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RESEARCH ARTICLE

A GIS-Based Multicriteria Decision Framework for Provincial and Regional Distribution Centers: Integrating Land Capability (SKL) and Accessibility Metrics in South Kalimantan, Indonesia

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Abstract

This study develops a GIS-based multicriteria decision analysis (GIS-MCDA) framework to identify priority locations for Provincial Distribution Centers (PDP) and Regional Distribution Centers (PDR) in South Kalimantan Province. Its principal contribution is the integration of Land Capability Units (SKL), which represent the intrinsic physical suitability of land, with accessibility and utility indicators that capture operational support. The framework employs a vector-overlay procedure that combines thematic layers, standardized scores, and a Weighted Linear Combination (WLC). The SKL component is weighted at 0.55, while the accessibility-utility component is weighted at 0.45, reflecting the premise that physical land suitability constitutes a fundamental threshold that cannot be fully offset by high accessibility alone. The results show that class S2 dominates the study area, covering 1,566,737.61 ha (42.22%), followed by S3 at 1,037,104.41 ha (27.95%) and S4 at 1,004,058.64 ha (27.06%). By contrast, S1 covers only 68,751.95 ha (1.85%), while class N accounts for 34,496.78 ha (0.93%). These findings indicate that most of South Kalimantan is conditionally suitable, meaning that PDP/PDR development generally still requires technical adjustment, infrastructure improvement, or a combination of both. Spatially, the most prospective areas are concentrated in the Banjarbakula metropolitan corridor and several strategic logistics nodes. Overall, the study demonstrates that distribution center location decisions should simultaneously account for physical land resilience and operational efficiency in order to support more adaptive, measurable, and policy-relevant regional logistics planning.

Keywords: GIS-MCDA, Land Capability, Regional Logistics, Distribution Center, South Kalimantan

1. Introduction

Provincial Distribution Centers (PDP) and Regional Distribution Centers (PDR) are increasingly recognized as strategic consolidation nodes that shape the efficiency, reliability, and resilience of regional logistics systems. By centralizing storage, consolidation, and distribution functions, PDP/PDR facilities can reduce logistics costs, shorten lead times, stabilize the supply and prices of essential commodities, and strengthen regional competitiveness, especially in areas characterized by dispersed production zones and dependence on multimodal transportation (Petris et al., 2024; Vargas-Muñoz et al., 2025; Ye et al., 2025). In archipelagic and corridor-based settings, distribution centers also function as interface infrastructure that synchronizes flows across land-river-sea networks, where disruptions in one segment can rapidly propagate through the wider supply chain (Amin et al., 2024; Li et al., 2023; Retamero and Orive, 2025).

This relevance is particularly evident in South Kalimantan Province, where the metropolitan core, hinterland production areas, and coastal export gateways form a distinctive logistics geography. The Banjarbakula metropolitan corridor (Banjarmasin-Banjarbaru and the surrounding area) functions as the principal regional distribution and service center, supported by production areas in the central and northern parts of the province, as well as coastal and industrial gateways linked to domestic and international markets. In this configuration, logistics corridor performance depends not only on infrastructure availability but also on the appropriateness of distribution node placement to reduce spatial friction, maximize accessibility, and sustain operational continuity (Retamero and Orive, 2025; Yu et al., 2025). Accordingly, selecting PDP/PDR locations is not merely a matter of land availability; it is a multicriteria planning decision with long-term implications for corridor congestion, land-use conflict, infrastructure maintenance costs, and vulnerability to environmental hazards.

Despite this strategic importance, the selection of PDP/PDR locations is often driven by pragmatic considerations such as land availability, proximity to urban activity centers, or short-term political and investment preferences rather than by transparent multicriteria evaluation (Onstein et al., 2019). As a result, locations that appear operationally attractive may not be physically suitable for warehousing and logistics functions in the long term. For distribution facilities, land suitability is closely associated with site stability, drainage performance, soil and foundation conditions, water availability, erosion susceptibility, waste disposal capacity, and disaster risk, all of which directly affect site preparation costs, operational disruption, and life-cycle maintenance requirements (Özder, 2025). In the Indonesian context, the challenge of integrating land-use and transport systems in the designation of service nodes has also been widely discussed, particularly regarding the role of infrastructure synergy in reducing spatial inefficiency (Taki et al., 2017).

In Indonesia, land suitability evaluation is generally operationalized through Land Capability Units (SKL). This assessment framework captures the intrinsic physical condition of land through parameters such as morphology, workability, slope stability, foundation stability, water availability, drainage, erosion, waste-disposal capacity, and disaster susceptibility. Previous studies indicate that SKL-based analysis is effective for deriving land capability classes relevant to spatial planning and regional development decision-making (Hartati et al., 2023). However, SKL outputs are often applied in isolation and are rarely integrated with logistics-oriented operational indicators such as access to arterial roads, utilities, and transport infrastructure.

Within Indonesian geospatial and regional planning practice, integrative spatial approaches are becoming increasingly important for linking land biophysical characteristics, infrastructure accessibility, and the need for measurable decision-making (Taki et al., 2017; Taki and Maatouk, 2018). The integration of land use and transport systems is a key prerequisite for determining regional service nodes in a more systematic and spatially efficient manner (Taki et al., 2017). Spatial statistical analysis can also support more objective identification of potential locations, particularly in complex and rapidly developing regions (Taki et al., 2017). From a physical-environmental perspective, disaster mitigation should be treated as an inherent component of area evaluation rather than as an additional consideration introduced after location selection (Zamroni et al., 2020). The use of remote sensing data and spatial mapping can further improve the accuracy of identifying surface characteristics for spatial evaluation (Rizki et al., 2017). In addition, spatially explicit geological hazard analysis is relevant to supporting development decisions that are more adaptive to environmental and disaster risk (Khalqillah et al., 2025).

