Journal of Supply Chain Management Systems
13 (1) 2024, 01-12
http://publishingindia.com/jscms/

Mapping India's Foreign Trade Path: Strategic Logistics Gravity Centres

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Abstract

This research paper studies a region with significant potential scope to be developed as the all-encompassing logistics solution to international trade movements within India. With India's export and import market enjoying a prolonged period of growth supported by the government's favourable policies, there is an extensive scope for developing support industries. The infrastructure supporting export-import businesses in India needs an overall enhancement. Specifically, the logistics industry in India is quite skeletal, though rapidly developing. Moreover, its development is erratic and need-based. It requires planned and structured growth, a design-based progression. Systematically developing a potential region is a basic requirement. In our study to identify and evaluate a geographical cluster in India capable of serving seaports, airports, and trade districts, we have used a multi-criteria decision-making approach. While geographical distance is a prime influencing factor, other determinants like connectivity, population density, geography, and GDP of the potential districts also play a critical role. The study adopts a novel approach by holistically examining all international trade factors, including major sea and air ports as well as principal export-import districts. While the Gravity Model is used to synergize the multifaceted information, an advanced evaluation derives a comprehensive analysis of potential locations. The study culminates in a proposal for the strategic development of logistics centres to boost India's international trade. This study provides valuable insights to develop logistics infrastructure and strategy for service providers and businesses. It is limited by the reliance on generalised data available in the public domain and by the exclusion of explicit modes of transport and commodities. This paper delves deep into analysing, calculating, and providing actionable insights toward developing a potent region for logistics. The study recommends sustained development in a particular area to reduce logistics costs and increase efficiency and speed.

Keywords: Logistics Infrastructure, India Global Trade, Logistics Centre, Gravity Model

Introduction

India's International trade has been growing exponentially; the growth rate was 18.61% in 2021. The total goods and services exported and imported are over 20% of the GDP (Worldbank.org. (n.d.). *India Trade Statistics | WITS*). Consequently, India's International trade has ascended the World Bank's Logistics Performance Index (LPI) ranking to the 38th position (International Scorecard Page | Logistics Performance Index (LPI). (2023). [online] *lpi.worldbank.org*). India exports and imports multiple commodities across the globe. The trade and movement of these commodities originates from and culminates in several locations, often remote, across the country. These commodities often move on to different consumption points. Therefore, it is accurate to say that the thriving export and import industry heavily depends on the intensive foundation of the logistics sector to facilitate the movement of goods.

Aggregated logistics costs for India fall in the range of 7.8%–8.9% of the GDP for 2021-22 (Kapoor & Singh, 2023). Some of the objectives of the National Logistics Policy (NLP) of India 2022 (dpiit.gov.in *National Logistics Policy 2022*) are to promote intermodality and multi-modality, optimise and upgrade logistics infrastructure, and facilitate integration with the global value chain. It is evident that the government intends to reinforce the logistics infrastructure to enhance efficiencies and reduce costs.

Foreign trade with India is routed through multiple international exit and entry points. India's leading export and import districts are in coastal areas as well as the hinterland. The movement of goods for export and import is pan-India, sometimes from one end of the country to the opposite end. Frequently, there is movement across multiple states.

The seaports, airports, and trade districts are spread far and wide across India. There is substantial transport

movement to and from their locations. The extensive inland movement is complemented by logistics centres. These logistics centres provide a convergence point for exporters and importers. They bring in speed and efficiency in transport. Logistics centre facilities are also used for consolidation or break-bulk operations and Value -Added Services (VAS).

We aim to identify high-potential locations that can be developed as logistics centres to provide a critical support base for boosting international trade movements nationwide. We are working holistically to leverage significant seaports, airports, and global trade districts.

The logistics fraternity often uses the 1962 Tinbergen Gravity Model to determine these logistics centres. The Tinbergen Gravity Model revolutionised the analysis of international trade movements (L. Capoani, 2023). It explores diverse approaches to understanding trade dynamics between and within countries through varying model variables and analytics.

This study uses the Gravity Model as its starting point. The objectives of this study are multidimensional and unique. Our primary aim is to evaluate the potential logistics cluster in India that would be most suitable to develop. We intend to identify a particular possible region that can serve various purposes of international trade, like break bulk, consolidation, short-term storage, or a Value-Added Service (VAS) facility. We evaluate this option using the Gravity Model.

Secondly, we plan to recommend an adaptable framework for service providers and businesses in the Indian export and import market to build their logistics infrastructure network. The framework will encompass a broader canvas for evaluating optimum logistics solutions.

Although these logistics centres have considerably different typologies and hierarchies in different regions, in this study, we have adopted a fixed hierarchy (Higgins et al., 2012).

