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Strategic Development of Logistics Distribution Centers in Port Hinterland Regions – A Case Study of Croatia's Bakar Industrial Zone

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ABSTRACT

This paper provides a systematic literature review regarding the strategic development of the logistics distribution centers in port hinterland regions, specifically on the Bakar Industrial Zone as a case study. The search of the ISI Web of Science database, combined with the research objective criteria, revealed a total of 17 key papers for the study. Based on the thematic relevance, the papers were grouped into six research clusters: General overview and background, Problem definition and conceptual framework, Optimization models and algorithmic approaches, Simulation and empirical studies, Supply chain integration and network optimization, and Sustainability and efficiency considerations. Cluster content analysis identified nine proposed strategic guidelines for sustainable development of logistics distribution centers: Infrastructure modernization and investment, Supply chain integration, Advanced optimization and algorithm adoption, Green and sustainable practices, GIS and digitalization integration, Uncertainty management via grey systems, Simulation and empirical validation, Continuous improvement and sensitivity analysis, and Integrated decision support systems. Together, these nine strategic guidelines advance the sustainable development of LDCs by ensuring the state-of-the-art infrastructure, integrated supply chain planning, advanced optimization and digital technologies, and adopting green practices to improve operational efficiency and reduce the impact on the environment. The above guidelines were implemented on the Bakar Industrial Zone case study, in order to improve infrastructure, harmonize regulations, attract investments and apply sustainable solutions.

1 Introduction

As an essential part of the supply chain, Logistics Distribution Centers (LDCs) are considered very important in the current globalized economy, which ensures efficient flow of products [1]. LDCs are where freight is consolidated, warehoused, packaged, decomposed and added to in other specified ways during global or regional freight distribution [2]. These centers are serving basic functions such as receiving, storing and shipping goods aiming at minimizing the inventory cost and production cost according to [3]. Strategic location also matters, because the LDCs situated close to major transport points can accelerate distribution and enhance the performance of the supply chain [4]. Research has shown that successful LDC implementation can lead up to a 25% reduction in operational costs as a result of rationalised transportation and reduced levels of unnecessary stock [5]. Furthermore, the development of technologies, such as automation, digitalization, integration of blockchain and IoT systems, has been demonstrated to further improve the logistics efficiency and transparency [6–8]. Lastly, application of the state-of-the-art technologies such as autonomous truck platooning will enable the potential directions for the more efficient distribution process in the hinterland regions of ports [9].

LDCs face a number of obstacles to their function. Traffic jams and lack of infrastructure, especially in areas that have high cargo volumes, result in delays and increased operational costs [10]. Disparate and fragmented regulatory systems and cumbersome customs procedures tend to have administrative delays in the operational efficiency, thus hindering smooth functioning [11]. Furthermore, despite significant research that has been conducted on the functional and operational aspects of LDCs, current literature still reflects a paucity of broad strategic development orientation. It is this gap that the authors aim to address by critically examining recent bibliometric and certain qualitative studies, which categorize research into thematic segments, without producing practical implementable roadmaps for practitioners and policy makers [12] [13] . To alleviate the above-mentioned gap, a systematic literature review of strategic guidelines included in the literature in relation to the sustainable development of LDCs is proposed in this paper. The main scientific objective is to create a database containing the main publications on LDCs sustainable development from WOS database, extract the main scientific knowledge from content analysis of the inquired database in the issues of research cluster formulation, to explore research clusters so as to offer key strategic guidelines for LDCs sustainable development and potential implementation opportunities on the case study of Bakar Industrial Zone, and to summarize the crucial findings from SLR and strategic guidelines in connection with the case study of Bakar Industrial Zone.

2 Systematic Literature Review: Main Research Insights

A Systematic Literature Review (SLR) is a methodological technique used to systematically synthesize the available research evidence in order to answer a clearly formulated research question. This method is frequently used in many scientific areas such as computer science, software engineering, transport engineering, medicine, social sciences, with the purpose of systematically collecting, evaluating, and integrating findings from the literature. Unlike conventional literature reviews, which rely on authors' opinions to draw conclusions, SLRs are conducted according to predefined protocols which are designed to reduce bias; increase transparency; and generate findings; that are reliable and scientifically replicable [14]. The next four major steps on conducting a SLR are given as:

- Step 1: Define the research objective: The research objective guides the entire review process, including: (1) The literature search, (2) Study selection, and (3) Data synthesis. In step 1 of the study, the review goals are determined and a Boolean search term query is constructed that resulted in 41 articles;
- Step 2: Comprehensive literature search: Data extraction from multiple scientific databases via Boolean search term operator employment. The search term query is executed and obtained 41 articles;
- Step 3: Screening of selected studies: The selected studies are filtered on basis of predefined inclusion and exclusion criteria. We applied predefined inclusion/exclusion criteria (document type: article, English language, title/abstract relevance, citation impact) to those 41 records, narrowing the set to 17 core articles.
- Step 4: Extract and synthesize data: Data extraction involves collecting relevant information from the included studies, such as study design, sample size, and key findings. This data is then synthesized to provide a comprehensive overview of the evidence. The full texts of the 17 articles were thoroughly evaluated, which enabled to categorize them into six thematic areas. Further articles' evaluation resulted in the revelation of strategic guidelines for sustainable LCD development.

In this study, the authors employ a systematic literature review methodology to evaluate recent trends in Strategic Development of Logistics Distribution Centers in Port Hinterland Regions with the research objective to develop strategical recommendations for their sustainable development. Figure 1. depicts the four-step SLR approach utilized within the entire study.

Figure 1 reveals that the study followed a systematic four-step SLR process. First, an ISI Web of Science search was conducted using predefined criteria, which initially retrieved 41 articles. Next, the dataset was refined by filtering based on citation relevance, resulting in a selection of 17 articles. These articles were then subjected to content analysis and organized into six distinct research clusters for thematic clarity. Finally, strategic guidelines were developed from the synthesized findings, providing future research directions for the sustainable development of logistics distribution centers.