Against this background, GIS-based multicriteria decision analysis (GIS-MCDA) has emerged as a powerful approach for facility siting and spatial prioritization. GIS-MCDA enables the integration of multiple indicators through standardization, weighting, and the combination of spatial information, thereby making decision-making more explicit than approaches based on a single criterion or intuition alone (Feng et al., 2023). However, many logistics facility siting studies place greater emphasis on accessibility, such as proximity to roads, markets, or activity centers, while treating the physical condition of land more narrowly or representing it only through general environmental proxies (Abd et al., 2020). For warehouse and distribution center investments, connectivity efficiency must be balanced with biophysical land resilience to minimize long-term operational disruption and maintenance costs. Empirical evidence from Indonesia on spatial decision frameworks that explicitly integrate SKL-based land capability as the intrinsic physical foundation with accessibility-utility as the determinant of operational feasibility remains limited, particularly for PDP/PDR siting at the provincial scale (Chumaidiyah et al., 2023). The absence of such integration reduces decision traceability and weakens the justification for policies in technical audits, cross-sector coordination, and investment appraisal. Contemporary GIS-MCDA practice increasingly requires a clear indicator structure, explicit weighting logic, and communicative outputs so that planning decisions can be defended both scientifically and administratively (Feng et al., 2023). In the land evaluation tradition, classes such as S1, S2, S3, S4, and N have long been used as communication devices to translate multi-parameter assessments into planning-ready categories (Younes et al., 2026). However, in the context of logistics facility placement, these classes are still rarely produced from a framework that transparently balances physical land capabilities with operational accessibility on a provincial scale. The need for a transparent and replicable spatial evaluation framework is therefore becoming increasingly important, especially when location decisions must consider more than one dimension of the assessment (Taki et al., 2017; Taki and Maatouk, 2018). Although previous studies have examined the integration of land use and transportation, spatial statistical analysis, satellite-based mapping, and geological hazard mitigation, research that specifically combines SKL-based land capacity with operational accessibility indicators for determining distribution centers at the provincial scale remains limited (Khalqillah et al., 2025; Rizki et al., 2017a; Zamroni et al., 2020).

To address this gap, this study develops and tests a GIS-MCDA decision framework based on vector overlay to prioritize PDP/PDR locations in South Kalimantan Province by integrating: (1) SKL-based land capability as the intrinsic physical foundation of site feasibility; and (2) accessibility-utility indicators as determinants of operational feasibility and cost efficiency. The proposed framework applies a Weighted Linear Combination (WLC) to integrate standardized attribute scores from thematic layers into a Suitability Index (SI) that represents the composite level of site feasibility. The SI is then classified into S1-S2-S3-S4-N suitability classes, accompanied by the identification of dominant limiting factors to explain why certain areas fall into lower suitability categories (Molla, 2024; Zhai et al., 2025; Mulualem et al., 2025).

In practical terms, this study conceptualizes PDP/PDR site selection as a multicriteria planning problem that should be transparent, auditable, and reproducible rather than as a simple proximity-based decision. The study makes two contributions. First, it offers a structured integration of nine SKL parameters: morphology, workability, slope stability, foundation stability, water availability, drainage, erosion, waste disposal capacity, and hazard vulnerability, with accessibility indicators representing proximity to key operational support systems, including arterial roads, city centers, settlements, electricity, telecommunications, and strategic transport infrastructure. Second, it produces decision-ready suitability maps that go beyond a binary suitable/unsuitable distinction by providing graded classes aligned with land evaluation logic and policy communication needs (Anteneh, 2021; Younes et al., 2026).

The overall objective of this study is to develop and validate a GIS-MCDA framework for prioritizing PDP/PDR locations in South Kalimantan Province by explicitly integrating SKL-based land capability and accessibility-utility metrics. Specifically, the study seeks to:

1. Formulate a criteria system and weighting scheme that combines SKL land capability parameters and accessibility-utility indicators for logistics site selection.
2. Construct a Suitability Index (SI) through score standardization and weighted integration across

thematic layers within a Weighted Linear Combination (WLC) framework.

3. Produce decision-ready suitability classification maps (S1-S2-S3-S4-N) and identify the dominant limiting factors that reduce suitability in different areas.

The urgency of this study lies in the long-term consequences of poorly locating logistics centers. Misplaced PDP/PDR facilities can trigger corridor congestion, intensify land-use conflict, increase infrastructure maintenance costs, and heighten operational vulnerability to flooding, drainage failure, and soil instability. In this context, a transparent GIS-MCDA framework offers a practical tool for provincial and regional planners to justify logistics investment, align infrastructure provision with land resilience, and communicate trade-offs more explicitly to stakeholders and decision-makers (Feng et al., 2023). For South Kalimantan, where development priorities increasingly depend on integrated corridor performance and the efficiency of coastal gateways, an approach that simultaneously accounts for connectivity efficiency and land capability is essential to ensure that PDP/PDR investment is both efficient and adaptive to biophysical constraints.

2. Data and Methodology

This applied study employs a quantitative spatial approach based on GIS-MCDA to support the prioritization of Provincial Distribution Center (PDP) and Regional Distribution Center (PDR) locations in South Kalimantan Province. The analysis was conducted within the provincial administrative boundary by integrating two main groups of criteria: SKL-based land capability, the intrinsic physical component, and accessibility-utility, the operational component. The SKL component comprises nine parameters: morphology, workability, slope stability, foundation stability, water availability, drainage, erosion, waste disposal, and disaster susceptibility, while the accessibility-utility component includes proximity to city centers, major roads, settlements, electricity networks, telecommunications, and strategic transport infrastructure. The spatial data were derived from a Digital Elevation Model (DEM) and a range of thematic regional planning maps, including road networks, electricity infrastructure, telecommunications networks, city centers, settlements, and transport infrastructure, which were used to generate suitability maps, accessibility-utility maps, priority maps, and SKL warehousing maps as the basis for spatial analysis. Prior research shows that spatially grounded assessment is effective for mitigating physical-environmental risk in Indonesia (Zamroni et al., 2020).

All datasets were first standardized to a common coordinate projection system, clipped to the study area boundary, and then processed through topology cleaning, geometry standardization, and attribute harmonization to enable consistent integration within a vector-analysis environment. The analytical workflow involved preparing and combining thematic layers, assigning standardized scores to each criterion, and applying weights through a Weighted Linear Combination (WLC) based on technical considerations, planning priorities, and the operational requirements of the logistics system.