- First layer: Warehouse and Distribution Centre
- Second layer: Freight Transportation and Distribution
- Third layer: Gateway Cluster

We work under the pretext of the limited literature on Indian logistics infrastructure. We will explore India's international trade zones to determine potential optimal logistics centres. We will work toward a result of analysing and devising a more practicable and efficient logistics cluster that may be a better option than the one commonly used.

The location of logistics centres is critical for them to support trade movements beneficially and profitably. Besides other important factors impacting their suitability, the primary requirement is a central location. We start with three Centres of Gravity (CoGs)—one for the 12 seaports, one for the 12 airports, and one for the 30 trade districts. These are locations with high potential to serve the trade movements.

We will conclude the study by assigning a score to determine the optimality and feasibility of each potential location.

The paper presents its objectives, including evaluating potential logistics clusters and proposing a framework for infrastructure development. The Literature Review and Data Collection methods provide the background to the research. While the Research Design details the study's calculations and analytical approach, the Results and Discussions section elaborates the findings with their purposeful implications. The paper concludes with a direction for action and scope for further studies.

Literature Review

Summaries of literature reviewed:

India's international trade faces several domestic challenges— patchy distribution networks, reducibly long lead times, and rigid regulatory requirements (Wahab et al., 2023).

In the developing economies of South Asia and the ASEAN countries, the service industries catering to exporters and importers need to be improved. The disparity in service levels is stark, especially compared to the well-developed North American and European economies (Nasir & Kalirajan, 2016).

Analysis reveals that India's west coast container terminals have a significant advantage over the east coast terminals. Additionally, minor port terminals are superior in operational efficiency than significant port terminals (Iyer & Nanyam, 2021).

In the long term, developed infrastructure significantly boosts exports and trade deficits in developing countries. Improvement in infrastructure leads to a substantial increase in exports and a corresponding reduction in trade deficits. Therefore, infrastructure is crucial in promoting productive, efficient, and cost-effective international trade (Rehman et al., 2023).

Enhancing transport infrastructure and improving logistics quality are vital strategies for boosting international trade. By developing superior transport networks and efficient logistics systems, countries build a significant edge in logistics-intensive industries, thereby amplifying overall trade performance on a global scale (Park, 2020).

Better logistics spearheads higher exports and imports. Specifically, customs efficiency and transport infrastructure significantly influence trade. Continual investment in logistics positively impacts international trade. This makes it highly important for economic policy and trade facilitation (Gani, 2017).

Recent developments in India's logistics sector are driven by a substantial influx of investments to grow and enhance operational performance (Sudan & Taggar, 2021).

Characteristics of Indian airport and air freight demand are closely correlated and directly impact freight movement. Studying air freight indicates factors like city industrial units and population size as critical determinants. It influences the freight movement capabilities (Veerappan et al., 2020).

Supply networks are built on interdependences between the various modes of transport and their connection with terminals. Transport activities are interconnected in nature, and these relationships impact the efficiency and effectiveness of supply chains (Eriksson et al., 2022).

As mentioned earlier, India's International trade has ascended the World Bank's Logistics Performance Index (LPI) ranking to the 38th position (International Scorecard Page | Logistics Performance Index (LPI). (2023). [online] lpi.worldbank.org). The LPI is an interactive benchmarking tool created by the World Bank to help countries understand their performance in trade logistics and identify opportunities for improvement. Feedback from global logistics professionals through surveys, alongwith detailed, high-frequency shipping and freight data is used to determine the LPI (Arvis, Jean-François et al., 2018).

The LPI evaluates countries based on six key areas: customs efficiency, trade and transport infrastructure, international shipments at competitive prices, logistics quality and competence, tracking and tracing consignments, and timeliness. It also incorporates additional metrics, such as container shipping, aviation logistics, postal services, import/export delays, and specific issues faced by landlocked nations (Dang & Yeo, 2018).

The LPI's purpose is to guide countries toward logistical improvement. Macro factors considered for improvement include national and international policies on trade and logistics, infrastructure development, customs regulations, and the adoption of technology and practices that facilitate trade and transportation. Micro factors involve the operational efficiency of logistics service providers, specific customs and border agency practices, and the technological capabilities of companies and organisations within the logistics sector.

India's ascension in the LPI ranking encourages a shifting away from traditional establishments and exploring progressive avenues. Substantial advantage can be leveraged by creating newer, high-potential geographic areas as logistics centres, which promotes international trade.

The attention of researchers is mainly focused. They may study specific commodities, particular trade zones, a trade block, or individual ports. However, developing regions are yet to be studied in depth. This study aims to address this gap by systematically exploring and identifying regions within India that hold a prospect of developing into significant logistics centres and contributing to national and international trade efficacy.

Data Collection

We collected data mainly from periodic publications on Indian government websites, namely the Ministry of Commerce and the Ministry of Ports, Shipping, and Waterways. The base year for this report is the year 2021-22. It is the most appropriate period as most of the research work is done in the second half of 2023. Since the Government of India has published these reports, we find them the most accurate information for this study.

