IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 12 Issue 07, July 2025
ISSN (Online) 2348 – 7968 | Impact Factor – 6.72
www.ijiset.com

Mitigating Route Scheduling and Resource Allocation Challenges in the Logistics System: A Survey of the Roles of Transportation and Assignment Problems

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ABSTARCT
The increasing complexity of logistics systems due to urbanization, fluctuating customer demands, and sustainability challenges has necessitated the development of efficient resource allocation models. One of the key problems faced is the optimal assignment of limited resources such as personnel, storage, and transportation routes under constraints of time, cost, and environmental impact. Existing logistics frameworks often struggle to deliver real-time, cost-effective, and adaptive solutions, especially in dynamic and uncertain environments. This paper aims to explore the application of the assignment problem and transportation models in optimizing resource allocation and route scheduling within logistics systems. A systematic literature review approach was adopted to analyze past and current research trends in assignment and transportation optimization, focusing on both classical operations research techniques and modern AI-enhanced solutions. The findings reveal that classical methods such as linear programming, the Hungarian algorithm, and Vogel's approximation method remain foundational. However, they are increasingly being hybridized with advanced algorithms like heuristic multi-objective evolutionary methods, tabu search, ant colony optimization, and graph neural networks. These models have significantly improved accuracy, workload balance, and operational efficiency in scenarios ranging from warehouse picking to vehicle routing. The study recommends the integration of classical optimization frameworks with intelligent systems such as IoT, cyber-physical platforms, and machine learning to enhance flexibility and scalability in logistics operations. Future work should explore large-scale deployment of AI-driven models, their compatibility with real-time logistics data, and the incorporation of environmental impact assessments to align with sustainable development goals.
Keywords: Route Scheduling, Resource Allocation, Logistics System, Transportation Problems, Assignment Problems

1. Introduction

Businesses are challenged by global competition and changing client demands, which is causing the industry to undergo fundamental changes. In light of these circumstances, Industry 4.0 is currently the primary idea for addressing these production difficulties. In order to create a fresh image of the state of logistics research [2] attempts to rigorously unite several research techniques

to a Logistics 4.0 framework, as there is currently no similar overarching concept in the field. A thorough framework for Logistics 4.0 is given in the study. Prior to conducting a comprehensive literature review of 114 articles on the topic, the term Logistics 4.0 is further defined. In order to enable supply chains to improve their performance and response times, comprehensive improvements to logistics are now required due to the technological advancements in global producing systems brought about by the 4.0 revolution. Thus, the idea of Logistics 4.0 was created by [2]. Even though the concepts of Logistics 4.0 have been adopted by many industrialized nations, there is still a gap in its research and implementation globally according to the study. The trends and difficulties in implementing Logistics 4.0 are examined in this article. Logistics management is a critical component of success for organizations working in the retail industry. As the popularity of online shopping continues to expand, businesses must develop effective logistics strategies to please customers, minimize costs, and maintain a competitive advantage. The study by Gomes *et al.*, [3] provides a thorough analysis of e-commerce logistics management, emphasizing the opportunities, problems, tactics, and solutions that can help businesses enhance their logistics operations and thrive in a cutthroat industry. A literature review's technique, which entails a methodical and structured examination of published scientific articles pertaining to the subject, was used.

However, logistical platforms (LP) are business models intended to improve the performance of all logistical activities of a supply chain (SC). About logistics platforms, the scientific literature describes the management, implementation, importance, typologies, comparisons with foreign platforms, as well as cited case studies therein. The literature also identifies a number of technological adoption patterns and the difficulties brought on by the quick development of said technology. Hence, Cote *et al.*, [4] provided an explanation of an LP and its significance to its SC. The study further went over eight different kinds of LPs, their uses, and the stages of implementation that go along with them. This significant collection of publications, which we have compiled, aims to use mathematical concepts to address challenging issues. The literature on operational control of discrete event logistics systems (DELS) is reviewed and categorized in the research by Sprock *et al.*, [5]. The movement of objects through a DELS is controlled by operational control. Based on the control choice that the analytical model is designed to support, each control problem that has been addressed in the reviewed literature is categorized. Abstract functional definitions that concentrate on the inputs, outputs, and variables of the analytical model define these control decisions. This categorization of control problems demonstrates that, either alone or in combination, five different types of atomic control choices are required to cover the literature. Decision-support analysis models can be found and interoperable thanks to standard functional definitions of operational control decisions.

