ISSN: 2710-0723

Literature Review: Application of MCDM Methodology to Logistics Location Problems

Mingke Zhang, Jinwu Duan

College of Economics and Management, Southwest Petroleum University, Chengdu, Sichuan, China

Abstract

This article provides a comprehensive overview of the application of Multi-Criteria Decision Making (MCDM) methods in the field of logistics location selection. It traces the historical development of MCDM methods from their inception in the 1970s to the sophisticated models and algorithms used today, highlighting the evolution from simple models to complex, intelligent algorithms that incorporate environmental and social considerations. The article emphasizes the importance of combining various MCDM methods to leverage their strengths and address their limitations. It showcases the successful application of these hybrid models in diverse scenarios, such as urban transit hub optimization, inland dry port selection, and the positioning of emergency logistics centers. The article concludes by identifying current challenges, such as handling uncertainties and the complexity of models, and suggests future directions for research, including the development of adaptive models and the integration of artificial intelligence and big data analytics to enhance decision-making in logistics location selection.

Keywords

Logistics System Optimisation; Location Problem; MCDM.

1. Introduction

In supply chain management, there is an undeniable key issue: logistics location selection. It involves various aspects of business operations, affecting a company's cost-effectiveness, service quality, and strategic planning.

Logistics location selection has a direct impact on a company's operating costs. Through reasonable site selection, companies can reduce transportation distance and time, thereby lowering transportation costs. At the same time, an appropriate location can also reduce inventory costs and enhance overall economic benefits. The rationality of site selection determines the speed of a company's response to customer needs and the level of service. Facilities close to customers or markets can provide faster delivery services, enhance customer satisfaction, and thus strengthen the competitiveness of the company. Moreover, logistics site selection is also part of a company's long-term strategic planning. With changes in the market and the development of the company, site selection decisions need to be forward-looking and flexible to ensure that the company still has a competitive edge in the future.

However, logistics site selection decisions also face many challenges and complexities. Firstly, site selection typically requires consideration of multiple criteria, such as geographical location, transportation conditions, labor costs, environmental regulations, market proximity, etc., and these criteria may conflict with each other. Secondly, factors such as market demand, transportation costs, and policies change over time, and site selection decisions need to take these dynamic changes into account. Additionally, the scale and capacity of logistics facilities add to the complexity of site selection, requiring predictions of future business growth and demand changes.

This article reviews the literature on the use of Multi-Criteria Decision Making (MCDM) methods for logistics site selection. It systematically summarizes the development history and current state of research in this field, aiming to provide references for the content and methods of using MCDM methods for logistics site selection, as well as for future research trends..

2. Development History

The application of Multi-Criteria Decision Making (MCDM) methods in logistics location research can be traced back to the 1970s when logistics and supply chain management began to gain attention. As location issues are a key component of the logistics system, they naturally became the focus of research.

In the 1970s, with the development of operations research and decision science, MCDM methods started to be applied to logistics location problems. Initial methods included simple weighted scoring and the Analytic Hierarchy Process (AHP). The introduction of these methods marked a shift in logistics location decision-making from single criteria to multiple criteria, taking into account various factors such as cost, transportation time, and service level. In the 1990s, with the advancement of computer technology, more complex MCDM methods such as Data Envelopment Analysis (DEA), Genetic Algorithms (GA), and Simulated Annealing (SA) began to be applied to logistics location. These methods could handle more complex decision-making environments, such as nonlinear problems, multi-objective optimization, and dynamic location issues. Entering the 21st century, the application of MCDM methods in logistics location has become more diversified and integrated. Researchers started to combine MCDM methods with other decision-making tools, such as Geographic Information Systems (GIS) and expert systems. More MCDM models specifically for logistics location emerged, such as GIS-based MCDM models, which could provide spatial analysis and visualization, helping decision-makers better understand location issues. In recent years, with the development of artificial intelligence and machine learning technologies, intelligent algorithms such as fuzzy logic, neural networks, and ant colony optimization algorithms have been applied within MCDM methods to solve logistics location problems. These intelligent algorithms can handle large-scale decision-making problems and provide more accurate predictions and optimization results. As concerns for environmental sustainability grow, MCDM methods in logistics location research have also begun to consider environmental impacts and social responsibilities. Researchers have developed comprehensive evaluation models that include environmental and social criteria to achieve a balance between economic, environmental, and social triple bottom lines.