The data is published with volumes for major seaports and airports and the export value for significant districts. The airport volume data is in metric tons. While the seaport volume data was in kilotons, we converted it into metric tons to maintain uniformity and ease of calculation. The export value for the districts is in millions of USD. (Airports Authority of India, 2022. Retrieved from https://www.aai.aero/en/business-opportunities/aai-traffic-news Ministry of Ports, Shipping and Waterways, 2022. Retrieved from https://shipmin.gov.in/content/basic-port-statistics-2021-2022).

We have chosen 12 major seaports, 12 major airports, and 30 top export-import districts for our study. We identified the location coordinates for these seaports, airports, and districts. The district data published for April-Sept 2021 is taken as a base, as it is more to understand the mass of exports (pib.gov.in, 2021).

The Export Preparedness Index 2022 is published by the NITI Aayog (Planning Commission of India). We have used this report for the valuation of the state-level evaluation (Kapoor & Singh, 2023).

We have used accessible data sources to compile district geography characteristics. Terrain features, agricultural land distribution, and altitude measurements were primarily extracted from state government repositories. These sources were selected based on their accessibility and relevance to the study's focus. The economic and demographic data of the districts is also collected through respective state government departments and their publications (Reference 8 to 13, 23, & 26: Maharashtra government website on districts. Retrieved from https://www.maharashtra.gov.in/Districts Maharashtra government website Survey Reports. Retrieved from https://mahades.maharashtra.gov.in Telangana State Statistical Abstract. (2022). Retrieved from https://telangana.gov.in).

Research Design

To determine the most suitable zone for international trade in India, we identified the Centre of Gravity (CoG) using location coordinates and volumes or values.

Three different Centres of Gravity (CoGs) are determined. One is for the seaports, one is for the airports, and one is for the top export-import districts of India. We compute the coordinates of these three locations and chart them out on the map.

Their geographical coordinates represent each seaport, airport, and district (X_i, Y_i). The volume of seaports and airports in metric tons (MT) and the dollar value of district ports are also considered. The Centre of Gravity is calculated as:

Formula for CoG

(X_i, Y_i) represent the longitude and latitude of the i^{th} location.

V_i represents the volume or value of the i^{th} location.

Is the total number of locations. Longitude of the CoG: X_{CoG}

$$XCoG = \sum_{i=1}^{n}(Xi \times Yi) \div \sum_{i=1}^{n} Vi \qquad \text{Equation 1}$$

Latitude of the CoG: YCoG

$$YCoG = \sum_{i=1}^{n}(Xi \times Yi) \div \sum_{i=1}^{n} Vi \qquad \text{Equation 2}$$

This gives us the coordinates for three CoGs— the CoG of seaports, the CoG of airports, and the CoG of the top districts.

Furthermore, using the geometrical approach, we identify three intermediate points. An intermediate point marks the approximate centre between two CoG points. These three intermediate points between the CoGs mark the coordinates of three more potential locations.

A total of six strategic locations are identified and analysed as potential logistic centres. For clear referencing within this paper, each area is represented by a unique code sequentially from W1 to W6.

Table 1: Potential Logistics Centre Locations

Potential Location	Code
CoG Sea Ports	W1
CoG Airports	W2
CoG Export districts	W3
~Geometric Midpoint 1	W4
~Geometric Midpoint 2	W5
~Geometric Midpoint 3	W6

The gravitational formula applied generates specific geographical coordinates. Inputting these coordinates into Google Maps (2023) ascertains the precise village and district location on the map. This utilisation of geocodes through Google Maps accurately pinpoints the areas of interest. The coordinates correspond accurately with the map shapefiles provided by the Survey of India, facilitating the accurate rendering of maps.

Using a basic spatial analysis technique, we assess the proximity of locations in terms of straight-line distance. Each location option is measured using the Euclidean distance. To make this measurement more meaningful, a volume-distance ratio is also derived. Summing and evaluating these scores gives us a CoG Suitability Score for each location's potential as a logistics centre.

The Formula for Euclidean Distance

(X_i, Y_i) represent the longitude and latitude of the i^{th} seaport/airport/district.

i = 1, 2, 3, …n

n = is the number of seaports/airports/districts

(X'_j, Y'_j) represent the longitude and latitude of the potential location W.

j = 1, 2, 3, 4, …6

D_{ij} is the Euclidean distance between the i^{th} seaport/airport/district and the j^{th} potential location.

$$D_{ij}=\sqrt{(Xi - X'j)^2 + (Yi - Y'j)^2} \quad \text{Equation 3}$$

The Suitability (S) of each of the six warehouse locations is evaluated concerning each seaport, each airport, and each export-import district. The final suitability score of a warehouse is the sum of suitability scores concerning all the seaports, airports, and districts.