Table 1. Sources and Characteristics of Geospatial Datasets Used in Analysis

Dataset	Data Provider	Year of Acquisition	Purpose
Digital Elevation Model (DEM)	Ina-Geoportal	2018	SKL parameter development
Road Network	South Kalimantan RTRWP	2023-2042	Road network accessibility
Electricity Infrastructure	South Kalimantan RTRWP	2023-2042	Electricity utility accessibility
Telecommunications Network	South Kalimantan RTRWP	2023-2042	Telecommunications accessibility
City Center	South Kalimantan RTRWP	2023-2042	Proximity to activity centers
Settlement	South Kalimantan RTRWP	2023-2042	Consideration of conflict/functional separation
Transport infrastructure	South Kalimantan RTRWP	2023-2042	Proximity to ports, airports, and other transport facilities

In this study, the SKL component was assigned a weight of 0.55. In contrast, the accessibility-utility component was assigned a weight of 0.45 (Table 2) because SKL reflects the intrinsic physical suitability of land, which is fundamental to the development of warehousing and logistics facilities. In principle, physically unsuitable land cannot be fully compensated for by high accessibility, whereas limitations in accessibility and utilities can, to some extent, still be improved through road development, utility provision, and supporting infrastructure investment. Accordingly, the intrinsic physical component was treated as slightly more influential than the operational component so that the analysis would not merely emphasize distribution efficiency, but would also ensure technical feasibility, land resilience, and long-term development sustainability. The integrated results were subsequently classified into suitability classes S1, S2, S3, S4, and N to support the interpretation of PDP/PDR development priority zones at the provincial scale. The principal outputs targeted were: (1) an S1-S2-S3-S4-N suitability map; (2) an interpretation of the dominant limiting factors associated with lower suitability classes; and (3) a comparative evaluation of candidate PDP/PDR locations.

The research design followed a systematic spatial decision-making framework comprising data collection and standardization, the determination of criteria and sub-criteria (Dragi, 2024), normalization and scoring, MCDA weighting, weighted overlay, and S1-N classification (Hani et al., 2023). GIS preprocessing included coordinate system standardization (Lemenkova and Debeir, 2023), network topology cleanup (Kukulska et al., 2019), and the construction of distance rasters for each accessibility indicator (Delamater et al., 2012). Once all indicator layers had been prepared, each was standardized to a common assessment scale through scoring or normalization procedures. In this study, standardization was implemented by reclassifying categories into ordinal scores from 1 to 4, as presented in Table 2. This procedure removed differences in units and value ranges across indicators, making them suitable for aggregation into a composite index. Conditions considered more operationally favorable for example, locations closer to main roads or city centers were assigned relatively higher scores (Kourtzanidis et al., 2021).

Table 2. Criteria-Sub-Criteria, Scoring Rules, and MCDA Weights

Groups	Subcriteria	Data Type	Scoring Rules	Preference Direction	Weight (w)
SKL (0.55)	SKL composite warehouse land capability	Classes	Very high = 4; Somewhat high = 3; Medium = 2; Low=1; Very low=0	The higher the better	0.55
Accessibility-Utility (0.45)	Distance to city center	km	0-10=4; 10-20=3; 20-30=2; >30=1	The closer the better	0.10
	Distance to main road	m	≤500=4; 501-1.000=3; 1,001-1,500=2; >1.500=1	The closer the better	0.12
	Distance to settlement	km	>6=4; 4-6=3; 2-4=2; 0-2=1	The farther the better (less conflict)	0.06
	Distance to the power grid	m	0-100=4; 101-500=3; 501-1,000=2; >1,000=1	The closer the better	0.07
	Distance to telecommunications	km	0-7=4; 7-14=3; 14-21=2; >21=1	The closer the better	0.05
	Distance to transport infrastructure	km	0-10=4; 10-20=3; 20-30=2; >30=1	The closer the better	0.05
	Amount weight				1.00

In contrast, conditions associated with greater operational bottlenecks, such as poor drainage or elevated vulnerability, were assigned lower scores (Abdrabo et al., 2023). This approach is consistent with larger-is-better and smaller-is-better normalization practices commonly used in the construction of vulnerability, sustainability, and livability indices. Weighting was conducted through structured expert judgment (Boix-Cots et al., 2023) based on planning relevance, technical considerations, and the operational needs of the logistics system.

The Land Capability (SKL) component was assigned a weight of 0.55, while the accessibility-utility component received a weight of 0.45. The slightly higher weight assigned to SKL reflects the assumption that land capability constitutes a fundamental intrinsic physical feasibility threshold for warehousing and logistics development. By contrast, limitations in accessibility and utilities, although operationally important, can still be improved through infrastructure intervention and investment in supporting networks. This weighting structure, therefore, reflects the analytical premise that physically unsuitable land cannot be fully compensated for by high accessibility. Accordingly, the biophysical-intrinsic component was positioned as slightly more dominant than the accessibility-operational component in constructing the decision model.

The spatial suitability index was then calculated for each grid cell using a Weighted Linear Combination (WLC) model, or weighted overlay: SI = sum (wi x si), where si denotes the standardized indicator score and wi denotes the indicator weight (Yin et al., 2020). Technically, the overlay can be implemented using GIS tools that support weighted overlay or weighted-sum raster operations (Ergün, 2025), thereby ensuring transparency and reproducibility from the reclassification scheme through to the final weighted integration.

Candidate PDP/PDR locations were not identified randomly from the suitability surface. Instead, they were derived from strategic locations listed in South Kalimantan Provincial Regulation Number 6 of 2023, which outlines the provincial spatial structure, growth centers, logistics corridors, and priority development areas. The selected candidates were then aligned with existing or planned logistics-supporting infrastructure, such as ports, airports, major roads, and regional service centers. The candidate set, therefore, represents planning-relevant alternatives for comparative evaluation rather than a fully exploratory search across all possible locations.

The continuous SI values were subsequently classified into S1, S2, S3, S4, and N to produce a decision map suitable for policy formulation. The S (suitable) and N (not suitable) grouping is conceptually aligned with the FAO land evaluation tradition (Razvanchy and Fayyadh, 2022), which maps land according to the degree of suitability for a given use and the limitations attached to that use. This approach translates a numerical suitability index into communicative, categorical classes ready for policy application (Lifeng Li, 2021).

For candidate evaluation, SI scores and accessibility profiles were compared across the selected PDP/PDR locations to identify each location's strategic role within the provincial logistics system (Kannan et al., 2021).