From the development history outlined above, it is evident that the application of MCDM methods in logistics location research has continuously evolved, from initial simple models to today's complex intelligent algorithms, reflecting the complexity and diversity of logistics location decision-making. With technological advancements and the development of globalization, the application of MCDM methods in the field of logistics location will continue to expand to meet the changing market demands and environmental challenges.

3. Current Research Status

3.1. Location Methods based on Optimization Theory

Location research has garnered the interest of scholars across various disciplines. The methods for addressing location problems primarily fall into two categories. One is based on optimization theory, with the fundamental principle of solving being: to construct a mathematical model for location optimization according to the individual/multiple objectives and characteristics of the location problem, the known conditions available, various constraints imposed, and the interrelationships among different elements. Then, precise or approximate solution methods/algorithms are applied to solve the formulated optimization model, ultimately deriving the optimal location scheme for the problem[1]. Typical methods include the Center of Gravity method [2], the P-Center method[3], the P-Median method [4], and the Coverage Model method [5]. However, these models only consider some factors, such as the distance and time from distribution centers to customers, the capacity limitations of distribution centers, the capacity limitations of delivery vehicles, vehicle type restrictions, and customer satisfaction. For instance, Ben Mohamed et al.[6] divided a network into two capacitated delivery echelons: each echelon has a specific location-allocation-transportation scheme that must meet future demands. The aim is to determine the number and location of storage and distribution platforms, as well as the capacity allocation from the first echelon to the second echelon platforms. This is a capacitated vehicle routing problem with multiple warehouses, which is solved using branch-and-cut and pricing algorithms. Kyriakakis et al.[7] proposed a Hybrid Tabu Search - Variable Neighborhood Descent (HTS-VND) metaheuristic algorithm to solve the cumulative capacity restriction vehicle routing problem with time windows. Meidute-Kavaliauskiene et al. [8]presented a multi-period, multi-regional perishable product supply chain considering procurement time, periodic cost, and customer satisfaction, aiming to minimize the total cost, delivery time, and pollutant emissions in the network while maximizing customer satisfaction. In the process of constructing the aforementioned models, the number of objectives and constraints continually increases to more closely approximate real-world descriptions, which adds to the difficulty of solving the problem. Moreover, most models only consider a limited set of objectives and constraints, thus restricting the problem's description [9].

3.2. Location Methods based on Scoring and Ranking of Influencing Factors

These location methods are mainly applied in situations where multiple alternative proposals and their associated attribute indicators/influencing factors have already been identified. The basic principle involves using appropriate evaluation methods to assess the proposed alternatives based on the selected attribute indicators, then ranking them according to the evaluation results, and finally selecting the most suitable optimal location scheme following certain rules. Typically, there are numerous and complex factors that influence location decisions, including natural conditions, geographical location, transportation convenience, comprehensive strength/competitiveness, and the rationality of the overall layout [10]. This is a process of analyzing multiple potential alternatives based on a series of attribute indicators (a single indicator cannot reflect the complexity of the actual situation). Therefore, the location problem can be viewed as a MCDM (Multi-Criteria Decision Making) problem, involving the comprehensive evaluation and ranking of multiple research objects with multiple attribute indicators. MCDM methods are capable of handling complex decision-making problems with different types of data[11], and have been proven effective and feasible for the multi-scheme evaluation of multi-indicator systems[12-14]. Hence, choosing the appropriate MCDM method is key to the analysis and assessment.

Pham, Thi Yen et al. [15] developed a hybrid model combining fuzzy Delphi method and TOPSIS to address Vietnamese logistics center location issues under uncertain information, highlighting freight demand, market proximity, production areas, customer proximity, and transportation costs as key factors. The study identified the northeastern provinces of Ho Chi Minh City as the optimal site, followed by North Hanoi and Da Nang.