The bibliographic dataset comprising published articles on logistics distribution centers strategic development is compiled from the Web of Science (WoS)

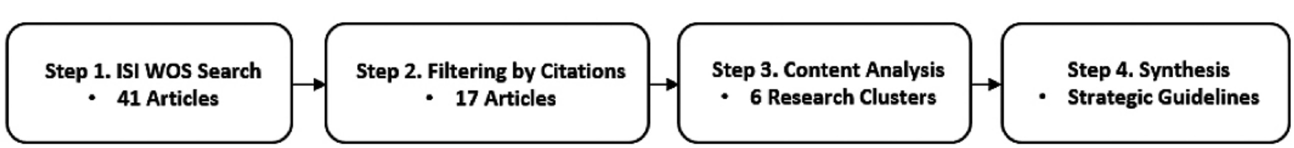

Figure 1 The four – step Systematic Literature Review Approach

Table 1 Keyword search and Boolean Search Term Utilization in Web of Science Database

Step	Action/ Filter	Article Number
1	Initial ISI Web of Science Search using "Logistics Distribution Centers" OR "Warehouse Management" AND "Supply Chain Management" AND "Green Supply Chain Management"	41
2	Refine by Document Type: Article	40
3	Refine by Language: English	30
4	Information Filtering: Screen titles/ abstracts/ keywords for explicit focus on strategic or sustainable development of logistics distribution centers	17

* The literature search was conducted on 25th February 2025. The search process contains the following attributes: **Timespan**: All years; **Indexes**: SCI-EXPANDED, SSCI, ESCI

Table 2 A list of the 17 Articles extracted from WoS for the Systematic Literature Search

Cluster	Reference	Citations
General Overview and Background	Pavlić Skender, H., Zaninović, P. A., & Lolić, A. The Importance of Logistics Distribution Centers as Nodes in Logistics Networks. *Pomorstvo* 2019, 33(2), 149–157. [1]	1
	Lee, P. T.-W., & Song, Z. Exploring a New Development Direction of the Belt and Road Initiative in the Transitional Period Towards the Post–COVID-19 Era. *Transportation Research Part E: Logistics and Transportation Review* 2023, 172, 103082. [16]	19
Problem Definition and Conceptual Framework	Li, G., Jin, F., Chen, Y., Jiao, J., & Liu, S. Location Characteristics and Differentiation Mechanism of Logistics Nodes and Logistics Enterprises Based on Points of Interest (POI): A Case Study of Beijing. *J. Geogr. Sci.* 2017, 27, 879–896. [17]	38
	Wu, Z., Xu, J., & Xu, Z. A Multiple Attribute Group Decision-Making Framework for the Evaluation of Lean Practices at Logistics Distribution Centers. *Ann. Oper. Res.* 2016, 247, 735–757. [18]	24
	Zhou, L., Zhang, G., & Liu, W. A New Method for the Selection of Distribution Centre Locations. *IMA J. Manag. Math.* 2017, 28, 421–436. [19]	5
Optimization Models and Algorithmic Approaches	Yang, L., Ji, X., Gao, Z., & Li, K. Logistics Distribution Centers Location Problem and Algorithm under Fuzzy Environment. *J. Comput. Appl. Math.* 2007, 208, 303–315. [20]	80
	Pan, J.-S., Fu, Z., Hu, C.-C., Tsai, P.-W., & Chu, S.-C. Rafflesia Optimization Algorithm Applied in the Logistics Distribution Centers Location Problem. *J. Internet Technol.* 2022, 23, 1541–1555. [21]	18
	Sun, H., Gao, Z., & Wu, J. A Bi-Level Programming Model and Solution Algorithm for the Location of Logistics Distribution Centers. *Appl. Math. Modell.* 2008, 32, 610–616. [22]	14
	Mei, Z., Chi, X., & Chi, R. Research on Logistics Distribution Center Location Based on Hybrid Beetle Antennae Search and Rain Algorithm. *Biomimetics* 2022, 7, 194. [23]	2
	Khairunissa, M., & Lee, H. Hybrid Metaheuristic–Based Spatial Modeling and Analysis of Logistics Distribution Center. *ISPRS Int. J. Geo-Inf.* 2022, 11(1), 5. [24]	2
	Chi, R., Mei, Z., & Chi, X. A Hybridization of Cuckoo Search and Differential Evolution for the Logistics Distribution Center Location Problem. *Math. Probl. Eng.* 2019, Article ID 7051248. [25]	22
	Qishan, H., & Hong, L. Location of Logistics Distribution Center with Grey Demand and Grey Production Capacity Based on Hybrid PSO. *Proc. 2010 IEEE Int. Conf. Syst. Man Cybern.*, 2010, 86–91. [26]	2
Simulation and Empirical Studies	Chen, T.-L., Chen, J. C., Huang, C.-F., & Chang, P.-C. Solving the Layout Design Problem by Simulation–Optimization Approach: A Case Study on a Sortation Conveyor System. *Simul. Model. Pract. Theory* 2021, 106, 102192. [27]	8
	Sun, Y., Geng, N., Gong, S., & Yang, Y. Research on Improved Genetic Algorithm in Path Optimization of Aviation Logistics Distribution Center. *J. Intell. Fuzzy Syst.* 2020, 38, 1–9. [28]	14
Supply Chain Integration and Network Optimization	Nemati, Y., & Hosein Alavidoost, M. H. A Fuzzy Bi-Objective MILP Approach to Integrate Sales, Production, Distribution and Procurement Planning in a FMCG Supply Chain. *Soft Comput.* 2019, 23, 4871–4890. [29]	28
	Zhang, Q., Wang, H., & Liu, H. 4-Stage Distribution Network Optimization of Supply Chain with Grey Demands. *Kybernetes* 2012, 41, 633–642. [30]	3
Sustainability and Efficiency Considerations	Ene, S., Küçükoğlu, İ., Aksoy, A., & Öztürk, N. A Genetic Algorithm for Minimizing Energy Consumption in Warehouses. *Energy* 2016, 114, 973–980. [31]	59

database, which is widely acknowledged as one of the most renown scientific databases in academia. Web of Science has consistently been utilized as a reliable source of bibliographic information in literature reviews across various fields, including supply chain management [15]. The literature search process in WoS is presented in Table 1.

From an initial topic-based search on Web of Science using the keywords "*Logistics Distribution Centers*" OR "*Warehouse Management*" AND "Supply Chain Management" AND "*Green Supply Chain Management*," 41 articles were identified. Restricting results to articles reduced the count to 40. Further refining by language (English) yielded 30 articles, and finally, applying the independent title, abstract, and keyword screening options and covering all publication years in the SCI-EXPANDED, SSCI, and ESCI indexes (search conducted on 25 February 2025) resulted in 17 articles for review. Studies that were excluded are those that marginally addressed logistics distribution centers; and employing algorithm comparisons. All searches covered the entire timespan of the SCI-EXPANDED, SSCI, and ESCI indexes.