Since raising the quality of logistics services for clients frequently results in higher logistical costs, logistics cost management is linked to certain particular difficulties. Furthermore, cutting the price of one logistical component raises the price of another, thus raising the whole cost of logistics. In order to facilitate the optimization of logistics activities the primary focus of research and a crucial practical tool for logistics management a number of cost models have been developed. Therefore, study by Muha [6] is to ascertain whether the problems associated with logistics cost management are being addressed by current scientific research of the treatment of specific logistical cost categories and procedures. In a similar study, the main purpose of Martins *et al.*, [7] is to present an overview of the applications of sustainable practices in logistic operations performed by Brazilian companies. To reach this objective, the following steps were carried out: (1) a review of the literature on logistics systems and sustainability in logistics activities; (2) the collection of sustainability reports published by companies that perform logistics operations, which are recognized in Brazil;

(3) a content analysis of the reports collected and (4) a discussion of the results, cross-checked with the literature and the extrapolation of conclusions. It was possible to identify 22 sustainable practices, and these practices were grouped into five macro areas. The authors of the paper believe that the findings presented here can be useful for professionals and researchers in the implementation of sustainability practices in logistics systems

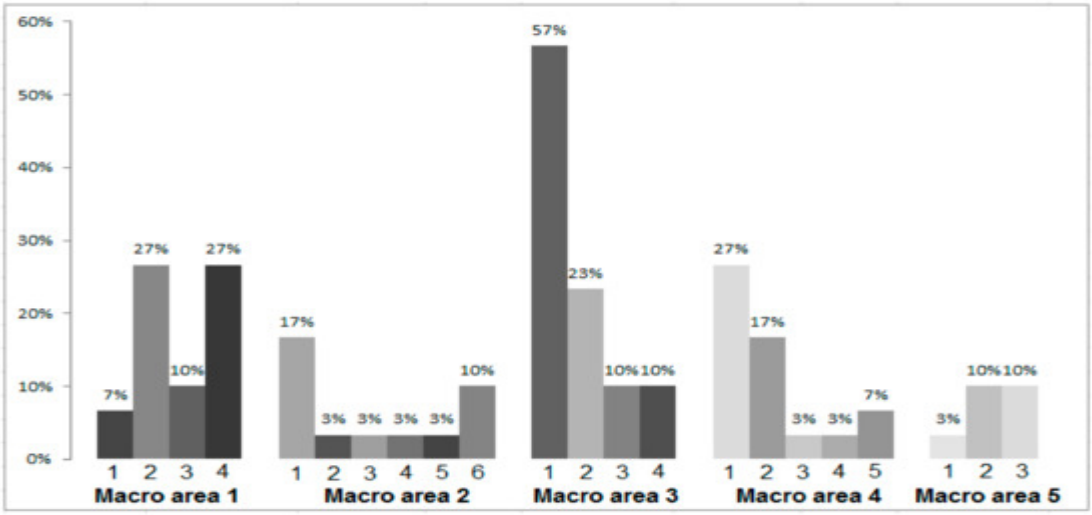


Figure 1: Percentage of Companies that Develop each Practice of the Logistic Martins *et al.*, [7]

In the modern world, technologies and market requirements are constantly changing, and the introduction of modern information systems is necessary for the successful functioning of companies in the field of trade and logistics. These systems automate processes, simplify management and increase efficiency. The advantages of implementing information systems are discussed in this article, as well as the problems that companies may face in this process. The inconsistency of the company's hardware architecture and network with the requirements, as well as the lack of resources, including qualified personnel and finances, are the main problems. Incorrect choice of information system or resistance from employees can also cause problems Zhilkina *et al.*, [8]. The concept of sustainable logistics and supply chain management (SL&SCM) has gained popularity in academia since the turn of the 20th century, with over 5000 publications published in the last 30 years. The purpose of Wang *et al.*, [9] is to review the literature on SL&SCM published between 1994 and 2019 and provide insights and future research directions. To do this, 2809 publications were selected from the WoS and Scopus databases, and a bibliometric overview of SL&SCM was presented. Next, a visual collaboration network based on VOSviewer® and Bibliometric® was presented, and finally, visual thematic trends, challenges, and opportunities are presented.