Kang, Yllah Okin et al. [16] used GIS and MCDM with AHP for systematic and objective analysis of landfill site selection in Kinshasa, DRC, integrating spatial datasets to generate suitability

ISSN: 2710-0723

maps. The findings underscore the urgency for in-depth analysis of future landfill sites, emphasizing environmental impact minimization and community health risk reduction.

Moslem et al.[17] proposed a hybrid Decomposed Fuzzy AHP-CODAS model to optimize parcel locker location in Dublin's last-mile delivery, prioritizing safety and identifying post offices as the best locations, effectively capturing data uncertainty for informed decision-making.

Aljohani and Thompson[18]introduced a multi-criteria spatial assessment framework for optimizing the location of freight consolidation facilities in Melbourne's city center, using GIS and MCDM with 11 decision criteria. TOPSIS ranked 20 candidates, favoring industrial areas with good road access and proximity to goods recipients, with sensitivity analysis revealing the impact of operational requirements and residential proximity preferences on site suitability.

Önden et al.[19]identified factors and weights affecting logistics center location through expert surveys and used GIS for spatial analysis to find suitable locations for new logistics centers serving urban areas, demonstrating the method's applicability in Istanbul.

Önden et al.[20]proposed a spatial multi-criteria evaluation method combining F-AHP and GIS to assess the suitability of logistics center locations, focusing on 19 developing centers in Turkey and considering seven decision criteria, revealing the importance of location for logistics network efficiency and cost reduction.

Feng et al. [21]introduced a novel MCDM and GIS-based method for emergency logistics center (ELC) site selection, identifying nine key criteria and using entropy and CRITIC methods to determine weights, resulting in a ranking of alternatives in Xi'an, China, with a high sensitivity to weight changes.

Eren and Katanalp[22]developed a GIS-based method using FL, AHP, VIKOR, and psychometric-VIKOR for bike-sharing station location selection, considering land use types to enhance system sustainability and efficiency.

Żak and Węgliński[23] presented a two-stage procedure for logistics center location, using Electre III/IV for macro-regional analysis and ranking, followed by micro-analysis for precise site selection, identifying optimal regions in western and central Poland.

Ao Xuan et al. [24] applied a hybrid MCDM approach for hydrogen production plant location in Uzbekistan, with solar radiation, sunshine duration, and wind speed as key criteria, ranking Bukhara province as the most suitable site.

Wang et al.[25] selected optimal sites for biorefineries using GIS-based MCDM and developed a mixed-integer linear programming model for strategic and tactical planning under uncertainty, providing reliable solutions considering decision-makers' risk tolerance.

Liu Xiaofeng et al. [26] proposed an ANP-based model for logistics center site evaluation, categorizing factors into economic, social, and technical aspects and providing a scientific decision support tool by considering uncertainties and interdependencies.

Table 1 presents the advantages and limitations of various MCDM methods most commonly used in location problems.

ISSN: 2710-0723

Table 1. Multi-attribute decision-making methods and their characteristics

Methodology	Advantages	Limitations
AHP	Flexible, proficient and easy to calculate, with the possibility of creating a hierarchy of indicators and calculating subjective weights	No consideration of interactions between indicators
TOPSIS	Can reflect proximity/overall similarity between options and the ideal option	The inability to distinguish between the advantages and disadvantages of schemes on the mid-penetration lines of positive and negative ideal solutions does not reflect the differences in the trends of exponential changes
GRA	It is possible to measure the similarity of the shape of the curves between the sequences of programmes	The proximity and numerical directionality of the programme sequences are not taken into account, and the overall evaluation of the system programme is somewhat flawed
ELECTRE	Applies when there are non-comparable programmes	More parameters need to be defined and the calculation process is complex
PROMETHEE	Indicators do not need to be standardised and information loss can be avoided	Failure to consider the risk aversion of decision makers
VIKOR	Ability to take into account the best interests of the whole and the least regrets of individuals, with a simple calculation process	Poor accuracy of evaluation results for uncertainties
TODIM	Capable of reflecting decision makers' loss and risk aversion and preferences	Parameters involved are not clearly defined and evaluation results are highly dependent on the values taken by decision makers
DEMATEL	Consistency errors due to too many comparisons can be avoided	Failure to reflect the ambiguity of decision information and the subjectivity of decision support systems
BWM	Can reduce the number of comparisons and provide consistent comparisons, with simple calculations and relatively reliable results	Requires subjective judgement and scoring by multiple experts, which is somewhat subjective