The qualitative analysis structured the 17 selected articles into six research clusters: General overview and background; Problem definition and conceptual framework; Optimization models and algorithmic approaches; Simulation and empirical studies; Supply chain integration and network optimization; and Sustainability and efficiency considerations. Table 2 contains the selected articles within their respective clusters in which they are allocated.

The concordance to Table 2 shows that the dominated topic related to strategic development of logistics distribution centers is the Optimization models and algorithmic approaches cluster (with the largest total of 140 citations from six articles) in which an emphasis on heuristic and metaheuristic techniques for the purpose of optimizing location decisions is observed. Remarkable papers include Yang et al. (2007) having 80 citations as well as Chi et al. (2019) with 22 citations which are both focusing on hybrid optimization approaches. Sustainability and Efficiency Considerations, presented by Ene et al. (2016) with 59 citations indicates that energy-efficient warehouse operations is one of the most important aspect of green supply chain strategy. The Problem Definition and Conceptual Framework (67 citations, three articles) refers to logistics center location problem and uncertainty management with (Li et al. (2017) as the major study (with 38 citations). The General Overview and Background research cluster (20 citations, two articles) provides an overview to the importance of logistics distribution centers in supply chains with Lee and Song (2023) as main contributor (19 citations). Supply Chain Integration and Network Optimization (31 citations, 2 articles) looks at the role of distribution centers in network design, while Nemati and Alavidoost (2018) provide a critical take on integrated sales and operations planning (28 references). Finally, Simulation and Empirical Studies (22 citations, two articles) consider case studies and decision-making from simulations, with Sun et al. (2017) being the seminal article (14 citations). The clusters via content analysis approach are detailed in the next section.

3 Systematic Literature Review Main Insights

This section provides a structured synthesis of the selected studies regarding logistics distribution centers, highlighting key insights from the systematic literature review. This section is organized into six following thematic research areas which are elaborated in the following subsections.

3.1 General Overview and Background

This research area focuses on strategically located LDCs integrating multimodal infrastructure, resilience and sustainability.

Pavlić Skender et al. (2019) highlight LDCs as key nodes that are considered to be links between manufacturing sites and final markets to facilitate cross-national trade [1]. Their analysis for Western and Central Europe reveals that the major LDCs use their proximity to ports, airports, and multimodal transportation centers in order to efficiently and economically serve large hinterlands. Cities like Antwerp, Rotterdam, Amsterdam, and Hamburg are able to have high throughput despite road congestion due to advanced infrastructure integrated into their logistics networks. On the other hand, Croatia's geopolitical position that benefits from well-established European corridors is hampered by outdated infrastructure and insufficient infrastructure upgrade efforts. Lee and Song (2023) study the COVID-19 pandemic and geopolitical risks—particularly those in the China–U. S. trade tensions and the Russia–Ukraine war — had soured LDC operations in the context of the Belt and Road Initiative (BRI) [16]. They suggest a wide research agenda to rejuvenate BRI logistics, such as predicting LDC capacity in a slowdown of PRC growth, designing efficient inter-center transport networks, creating sea–rail intermodal corridors in NEA, testing infrastructure investment influences, establishing green shipping corridors, restructuring the port governance in 6th-generation ports, planning for integrated humanitarian logistics systems, calculating supply chain security and energy risks, and transferring smart-port practices to the big terminals. The scholars argue that in the face of current challenges and in support of long-term development, investment can only be maximized by strategic policy reform, stronger stakeholder collaboration, faster digitalization, and more focused decarbonization by the BRI LDCs.

3.2 Problem Definition and Conceptual Framework

The study of logistics center agglomeration and fuzzy-rough multiobjective optimization in the presence of uncertainty is the main topic of this research area.

Li et al. (2017) employ the data from Tencent Online Maps in Beijing and demonstrate that for the logistics distribution centers and the entities that operate them, their co-agglomeration tends to be in downtown edges, suburbs and beyond – which resembles a specific spatial structure [17]. They differentiate between government-controlled public logistics parks and corporate-controlled terminal facilities, and show that location of transportation routes and land-use authorities interact with corporate strategies for asset allocation to play an important part in their development. But the level of integration between public and private is not satisfactory, which may increase distribution cost, so the authors propose enhanced classification system and data verification of multi-source to improve the ability of describing the spatial role and spatial dynamic of the urban down logistics network. Wu, Xu and Xu (2015) propose a two-tuple fuzzy linguistic model for multi-attribute group decision-making by integrating consensus reaching and entropy-based weight determination [18]. When applied to a distribution center of a commercial tobacco company in Sichuan, the model evaluates six factors, including management, product quality, customer service, staff quality, operational standardization and quality control, and ranks management as the most important. The results have also verified the validity of the framework and the potential to be further applied in evaluating logistics centers under uncertain information. Zhou, Zhang and Liu (2015) consider the location problem under data inaccuracy and present a Rough Multi-objective Synthesis Effect model [19]. In this way the rough membership degree of the problem's feasible region is incorporated into a set of multi decision objective functions, leading (in a number of) to crisp multi-objective programming models which correspond to different risk preferences of an end-decision making agent. Solutions obtained based on a rough simulation genetic algorithm are superior to other existing methods based on fuzzy in the sense that a more balanced trade-off between objectives and failure risk is provided, as illustrated by the comparative case studies.

3.3 Optimization Models and Algorithmic Approaches

This research area deals with hybrid metaheuristics and fuzzy-chance-constrained programming applied to robust logistics center siting optimisation.

