



Where Should E-Commerce Fulfillment Hubs Be Located? A GIS-MCDM Framework for Supporting SMEs in Libya

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ABSTRACT

E-commerce in emerging and fragile markets often develops faster than the physical logistics systems required to support reliable and efficient order fulfillment. This study develops an integrated geographic information system (GIS) and multi-criteria decision-making framework for evaluating candidate cities for e-commerce fulfillment hubs in Libya. Twelve urban and logistics nodes were assessed using eight benefit-oriented criteria: market demand, road accessibility, port accessibility, airport accessibility, small and medium-sized enterprise (SME) activity, land affordability, national service centrality, and operational resilience. CRITIC derived objective criterion weights from the contrast and correlation structure of the decision matrix, while TOPSIS was employed to rank the candidate cities according to their overall suitability. Radial basis interpolation was subsequently used to visualize demand, multimodal accessibility, and composite suitability patterns across the study area. The results identify Misrata as the highest-ranked location, followed by Benghazi and Tripoli. Misrata combines port strength, road accessibility, land affordability, industrial and SME activity, and national centrality; Benghazi provides the strongest eastern anchor; and Tripoli offers the largest market and SME concentration. Sensitivity analysis confirms that these three cities remain within the leading group under demand-led, infrastructure-led, SME-support, and resilience-led scenarios. The proposed framework provides a transparent and replicable decision-support tool for public agencies, logistics providers, and SME-support organizations seeking to prioritize fulfillment investments and develop phased logistics networks.

1. Introduction

E-commerce changes the relationship between retail demand and logistics space. Online orders are smaller, more frequent, geographically dispersed, and subject to tighter delivery expectations than conventional wholesale flows [1]. The physical response is a network of fulfillment centers, sorting facilities, urban depots, pickup points, and last-mile stations [2]. Their location affects delivery time, inventory positioning, operating cost, service reliability, and the ability of smaller firms to reach markets beyond their immediate locality [3].

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The location problem is especially important in countries where the digital market is emerging while logistics capacity remains fragmented. In such settings, individual small and medium-sized enterprises (SMEs) may be unable to operate their own warehouses, negotiate favorable transport contracts, or provide nationwide delivery [4]. Shared fulfillment hubs can reduce these constraints by combining storage, order processing, packaging, returns management, and transport consolidation. The decision is nevertheless spatial and multi-dimensional. A site close to a large market may be expensive or poorly connected to the rest of the country, while a port-oriented location may not provide sufficient access to final consumers [1, 5].

Libya provides a relevant case. Population and economic activity are concentrated mainly along the northern coastal corridor, but the country extends over a large territory and includes widely separated urban centers. The private sector is dominated by small firms, while institutional uncertainty, finance constraints, infrastructure gaps, and uneven market access continue to affect business development [6, 7]. OECD and World Bank assessments have repeatedly emphasized the role of SMEs, logistics, ICT, and private-sector diversification in reducing dependence on hydrocarbons and broadening employment opportunities [8]. A shared e-commerce fulfillment network could support that agenda, but no transparent national framework has been developed to identify the most suitable initial hub locations.

Facility location has been studied through mathematical optimization, multi-criteria decision-making (MCDM), geographic information systems (GIS), and combinations of these approaches [9, 10]. Optimization models are effective when reliable demand, cost, and network data are available. GIS-based MCDM is useful at an earlier planning stage because it can combine quantitative and qualitative indicators, represent spatial variation, and make trade-offs visible to decision-makers [11]. Recent studies have extended these approaches to e-commerce warehouses, parcel lockers, urban logistics centers, and green logistics facilities [12, 13].

This study asks: Which Libyan cities provide the strongest conditions for shared e-commerce fulfillment hubs that support SMEs? It makes three contributions. First, it reframes fulfillment-hub location as an SME support and market-access decision rather than only a transport-cost problem. Second, it integrates objective CRITIC weighting with TOPSIS ranking and national-scale spatial visualization. Third, it links city-level location selection with the next stage of site-level evaluation, thereby providing a structured basis for logistics planning and investment analysis.

2. Literature Review

2.1 E-commerce fulfillment and the spatial organization of logistics

Fulfillment facilities connect digital transactions to physical delivery. Their functions include receiving goods, inventory storage, order picking, packaging, sorting, dispatch, returns, and information exchange. Location decisions therefore affect both upstream access to suppliers and downstream access to customers. The rapid growth of e-commerce has also increased the importance of last-mile performance, where distance, congestion, failed deliveries, and fragmented order volumes can create a high cost per shipment [14, 15].