The formula for the Suitability Score

$V(S_i)$ is the volume or value of the seaport/airport/district

$D_i(S_i, W_i)$ is the distance between the W^{th} potential location and S_i^{th} seaport/airport/district

The Total Suitability Score for the location W_i:

$$\sum_{i=1}^{12} V(Si) \div Di(Si, Wi)^2 \quad \text{Equation 4}$$

This scoring process prioritises locations not only on their geography but also on their business capacity and capability. It rates potential based on an area's proximity to demand centres and the substantial trade volume or value they promise.

We have used the weighted factor method to evaluate these potential locations to draw more meaningful and valuable inferences. We have considered some vital, relevant factors (Battal, 2020; Essaadi et al., 2016) to evaluate the suitability of each location. Once assessed, all the values are normalised.

Each logistics centre is scored on certain factors like:

Table 2: Key Factors to Evaluate the Suitability of Locations

Factor	Description	Relevance
Connectivity	Access to major highways and transport networks.	Essential for deeper market reach and efficient transportation of goods.
Population Density	Human resource directly impacts operational efficiency in labour-driven logistics.	Higher population density allows a larger available workforce.
Geography	Including its terrain and landscape, hilly or mountainous areas, river and bank regions, deserts, marshlands, etc.	Significantly impacts logistics in terms of mode and speed of transportation.
District GDP	Defines the infrastructural soundness and market vibrancy.	Higher GDP districts might have better infrastructure and market opportunities for logistics centres.
Export Preparedness Index Rating	A government rating that provides insights into the policy, ecosystem, and performance of exports in each state.	Better export capabilities and affirmative policies of a state influence the strategic placement of logistics centres.

Population Density, District GDP, and Export Preparedness Index (EPI) Ratings are measured in direct numeric values. Connectivity and Geography are defined using a 5-point Likert scale:

1 —Poor, 2 —Below Average, 3 —Average, 4 —Good, 5 —Excellent

This scale encompasses a broad range of connectivity values— from very low to very high.

We use the Analytic Hierarchy Process (AHP) to assign weights followed by a Consistency Index Check. Since the unit of measurement is different for each factor, the data is first normalised, and then the weights are applied for score calculation.

Table 3: Weighted Ranking of Suitability Factors

Factor	Rank
Population Density	4
District GDP	2
Connectivity	5
EPI Rating	1
Geography	3

* Factors are ranked from 1 to 5, with 5 being most important and 1 being least important.

The geographical proximity and connectivity of a location to key ports significantly influence the dynamics of international trade. This fundamental aspect impacts lead times for exporting and importing goods and is crucial in determining the availability and diversity of raw materials and finished products in a specific area.

The geographical characteristics of a region significantly influence the foundational elements of its infrastructure development. Precisely, locations with extensive agricultural activity or dense forest coverage present challenges for establishing logistics centres. The trade-offs between land use for agriculture or forest preservation and industrial development must be carefully evaluated to ensure a sustainable and equitable approach to infrastructure planning. This assessment addresses immediate logistical needs while considering such developments' long-term environmental and socio-economic impacts.

The operational efficiency of logistics centres is heavily contingent upon the availability of labour. In scenarios where labour viability could be higher, these centres face significant challenges in scaling their throughput to meet fluctuating demand. A continuous and adaptive approach to managing the workforce is essential. The proximity of available labour pools equips these centres with the flexibility necessary to respond dynamically to changes in demand.

A district's Gross Domestic Product (GDP) is a pivotal indicator of its economic health and its capacity to support various business activities, particularly in the logistics sector. This connection stems from the fundamental understanding that a region's GDP reflects its ability to produce goods and services and participate in trade. Such economic robustness provides a fertile ground for logistics centres to operate and flourish.

The EPI for India represents a pivotal tool in understanding and enhancing the country's export capabilities, particularly in its diverse regional landscapes. The Index offers a nuanced and comprehensive analysis of India's export trends, focusing on ground-level performance and the collective efforts of both the central and state governments. Aligning the establishment of a logistics centre with regions that have high EPI ratings is a strategic decision that yields long-term benefits. It ensures the centre is well-positioned to capitalise on existing export strengths, contributes to regional economic growth, and maintains a competitive edge in the dynamic global trade environment.

Comparison Matrix

We use AHP to prepare a comparison matrix. It is a 5x5 matrix where each element V_{ij} is the importance of the Factor *i* divided by the importance of Factor *j*.

F represents the Importance Rank of a Factor.

V_{ij} is the comparison value of Factor *i* against Factor *j*.

$$V_{ij} = \frac{Fi}{Fj} \qquad \text{Equation 5}$$

We normalise the initial matrix by dividing each entry by its column total and then calculating the average of each row.