3. Result and Discussion

3.1. Data Quality and Scope of Analysis

The suitability analysis for Provincial Distribution Centers (PDPs) and Regional Distribution Centers (PDRs) was conducted within the administrative boundaries of South Kalimantan Province, using 2025 as the reference year. The geospatial data encompass two main groups of variables: SKL-based land capability, which represents biophysical and technical feasibility, and accessibility-utility, which represents operational support in relation to road networks, city centers, settlements, electricity networks, telecommunications, and strategic transport infrastructure. All spatial datasets were standardized to a common coordinate projection system, clipped to the study area boundary, and processed through topology cleaning, geometry standardization, and attribute harmonization to enable consistent integration within a vector analysis environment. This step was essential to ensure spatial consistency, the accuracy of relationships among objects, and the traceability of the analytical process within the GIS-MCDA framework, so that the results reflect not only substantive suitability patterns but also a clear and defensible methodological basis. (Deng et al., 2014).

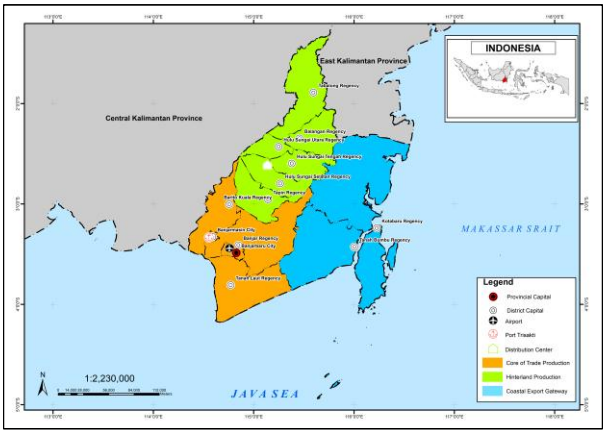

Fig 1. Administrative boundaries of South Kalimantan Province and Logistics Cluster

Spatially, the study area can be interpreted into three functional logistics zones: the Banjarbakula metropolitan core as the principal regional trade and service center; Banua Anam as a production-support zone; and the coastal export gateway, represented by the southern and eastern coastal areas. This functional zoning provides an important regional context for interpreting suitability patterns because the role of PDP/PDR locations in South Kalimantan is determined not only by local land conditions but also by their position within the broader production-distribution-export system.

Core production and trade locations in the Banjarmasin-Banjarbaru area and its surroundings offer high accessibility and infrastructure, making them highly suitable as regional PDP/PDR nodes. Hinterland production locations in the central and northern parts of the province function as commodity-supply areas, with suitability shaped by land accessibility and transport connectivity to the core locations. Meanwhile, coastal locations serving as export gateways play a strategic role in external distribution, particularly when direct access to ports and major shipping routes is available, although their feasibility must still be assessed in light of biophysical and environmental constraints.

3.2 Factor map: Land Capability (SKL) and Accessibility Metrics

(a) SKL-Based Land Capability for Warehousing and Logistics Functions

The composite SKL map shows that land capability for warehousing and logistics development is unevenly distributed across South Kalimantan. In general, the provincial pattern is dominated by moderately high and medium land capability classes, while the very low class occupies a relatively small share of the candidate-related areas assessed. This suggests that much of the province is biophysically suitable for logistics functions, although many locations remain subject to specific technical constraints such as limited drainage capacity, inundation potential, erosion susceptibility, and foundation instability. It is important to note that the composite SKL layer in this study represents only intrinsic physical land capability derived from the synthesis of nine SKL parameters: morphology, workability, slope stability, foundation stability, water availability, drainage, erosion, waste disposal capacity, and hazard vulnerability. Accordingly, the SKL composite should be interpreted as a biophysical-technical feasibility surface, while accessibility and utility are treated separately in the subsequent GIS-MCDA stage in order to avoid conceptual overlap between intrinsic land capability and operational accessibility.

This interpretive framework is consistent with land capability and land suitability evaluation principles that treat biophysical limits as key determinants of the feasibility of spatial use (Kim, 2022). In addition, the use of spatial data and satellite imagery to identify biophysical constraints and their environmental distribution has become an established approach in Indonesian landscape analysis, as demonstrated by previous spatial mapping studies (Rizki et al., 2017).

The candidate-based SKL summary in Table 3 reinforces this pattern. Within the assessed candidate areas, the “Suitable” class constitutes the largest share at 608.30 ha, followed by “Moderately Suitable” at 251.36 ha, “Highly Suitable” at 22.61 ha, and “Low Suitability” at only 5.05 ha. This distribution indicates that most candidate-related land parcels are not uniformly ideal, but instead fall within intermediate physical suitability classes that remain feasible for development with varying degrees of technical adjustment. Trisakti Port and Syamsudin Noor Airport show the strongest representation of higher SKL suitability among the evaluated candidates, whereas KEK Mekar Putih displays a broader spread across the low, medium, and suitable classes, indicating greater internal heterogeneity in physical conditions.

The composite SKL map for warehousing and logistics is the result of synthesizing several spatial parameters that represent the suitability of land for warehousing and regional logistics functions. The parameters compiled in this analysis represent physical land conditions, while accessibility to major transportation networks and proximity to strategic distribution nodes such as ports and airports are evaluated separately through the accessibility component. The analysis shows that higher land capability classes are generally associated with locations that can support logistics development more effectively, whereas medium- to low-capability classes are shaped by physical land characteristics that are less conducive to large-scale logistics activity.