Research on e-commerce logistics shows that facility type and spatial scale matter. Large fulfillment centers tend to prioritize regional accessibility, land availability, and connections to major transport infrastructure. Smaller delivery stations and parcel lockers place more emphasis on customer proximity, density, pedestrian or vehicle access, and operating convenience. Güven Güney and Yüzer [1] argues that location criteria differ across the e-commerce facility hierarchy. Sakulin *et al.* [16] similarly demonstrates that spatial decision support can narrow the set of feasible warehouse areas before detailed evaluation. Studies of parcel lockers have used fuzzy AHP and GIS-MCDM to address accessibility and uncertainty in last-mile systems [13, 17].

For SMEs, shared fulfillment services may be more important than ownership of the facility. A common hub can aggregate demand, provide standardized packaging and tracking, coordinate third-party logistics, and facilitate access to digital marketplaces. This can reduce fixed logistics costs and improve reliability. The hub can also act as a service platform offering inventory information, returns handling, customs support for imported products, and training in digital selling [4, 18].

2.2 Facility-location criteria

Warehouse and logistics-center location involves economic, geographic, infrastructure, market, environmental, and institutional criteria [1, 19]. Classical considerations include demand proximity, transport cost, road access, land price, labor availability, supplier proximity, and potential for expansion. Contemporary e-commerce studies add delivery-time expectations, digital connectivity, returns flows, urban restrictions, and compatibility with last-mile modes [20, 21].

GIS is suitable for criteria that vary across space, such as distance to roads, ports, airports, population, and settlements [22]. MCDM is suitable when criteria are measured in different units and contain conflicting preferences [23]. The integration of both tools provides a staged process: spatial data identify feasible zones, criterion weights represent their relative information or importance, and a ranking method compares alternatives. Recent studies apply multi-stage geospatial models, fuzzy GIS-MCDM, and suitability mapping to logistics facilities and related spatial decisions [24, 25].

The literature nevertheless has two limitations for the present context. First, much of it assumes dense urban data and mature parcel networks. Second, it often treats logistics performance as the final objective without examining how shared facilities can expand market access for SMEs. A national model for Libya therefore requires criteria that capture market scale, multimodal connectivity, business activity, spatial balance, cost, and resilience.

2.3 GIS-MCDM methods and research gap

MCDM methods differ in how they derive criterion weights and rank alternatives. Expert-based techniques such as AHP and BWM are appropriate when informed judgments can be collected and converted into consistent weights [10, 26]. Objective methods such as entropy and CRITIC derive weights from the structure of the decision matrix. CRITIC assigns greater weight to criteria with stronger contrast and lower redundancy [27]. TOPSIS ranks each alternative according to its distance from positive and negative ideal solutions and has been widely applied across location and infrastructure decisions [25, 28]. Combining a weighting method with a separate ranking procedure provides a transparent and reproducible structure for complex decisions. The CRITIC-TOPSIS combination is computationally straightforward and appropriate for national-scale facility-location analysis.

The research gap is not the absence of location models in general. It is the absence of a Libya-specific framework that connects e-commerce logistics, SME support, and spatially balanced national service. This study addresses that gap at the city-screening level; individual land parcels are reserved for the subsequent site-selection stage.

3. Methodology

3.1 Study design and unit of analysis

The study uses a two-stage logic. The first stage screens cities that could host national or regional fulfillment hubs. The second stage, outside the scope of the current paper, would identify specific parcels within the leading cities using road-network travel times, zoning, land ownership, utilities, hazard exposure, and investment cost. As shown in Figure 1, twelve candidate cities were selected to represent the principal population markets, ports, airports, road junctions, and regional service

centers: Tripoli, Misrata, Benghazi, Zawiya, Khoms, Zliten, Sirte, Ajdabiya, Tobruk, Derna, Gharyan, and Sabha.