Table 4: Normalised Comparison Matrix

Factors	Connectivity	Population Density	Geography	District GDP	Export Preparedness Index Rating	Final Weight
Connectivity	0.3333	0.3333	0.3333	0.3333	0.3333	**33%**
Population Density	0.2667	0.2667	0.2667	0.2667	0.2667	**27%**
Geography	0.2000	0.2000	0.2000	0.2000	0.2000	**20%**
District GDP	0.1333	0.1333	0.1333	0.1333	0.1333	**13%**
Export Prepared-ness Index Rating	0.0667	0.0667	0.0667	0.0667	0.0667	**7%**

Each row of the normalised matrix represents the priority vector, which means the normalised weights of the factors.

Formula for Consistency Index

CI = (ƛmax-n)/(n-1) Equation 6

where,

n is the number of factors.

λmax is the principal eigenvalue.

The weighted sum vector is calculated by multiplying the original comparison matrix with the priority vector. The priority vector is the average of the rows of the normalised comparison matrix.

λmax is calculated by using the average of the weighted sum vector divided by the corresponding priority vector.

In our case, the principal eigenvalue is approximately 5, which is equal to the number to factors (n). The Consistency Index (CI) remains very close to zero. This means that the matrix is consistent and the weights derived from the priority vector are reliable.

The total score is calculated by multiplying the normalised score with weights. This score is then integrated with the CoG model score. They are ranked from 1-6. The location with the highest score is considered most suitable and is ranked 1.

A Sensitivity Analysis is conducted on the CoG model using the volume or value. The sensitivity analysis includes five scenarios:

- *Market Improvement:* Assesses the impact of a 10% increase in volume at critical locations.
- *Trade Expansion:* Evaluate the effects of a 25% increase in volume at various hubs.
- *Trade Dynamics Shift:* Analyses the impact of a 25% decrease in volume at initial ports and districts.
- *Market Contraction:* Examines the result of a 10% decrease in volume at significant ports and districts.
- *Rapid Growth:* Studies the possible effects of a 50% increase in volume at the top locations and a 25% increase at others.

Result and Discussion

Charting the coordinates of the three identified CoGs on the map forms a triangle. The other three additional potential locations fall within the region of the triangle.

The CoGs of sea, air, and district are shown on the map. The triangular area of 29,500 square km is optimal for logistics centres.

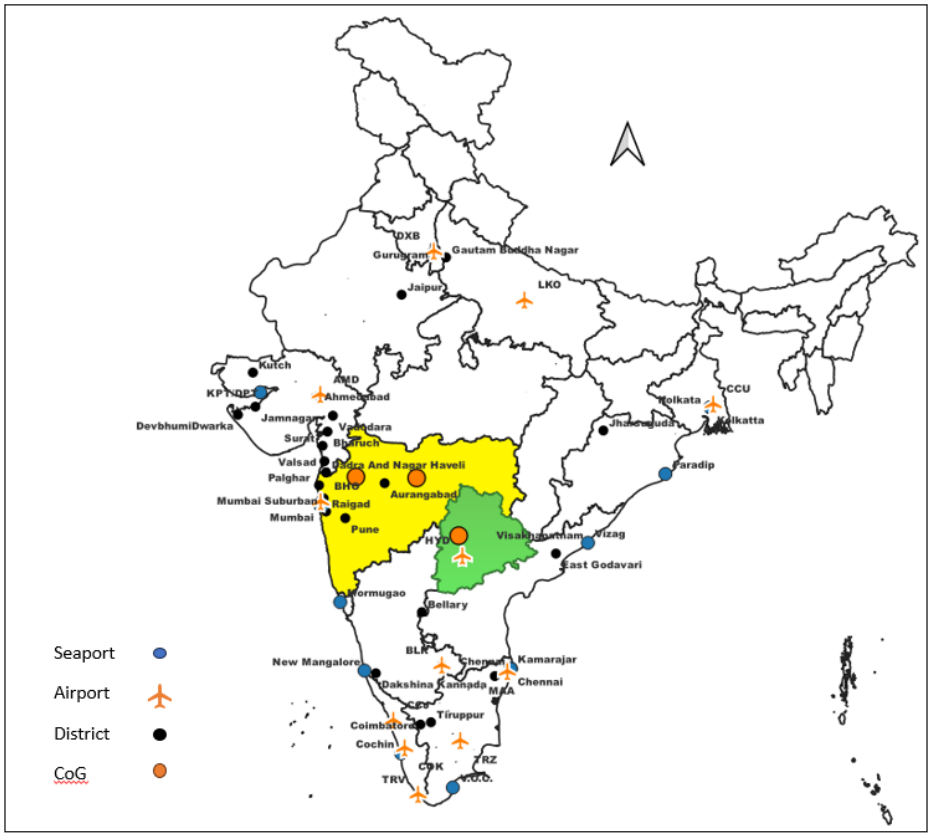

Image 1: Map of Key Shipment Hubs and Districts in India

The region is mainly in the state of Maharashtra, partially extending into Telangana; it is focused on the border of the two states. Maharashtra is a coastal state. Telangana is landlocked state. It is comparatively new, recently constituted in 2014. This region is situated in the southwest-central of India.