Naumenko *et al*,.[10] the proposed model for optimizing the logistics system of an enterprise using information technology. The motivation to build the model emphasizes the critical role that new information technologies play in significantly increasing the availability of data of a wide variety of types related to the transportation process and servicing logistics tasks. In particular, the ability to operate in real-time with a significant amount of detailed data collected locally can potentially improve the accuracy of information about critical unobserved characteristics of the production process. Among such unobservable values according to the study, one can indicate various kinds of attributes of the efforts made by the organization and individual employees to achieve different goals and objectives of providing logistics services. In a similar study, Li [12] aims to explore the significance of using big data analytics to optimize logistics management for

sustainable development. In today's global landscape, effective logistics management is essential for fostering sustainable development across industries. The four main areas of current logistics management challenges are the cost of raw materials, one-stop solutions, service evaluation, and the efficiency of goods delivery. Integrating big data analytics into logistics operations has emerged as a transformative approach to boost efficiency, minimize waste, and mitigate environmental impact.

The complexity of supply chains in today's global marketplace demands flexible and sustainable management techniques. These problems are frequently not adequately addressed by traditional analytical techniques, necessitating the use of more sophisticated strategies. The study by Pasupuleti *et al.*,[12] improves inventory management and logistics by utilizing cutting-edge machine learning (ML) approaches. They used a range of machine learning algorithms, such as regression, classification, clustering, and time series analysis, on historical data from a global retail company, including sales, inventory levels, order fulfillment rates, and operating costs. Significant gains were made in several important operational areas as a result of the use of these ML models. They were able to reduce overstock and stockouts by 10%, increase demand forecasting accuracy by 15%, and predict order fulfillment timelines with 95% accuracy. Similarly, the study by Boujarra *et al.*, [13] examines how deep learning is affecting logistics, a sector dealing with growing issues including accuracy, efficiency, and quick demand. A game-changing technology that has the potential to revolutionize supply chain management is deep learning. The study further looks at the fundamentals of machine learning, deep learning, and learning and artificial intelligence before to delving into practical logistical applications. The advantages of process automation, route planning, and inventory optimization are demonstrated by successful company instances. Data security is one of the challenges that are examined, along with other exciting opportunities and technical advancements. Finally, the study gives readers a well-informed understanding of the opportunities and difficulties of implementing these cutting-edge technologies and raises important questions regarding the crucial role that deep learning plays in the digital transformation of logistics.

2. Literature Review

A well-known operations research problem is the transportation problem, which entails determining the best method for moving items from one location to another. In the discipline of operations research, the transportation problem has grown in significance as globalization and the creation of intricate distribution networks have increased. Malacký & Madleňák [14] reviewed the literature on transportation issues and how they have been resolved. The different kinds of transportation issues and the potential solutions are examined by the writers. The primary algorithms used to solve transportation problems are presented in the article along with an examination of the various restrictions and goals that can be used to create them. The operational management of the transportation and distribution problem of different items was examined in the review study by Gupta & Gulati [15]. Along with minimizing expense, time, and travel, the primary goal is to maximize profit. The transportation problem has countless real-world applications in operational research. In order to obtain a notable initial basic viable solution for TPs, we suggest in this review study an efficient improvement of algorithms in the solution phase. Several techniques, including the NWCR, LCM, Vogel approximation method, SS method, Modified Distribution method, BCM, and MM method, are utilized to find the optimum answers. These techniques yield the most optimal first fundamental solution.