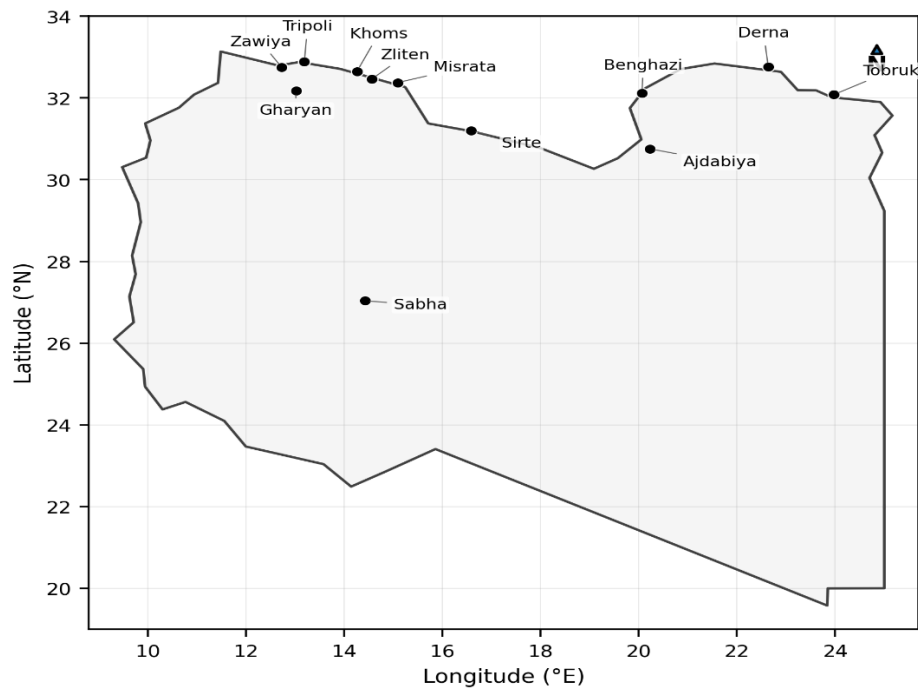


Fig. 1. Study area and candidate cities included in the Libya-wide analysis

3.2 Criteria and data construction

Eight criteria were used, as shown in Table 1. The complete city-level decision matrix is reported in Table 2 to make the calculations reproducible. Raw indicators were converted to a 0-100 scale and oriented so that larger values consistently represent greater suitability. Market scale, transport connectivity, business activity, land affordability, national service centrality, and operational resilience were then combined within a single analytical structure.

Table 1

List of the criteria used

C1	Market demand	Benefit	Relative urban market size and potential order volume.
C2	Road accessibility	Benefit	Position on major corridors, junction function, and intercity reach.
C3	Port accessibility	Benefit	Access to commercial seaports and imported inventory flows.
C4	Airport accessibility	Benefit	Access to airports and time-sensitive cargo or managerial travel.
C5	SME activity	Benefit	Relative concentration of commercial and productive SMEs.
C6	Land affordability	Benefit	Relative affordability of warehouse land and expansion; higher values indicate lower land-cost pressure.
C7	National centrality	Benefit	Ability to serve multiple population corridors from a balanced location.
C8	Operational resilience	Benefit	Continuity potential under infrastructure or regional disruption.

3.3 CRITIC weighting

The CRITIC procedure begins by orienting and normalizing the decision matrix. For each benefit-oriented criterion, the normalized value is calculated as [27]:

$$x_{ij} = \frac{a_{ij} - \min_i a_{ij}}{\max_i a_{ij} - \min_i a_{ij}} \quad (1)$$

where a_{ij} is the original score of city i on criterion j , and x_{ij} is its min-max normalized value. Land cost was represented as land affordability so that lower cost produces a higher suitability score:

$$A_i = 100 \frac{L_{\max} - L_i}{L_{\max} - L_{\min}} \quad (2)$$

where L_i is the original land-cost value or cost index, and $L_{\max}$ and $L_{\min}$ are its largest and smallest values. For each normalized criterion, CRITIC calculates the sample standard deviation:

$$\sigma_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^m (x_{ij} - \mu_j)^2} \quad (3)$$

where μ_j is the mean of normalized criterion j . The relationship between criteria j and k is measured by the Pearson correlation coefficient:

$$r_{jk} = \frac{\text{cov}(x_j, x_k)}{\sigma_j \sigma_k} \quad (4)$$

The information content of criterion j combines its contrast intensity and its conflict with the remaining criteria:

$$C_j = \sigma_j \sum_{k=1}^n (1 - r_{jk}) \quad (5)$$

where σ_j is the standard deviation, r_{jk} is the correlation coefficient, and n is the number of criteria. The final CRITIC weight is:

$$w_j = \frac{C_j}{\sum_{j=1}^n C_j} \quad (6)$$

The resulting weights are nonnegative and sum to one.

3.4 TOPSIS ranking

TOPSIS was applied to rank the candidate cities using the CRITIC weights [25, 28]. First, the benefit-oriented matrix was vector-normalized:

$$q_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (7)$$

The normalized values were multiplied by the CRITIC weights:

$$v_{ij} = w_j q_{ij} \quad (8)$$

Because all criteria were benefit-oriented, the positive and negative ideal values were:

$$v_j^+ = \max_i v_{ij}, \quad v_j^- = \min_i v_{ij} \quad (9)$$

The Euclidean distances from the two ideal solutions were calculated as:

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, \quad D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (10)$$

The closeness coefficient of city i was then obtained as:

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (11)$$

where D_i^+ and D_i^- denote the distances from the positive and negative ideal solutions. A larger closeness coefficient indicates a more suitable candidate city.