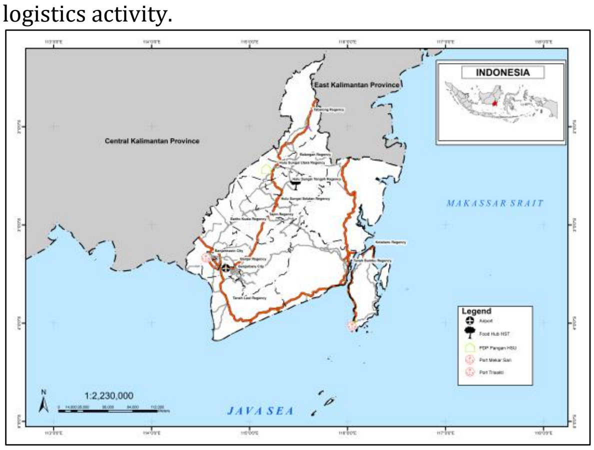

Fig 2. Composite SKL Map/Land Capability Class For Warehousing/Logistics

Table 3. Expansion of Land Development Capabilities for Warehousing/Logistics

No	Location	Low Development	Medium Development	Fairly Appropriate Development	Perfectly Fit Development
1	G.Subarjo Street			6.71 Ha	
2	HSU Market		2.83 Ha		1.16 Ha
3	Pantai Hambawang HST Market			3.20 Ha	0.27 Ha
4	Trisakti Port			0.01 Ha	7.17 Ha
5	Port & Logistic KEK Mekar Putih	5.05 Ha	152.27 Ha	423.14 Ha	3.85 Ha
6	Syamsudin Noor Airport (BJB)		96.26 Ha	175.24 Ha	10.16 Ha
	Amount	5.05 Ha	251.36 Ha	608.30 Ha	22.61 Ha

Table 4. Summary of Accessibility Metrics

Location Candidates	Main Road Distance	Distance to City Center	Distance of Transport Infrastructure	Settlement Distance	Electrical Distance	Telecommunications
Banjarmasin (Trisakti/Gub.Soebarjo)	≤1.000 m	4.48 km	0-10 km	0-2 km	804.12 m	59.4 km
Banjarbaru (Logistik Darat &Udara)	≤1.000 m	7.77 km	7.35 km	1.53 km	2,163.59 m	51.6 km
HSU (PDP pangan-pasar kerajinan)	≤100 m	6 km	4.4 km	0.49 km	8,096.65 m	170 km
HST (Pasar panatai hambawang)	≤500 m	9.5 km	8.2 km	0.16 km	531.37 m	158 km
Kotabaru (KEK Mekar Putih)	≤500 m	85 km	56 km	1.6 km	58,950.75 m	59 km

(b) Accessibility and Utility Metrics

The accessibility pattern confirms the hierarchical structure of South Kalimantan's logistics system. The Banjarbakula cluster functions as the main regional distribution core, supported by inland candidates in the Banua Anam cluster and by Kotabaru/KEK Mekar Putih as a coastal export gateway. These functional relationships are reinforced by primary and secondary corridors that connect production areas to consumption centers and external distribution routes.

At the candidate level, Banjarmasin (Trisakti/Gub. Soebardjo) exhibits the strongest overall operational accessibility, marked by proximity to the main road network (≤1,000 m), the city center (4.48 km), settlements (0-2 km), and the electricity grid (804.12 m). Banjarbaru also demonstrates a strong accessibility profile, particularly in relation to the main road network (≤1,000 m), land-air transport infrastructure (7.35 km), proximity to the city center (7.77 km), and settlement distance (1.53 km), which supports its role as a regional logistics node within the Banjarbakula corridor. In the Banua Anam cluster, both HSU and HST are well positioned relative to major roads and settlements, indicating strong support for food distribution and hinterland-based subregional functions. However, their distance from electricity and telecommunications infrastructure suggests a greater need for supporting networks. Kotabaru (KEK Mekar Putih) occupies a different strategic position: it is relevant as an export gateway and coastal industrial node, but its greater distance from the city center and certain support networks suggest a more selective operational profile than that of the Banjarbakula candidates.

The distance map reveals a pronounced contrast between areas located close to major infrastructure and those situated farther away. For example, many areas are more than 1,500 m from major roads and more than 1,000 m from the electricity network, which may increase development costs due to the need for road access, utility connections, and logistics support services. By contrast, proximity to city centers and transport infrastructure is more evenly distributed, indicating that site selection opportunities are determined primarily by the combination of criteria and the trade-offs among them. This pattern is typical of GIS-MCDA studies on facility siting, in which accessibility and utility directly influence both cost and operational performance (Montgomery and Dragic, 2016).

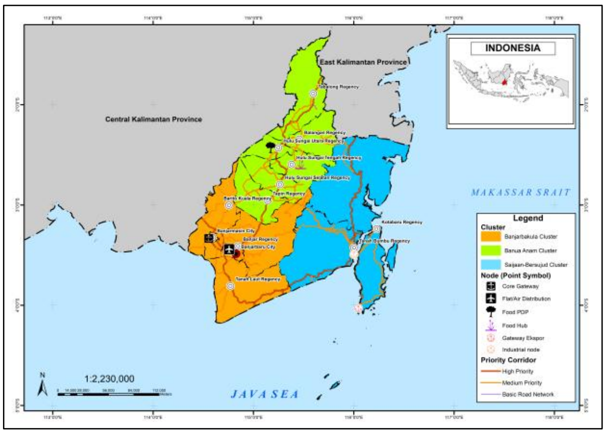

Fig 3. Key Accessibility Map

3.3 GIS-MCDA-based Suitability Index

Using a GIS-MCDA approach based on vector overlay, all criteria within the SKL and accessibility-utility components were first assigned standardized scores according to the established scoring rules and then integrated through weighting to produce the Suitability Index (SI) as a composite representation of site feasibility. Within this framework, SI should not be interpreted merely as a continuous spatial surface, but rather as a spatial synthesis generated by combining thematic layers and standardized attributes that represent the interaction between intrinsic physical land suitability and operational support. The SI map therefore shows the relative distribution of suitability levels across the study area, based on the systematic integration of all criteria used in the analysis.

Spatially, the integrated results indicate that higher suitability values tend to be concentrated in areas that combine stronger land capability with stronger operational accessibility, especially within the Banjarbakula metropolitan corridor and several strategic logistics nodes that are already developed or planned. Lower suitability values, by contrast, are generally found in areas constrained by biophysical limitations such as drainage problems, inundation potential, erosion, or land instability, as well as in areas with weaker operational support, such as proximity to arterial roads, electricity networks, and strategic transport infrastructure. Accordingly, the SI map should be read as the outcome of attribute-based spatial integration and thematic weighting rather than as a simple proximity map, as it reflects the combined relationships among land conditions, infrastructure support, and the needs of the regional logistics system.