From the perspective of operational research, a related study by Mohri *et al.*, [16] provides a thorough analysis of the field of hazardous material transportation. Network design issues, hazardous routing, and routing-scheduling are the main topics of the article. The review paper aims to: (1)

examine the assumptions, goals, constraints, choices, input parameters, fundamental modeling/solution techniques, and case studies of the models; and (2) highlight the fundamental characteristics and difficulties in creating the models with various modes of transportation. Furthermore, a comprehensive, in-depth, micro-level evaluation of the literature identifies the most important research gaps. Lastly, a list of promising avenues for further research is suggested so that the authorities can make better choices. Improvements in transportation have an impact on socioeconomic and technical advancement, and numerous academics have studied different transportation issues. In order to demonstrate a comprehensive analysis of such transport challenges, the Analytic Hierarchic Process (AHP) is utilized to list the relevant criteria and options, Moslem *et al.*, [17]. The PRISMA protocol, a systematic review approach, is used during the review process. This work's contribution is emphasized, as are the AHP enhancements that enhance decision-making assistance. In order to achieve this, recent studies show the pertinent findings of 58 publications that were released between 2003 and 2019. The findings showed that the majority of researchers used the traditional AHP approach to address transportation-related difficulties, with public transportation being the most important issue and logistics challenges coming in second.

(a) Assignment Problem

An essential component of warehouse management systems is the storing of items. Because of the amount of products, the unpredictability of demand and the need for quick customer service, this business is very hard even though it is sometimes seen as simple. Furthermore, it frequently takes difficult choices to optimize logistical resources to maintain an effective operating flow, such as the distribution of storage spaces. Hence, the study, Reyes **et al.,** [18] examines scholarly works on the storage location assignment problem that were published between 2005 and 2017 in this paper. The literature is categorized based on the goals, approaches to solving problems, and associated factors. There are also recommendations for additional research. In optimization and graph theory, the assignment issue can take many different forms. It can be transformed into routing, distribution, and scheduling problems by adding new constraints or altering some of the existing ones.

One of the goals by Seda [19] is to demonstrate such relationships. The question of whether some of the derived problems are solvable for larger cases emerges because of their exponential temporal complexity. Since the computational core of software tools, embedded in GAMS, is deterministic in nature, it is preferable to the conventional method based on the application of approximate or stochastic heuristic approaches. The study further notes that in location-based tasks, the problem may arise of adding another center to an existing network of centers to improve the coverage of an area. An example might be an expansion of the existing supermarket network of a chain store. Here it is suggested to use one of the properties of the Voronoi diagram, a data structure known from computational geometry: Assume a Voronoi diagram with its sites represented by the current centers. The point *q* is the vertex of the Voronoi diagram if and only if the *largest empty circle*C(q) contains three (or more in a degenerate case) sites on its boundary and none inside. Among these circles, we determine the one with the largest diameter, and its center is then the optimal position for the location of the new center, as depicted in figure 2.

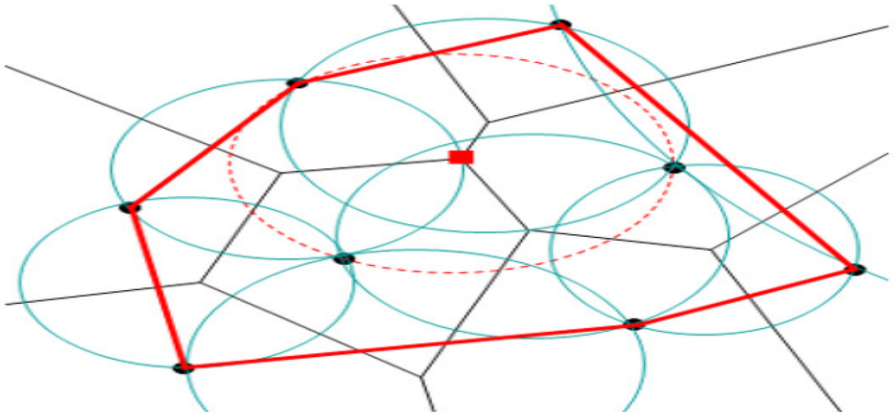


Figure 2: Finding a New Location using the Largest Empty Circles, Seda [19]

Through the implementation of a series of projects with pre-allocated finances, municipalities service organizations play a significant role in strategic planning and community development that takes into account future changes and societal developments. Project requirements, finances, and standards vary from city to city and from community to community. It is an NP-Hard problem to fairly distribute diverse projects to municipalities while making sure that different skills are provided to reach developmental roles. Assuming that every municipality possesses the same strategic traits. The issue is how to allocate a collection of projects with varying budgets to every municipality while maintaining a minimum budget gap between them. To derive equity distribution between municipalities, (Jemmali, 2021) developed lower bounds and eleven heuristics to be utilized in the branch-and-bound algorithms. The performance of the developed heuristics, lower bounds and the exact solutions are presented in the experimental study.