3.5 Spatial representation

The city indicators and TOPSIS results were mapped in a longitude-latitude framework. A radial basis function (RBF) surface was fitted to the city points to communicate broad spatial patterns rather than parcel-level conditions [29]:

$$S(x, y) = \sum_{l=1}^m \lambda_l \phi(\sqrt{(x - x_l)^2 + (y - y_l)^2}) \quad (12)$$

where $S(x, y)$ is the interpolated surface, λ_l is the fitted coefficient for city l , $\phi(\cdot)$ is the radial basis function, and (x_l, y_l) is the city coordinate. The surfaces were clipped to the national boundary. The multimodal-accessibility surface used the arithmetic mean of road, port, airport, and national-centrality indicators.

3.6 Sensitivity analysis

Five weighting structures were evaluated: the base CRITIC model and four policy scenarios. In C1-C8 order, the scenario vectors were demand-led (0.28, 0.14, 0.09, 0.08, 0.16, 0.08, 0.10, 0.07), infrastructure-led (0.12, 0.22, 0.20, 0.15, 0.10, 0.06, 0.09, 0.06), SME-support (0.18, 0.12, 0.08, 0.08, 0.27, 0.08, 0.10, 0.09), and resilience-led (0.14, 0.13, 0.10, 0.10, 0.12, 0.07, 0.13, 0.21). Each vector sums to one. Stability was summarized by the mean closeness coefficient across S scenarios:

$$CC_i = \frac{1}{S} \sum_{s=1}^S CC_i^{(s)} \quad (13)$$

The rank range was calculated as:

$$RR_i = \max_s R_i^{(s)} - \min_s R_i^{(s)} \quad (14)$$

where $R_i(s)$ is the rank of city i under scenario s . A smaller rank range indicates greater positional stability.

4. Results

4.1 Spatial patterns of demand and access

The demand surface shows a strong western concentration around Tripoli and a second major eastern concentration around Benghazi, Figure 2. Misrata forms a substantial central-coastal market and production node. Smaller coastal cities contribute to a continuous band of potential demand, while Sabha represents the main southern node but remains separated from the largest northern markets.

The accessibility pattern is less concentrated than demand, Figure 3. Misrata benefits from the combined effect of port access, a central position on the coastal route, and connections toward inland markets. Tripoli and Benghazi remain strong multimodal nodes, while Sirte and Ajdabiya obtain value from corridor centrality despite their smaller markets. Tobruk is strong in port access but geographically peripheral for national distribution.

4.2 Criterion weights

CRITIC produced a differentiated weight structure based on the contrast and correlation pattern of the revised all-benefit matrix. Land affordability received the largest weight (0.233), followed by national centrality (0.153). Demand (0.112), airport accessibility (0.111), SME activity (0.111), and

port accessibility (0.107) formed a middle group, while road accessibility (0.091) and resilience (0.081) received smaller weights. Figure 4 presents the resulting weights.