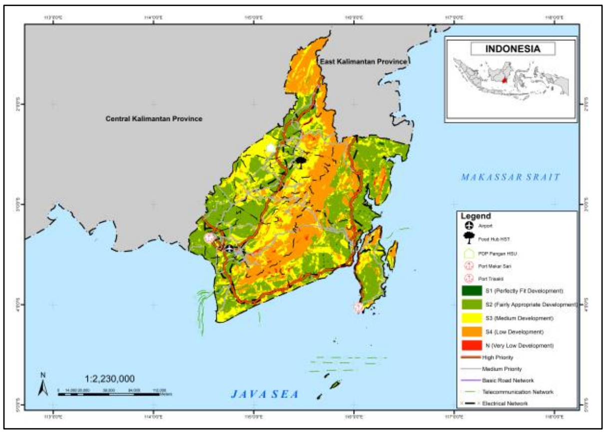

Fig 4. Suitability Index Map (continuous) Derived from Weighted Overlay (SI).

3.4 Final Suitability Classes (S1-S2-S3-S4-N)

The composite suitability values obtained from integrating the SKL and accessibility-utility layers were subsequently classified into five final suitability classes: S1 (Perfectly Fit Development), S2 (Fairly Appropriate Development), S3 (Medium Development), S4 (Low Development), and N (Very Low Development). This classification translates the integrated attribute and weighting results into a more operational categorical form, thereby facilitating spatial interpretation, communication of results, policy direction, and investment prioritization in regional logistics planning. The final suitability classes should therefore be understood not as derivatives of a continuous decision surface, but as categorical representations of location feasibility produced through the systematic combination of criteria within a vector-overlay GIS-MCDA framework.

The final classification shows that S2 is the most dominant class, covering 1,566,737.61 ha (42.22%), followed by S3 at 1,037,104.41 ha (27.95%) and S4 at 1,004,058.64 ha (27.06%). By contrast, the highest suitability class, S1, covers only 68,751.95 ha (1.85%), while class N accounts for 34,496.78 ha (0.93%) of the province's total area. These results indicate that most of the study area falls into conditionally suitable categories rather than fully developed land.

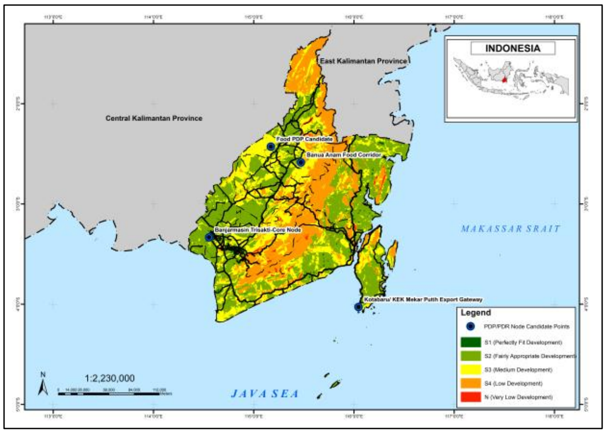

Fig 5. Map of Suitability Classes S1-S2-S3-S4-N

Substantively, this pattern confirms that South Kalimantan Province has sufficient potential for PDP/PDR development, but most locations still require technical adjustments, infrastructure improvements, or a combination of both. The dominance of classes S2 and S3 indicates that many locations are sufficiently feasible to warrant consideration, yet still face specific constraints, either in the form of biophysical limitations such as drainage, inundation, erosion, and land stability, or operational limitations such as road access, electricity, telecommunications, and strategic transport infrastructure. The relatively small extent of S1 indicates that locations combining strong physical land resilience with strong operational accessibility remain limited at the provincial scale. Class N, meanwhile, should be understood as areas with severe ecological or technical constraints that make them unsuitable for prioritization in large-scale warehousing and logistics development. This interpretation is consistent with land suitability evaluation principles, which hold that suitability classes reflect varying degrees of feasibility, along with the intervention consequences associated with them. It is also consistent with land evaluation logic in which suitable classes may still require different technical measures depending on the dominant constraints (Kim, 2022).

Table 5. Scope and Percentage of S1-S2-S3-S4-N Conformity Classes

Classes	Wide (Ha)	Presentase
S1 (Perfectly Fit Development)	68,751.95	1.85%
S2 (Fairly Appropriate Development)	1,566,737.61	42.22%
S3 (Medium Development)	1,037,104.41	27.95%
S4 (Low Development)	1,004,058.64	27.06%
N (Very Low Development)	34,496.78	0.93%
Total	3,711.149,39	100.00%

3.5 Dominant Limiting Factors and Spatial-Technical Interpretation

The GIS-MCDA results confirm that PDP/PDR site selection in South Kalimantan is fundamentally shaped by the interaction between two main dimensions: biophysical land capability and operational accessibility. The limited extent of class S1 indicates that locations performing strongly on both dimensions are rare, while the concentration of classes S2 and S3 reflects the prevalence of partial suitability, in which one group of variables supports development but another introduces constraints.

From a spatial-technical perspective, the dominant limiting factors can be interpreted in two broad categories. In biophysically constrained areas, the main limiting factors are drainage limitations, inundation potential, erosion susceptibility, foundation instability, and hazard vulnerability. These variables function as hard constraints because they directly affect construction costs, maintenance requirements, and the long-term resilience of warehousing and logistics facilities. In operationally constrained areas, the dominant limiting factors are long distances to main roads, electricity infrastructure, telecommunications support, and strategic transport gateways. These variables reduce suitability not because the land is intrinsically unsuitable, but because development would require a higher level of supporting investment before efficient logistics operations could be achieved.

This interpretation helps explain why lower suitability classes should not be read as uniformly unsuitable land. Rather, they represent areas downgraded by different dominant constraints, each of which implies a different intervention strategy. Areas constrained primarily by land capability require engineering mitigation and environmental treatment, whereas areas constrained primarily by accessibility require network provision and phased infrastructure investment.

This pattern is consistent with the geospatial character of South Kalimantan, which is dominated by lowland wetlands, river corridors, and unevenly distributed pockets of activity centers. In terms of land capability, indicators such as drainage, inundation, and erosion potential, foundation stability, and disaster vulnerability serve as hard constraints that reduce the operational feasibility of warehousing and logistics, as they have direct implications for site preparation costs, maintenance, and the risk of service disruption.

Conceptually, these findings reinforce the argument that logistics location decisions should be based on a transparent, traceable MCDA framework, as the final decision emerges from the interaction of multiple criteria rather than from simple proximity to a city center or the mere availability of land. The GIS-MCDA literature likewise emphasizes the importance of criteria structure, normalization, weighting, and weighted overlay as mechanisms for making spatial decisions more explicit and replicable (Malczewski, 2007).