Most of the area is situated in Maharashtra, traditionally a region brimming with industrial activity and still holds vast potential for logistics centres. On the other hand, Telangana is a rapidly growing state. As per our study, its location presents extensive opportunities to teach logistics activities.

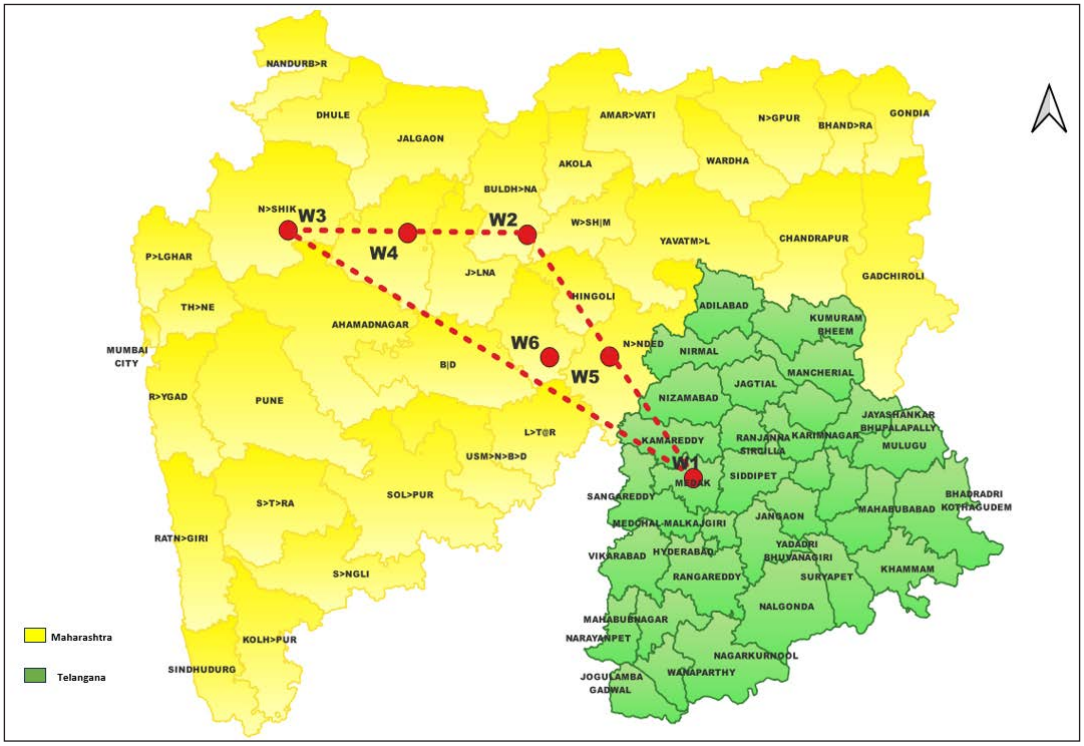

Image 2: 6 Potential Locations

Five potential locations are situated in Maharashtra, and one is in Telangana. 94% of the triangular region is in Maharashtra, with only 6% extending into Telangana.

The Suitability score of all six locations is reported in the table below.

Table 5: Suitability Score Card

Locations Code	W1	W2	W3	W4	W5	W6
Factors						
Connectivity	0.25	0.25	0.33	0.17	0.25	0.25
Population Density	0.23	0.19	0.27	0.24	0.23	0.20
Geography	0.20	0.15	0.10	0.10	0.15	0.20
District GDP	0.03	0.03	0.13	0.07	0.05	0.03
Index Ranking	0.05	0.07	0.07	0.07	0.07	0.07
Total Score for Factors	0.76	0.69	0.90	0.64	0.74	0.75
CoG model score	0.23	0.28	1.00	0.20	0.19	0.24
Grand Total score	0.99	0.97	1.90	0.85	0.93	0.98
Rank	2	4	1	6	5	3

As per the scores, W3 and W1 are the top two locations. Scores of the remaining locations point to tremendous potentiation opportunities for each.

A sensitivity analysis with variations in volume demonstrates that the CoG remains mainly within the triangular 29,500 square km area. For a few scenarios,

the CoG varies slightly out of the area, up to a 65 km distance. The analysis reveals that this region is apt for logistics centre development.

Five scenarios are reviewed by varying each parameter individually while keeping others constant. Separate analyses are done for the sea, air, and district CoGs.