Group role assignment (GRA) problems are reviewed and expanded from a new perspective in this article, which systematically creates a new category of assignment problems. Zhu [20] outlines three new major assignment problems to make GRA+ problems comprehensive and cohesive after examining seven related GRA with Constraints (GRA+) problems. Furthermore, the article establishes additional requirements for the stated problems to have workable solutions, proves a number of new related theorems, and confirms the difficulty of the recently defined problems. The importance of the theoretical work offered is fully confirmed in this article, which also offers a generalized formalization of this category of problems that is, the one extremely abstract optimization issue that is stated for the first time.

(b) Exploring the Transportation Problem Model in Route Scheduling Optimization for Logistics System

Logistics firms struggle with effective scheduling and routing in order to satisfy changing delivery expectations as a result of the explosive expansion of e-commerce. In order to maximize truck routing with Radio Frequency Identification (RFID) technology, Guo *et al.*,[21] suggests a revolutionary logistics scheduling approach. A model for scheduling vehicles is created. An adaptive taboo search method in conjunction with a nearest neighbor algorithm is used to handle the random consumer demand and service time problems. Comparative experiments demonstrate the performance of the improved method in completing tasks and reducing queueing time compared to other methods. Future work and limitations are discussed. The link that directly connects customers

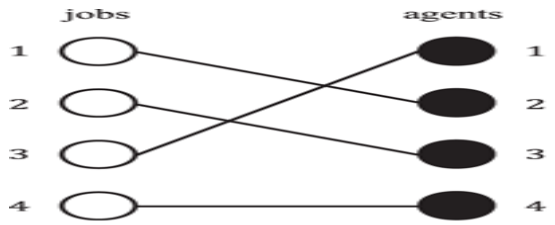
in logistics operations is logistics distribution. Distribution costs make up a significant amount of all logistical expenses. The cost, benefit, and service level of logistics distribution are all significantly impacted by reasonable truck routes. One of the main areas of research in the field of logistics distribution is the optimization of vehicle routes through the use of rational and scientific methodologies. Among these, current research focuses on the issue of delivery vehicle route optimization within a time constraint. The most recent intelligent optimization methods are the artificial fish swarm algorithm, ant colony algorithm, simulated annealing technique, and tabu search algorithm. The development of these algorithms offers fresh approaches to the delivery vehicle transportation challenge. Thus, Gan [22] examines the construction of a vehicle allocation route problem model with a time frame. Based on fish swarm algorithm and ant colony algorithm, a hybrid optimization algorithm is proposed for the distribution route optimization problem.

Emergency logistics services are crucial in preserving lives and minimizing damage in the immediate aftermath of major disasters. Reliable transport time data for accessible routes is essential for effective relief logistics routing. However, until a car is on the road, this information cannot be precisely determined. The study by (Zhang and Liu, 2021) simulates the information obtaining process using a multiperiod online decision-making problem, taking into account the relationship between logistics operations and information acquisition. This challenge can be referred for emergency resource scheduling scenarios in which earlier decisions effect knowledge for future logistics planning. The basic model is a multi-trip cumulative capacitated vehicle routing problem with unpredictable transit time. Cross-docking is the practice of loading commodities straight into departing vehicles after unloading them from incoming ones. By eliminating or reducing storage expenses, space needs, and inventory use, cross-docking streamlines supply chains and enables them to deliver products to markets more quickly and effectively. In order to arrange transportation routing and cross-docking in a reverse logistics network, a mixed-integer linear programming model was created [24]. Additionally, various traffic patterns are taken into account in order to lower fuel usage, which lowers pollutants and emissions. The suggested model is an NP-hard issue that is multi-product, multi-stage, and non-deterministic polynomial-time.