Yang et al. (2007) present the distribution-center location problem under uncertainty as a fuzzy chance-constrained program for minimizing the total system cost to find the optimal facility location [20]. They solve this model with a hybrid heuristic -namely, they combine tabu search, genetic algorithms, and fuzzy simulation- and validate with numerical experiments that the method is well-suited for facing robustness and parameter sensitivity issues. Pan et al. (2022) introduce Rafflesia Optimization Algorithm (ROA), an evolutionary metaheuristic based on lifecycle characteristics of the parasitic plant [21]. ROA switches between local search (insect attractant), efficiency pruning (insect swallowing), and global search (seed dispersal) to get out of local optima. Validated on CEC2013 problem set and practiced in location problem, the ROA performs better than the seven benchmark approaches in terms of solutions quality, whereas the authors also mention about stability, which is more conducive to improve as a future research direction. Sun, Gao, and Jianjun (2007) formulate a bi-level programming model in which an upper-level problem minimizes a planner's facility costs and a lower-level problem minimizes its customers' distribution costs [22]. They propose a simple reaction-function heuristic to search for equilibria and numerically illustrate and validate its feasibility and benefits, concluding that more complex reaction functions may further improve performance. Mei et al., (2022) extend the Rain Algorithm with Beetle Antennae Search swarm-based hybrid algorithm to build a method which is able for better global exploration and fast convergence [23]. Both experimental results on benchmark problems and a practical location case demonstrate that this Beetle Antennae–Rain hybrid is superior to Beetle Antennae and Rain alone and other classical heuristics in accuracy and efficiency. Khairunissa and Lee (2021) combine GIS spatial analysis (in the form of hotspot analysis, Moran I and Getis-Ord statistics) with a particle-swarm/genetic hybrid for location efficiency regarding Korea Post distribution centers [24]. The computation time and cost of their approach is less than baseline metaheuristics, demonstrating the advantages of spatially informed hybrid algorithms in logistics planning. Chi et al. (2019) present a Cuckoo Search–Differential Evolution algorithm using Lévy-flight exploration and adaptive mutation [25]. The tested problems include well-known benchmark functions and a logistics location problem, demonstrating a faster convergence and better best-solution quality; the future work focuses on how to extend the proposed method to the multi-objective and large-scale problems. Qishan and Hong (2010) consider data uncertainty and present an approach in which grey demands and grey production capacities are modelled for a chance-constrained model that is solved with the help of a hybrid PSO algorithm [26]. The studies demonstrate that the model is effective in ambiguity treatment and good for decision-making in DCS problem under uncertainty.

3.4 Simulation and Empirical Studies

The simulation-optimization and adaptive genetic algorithms to improve throughput and routing inside a distribution system are the main focus points of this research area.

Chen et al. (2021) focus on the rising tide of e-commerce parcel flow and present a simulation-optimization technique to improve sortation performance in a logistics distribution center [27]. They present a hybrid genetic algorithm with local search (LSGA) for obtaining conveyor-layout-shortcuts to maximize throughput and use response surface methodology for tuning parameters. An extensive case study proves that their method is superior to the previous algorithms, in terms of efficiency and reliability. The authors further propose that the model may be developed for truck scheduling, detailed cost optimization and more complicated distribution environment, which could enhance the practicability of the model. Sun et al. (2017) argue that as freight demand grows and service quality is required to be maintained, instead of mere expansion of capacity, air cargo operators should plan the optimal placement of distribution nodes and routing strategy [28]. They propose an adaptive genetic algorithm, in which mutation rates change in response to the optimisation algorithm, for enhancing the convergence of the local search. The model is used to solve two revenue optimisation problems; the first problem involves integrating passenger aircraft emphasis and freight routing to maximize revenue, and the second problem involves scheduling full-cargo aircraft and optimising the routes. For medium size airlines, heuristic results show considerable improvement in operational efficiency.

3.5 Supply Chain Integration and Network Optimization

Fuzzy-S&OP integration and grey-system metaheuristics for cost-efficient, uncertainty-robust supply chain optimization are main focus points of this research area.

To coordinate sales, production, distribution, and procurement in a multisite manufacturing network, Nemati and Hosein Alavidoost (2018) propose three bi-objective fuzzy mixed-integer linear programming models, namely fully integrated S&OP, partially integrated S&OP, and decoupled planning [29]. Their fuzzy S&OP models, tested on authentic data set from a large Iranian dairy supply chain, perform better than their crisp counterparts by providing lower overall supply-chain costs and higher service levels, respectively when uncertainty prevails. Sensitivity analysis shows that the full model is the most efficient one, with the partially integrated one slightly worse than that, and the decoupled one is significantly inferior, which implies the operational performance of deep functional integration in the S&OP processes. Zhang, Wang and Liu (2012) deal with demand uncertainty for the design of distribution network by using grey systems theory to construct a chance-constrained programming model [30]. They are able to solve this model by a hybrid particle swarm optimization algorithm combined with grey simulation techniques. In an intensive case study with multiple suppliers, producers, distribution centers, and retailers, their methodology obtained a minimum total cost of 36 062 currency units and a success rate of 90% in the simulation trials with an average computing time of 42 seconds. This indicates that the combination of grey system models and state-of-the-art metaheuristics can be efficient to deal with uncertainty and improve decision-making in SC distribution network optimization.

3.6 Sustainability and Efficiency Considerations

In this research area, the problem of genetic-algorithm batching and routing optimization is addressed on green warehouse AGV order-picking energy consumption.

Ene et al. (2016) introduce green supply chain management to warehouse order-picking and propose a genetic algorithm to co-ordinate batching and routing decision in a picker-to-part system [31]. Solving a generic warehouse model and different order volumes, we find the algorithm generates near-optimal layouts with small CPU time and it provides more energy savings with more orders. The manuscript also showcases concrete eco-friendly projects—such as the introduction of state of-the-art energy saving forklifts, the adoption of packaging materials that are recyclable and the transition to a paperless information system—aiming at eventual minimization of its environmental impact. By showing both PCA and GIOR are optimal/efficient both in terms of operations and environmental sustainability, Ene et al. confirm the benefits of incorporating green level in warehousing, and they advise potential research on decision-making platforms that combine storage assignment, batching, and routing under the objective of minimizing energy.

4 Strategic Guidelines for Sustainable Development of Logistics Distribution Centers

The six clusters emerged from SLR provide valuable implications on recent practices to handle and optimize logistics distribution centers. Based on the above observations and conclusions, we established strategic directions for promoting the sustainable evolution of logistics distribution centers, including: infrastructure modernization and investment, continuous improvement and sensitivity analysis, advanced optimization and algorithm adoption, uncertainty management via grey systems, GIS and digitalization integration, simulation and empirical validation, supply chain integration, green and sustainable practices and integrated decision support systems. A more in-depth discussion of these strategic recommendations can be found in Table 3.