3.6 Land Suitability (SKL) vs Utility Accessibility Trade-off

The results reveal a fundamental spatial dichotomy between intrinsic physical land feasibility and accessibility-utility efficiency, indicating that the siting of Provincial Distribution Centers (PDP) and Regional Distribution Centers (PDR) requires carefully calibrated policy trade-offs. In this study, the application of Weighted Linear Combination (WLC) within a vector-overlay GIS-MCDA framework enables inter-criteria integration by combining standardized attribute scores and thematic weights, such that strengths in one dimension can, to a certain extent, offset limitations in another. The trade-offs identified here should therefore be understood not as variations in a continuous suitability surface, but as the outcome of spatial integration across thematic layers representing the interaction among land capability, accessibility, and utility support within the context of regional logistics planning. Based on these integrated results, two principal forms of trade-off were identified as the basis for evaluating and formulating PDP/PDR siting policy:

1. Superior accessibility but lower SKL (S2/S3 mainly due to physical factors): locations near major transport corridors and economic activity centers are highly attractive operationally because they can reduce primary distribution costs. However, in lowland or flood-prone areas, the composite SKL value tends to be moderate to low. This indicates that site selection in such zones requires additional investment in technical mitigation measures, such as land elevation, foundation reinforcement, and the construction of macro-drainage systems, in order to ensure the long-term continuity of warehousing functions under physical-environmental stress.
2. High SKL but inadequate accessibility and utilities (S2/S3 mainly due to access factors): this typology refers to areas with relatively stable physical-biophysical conditions but lower overall suitability because of limited accessibility, especially long distances to major roads, electricity networks, and strategic transport infrastructure. From a logistics-economic perspective, development in these areas entails high initial costs because substantial investment is required to provide connectivity and supporting utilities. The most rational strategy for this typology is therefore phased development, beginning with land reservation in physically stable areas and then gradually extending feeder roads and utility networks.

Methodologically, the weighted linear combination approach in GIS is designed to capture trade-offs, or compensation effects, among criteria, making it well-suited to facility siting problems that require operational and technical compromise (Dehimi, 2021). Substantively, these findings confirm that locations capable of simultaneously satisfying both physical feasibility and operational support remain relatively limited, as reflected in the small proportion of class S1 in the final classification. Strategic decision-making by local governments therefore, cannot rely solely on proximity to activity centers or transport corridors; it must also consider the cost of mitigating physical constraints in highly accessible areas and the cost of providing new infrastructure in areas with better land capability. Giving analytical priority to SKL as the intrinsic foundation, while integrating accessibility and utility, provides a stronger basis for regional logistics planning that is not only economically efficient but also technically feasible and more sustainable in the long term.

3.7 Candidate Location Evaluation

The candidate locations evaluated in this study were not generated randomly from the suitability surface. Rather, they represent strategic sites associated with existing distribution nodes and regional logistics directions in South Kalimantan, including the Banjarbakula core, Banua Anam, and the coastal gateway of Kotabaru. The candidate evaluation should therefore be understood as a comparative strategic assessment rather than as a purely exploratory search for new sites.

The results reveal two main candidate typologies. The first consists of locations with strong accessibility but moderate physical constraints. This pattern is most evident in the Banjarbakula core, particularly Banjarmasin and Banjarbaru, where proximity to major roads, urban service centers, and transport infrastructure makes these locations highly attractive from an operational perspective. However, these areas may still require engineering responses to local physical constraints, especially in lowland or flood-prone environments. The second typology consists of locations with relatively stronger physical capability but weaker supporting accessibility. This pattern is more characteristic of inland or peripheral candidates where land may be more stable, but where distance to electricity networks, telecommunications, or transport gateways increases the cost of bringing the site up to full logistics-service standards.

At the candidate level, Banjarmasin (Trisakti/Gub. Soebardjo) and Banjarbaru emerge as the strongest metropolitan-core logistics candidates because of their superior accessibility profiles and strategic roles within the Banjarbakula corridor. HSU and HST remain relevant as food-based inland PDP/PDR candidates due to their strong proximity to roads and settlements and their roles within the Banua Anam production-support system. Kotabaru (KEK Mekar Putih), meanwhile, should be interpreted as a gateway-oriented candidate whose strategic value lies in coastal and export logistics rather than in metropolitan-core distribution. Candidate comparison in this study is therefore more appropriately understood as a functional prioritization of logistics roles than as a single, uniform ranking based on a single dominant variable.

3.8 Relevance to Previous Research and Contextual Contributions

Overall, these findings are consistent with the broader direction of GIS-MCDA research, which shows that location decisions in complex spatial systems become more robust when criteria are explicitly structured and tested through weighting and overlay schemes rather than through single-factor judgment alone (Malczewski, 2007). The contextual contribution of the South Kalimantan case lies in its stronger emphasis on the SKL-based land capability component as the intrinsic physical foundation of site evaluation. By contrast, many logistics siting studies prioritize market or transport proximity alone. By including SKL parameters, morphology, workability, slope, and foundation stability, water availability, drainage, erosion, waste disposal, and disaster vulnerability alongside accessibility metrics such as roads, electricity, telecommunications, city centers, and transport infrastructure, this study demonstrates the importance of balancing physical feasibility with operational efficiency. As shown in Table 3, land capability in South Kalimantan is not uniform, with the "Suitable" class dominating at 608.30 ha. This indicates that, without consideration of SKL, distribution center siting would face a substantial risk of being constrained by land stability and long-term infrastructure maintenance costs.

The integration of SKL criteria is reinforced by the accessibility metrics mapped in the Key Accessibility Map (Figure 3). The results show that highly accessible nodes, such as those in the Banjarbakula cluster, are located close to major roads (≤1,000 m) and strategic transport infrastructure such as ports and airports. These distance metrics, which also account for electricity and telecommunications utilities, function as cost drivers that determine whether a physically stable parcel of land can also be operated efficiently from a logistics perspective.