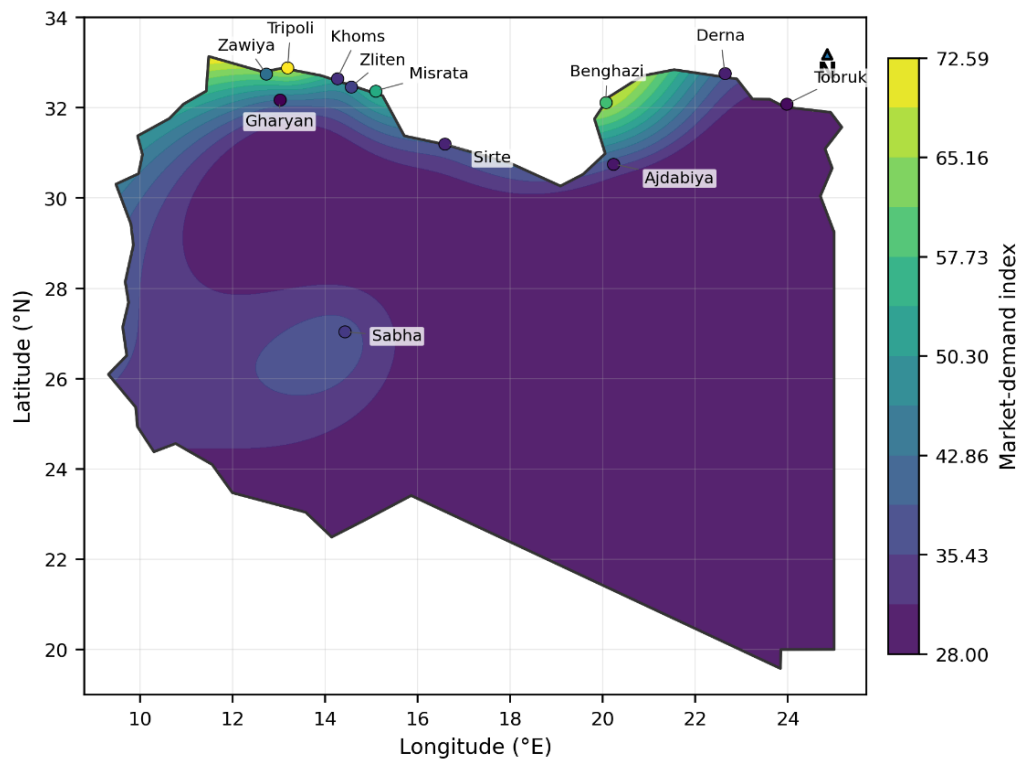


Fig. 2. Interpolated market-demand surface derived from the demand indicator of the candidate cities

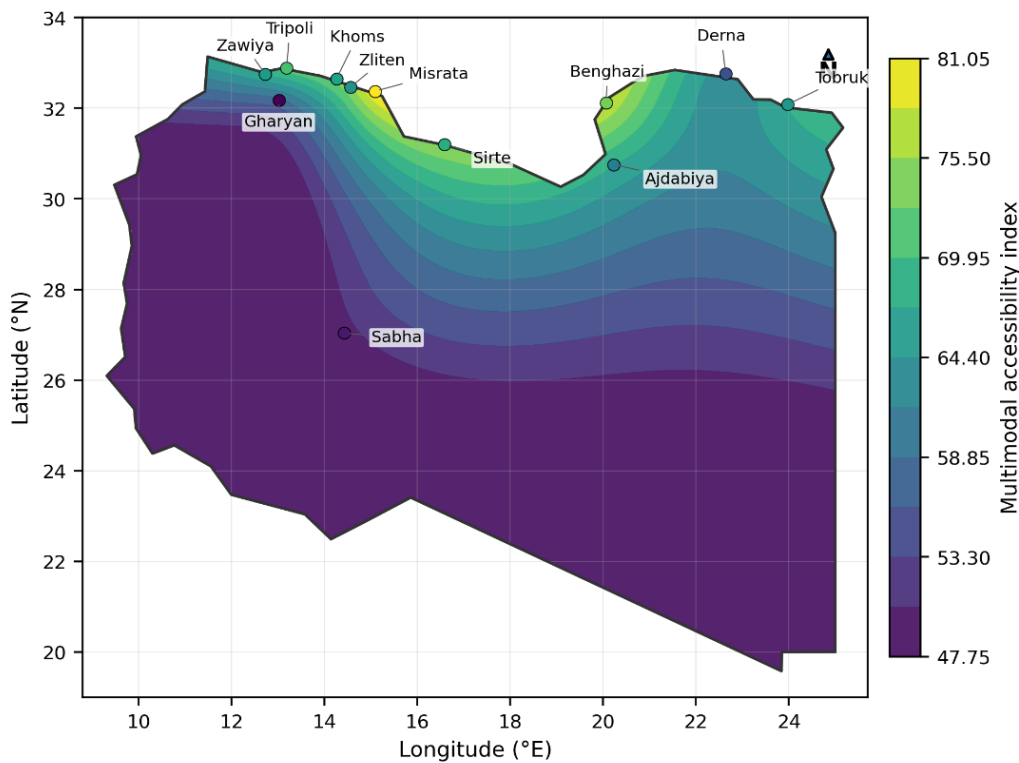


Fig. 3. Multimodal logistics-accessibility surface based on the arithmetic mean of road, port, airport, and national-centrality indicators

