biographies

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Dr Deena Roy is a faculty member in the Department of Management Studies at Middle East College (MEC), Muscat, Oman. She has a huge academic and supervisory experience in applied research areas. Dr. Deena has guided several projects and has been part of many research projects, as an active contributor to the academic research through conferences and journal publications. Her mentorship and academic guidance played a vital role in shaping the methodological rigor and practical relevance of this study.