(c) Applications of the Assignment Problem in Resource Allocation for Logistics Systems

One of the most important factors in promoting economic growth in an urban environment is the movement of products. There are a number of problems with city commodities transportation, such as energy and environmental problems. The idea of city logistics was developed in response to the challenges associated with product transportation in metropolitan areas. The employment of many kinds of vehicles, particularly small vehicles, to move goods is one of the city's logistics solutions. In order to handle the heterogeneous vehicle routing problems in the setting of city logistics, thus, Iswari & Setiawan [25] created an assignment first routing second (AFRS) method. The assignment problem and the traveling salesman problem are the two mathematical models into which the algorithm is separated. One of the most important criteria for businesses in the service industry is the effective planning and management of personnel resources. The goal of the Central Operations Department for banks is to deliver the finest operational service with the highest efficiency given the limited labor resources in the departments. The department receives a lot of transactions from branches or directly from clients. An actual assignment problem that was categorized as a generalized assignment problem was examined by Cetin *et al.,* [26]. The literature survey part listed and analyzed related algorithms for the problem's solution.

The pick-and-pass system (PKPS) has the potential to become an intelligent warehouse picking system based on cyber-physical systems (CPS) as a result of the development of artificial intelligence (AI) and the expanding use of IoT and cloud computing. In order to solve the NP-hard storage assignment problem (SAP) for order picking activities in an e-commerce-based warehouse, Tu *et al*.,[27] suggests a CPS-based PKPS with a heuristic multi-objective evolutionary algorithm. The suggested algorithm takes into account both emergency replenishment during picking operations and the workload balance between picking lines. The study concludes by demonstrating the effectiveness of the suggested algorithm in raising the picking operations' efficiency based on software simulation. In fields like robotics, telecommunications, and logistics, linear assignment problems are well-known combinatorial optimization issues. Even in modest settings, it is generally computationally impossible to acquire an ideal solution to such problems; hence, heuristic methods are frequently employed to identify near-optimal answers. Using a bipartite graph to represent the problem structure and a message passing Graph Neural Network (GNN) model to train the correct mapping, (Aironi et al., 2024) explores a general-purpose learning technique to achieve the correct assignment permutation.



$$\phi = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 1 & 4 \end{pmatrix}$$

$$X_\phi = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Algorithm 1. Hungarian Algorithm

Input: Cost matrix $C \in \mathbb{R}^{N \times N}$
Output: Assignment matrix $A \in \{0;1\}^{N \times N}$
Step 1. Subtract the smallest element in each row from all elements in that row.
for $i \leftarrow 1$ to N **do:**
  $m_i = min(C_{i,:})$
  for $j \leftarrow 1$ to N **do:**
    $C_{i,j} = C_{i,j} - m_i$
Step 2. Subtract the smallest element in each column from all elements in that column.
for $j \leftarrow 1$ to N **do:**
  $m_j = min(C_{:,j})$
  for $i \leftarrow 1$ to N **do:**
    $C_{i,j} = C_{i,j} - m_j$
Step 3. Draw the minimum number of lines to cover all zeros in C.
$l \leftarrow$ minimum_lines_to_cover_zeros(C)
if $l == N$ **then:**
  if $C_{i,j} == 0$ **then:**
    $A_{i,j} \leftarrow 1$
  else:
    $A_{i,j} \leftarrow 0$
  return A
else:
  Step 4(a). Extract the submatrix C^* by selecting the columns and rows not yet covered.
  $C^* = C -$ {covered_rows_and_columns}
  Step 4(b). Find the smallest element in C^*
  $n \leftarrow \min(C^*)$
  Step 4(c). Subtract n from each row of C^*,
  for $i \leftarrow 1$ to $|C^*|$ **do:**
    $C_{i,:} = C_{i,:} - n$
  Step 4(d). Add n to each column of C^*,
  for $j \leftarrow 1$ to $|C^*|$ **do:**
    $C_{:,j} = C_{:,j} + n$
  Go back to **Step 3**

The Hungarian algorithm according to the study involves manipulating the weights of the bipartite graph in order to find a stable, minimum-weight perfect matching. However, most implementations use dynamic programming techniques by acting on cost matrix values, given the key observation that if a number is added to or subtracted from all of the entries of any one row or column of the cost matrix, then an optimal assignment for the resulting matrix is also an optimal assignment for the original cost matrix. The study finally shows the comparison between the accuracy obtained in terms of correct assignments and the cost accuracy as depicted in figure 3.