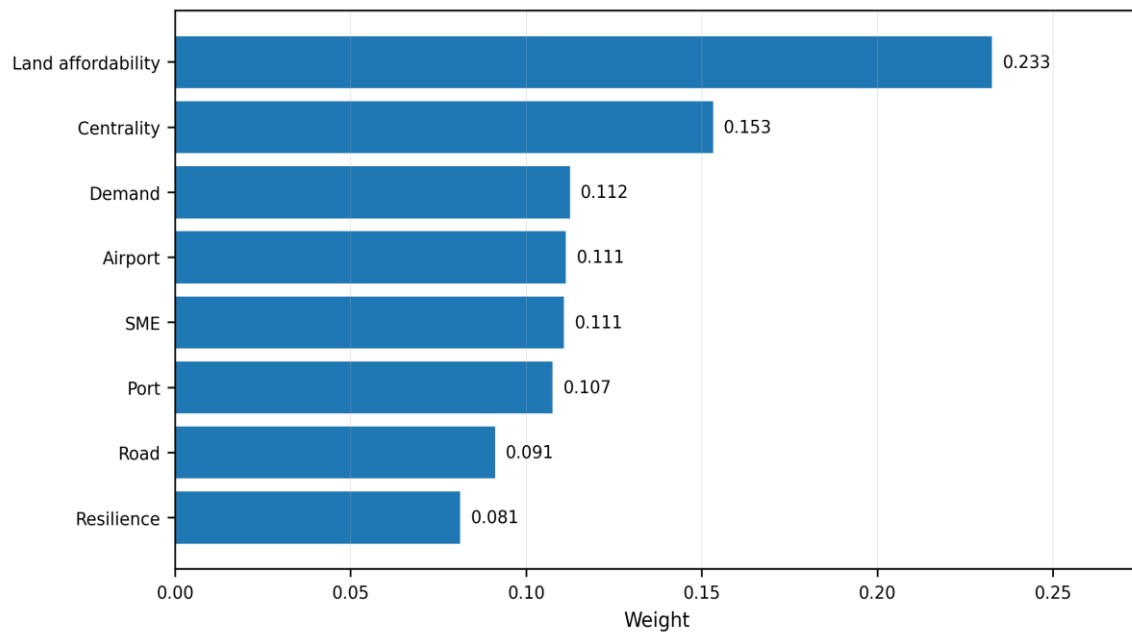


Fig. 4. Objective criterion weights obtained using CRITIC

4.3 TOPSIS ranking

Misrata ranks first with a TOPSIS coefficient of 0.744, as shown in Table 2. Its result reflects a balanced combination of port access, road accessibility, land affordability, industrial and SME activity, national centrality, and resilience. Benghazi ranks second (0.599) and provides the strongest eastern anchor through its market, port, airport, and regional-service functions. Tripoli ranks third (0.545); it records the strongest demand and SME indicators and high road and airport accessibility, but lower land affordability and western geographic concentration reduce its relative national-hub score.

Table 2
TOPSIS ranking

1	Misrata	0.744	72	95	100	78	82	55	88	82
2	Benghazi	0.599	78	82	85	88	80	42	70	75
3	Tripoli	0.545	100	88	65	92	95	30	66	70
4	Zliten	0.522	42	80	75	58	52	62	63	70
5	Khoms	0.497	38	83	80	62	48	58	64	72
6	Zawiya	0.485	54	82	72	70	65	48	60	68
7	Sirte	0.417	35	86	62	58	44	45	92	67
8	Gharyan	0.413	28	64	25	48	42	66	54	62
9	Tobruk	0.382	30	70	88	65	36	44	58	73
10	Derna	0.380	34	60	70	55	40	52	48	58
11	Ajdabiya	0.303	32	78	55	52	38	38	78	65
12	Sabha	0.207	40	58	10	62	46	35	72	55

The next group contains Zliten, Khoms, and Zawiya, followed by Sirte and Gharyan. Zliten and Khoms can support overflow, specialized storage, or feeder services along the central coast. Zawiya can serve the western coastal market, Sirte can function as a cross-dock or relay point, and Gharyan benefits from land affordability but has weaker port and market access. Tobruk and Derna support eastern regional coverage, while Sabha remains important for southern inclusion but is better positioned as a regional spoke or satellite depot than as the initial national hub. Figures 5 and 6 show the composite suitability pattern and revised city ranking.