Note: AHP (Analytic Hierarchy Process); TOPSIS (Technique for Order Preference by Similarity to Ideal Solution); GRA (Grey Relational Analysis); ELECTRE (Elimination et Choix Traduisant la Realite); PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluationsp ; VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje); TODIM (an acronym in Portuguese of interactive and MCDM); DEMATEL (Decision Making Trial and Evaluation Laboratory); BWM (Best-Worst Method).

3.3. Location Methods Combining Multiple Approaches

Considering the characteristics and strengths and weaknesses of different location methods, some scholars have combined various approaches, such as integrating qualitative and

ISSN: 2710-0723

quantitative methods, evaluation with optimization, and mathematical programming with intelligent algorithms. These combined location methods can account for the inherent attributes of logistics hubs while optimizing system costs and improving quality and efficiency. This integrated approach is gaining increasing attention and has been successfully applied in multiple location domains.

Yang Yang et al. [27] proposed an urban public transit hub layout optimization method based on hub attractiveness, addressing the layout problem of urban transit hubs in two stages. First, they introduced the hub attractiveness index to comprehensively evaluate the attractiveness of potential hub points from aspects of accessibility, public transit concentration, and connectivity. Second, considering the dual interests of passengers and operators, they established a multi-objective optimization model aimed at maximizing hub radiation area, minimizing similarity between hubs, and minimizing land costs. To improve solution efficiency and accuracy, they used a multi-objective genetic algorithm for model solving.

Chang et al. [28] proposed a two-stage framework for selecting inland cities and the best inland dry port location. First, they applied the fuzzy C-means clustering (FCM) method to screen candidate cities from the vast hinterland of Dalian Port, considering evaluation factors affecting site selection decisions. Second, they proposed a cost minimization linear programming model, combined with a genetic algorithm (GA), to select the best location and capacity level among the candidate cities.

Zhao et al. [29] proposed a segmentation method for urban metro networks, then selected indicators to evaluate the importance of metro stations based on complex network theory, and calculated the weights of each indicator using the Analytic Hierarchy Process (AHP). They used the TOPSIS model to assess the importance of metro stations and determine candidate metro distribution centers. Finally, combining logistics demand, they constructed a location model to minimize the total travel distance of couriers and determine the final metro distribution center.

Nguyen et al. [30] combined data mining, complex network theory, and gravity-based community structure methods to study the optimal location of land port hubs in inland transportation systems.

4. Conclusion

Multi-Criteria Decision Making (MCDM) methods have been extensively applied in logistics location decision-making, offering a robust framework for addressing the complex and multifaceted nature of site selection problems. By integrating qualitative and quantitative data, these methods enable a comprehensive evaluation of various factors such as transportation costs, market demand, land prices, and infrastructure, leading to more informed and efficient location choices. The use of MCDM methods, including AHP, TOPSIS, GRA, and others, has been demonstrated to enhance logistics operations by optimizing costs, improving service quality, and increasing operational efficiency.

Despite the significant advancements, there are still areas where MCDM methods in logistics location can be improved. One notable limitation is the challenge of dealing with uncertainty and the dynamic nature of logistics environments, which can affect the accuracy and reliability of decision outcomes. Additionally, the complexity of some MCDM models may require specialized knowledge and software, potentially limiting their accessibility to practitioners without extensive training.

Looking ahead, future research should focus on developing more adaptive MCDM models that can better handle the uncertainties and changes in logistics systems. There is also a need for user-friendly tools and software that can facilitate the application of these methods in practical settings. Furthermore, integrating emerging technologies such as artificial intelligence and big data analytics into MCDM frameworks could provide deeper insights and more precise

ISSN: 2710-0723

predictions for logistics location decisions. By addressing these areas, MCDM methods can continue to evolve and remain at the forefront of logistics location research, contributing to the advancement of the field.