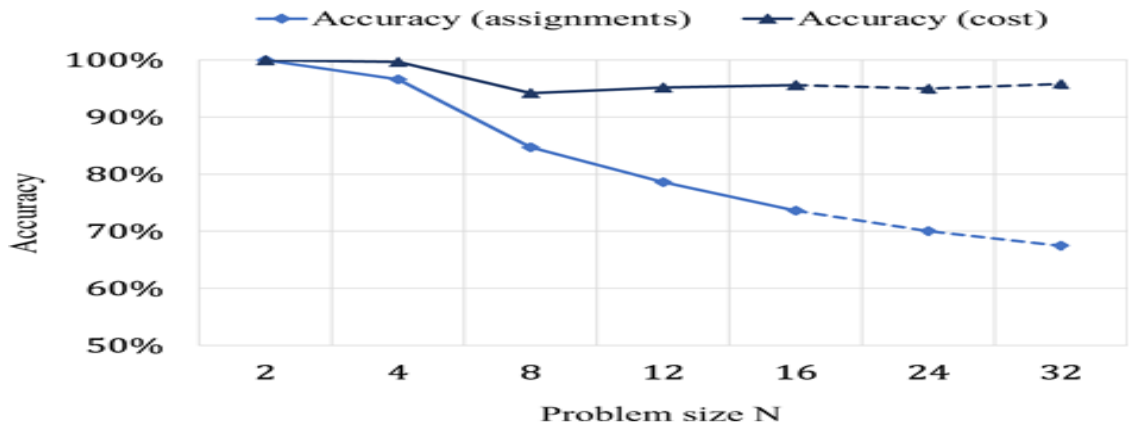


Figure 3: Trends in accuracy of exact assignments and deviation from the minimum attainable cost

3. Findings, Discussions and Future Work

(a) Findings

- The classical transportation problem continues to serve as a foundational model in logistics optimization, with traditional solution methods such as the Northwest Corner Rule (NWCR), Least Cost Method (LCM), Vogel's Approximation Method, and the Modified Distribution Method (MODI) still widely used due to their computational efficiency and simplicity.

- There is a growing application of heuristic and meta heuristic approaches, including artificial fish swarm algorithms, ant colony optimization, simulated annealing, and tabu search, which address the limitations of classical algorithms, especially for large-scale and dynamic logistics environments.

- Real-world constraints such as unpredictable customer demand, fluctuating service times, and traffic variations are being integrated into logistics models, requiring more adaptive and intelligent decision-making systems for transportation and scheduling.

- Assignment problems are increasingly applied in complex logistics scenarios such as warehouse storage, workforce allocation, and vehicle routing. The Generalized Assignment Problem (GAP) has proven especially useful in resource allocation tasks where capacity and compatibility must be considered.

(b) Discussions

- The persistence of classical transportation and assignment models underscores their foundational role, but their limitations in real-time, data-rich environments have led to a shift toward more flexible, hybrid approaches that combine traditional operations research with AI techniques.

- Heuristic and metaheuristic algorithms are particularly valuable in solving NP-hard problems like vehicle routing and warehouse storage, where obtaining an exact solution is often computationally infeasible. These methods provide near-optimal solutions within reasonable computational times.

- The integration of real-time data from IoT devices into logistics operations enhances decision-making capabilities. This is especially useful for adaptive vehicle scheduling, inventory replenishment, and warehouse management.

- The growing adoption of CPS and AI in warehouse systems illustrates the move towards intelligent logistics solutions that are capable of balancing operational efficiency, cost-effectiveness, and responsiveness in dynamic environments.