Table 6: Sensitivity Analysis Scenarios

Scenario	Description	Sea	Air	District
1	*Market Improvement* 10% increase in volume at key seaports (JNPT and Chennai), airports (Bengaluru and Hyderabad), and districts (Mumbai, Mumbai Urban, Gurugram, Bengaluru, Gautam Budh Nagar) indicating market improvement.	14 km outside the triangle area	Located within the triangle area	2 km outside the triangle area
2	*Trade Expansion* A 25% increase in volume at the last five seaports, airports, and the last ten districts suggests potential for significant trade expansion.	60 km outside the triangle area	Located within the triangle area	Located within the triangle area
3	*Trade Dynamics Shift* A 25% decrease in volume at the first five seaports, airports, and the first ten districts indicates a shift in trade dynamics.	62 km outside the triangle area	Located within the triangle area	Located within the triangle area
4	*Market Contraction* The 10% decrease in volume at JNPT and Chennai seaports, Bengaluru and Hyderabad airports, and Mumbai, Mumbai Urban, Gurugram, and Gautam Budh Nagar districts points to potential market contraction.	8 km outside the triangle area	15 km outside the triangle area	2.5 km outside the triangle area
5	*Rapid Growth* A 50% volume increase at the top 5 seaports and airports, along with the top 10 districts, and a 25% rise at the last five ports and 10 districts implies a differentiated potential for growth.	Located within the triangle area	13 km outside of the triangle area	28 km outside of the triangle area

*Sea ports, airports, and districts have been checked as separate groups, and their influence on the potential triangle area was assessed individually.

The coordinates of the CoGs derived through the Gravity Model usually lead to small villages. Relying solely on the socio-economic and geographic data of that specific location could present a constraint due to the potential scarcity of data at such a granular level. Consequently, we have expanded our analytical framework to encompass the socio-economic and geographic data of the entire district in which the CoGs are situated. This broader approach facilitates a more comprehensive assessment for the development of a logistics centre in and around the identified location. The focus is on population density, GDP, and the district's ranking in the state's Export Preparedness Index, as well as its connectivity to major highways. These metrics are foundational in our study.

W1 – Balanagar village, Medak district, Telangana This ranks two on our scorecard. It is the only location in the state of Telangana. It is, in fact, the CoG of sea exports. Telangana's recent formation as a new state may witness a massive boost in infrastructure development. It has the highest population density. Our score also shows a high potential to ascend to rank 1 if the state ranking and district GDP increase. Moreover, given that it is well-connected with highways, it has a high potential to become a vital logistics centre. Our Sensitivity Analysis indicates that it may become a surprise centre if supported by rapid development.

W2 – Ukali village, Buldhana district, Maharashtra This ranks four on our score card. Area-wise, Buldhana is the 15th largest district in Maharashtra. While its geography supports its potential, it needs better connectivity to become a promising logistics centre.

W3 – Niphad village, Nasik district, Maharashtra This ranks number 1 in our score. Nasik is the 3rd largest district in Maharashtra area-wise. It is part of the Delhi-Mumbai industrial corridor and well-connected to highways.

Nasik has a mountainous terrain. It is an agricultural area well-known for its grape farming. Apart from agriculture, Nasik also has several well-developed industries in the district. Our score shows that Nasik is already a preferred logistics centre with several advantages and top rank. However, with the limitations of being agricultural land and having almost reached its saturation point as an industrial district, Nasik does not offer much developmental opportunity.

W4 – Phulambri village, Aurangabad district, Maharashtra This ranks 6 in our score. Aurangabad is the 13th largest district by area and a central industrial hub in Maharashtra. Hills surround the district. Its geography promotes further development of a thriving logistics centre, provided connectivity is improved.

W5 – Kaudgaon village, Nanded district, Maharashtra This ranks 5 in our score. Nanded is the 11th largest district by area in Maharashtra. Although it is an underdeveloped region, the government is making considerable, all-round efforts for its upliftment and progress.

W6 – Pimpalgaon Nakhale, Parbhani district, Maharashtra This ranks 3 in our score. Parbhani is the 25th largest district in Maharashtra by area. The Godavari River and its tributaries crisscross the district. Our score shows that geography supports the logistics centre development, mainly because it already has reasonable connectivity.

While W3 Nipah, Nashik ranks number one, it has limited potential. Given their locations and untapped potential, Nanded and Medak are the most promising. They are among the most backward districts of India, with very little development. This unexploited potential presents immense and sustainable opportunities, especially in light of their conformation to the other determining requirements of an apt location. The other four places also offer high potential to serve India's international trade.

In all, we have six optimal locations for establishing logistics centres. Apart from these six locations, the entire region within the triangle is a good option for establishing logistics centres. Developing logistics infrastructure in this region will prove beneficial in terms of transport efficacy and cost.

The findings of this study to calculate the CoGs contribute significantly to theoretical and practical domains, as well as to policy formulation in international trade.