References

[1] Wang, Jiaxin, Xiaoxia Zhu, and Jia Jiang. Emergency Logistics Center Location Selection Based on Hybrid Multinattribute, 2016.

[2] Yang, D. Y., and Zhu, Y.: "Analysis of fresh retail front warehouse siting problem based on centre of gravity method and factorial analysis." Logistics Technology 42, no. 12 (2023): 92-97.

[3] Demange, Marc, Virginie Gabrel, Marcel Adonis Haddad, and Cécile Murat: "A Robust P-Center Problem under Pressure to Locate Shelters in Wildfire Context." EURO J. Comput. Optim. 8 (2020): 103-39.

[4] Rabie, Hassanein, and Saïd Salhi: "A New Hybrid-Heuristic Approach for Vertex P-Median Location Problems." International Journal of Advanced Computer Science and Applications (2022).

[5] Wang, Xiao-ming: "Location Selection of Marine Product E-Commerce Distribution Centers Based on Effective Covering Model." Journal of Coastal Research 110 (2020): 15 - 19.

[6] Ben Mohamed, Imen, Walid Klibi, Ruslan Sadykov, Halil Şen, and François Vanderbeck: "The Two-Echelon Stochastic Multi-Period Capacitated Location-Routing Problem." European Journal of Operational Research 306, no. 2 (2023): 645-67.

[7] Kyriakakis, Nikolaos A., Ioannis Sevastopoulos, Magdalene Marinaki, and Yannis Marinakis: "A Hybrid Tabu Search – Variable Neighborhood Descent Algorithm for the Cumulative Capacitated Vehicle Routing Problem with Time Windows in Humanitarian Applications." Computers & Industrial Engineering 164 (2022): 107868.

[8] Meidute-Kavaliauskiene, Ieva, Figen Yıldırım, Shahryar Ghorbani, and Renata Činčikaitė: "The Design of a Multi-Period and Multi-Echelon Perishable Goods Supply Network under Uncertainty." (2022).

[9] Xu, Jinghai, Xiaozhe Yin, Dingchao Chen, Jiwen An, and Gaozong Nie: "Multi-Criteria Location Model of Earthquake Evacuation Shelters to Aid in Urban Planning." International journal of disaster risk reduction 20 (2016): 51-62.

[10] Liu, Aijun, Yingxue Zhao, Xiaoge Meng, and Yan Zhang: "A Three-Phase Fuzzy Multi-Criteria Decision Model for Charging Station Location of the Sharing Electric Vehicle." International Journal of Production Economics 225 (2020): 107572.

[11] Long, Suzanna, and Scott E. Grasman: "A Strategic Decision Model for Evaluating Inland Freight Hub Locations." Research in Transportation Business & Management 5 (2012): 92-98.

[12] Ameen, Raed Fawzi Mohammed, and Monjur Mourshed: "Urban Sustainability Assessment Framework Development: The Ranking and Weighting of Sustainability Indicators Using Analytic Hierarchy Process." Sustainable Cities and Society 44 (2019): 356-66.

[13] Zeng, Shouzhen, Shyi-Ming Chen, and Kang-Yun Fan: "Interval-Valued Intuitionistic Fuzzy Multiple Attribute Decision Making Based on Nonlinear Programming Methodology and Topsis Method." Information Sciences 506 (2020): 424-42.

[14] Zeng, Shouzhen, and Yao Xiao: "A Method Based on Topsis and Distance Measures for Hesitant Fuzzy Multiple Attribute Decision Making." Technological and Economic Development of Economy 24 (2018): 969-83.

[15] Pham, Thi Yen, Hye Min Ma, and Gi Tae Yeo: "Application of Fuzzy Delphi Topsis to Locate Logistics Centers in Vietnam: The Logisticians' Perspective." The Asian Journal of Shipping and Logistics 33, no. 4 (2017): 211-19.