- The use of GNNs and graph-based modeling marks a significant development in solving complex assignment problems. These techniques allow for more generalized and data-driven solutions that can learn and adapt to various problem structures without explicit programming.

4. Recommendations and Future Work

4.1 Recommendations

- There is a need to integrate classical transportation and assignment models with modern data analytics tools and real-time information systems. While models like MODI, NWCR, and Vogel's Approximation have shown consistent results in structured environments, incorporating data-driven methods such as machine learning and predictive analytics could enhance adaptability to dynamic logistics settings.

- Logistics operations should increasingly adopt hybrid optimization techniques. As demonstrated by Gan [22], the combination of swarm intelligence and classical algorithms provides robust and flexible solutions to route optimization problems. Decision-makers are advised to implement such hybrid methods to improve solution quality and computational efficiency in large-scale logistics scenarios.

- Organizations involved in logistics, particularly warehouses and distribution centers, should explore the use of Cyber-Physical Systems (CPS) and Internet of Things (IoT)-enabled frameworks. The work of Tu et al. (2021) reveals that these systems significantly enhance the performance of storage and picking operations through automation and real-time feedback mechanisms.
- There is a strong case for financial institutions and service industries to adopt generalized assignment problem formulations for labor and resource planning. As seen in Cetin *et al.*,[26], applying these models can optimize task allocation and workforce utilization, improving operational efficiency.

- AI-driven solutions such as Graph Neural Networks (GNNs), as explored in Aironi *et al.*, [28], should be further explored for complex assignment problems. These models provide a promising path toward developing adaptive and scalable decision-making tools for various applications in logistics, robotics, and telecommunications.

- Policymakers and urban planners should consider the AFRS model introduced by Iswari & Setiawan [25] when designing city logistics frameworks. This approach offers a structured method for managing heterogeneous vehicle fleets and can lead to more sustainable urban delivery systems.

4.2 Future Work

- Future research should focus on the fusion of classical optimization techniques with advanced AI models such as reinforcement learning and deep neural networks to solve real-time logistics and transportation problems under uncertainty.

- Further investigation is required into the scalability and generalization of Graph Neural Networks (GNNs) for broader classes of assignment problems, especially in dynamic and high-dimensional logistics environments.

- There is room to explore the integration of blockchain technology with CPS-based warehouse systems to ensure secure and transparent data exchange among logistics stakeholders.

- More empirical studies are needed to validate the practical implementation of heuristic and hybrid metaheuristic methods in real-world logistics networks, particularly under fluctuating demand and supply chain disruptions.

- Future work should examine the environmental and economic impacts of assignment-based vehicle routing models like AFRS in city logistics, incorporating sustainability metrics and carbon footprint analysis.

- The development of decision-support systems combining traditional assignment algorithms with interactive visualization tools could enhance user understanding and adoption in logistics operations and strategic planning.

4. Conclusion

The integration of optimization models, particularly the transportation and assignment problems, plays a crucial role in enhancing the efficiency of logistics systems. These models have evolved significantly over the years, with classical methods still providing foundational solutions. However, with the increasing complexity of modern logistics, especially in urban environments, these traditional methods are being augmented by more sophisticated approaches, including machine learning, artificial intelligence, and IoT-based systems. The survey demonstrates that the combination of these advanced techniques with established optimization models has resulted in improvements in resource allocation, route scheduling, and overall operational efficiency. The findings suggest that incorporating real-time data and dynamic decision-making capabilities is key to addressing the challenges faced by logistics firms. Furthermore, while significant advancements have been made, there remains considerable potential for further improvement. The future of logistics optimization lies in the seamless integration of classical models with cutting-edge technologies, such as deep learning and reinforcement learning, to address the complexities of global supply chains. Ultimately, the continuous development of hybrid optimization models that combine human expertise with machine intelligence can provide the flexibility, accuracy, and sustainability required to optimize resource use, reduce operational costs, and improve the overall performance of logistics systems in a rapidly changing world. Therefore, future research should focus on refining these models, exploring their scalability in real-world applications, and evaluating their environmental and economic impacts, contributing to the achievement of more sustainable and efficient logistics operations.

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