Table 3 Strategic Guidelines for Sustainable Development of Logistics Distribution Centers

Research Cluster	Strategic Guideline	Description	Reference
General Overview and Background	Infrastructure Modernization and Investment	· Forecast and align LDC capacity with trade and economic trends · Optimize multimodal connectivity to enhance network efficiency · Promote the development and adoption of advanced logistics technologies · Foster collaborative public – private investment models	[1, 16]
Problem Definition and Conceptual Framework	Continuous Improvement and Sensitivity Analysis	· Incorporate sensitivity analyses into decision-making frameworks · Assess the impact of key parameters · Drive continuous improvements in logistics network design	[17] [18]
Optimization Models & Algorithmic Approaches	Advanced Optimization and Algorithm Adoption	· Explore the development and application of hybrid optimization models and metaheuristic algorithms (e.g., ROA, CSDE, BRA) for effective location selection. · Seek to reduce costs and improve throughput through advanced computational techniques.	[20] [21] [25] [26]
	Uncertainty Management via Grey Systems	· Formulate logistics distribution center location problems by integrating uncertainty management (e.g., fuzzy and grey systems) and asset classification. · Emphasize the importance of sensitivity analysis to continuously improve model accuracy.	[26] [30]
Simulation and Empirical Studies	GIS and Digitalization Integration	· Utilize simulation-optimization approaches and empirical case studies to validate theoretical models. · Incorporate GIS-based spatial analysis to refine decision-making and optimize logistics node locations in real-world settings.	[24]
	Simulation and Empirical Validation	· Employ simulation-optimization approaches · Use real-world case studies to validate theoretical models · Refine system designs for improved practical performance	[27] [28]
Supply Chain Integration and Network Optimization	Supply Chain Integration	· Focus on the integration of planning across sales, production, distribution, and procurement. · Aim to optimize network performance and reduce distribution costs by enhancing coordination among supply chain partners.	[29] [30]
Sustainability and Efficiency Considerations	Green and Sustainable Practices	· Integrate green supply chain management principles into logistics and warehouse operations. · Advocate for energy-efficient technologies, recyclable packaging, and decarbonization measures to minimize environmental impacts and enhance operational efficiency.	[27] [31]
	Integrated Decision Support Systems	· Develop comprehensive decision support systems · Integrate storage assignment, batching, and routing optimizations · Support strategic planning and operational excellence	[31]

The adherence to Table 3. provides the following strategic implications. General Overview and Background cluster sets forth the significance of logistics distribution centers in supply chain networks. Pavlić Skender et al. (2019) and Lee and Song (2023) have emphasized that the renewal of infrastructure and behavior for upgrading connectivity is a pressing requirement, including in areas where infrastructure is outdated and has to be adhered to in order to keep up with the competition [1, 16]. The research also highlights regional characteristics as for example in Croatia when is the limited investment in the infrastructure of modernization and it hinders both of logistics systems and a complex of distribution centers.

The research cluster Problem Definition and Conceptual Framework emphasizes the need to deal with uncertainty—using fuzzy and grey systems—and to constantly update the model's accuracy through sensitivity analysis. Li et al. (2017) and Wu et al. (2015) show how these methods enrich existing decision structures and promote more robust decision tools in dynamic market contexts, which take into consideration different asset categories from investment markets, and the potential of changing stakeholder demands [17,18].

The Optimization Models and Algorithmic Approaches cluster is focusing on the application of advanced optimization models and metaheuristic algorithms (e.g., ROA, CSDE, BRA) for solving complex logistics distribution center location problems. Yang et al. (2007), Pan et al. (2022), and Chi et al. (2019), looking at the proposed works presented until then, provide evidences on the effectiveness of hybrid or co-evolutionary algorithms to reduce costs, boost system throughput and attend to the local and global search interplays [20,21,25]. By the same token, Qishan and Hong (2010) demonstrate the usefulness of such methodologies in a non-deterministic environment, where the demand and production capacity fluctuates over time.

The Simulation and Empirical Studies cluster, represented by Khairunissa and Lee (2021), Chen et al. (2021), and Sun et al. (2017), underscores the importance of simulation-based and empirical research in validating theoretical models [24, 27, 22]. Through GIS-based spatial analysis and simulation-optimization methods, these works refine logistics node location strategies in real-world contexts, ensuring that proposed solutions are both practical and robust.

In the Supply Chain Integration and Network Optimization cluster, Nemati and Hosein Alavidoost (2018) advocate for comprehensive supply chain integration [29]. This approach underscores the benefits of coordinated planning across: Sales, Production, Distribution, and Procurement, leading to more efficient resource utilization, reduced costs, and improved service levels. Enhanced integration in these areas has the possibility of optimizing the performance of the entire supply chain network.

Finally, within the Sustainability and Efficiency Considerations cluster, Ene et al. (2016) and Chen et al. (2021) highlight the value of integrating green supply chain management principles into logistics operations [31, 27]. By encouraging the adoption of Energy-efficient technologies, Recyclable packaging, Decarbonization measures, these studies demonstrate how to minimize environmental impacts while simultaneously enhancing operational efficiency.

Together, these strategic implications provide a complete framework to direct the sustainable development of LDCs. They emphasize that to manage supply chain uncertainty effectively, technologies such as modernization and connectivity, integrated supply chain planning and optimal decision making, as well as advanced optimization approaches, environmentally friendly practices, empirical validation, and sound concept frameworks would be necessary.

5 Potential Application of Strategic Guidelines on The Bakar Industrial Zone

The Bakar Industrial Zone is a logistics and distribution hub located in the Kukuljanovo-Bakar area, in the Republic of Croatia, covering 500 hectares, of which 200 hectares are ready for further development [32] [33]. Land costs 65 to 120 euros per square meter and parcels are auctioned by open public tender. The zone is home to over 220 companies and employs upwards of 5400 people, making it a major economic center. Modern infrastructure, developed transport logistics, and attractive investment conditions are making this area very interesting for industrial and logistics operations. The continued growth and continued investment also reaffirms the position of the zone in the area as an influential investment center of the region, so it should be regarded as an opportunity for the development of business.

5.1 Industrial Zone Bakar: Investment Potential

The Bakar Industrial Zone represents a strategic hub for economic development, characterized by impressive quantitative metrics and significant investment potential, making it an attractive destination for new projects and the expansion of existing business activities [32] [33]. Figure 2 provides an aerial view of the Bakar Industrial Zone, highlighting existing business entities and parcels still available for development (marked with green outlines).