3.9 Policy Implications and Implementation Follow-up

The final suitability map provides a practical basis for differentiating follow-up strategies into five levels of action:

1. Priority zone (S1): S1 areas should be treated as priority zones for PDP/PDR development because they combine relatively strong physical feasibility with strong operational support and therefore require the least additional intervention. In these areas, the next steps should focus on field verification, confirmation of land status, and preliminary site design, including warehouse layout, circulation systems, and supporting logistics infrastructure.
2. Conditional zones (S2-S3): S2 and S3 areas remain feasible, but they should be approached as conditional development zones. Where suitability is reduced primarily by physical constraints, the priority response should be technical mitigation, including drainage improvement, elevation treatment, or soil and foundation reinforcement. Where suitability is reduced primarily by accessibility or utility deficits, the appropriate response is to provide feeder roads, electricity infrastructure, telecommunications support, and other complementary networks.
3. Restricted zone (S4): S4 areas should not be prioritized as primary PDP/PDR locations, but they may still be considered for long-term reserve functions, secondary storage, or low-intensity logistics support, provided they are justified by strategic needs and supported by a rigorous cost-benefit analysis.
4. Non-conforming zone (N): N areas should be avoided for large-scale logistics development because the degree of physical and environmental constraint is disproportionate to the expected benefits. These areas are more appropriately directed toward protection, conservation, or other non-intensive land-use functions.

3.10 Limitations

Several limitations should be acknowledged so that the results of this GIS-MCDA framework are interpreted appropriately and applied carefully in planning practice:

1. Subjectivity in weights and scoring rules. Although these may be informed by expert judgment and policy-based scoring rules, changes in weights can shift class boundaries in transitional areas (Dehimi, 2021).
2. The data used are mostly at the regional-provincial scale and therefore do not fully capture micro-scale site conditions, such as local soil variation, detailed elevation, actual utility provision in the field, social barriers, or land legality issues.
3. The accessibility component in this study is still represented through proximity or distance measures to infrastructure and activity centers. It therefore does not fully capture actual connectivity conditions such as road hierarchy, travel time, network capacity, congestion, and the reliability of logistics services.
4. This analysis has not yet fully integrated economic and social factors, such as land prices, land ownership status, land-use conflicts, and community acceptance, all of which strongly influence implementation feasibility in practice.

Accordingly, the results of this study are best understood as an initial basis for spatial screening and prioritization in support of decision-making. They should be complemented by field verification, more detailed site analysis, and additional non-spatial indicators before being used as the basis for final PDP/PDR location designation.

4. Conclusion

This study confirms that the selection of Provincial Distribution Center (PDP) and Regional Distribution Center

(PDR) locations in South Kalimantan Province constitutes a multicriteria spatial planning problem that cannot be explained solely by proximity to activity centers or infrastructure networks. Through a GIS-MCDA approach, the study integrates two main groups of criteria: SKL-based land capability, as the intrinsic physical foundation, and accessibility-utility, as the determinant of operational support. Within this framework, nine SKL parameters are combined with indicators of proximity to city centers, major roads, settlements, electricity networks, telecommunications, and strategic transport infrastructure to produce a spatial evaluation that is more systematic, measurable, and accountable. The weighting structure, which assigns 0.55 to SKL and 0.45 to accessibility-utility, indicates that physical land feasibility functions as a slightly more dominant threshold than operational factors, because physically unsuitable land cannot be fully compensated for by high accessibility.

The results show that South Kalimantan Province is dominated by suitability class S2, covering 1,566,737.61 ha (42.22%), followed by S3 at 1,037,104.41 ha (27.95%) and S4 at 1,004,058.64 ha (27.06%). By contrast, class S1, as the highest suitability category, covers only 68,751.95 ha (1.85%), while class N covers 34,496.78 ha (0.93%). This composition indicates that potential development space for PDP/PDR in South Kalimantan is available on a broad scale, but most of it still falls within conditionally suitable categories and therefore requires technical intervention, improved supporting networks, or a combination of both before it can be developed optimally. Biophysically, the dominant limiting factors include drainage limitations, inundation potential, erosion susceptibility, foundation instability, and disaster vulnerability. Operationally, reduced suitability is mainly driven by limited proximity to major roads, electricity networks, telecommunications networks, and strategic transport infrastructure. Lower suitability classes, therefore, do not necessarily imply absolute unsuitability; rather, they reflect different dominant constraints and thus require different response strategies.

The study also reveals a clear trade-off between intrinsic physical land feasibility and accessibility-utility efficiency. Locations that are highly advantageous from an operational standpoint, especially within the Banjarbakula metropolitan corridor, tend to face particular physical challenges, especially in lowland environments or potentially inundated areas, and therefore require mitigation measures such as land elevation, foundation reinforcement, and improved drainage systems. Conversely, locations that are relatively more stable physically in hinterland or peripheral areas often face limitations in supporting networks and therefore require phased investment in feeder roads, utilities, and regional connectivity. In the candidate evaluation, Banjarmasin (Trisakti/Gub. Soebardjo) and Banjarbaru emerged as the strongest metropolitan-core candidates because of their high accessibility profiles and strategic roles within the Banjarbakula corridor; HSU and HST remain relevant as food-based and subregional distribution candidates in the Banua Anam area; while Kotabaru (KEK Mekar Putih) is more appropriately positioned as a coastal and export gateway candidate than as a metropolitan-core distribution node. The study, therefore, does not merely produce a single ranking of locations but also clarifies the functional priority of each candidate within the provincial logistics system.

Methodologically and practically, this study contributes to regional planning by demonstrating that integrating SKL and accessibility-utility within a GIS-MCDA framework can provide a more transparent, communicative, and policy-ready basis for decision-making. The findings indicate that PDP/PDR development strategies should be differentiated according to the characteristics of each suitability class and its dominant limiting factors: S1 areas can be prioritized for early development; S2-S3 areas are feasible for phased development through a combination of technical intervention and supporting-network improvement; whereas N areas are not recommended for large-scale logistics development. Nevertheless, these results must be interpreted in light of the limitations of regional-scale spatial data, the subjectivity of scoring and weighting, the distance-based representation of accessibility, and the incomplete integration of economic and social factors. Future research should therefore focus on field verification, the inclusion of network variables based on travel time and service capacity, and sensitivity testing of the weights to strengthen the robustness of the findings. Overall, the study demonstrates that provincial-scale distribution center siting will be more robust when it is based on a balance among connectivity efficiency, physical land resilience, and regional logistics function within an integrated spatial evaluation framework.

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