[16] Kang, Yllah Okin, Helmut Yabar, Takeshi Mizunoya, and Yoshiro Higano: "Optimal Landfill Site Selection Using Arcgis Multi-Criteria Decision-Making (Mcdm) and Analytic Hierarchy Process (Ahp) for Kinshasa City." Environmental Challenges (2024).

ISSN: 2710-0723

[17] Moslem, Sarbast, Fatma Kutlu Gündoğdu, Serhat Saylam, and Francesco Pilla: "A Hybrid Decomposed Fuzzy Multi-Criteria Decision-Making Model for Optimizing Parcel Lockers Location in the Last-Mile Delivery Landscape." Applied Soft Computing 154 (2024): 111321.

[18] Aljohani, Khalid A, and Russell George Thompson: "A Multi-Criteria Spatial Evaluation Framework to Optimise the Siting of Freight Consolidation Facilities in Inner-City Areas." Transportation Research Part A-policy and Practice 138 (2020): 51-69.

[19] Önden, İsmail, Fahrettin Eldemir, A. Zafer Acar, and Metin Çancı: "A Spatial Multi-Criteria Decision-Making Model for Planning New Logistic Centers in Metropolitan Areas." Supply Chain Analytics (2023).

[20] Önden, Ismail, A. Zafer Acar, and Fahrettin Eldemir: "Evaluation of the Logistics Center Locations Using a Multi-Criteria Spatial Approach." Transport 33 (2016): 1-13.

[21] Feng, Zengxi, Gangting Li, Wenjing Wang, Lutong Zhang, Weipeng Xiang, Xin He, Maoqiang Zhang, and Na Wei: "Emergency Logistics Centers Site Selection by Multi-Criteria Decision-Making and Gis." International journal of disaster risk reduction 96 (2023): 103921.

[22] Eren, Ezgi, and Burak Yiğit Katanalp: "Fuzzy-Based Gis Approach with New Mcdm Method for Bike-Sharing Station Site Selection According to Land-Use Types." Sustainable Cities and Society 76 (2022): 103434.

[23] Żak, Jacek, and Szymon Węgliński: "The Selection of the Logistics Center Location Based on Mcdm/a Methodology." Transportation Research Procedia 3 (2014): 555-64.

[24] Ao Xuan, Hoa, Vuong Vu Trinh, Kuaanan Techato, and Khamphe Phoungthong: "Use of Hybrid Mcdm Methods for Site Location of Solar-Powered Hydrogen Production Plants in Uzbekistan." Sustainable Energy Technologies and Assessments 52 (2022): 101979.

[25] Wang, Mengmeng, Ling Ji, Yulei Xie, and Guohe Huang: "Regional Bioethanol Supply Chain Optimization with the Integration of Gis-Mcdm Method and Quantile-Based Scenario Analysis." Journal of Environmental Management 351 (2024): 119883.

[26] Liu, X. F., Chen, T., Liu, J. M., and Zhang, H. B.: "Site selection of logistics centres based on ANP." Industrial Engineering, no. 05 (2007): 136-40.

[27] Yang Yang, Yu Bin, Kong Lu, Sun Ruiping, and Yang Zhongzhen: "An optimisation method of urban bus hub layout based on hub charisma degree." Systems Engineering Theory and Practice 33, no. 09 (2013): 2422-29.

[28] Chang, Zheng, Theo E. Notteboom, and Jing Lu: A Two-Phase Model for Dry Port Location with an Application to the Port of Dalian in China.

[29] Zhao, Laijun, Huiyong Li, Meichen Li, Yan Sun, Qingmi Hu, Shirong Mao, Jianguang Li, and Jian Xue: "Location Selection of Intra-City Distribution Hubs in the Metro-Integrated Logistics System." Tunnelling and Underground Space Technology 80 (2018): 246-56.

[30] Van Nguyen, Truong, Jie Zhang, Li Zhou, Meng Meng, and Yong He: "A Data-Driven Optimization of Large-Scale Dry Port Location Using the Hybrid Approach of Data Mining and Complex Network Theory." Transportation Research Part E: Logistics and Transportation Review 134 (2020): 101816.