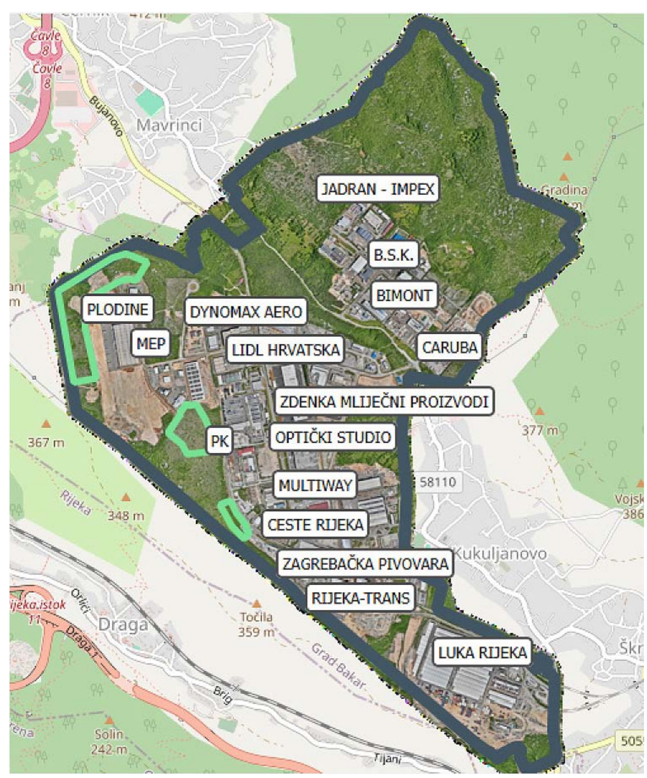

Figure 2 Aerial view of the Bakar Industrial Zone

From a sectoral perspective, an aerial view of the Bakar Industrial Zone reveals a diverse range of industries strategically distributed within the spatial plan [32] [33]. The map illustrates a varied industrial ecosystem, which includes:

- **Food and Beverages:**
  - *Zdenka Mliječni Proizvodi* (dairy product processing)
  - *Zagrebačka pivovara* (beer production)
- **Retail:**
  - *Lidl Hrvatska* and *Plodine*, representing leading supermarket chains.
- **Manufacturing and Engineering:**
  - Companies such as *Jadran – Impex*, *B.S.K.*, *Bimont*, and *Dynomax Aero* showcase manufacturing and specialized engineering activities.
- **Logistics and Distribution:**
  - *Rijeka-Trans*, *Multiway*, and *Luka Rijeka* emphasize the zone's robust logistics dimension, while *Ceste Rijeka* provides essential infrastructural services.
- **Other Services:**
  - Firms like *Caruba*, *Optički Studio*, and *MEP* demonstrate the zone's capability to host a variety of service-oriented companies.

These business entities underscore the multi-sectoral structure of the zone, effectively integrating production, retail, and logistics within a single industrial environment.

Located at the crossroads of major European transport corridors, the Port of Rijeka occupies a favorable geo-traffic position within the EU's transport network [34]. This prime location has made the adjacent Bakar Industrial Zone (Kukuljanovo) a major logistics-distribution center. Rijeka lies on Corridor Vb (TEN-T Mediterranean Corridor, Rijeka–Zagreb–Budapest) and connects via Zagreb to Corridor X toward Southeast Europe [35]. This strategic gateway provides direct maritime access to inland Central and Southeast Europe, enhancing the zone's appeal for logistics and distribution [36]. Adjacent to the port and linked to highways and rail, the Kukuljanovo zone enables efficient multimodal operations [37].

Recent infrastructure developments have further strengthened port–hinterland connectivity. The new state road D403 links Rijeka's western container terminal directly to the A7 highway, eliminating a bottleneck and integrating the port into the motorway network (Corridor Vb) [38]. Concurrently, the Rijeka–Zagreb railway is being modernized (double-tracked and upgraded) as part of Corridor Vb, boosting rail freight capacity to inland markets [39]. The port's Bakar basin is also being developed for Ro-Ro traffic, leveraging the industrial zone for vehicle distribution [40]. These enhancements show that the port's expansion augments the Bakar zone's value as a logistics-distribution center. Figure 3 maps the Port of Rijeka's position within the TEN-T network—highlighting Corridor Vb (green) and the Baltic–Adriatic Corridor (blue)—and locates the Bakar Industrial Zone immediately north of the main harbor basins, adjacent to critical rail sidings and the D-403 road link.

This geospatial integration further places emphasis on the Bakar Industrial zone's strategic importance as a logistics distribution center between gateway ports such as port of Rijeka and European inland transport corridors.

Figure 3 Port of Rijeka within the TEN-T network, highlighting Corridor Vb and the adjacent Bakar Industrial Zone

5.2 Analysis Of Infrastructure and Market Possibilities of The Bakar Industrial Zone

The analysis of the infrastructure and market opportunities in the Bakar Industrial Zone indicates a high level of development in transportation, utility, and logistics infrastructure, coupled with attractive investment conditions, making this zone exceptionally promising for future economic development [33] [41]. Table 4 illustrates how key elements—including prepared building plots, efficient transportation connectivity, and rapid documentation procurement—complement one another, thereby providing investors with a comprehensive overview of the zone's advantages.

Table 4 Key Elements of the Bakar Industrial Zone.

Category	Category Description
Prepared Construction Plots	· The construction plots are leveled and equipped with complete infrastructure, making them ready for the construction of industrial facilities. · At the entrance of each plot, connection shafts for all infrastructural services have been installed, and the plots are leveled using high-quality stone material with continuous load-bearing tests. · According to the spatial planning documentation (UPU), the plots can be divided into smaller parcels or merged into larger ones depending on investor needs, and they are designed for functional and rational use.
Investor Benefits	· Investors are offered the opportunity to operate in one of the most well-equipped infrastructural zones in Croatia, featuring an attractive business environment and a diverse range of economic activities. · The construction plots are ready for development without incurring additional land preparation costs, and options are available for either purchasing or establishing building rights for a duration of 30 years. · Installment payments are available for up to 12 monthly installments, while industrial buildings benefit from additional incentives, including special conditions for utility fees and other charges.
Spatial – Planning Documentation	· The Bakar/Kukuljanovo Industrial Zone is defined by the Urban Development Plan for the Kukuljanovo Industrial Zone and UPU 3. · Existing urban plans facilitate further development of the zone by utilizing remaining undeveloped areas and define space usage, the conditions for hosting economic activities, the size and shape of building plots, the placement of structures, parcel layout, waste management, and environmental protection measures. · Timely updates to the documentation enable modern business operations that align with market demands and investor needs.
Transportation Connectivity	· The Bakar Industrial Zone stands out for its exceptional geostrategic position and excellent transportation connectivity. · The zone is located in the hinterland of the City of Bakar (2 km) and the City of Rijeka (7 km), ensuring rapid connectivity between the Mediterranean and Central Europe. · Its close proximity and synergy with Bakar Port and Rijeka Port, along with the use of road, rail, and river transport, enable multimodal connectivity. · The zone also offers direct links to the Rijeka-Zagreb and Rijeka-Split highways, as well as major routes such as Rijeka-Trst and Rijeka-Ljubljana, and is connected by an industrial railway line to the Croatian railway system. · Proximity to Rijeka/Krk Airport (20 km) further enhances transportation integration.
Infrastructure Maturity Level	The zone hosts a well-developed infrastructure: · 5 km of industrial railway tracks with a transshipment ramp. · 17 km of road network, complemented by a water supply system for sanitary water. · A dedicated fire-fighting system capable of handling two separate fire zones. · A divided sewage system for both stormwater and fecal wastewater. · A high-voltage network supplied via a 110/35 KV transformer station. · Local gas supply provided through a pipeline. · A modern TT (power distribution) network along with public lighting.
Rapid Documentation Issuance	· According to the Construction Act, investors are enabled to rapidly obtain construction permits and all preceding administrative approvals. · The building plots have a resolved property-legal status, and an organized cadastre with complete information on the location, shape, and area of the cadastral parcels allows for swift action by designers and surveyors. · Developed and infrastructurally equipped transportation areas adjacent to the construction plots streamline the process of issuing confirmations on the master plan. · Extensive experience in advising investors further accelerates the process of obtaining the required documentation.