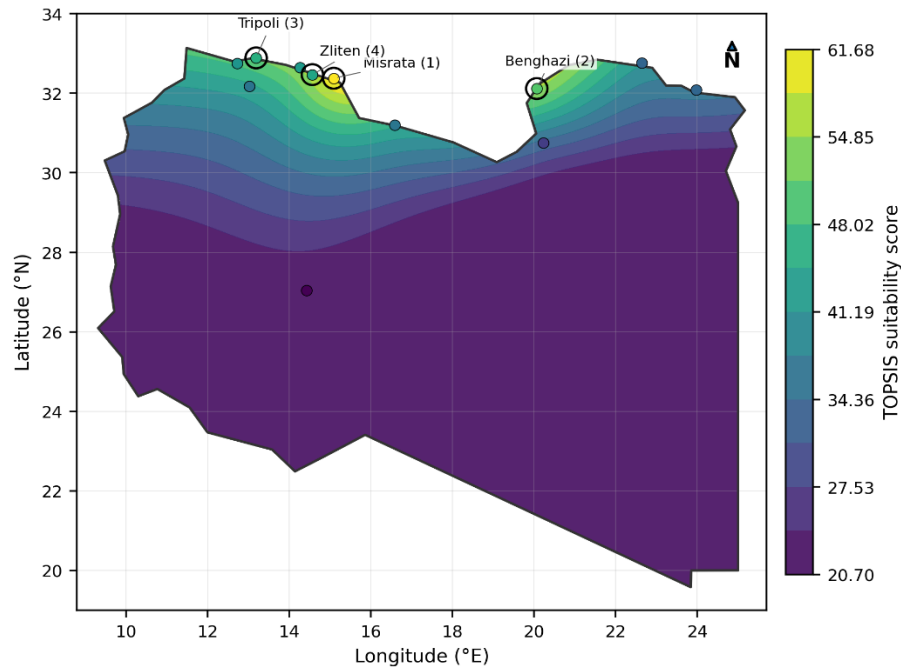


Fig. 5. Composite fulfillment-hub suitability and city ranking. Circles identify the four highest-ranked alternatives in the revised model

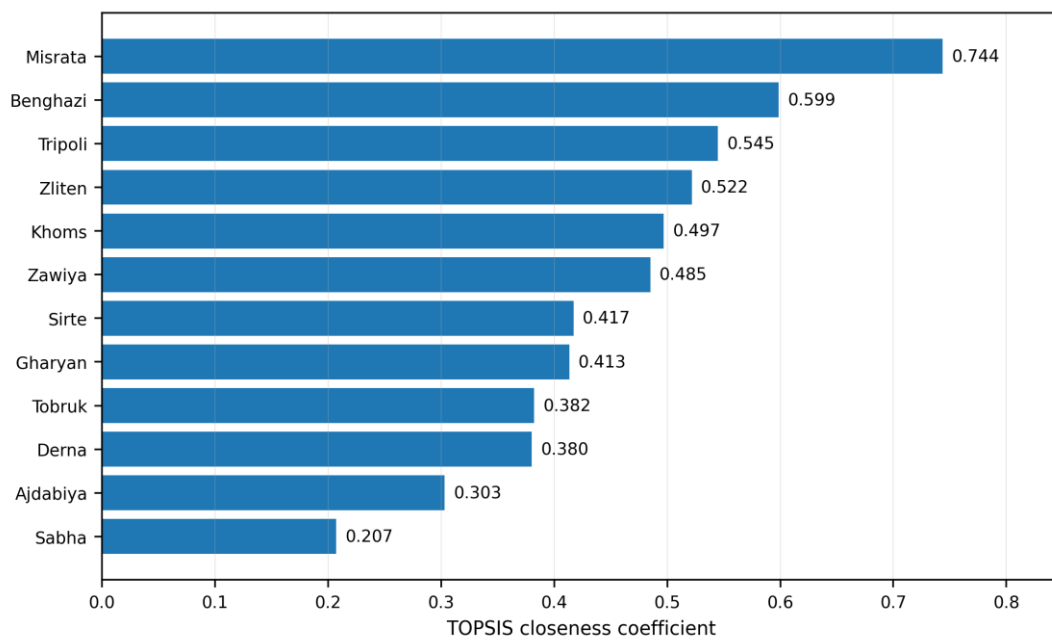


Fig. 6. TOPSIS closeness coefficients for the candidate cities

4.4 Sensitivity results

The sensitivity analysis confirms a stable leading group, as shown in Table 3. Misrata ranks first in the base CRITIC, infrastructure-led, and resilience-led models; Tripoli ranks first under demand-led and SME-support priorities; and Benghazi remains within the first three positions in every scenario. The ordering changes more clearly among the middle-ranked cities, especially Gharyan, Zliten, Khoms, Zawiya, Tobruk, and Sirte. The primary strategic decision is therefore the allocation of functions among three leading anchors rather than the selection of one universally dominant city.