5.3 Bakar Industrial Zone: Strategic Development

The Bakar Industrial Zone, located between Kukuljanovo and Bakar, brings strategic development to the coastal region of Croatia. The Zone has a geographically strategic location that provides direct access to critical highways, rail lines and ports, facilitating the movement of goods. Continuous expansion of upgrade of infrastructure and logistics capabilities have significantly improved the zone's competitive edge in the domestic as well as international markets. It also is providing abundant land that attracts new businesses, increasing the overall energy of the regional economy. The zone has become a sustainable center of economy by unifying networks for production, distribution and transportation. The City Development Strategy (CDS) 2014–2020 of the City of Rijeka and the County Development Plan (CDP) 2022–2027 of Primorje–Gorski Kotar County both list specific infrastructure, environmental and investment projects – including highway and rail upgrades, port hinterland links, wastewater treatment expansion and free-zone upgrades – designed to ensure optimal functionality and competitiveness of the zone [33] [42].

In accordance to the fact that the Bakar Industrial Zone serves as a key economic and logistics hub in the greater Rijeka area, the City of Rijeka Development Strategy for the period 2014-2020 coupled with the more recent Development Plan of Primorje – Gorski Kotar County for the 2022 – 2027 period identifies a series of infrastructure, environmental, and investment projects aimed at enhancing the functionality and competitiveness of the industrial zone [33] [42]:

1. Development of Gas and Utility Infrastructure:

- Since 2012, the Odorizacijska Stanica Rijeka Istok has been operational, enabling the distribution of natural gas to the Municipality of Čavle and the City of Bakar.
- Consequently, the production and distribution of mixed gas in the area have been completed.
- Further gasification of business and residential buildings is planned, along with an expansion of the gas network to the wider Rijeka region.
- The Bakar Industrial Zone is integrated into the wastewater drainage system, and the expansion of the central wastewater treatment facility is a key environmental priority.

2. Environmental Development and Sustainability:

- The construction of a network of recycling yards is planned; to date, 2 out of the planned 12 yards have been built.
- The first phase of wastewater treatment is expected to be completed soon, while the second phase is still in the planning stage.
- The establishment of an integrated environmental management system is planned to ensure the sustainability of industrial activities.

3. Strengthening Transportation Connectivity and Logistics:

- The Bakar Industrial Zone holds strategic importance for the development of the Rijeka transportation corridor and port infrastructure.
- A key completed infrastructure project is the construction of the D-403 road (valued at 66 million EUR), which will improve connectivity between the Rijeka port and inland areas.
- The zone is part of the development of the railway infrastructure within the European Corridor X, including the construction of a second railway line between Rijeka and Delnice (valued at 550 million EUR).
- The logistics zones of Bakar, Škrljevo, and Miklavija form an integrated system connected to the Rijeka port, enabling efficient storage and distribution of goods.

4. Energy Efficiency and Investments:

- The Bakar Industrial Zone is part of the FUTURA project, which aims to increase energy efficiency through the modernization of heating systems and the installation of thermostatic valves and splitters.
- Additional investments in the modernization of the energy network are planned to ensure a stable and environmentally friendly energy supply.

Based on the aforementioned facts, the Bakar Industrial Zone possesses a strong competitive foundation for the strategic development of the Rijeka region. The development of the Bakar logistics distribution center enhances the industrial zone's competitiveness through modern logistics services, improved transportation connectivity; the adoption of sustainable and environmentally friendly business practices that will, in the long term, reduce costs and enhance the zone's reputation.

In accordance with the stated insights, recommendations for the strategic development of logistics distribution centers in the Bakar Industrial Zone are presented [32,33,43]:

1. Prepared Construction Plots:

- **Recommendation:** Exploit pre-prepared construction plots that are leveled and equipped with complete infrastructure, enabling flexible parceling or consolidation of space to meet investors' needs [32].
- **Objective:** Accelerate the establishment of logistics facilities and ensure spatial adaptability for the development of large, complex industrial structures.

- **Possible Strategic Guideline Implementation:**
  - **Infrastructure Modernization and Investment** [1,16]: Emphasize modernizing existing facilities and improving connectivity, ensuring that prepared construction plots are fully equipped for immediate industrial or logistics use.
  - **Advanced Optimization and Algorithm Adoption** [20,21,25]: Utilize computational models (e.g., hybrid metaheuristics) to determine the most effective plot configurations and layouts, reducing setup costs and enhancing throughput.

2. Investor Benefits:

- **Recommendation:** Promote financing models that allow for installment payments of up to 12 monthly installments and offer special concessions on utility fees and charges [32].
- **Objective:** Reduce initial investment costs and enhance the attractiveness of the industrial zone for new investments.
- **Possible Strategic Guideline Implementation:**
  - **Supply Chain Integration** [29,30]: Coordinate investment incentives across different supply chain partners—such as producers, distributors, and logistics providers—to foster a more integrated and cost-effective network.
  - **Uncertainty Management via Grey Systems** [19, 26]: Incorporate grey or fuzzy modeling techniques to manage the variability in investment returns and market demand, thereby providing a more secure environment for potential investors.