Table 3
Sensitivity analysis

Misrata	0.744	0.666	0.809	0.721	0.745	0.737	2
Benghazi	0.599	0.697	0.756	0.711	0.702	0.693	1
Tripoli	0.545	0.834	0.706	0.820	0.731	0.727	2
Zliten	0.522	0.294	0.519	0.319	0.399	0.411	2
Khoms	0.497	0.269	0.537	0.288	0.398	0.398	1
Zawiya	0.485	0.413	0.569	0.455	0.468	0.478	2
Sirte	0.417	0.238	0.453	0.253	0.373	0.347	1
Gharyan	0.413	0.133	0.171	0.158	0.187	0.212	4
Tobruk	0.382	0.212	0.514	0.214	0.353	0.335	2
Derna	0.380	0.189	0.419	0.189	0.272	0.290	1
Ajdabiya	0.303	0.176	0.372	0.178	0.288	0.263	2
Sabha	0.207	0.175	0.143	0.179	0.195	0.180	2

The results support a hub-and-spoke interpretation rather than a single-facility solution. A first-stage network could use Misrata as a central consolidation and inventory node, Tripoli as the main western demand and urban fulfillment node, and Benghazi as the eastern regional node. Sirte or Ajdabiya could later operate as relay points that reduce east–west line-haul uncertainty, while Sabha could provide scheduled southern service. The exact configuration should be tested using order-level demand and road-network costs.

The leading group is consistent with the operational profiles of the three cities, although their roles differ. Misrata combines a commercial port, industrial and trading activity, central coastal access, and stronger land affordability than Tripoli. It can receive imported inventory, consolidate products from SMEs, and dispatch shipments both west and east. This result does not imply that Misrata should replace Tripoli as the largest consumer-market depot. It indicates that the functions of a national fulfillment platform and a metropolitan last-mile depot can be separated.

The study also clarifies how a fulfillment hub can support SMEs. The facility should not be designed only as warehouse space. Its service package should include shared inventory management, standardized packaging, barcode and order integration, returns processing, payment reconciliation, carrier allocation, delivery tracking, and basic export or customs support. A hub that provides only storage may have limited effect on digital market participation.

From a policy standpoint, the investment model may involve a private logistics operator, an SME-support institution, a free zone or port authority, or a public–private partnership. Public involvement is most defensible in shared digital infrastructure, access standards, training, data governance, and early coordination. Commercial warehousing and delivery operations should remain performance-driven and responsive to actual order volume.

The findings are consistent with the broader facility-location literature, which shows that market proximity alone is insufficient. Contemporary logistics sites must balance customer access, transport infrastructure, land constraints, environmental or operational risk, and network integration. The contribution of the present model is to place these trade-offs within Libya’s national geography and SME development needs.

5. Managerial implications and limitations

For logistics operators, the model identifies where detailed feasibility studies should be concentrated. Rather than collecting expensive parcel-level data for every city, firms can begin with Misrata, Tripoli, and Benghazi, then test alternative capacities and service territories.

For SMEs and digital marketplaces, the preferred network should reduce entry barriers through pay-per-use services. Pricing can combine storage, pick-and-pack, delivery, returns, and digital integration rather than requiring long warehouse contracts.

For policymakers, the decision should be assessed against national inclusion. A commercially efficient coastal network may still require scheduled service or satellite depots for southern cities. This can be addressed through network design rather than forcing the first major hub into a low-demand location.

The study has four limitations. First, the criteria operate at the city level and therefore do not capture parcel-level conditions within each urban area. Second, the road dimension is represented by an accessibility index rather than full route-based travel times on a routable network. Third, the model does not incorporate detailed zoning, utilities, ownership, flood exposure, or construction constraints. Fourth, the CRITIC weights are data-driven and could be complemented in future work with stakeholder-based weighting. These points define the scope of the analysis and indicate directions for further refinement.

6. Conclusion

This paper developed a GIS-MCDM framework for evaluating e-commerce fulfillment-hub locations in Libya. Eight market, infrastructure, business, affordability, spatial, and resilience criteria were evaluated for twelve candidate cities. CRITIC provided objective weights, TOPSIS generated the ranking, and RBF-based maps communicated demand, accessibility, and composite suitability patterns.

Misrata, Benghazi, and Tripoli form the leading group. Misrata provides the strongest balance for national consolidation; Benghazi provides the essential eastern anchor; and Tripoli offers the strongest western market and SME base. The practical implication is that Libya should not treat the problem as the search for one permanent national warehouse. A phased network is more appropriate: a central consolidation hub, metropolitan or regional nodes, and smaller relay or satellite facilities as order volume develops.

The next research stage should obtain geocoded order records from marketplaces and courier firms, build a road-network travel-time matrix, identify available industrial parcels, and estimate facility and delivery costs. BWM or Delphi can then be used to capture stakeholder preferences, while p-median or capacitated facility-location models can determine the number, capacity, and service territories of hubs. The framework presented here provides the structure for that more detailed analysis.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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