3. Spatial – Planning Documentation:

- **Recommendation:** Continuously update urban plans and spatial planning documentation to ensure clear development conditions and efficient use of space [32].
- **Objective:** Facilitate modern business operations and ensure that projects can adapt to both domestic and international market requirements.
- **Possible Strategic Guideline Implementation:**
  - **Continuous Improvement and Sensitivity Analysis** [17,18]: Perform ongoing reviews of spatial plans, using sensitivity analyses to evaluate how changes in zoning or land-use policies might affect logistics center performance.
  - **Simulation and Empirical Validation** [27, 28]: Employ simulation-optimization and real-world pilot studies to validate how proposed changes in planning documentation would impact LDC efficiency, ultimately refining long-term development strategies.

4. Transportation Connectivity:

- **Recommendation:** Leverage the geostrategic location of the industrial zone, which features direct access to highways (Rijeka-Zagreb, Rijeka-Split) and major routes (Rijeka-Trst, Rijeka-Ljubljana), and continue investing in multimodal connectivity with Bakar and Rijeka ports [32].
- **Objective:** Ensure efficient and secure distribution while reducing transportation costs.
- **Possible Strategic Guideline Implementation:**
  - **GIS and Digitalization Integration** [24, 25]: Use GIS-based spatial analysis and digital tools to plan and monitor transportation corridors, improving route optimization and connectivity across road, rail, and maritime networks.
  - **Green and Sustainable Practices** [27, 31]: Incorporate environmentally friendly transportation options—such as electric vehicles (forklifts) or optimized multimodal shifts—to reduce carbon emissions and align with broader sustainability goals.

5. Infrastructure Maturity Level:

- **Recommendation:** Continue the development and implementation of key infrastructure elements, including 5 km of railway industrial tracks, 17 km of road networks, and a stable water supply, sewage, and energy system [32].
- **Objective:** Enhance operational efficiency and competitiveness for logistics distribution centers within the industrial zone.
- **Possible Strategic Guideline Implementation:**
  - **Integrated Decision Support Systems** [31]: Develop comprehensive platforms that unify storage assignment, batching, and routing optimizations, ensuring cohesive infrastructure usage and real-time decision-making.
  - **Green and Sustainable Practices** [27,31]: Embed eco-friendly measures—like renewable energy sources and energy-efficient equipment—into infrastructural upgrades, thus minimizing the environmental footprint.

6. Rapid Documentation Issuance:

- **Recommendation:** Utilize the advantages of having construction parcels with resolved property legal status and a well-organized cadaster to expedite the issuance of construction permits and other administrative procedures [32].
- **Objective:** Reduce bureaucratic barriers and speed up the development of new projects.
- **Possible Strategic Guideline Implementation:**
  - **Continuous Improvement and Sensitivity Analysis** [17,18]: Integrate regular policy reviews and stakeholder feedback loops to re-

fine administrative workflows, ensuring that permitting processes remain efficient as project scales and requirements evolve.

- **Simulation and Empirical Validation** [27,28]: Test streamlined documentation procedures in pilot projects, validating time and cost savings before rolling out at scale.

The proposed strategies and recommendations offer guidelines for ensuring a strategic and comprehensive approach that integrates infrastructural, financial, regulatory, and administrative aspects, thereby enhancing the competitiveness and sustainability of logistics distribution centers in the Bakar Industrial Zone.

6 Conclusions

Logistics distribution centers (LDCs) are the special-purpose supply-chain facilities for consolidating, warehousing, packaging and shipping of goods in order to provide improved inventory management and costs savings. When located close to large traffic intersections, they can improve the network and allow for more efficient known capacities. Yet clogged roads, deteriorating infrastructure, fragmented regulations and customs processes frequently hamstring them and inflate costs. In order to determine best practices and state-of-the-art, a systematic literature review of seventeen influential papers that appeared in the ISI Web of Science was carried out and classified in six research streams: General overview and background, Problem definition and conceptual framework, Optimization models and algorithmic approaches, Simulation and empirical studies, Supply chain integration and network optimization, and Sustainability considerations.

Content analysis of these clusters yielded nine strategic imperatives for sustainable LDCs development: Infrastructure modernization and investment: Modernize essential infrastructure and transport connectivity to facilitate efficient logistics operations; Supply chain integration: Integrate planning process with supply chain partners' operations for improved effectiveness. Advanced optimization and algorithm adoption: Integration of hybrid algorithms to optimize the locations, minimize the cost, and maximize the throughput; Green and sustainable practices: Implementing green and sustainable practices to wrap the environmental impact; GIS and digitalization integration: Application of GIS tools and digital platforms for precise, optimized decisions; Uncertainty management via grey systems: Use of fuzzy and grey models to manage uncertainty of the operations; Simulation and empirical validation: Simulations are empirical studies to validate the logistics models; Continuous improvement and sensitivity analysis: Regularly perform sensitivity analyses to continuously tune operational performance; and Integrated decision support systems: Develop integrated systems for storage, batching, and routing to attain excellence.

The nine strategic guidelines towards sustainable development of LDCs in the Bakar Industrial Zone Case Study are provided based on the following real – world aspects of the Zone: Prepared construction plots: Fast track infrastructure upgrades and advanced optimization to layout flexible construction plots; Investor benefits: Employ supply chain integration and uncertainty management to provide tempting financing and reduce investor risk; Spatial – planning documentation: Make use of continuous improvement and simulation derived validation to update spatial plans to offer clear, agile development regulations; Transportation connectivity: Make use of integration (GIS, Digitalization) along with green practices to optimize multimodal routes and connectivity; Infrastructure maturity level: Develop decision support systems for integrated systems and refurbish infrastructure to safeguard robust, efficient utilities and networks; and, Rapid documentation issuance: Make use of continuous improvement and simulation processed validation to reduce the administrative processing time and the bureaucratic delay.

According to the findings of the research, future works could examine integrated models that blend advanced optimization methods, GIS-based analysis, and uncertainty handling to facilitate the strategic planning process of LCD. Comparative analysis on regulatory and infrastructural solutions and effect of hybrid algorithmic models on operational sojourn and sustainability for LDC are also suggested. It will be vital for industrial players to invest in, and pave the way for, development-worthy land by making infrastructure modernizations and strategic investments. In addition, promoting supply chain integration and regulatory harmonization contributes to an investment friendly environment, and the adoption of green practices and digital applications will support connectivity in transport, facilitate trade facilitation and ensure the sustainability of the logistics distribution centers in the long run.

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