Theoretically, this study sheds light on the lesser explored trade dynamics of how trade flows through sea and air ports, and the critical role of trade-oriented districts. It is important to note that none of the components of international trade can be compartmentalised. Given the expansive landscapes and multiple logistical gateways in the country, it is crucial to acknowledge that a holistic approach is required to ascertain and critically analyse the potential of a region. A thorough understanding of the theory of CoGs opens avenues to refine existing models of economic, geography, and international trade theory.

The study also offers a framework for policymakers to reassess and realign the infrastructure development strategies and trade promotion policies. Shifting focus toward developing the under-utilised regions for logistics centres helps prioritise investments in trade-oriented districts. It encourages policies toward regional development, trade facilitation, and the strategic expansion of trade networks.

From a practical standpoint, the advancements proposed in this study are a valuable tool for service providers and government agencies in logistics and infrastructure planning. By identifying the logistics gravity centres, stakeholders can strategically develop logistical networks, optimising resource allocation and enhancing operational efficiencies. Primarily, it facilitates better operational decision-making. On the broader canvas, it highlights areas where investments can yield the most impact, thereby improving the competitiveness of ports and raising the LPI of the country. These locations are especially advantageous for multi-modal facilities.

The development of Multi-Modal Logistics Parks (MMLPs) is a commendable step towards enhancing the efficiency and competitiveness of India's logistics sector. However, to maximise the benefits, it would be prudent to prioritise the strategic locations identified in our study, as these areas have the potential to provide an immediate boost to reducing logistics costs and improving efficiency. While infrastructure development does take time to materialise fully, focusing on the key areas mentioned can accelerate the reduction of logistics costs and enhance overall efficiency, making the MMLP initiative even more impactful (pib.gov.in, 2023).

Conclusion

This study highlights that the area of 29,500 square km is mainly in Maharashtra, which is already the top-ranking export state in India. However, given recent reports, Telangana is developing fast, and the border between two states may be the hot spot of these developments.

The government's National Logistics Policy has guided recent developments in India's logistics sector. Rapid infrastructural growth, especially of national highways, is leading to a more structured development in the logistics sector. Identifying areas suitable for supporting international trade will be the key to driving focused and effective growth.

Logistics infrastructure developed to serve key ports will primarily benefit international trade in India. It will reduce transport and warehousing costs and enhance profitability across the industry. It will also improve India's LPI rating, extending strategic advantages globally.

While every commodity has its complexities, the basic Gravity Model used in this study gives a general direction to explore the region within the triangular area to develop further the logistics infrastructure for a multimodal, break bulk, and cargo consolidation for international trade.

We acknowledge that this study is limited to the generalised international trade data published by the Government of India. Hence, this may not represent the complexities of the trade at the commodity level. However, given that the study includes major ports and export-import districts, we view this study as a value-add to the development of the area between the Indian state of Maharashtra and Telangana for future international trade facilitation.

References

Aai.aero. (2022). *AAI traffic news | Airports Authority of India*. [Online]. Retrieved June 30, 2023, from https://www.aai.aero/en/business-opportunities/aai-traffic-news March 2022, Summary, Annexure IV.

Battal, T. (2020). Understanding the logistics center location decision: What are the main decision criteria and evaluation methods. *International Journal of Logistics Economics and Globalisation*, *8*(2), 154-192. doi:https://doi.org/10.1504/ijleg.2020.108210

dpiit.gov.in. (2022). *National Logistics Policy 2022* (p. 17). [Online]. Retrieved October 22, 2023, from https://dpiit.gov.in

Capoani, L. (2023). Review of the gravity model: Origins and critical analysis of its theoretical development. *SN Business & Economics*, *3*(5). doi:https://doi.org/10.1007/s43546-023-00461-0

Essaadi, I., Grabot, B., & Fénies, P. (2016). Location of logistics hubs at national and subnational level with consideration of the structure of the location choice. *IFAC-PapersOnLine*, *49*(31), 155-160. doi:https://doi.org/10.1016/j.ifacol.2016.12.178

Gani, A. (2017). The logistics performance effect in international trade. *The Asian Journal of Shipping and Logistics*, *33*(4), 279-288. doi:https://doi.org/10.1016/j.ajsl.2017.12.012

Higgins, C. D., Ferguson, M., & Kanaroglou, P. S. (2012). Varieties of logistics centers. *Transportation Research Record: Journal of the Transportation Research Board*, *2288*(1), 9-18. doi:https://doi.org/10.3141/2288-02

https://www.maharashtra.gov.in/Site/1529/Districts. (2023a). *District Beed, Government of Maharashtra*. [Online]. Retrieved October 5, 2023, from https://beed.gov.in/

https://www.maharashtra.gov.in/Site/1529/Districts. (2023b). *District Buldhana, Government of Maharashtra*. [Online]. Retrieved October 21, 2023, from https://buldhana.nic.in/

https://www.maharashtra.gov.in/Site/1529/Districts. (2023c). *District Chhatrapati Sambhajinagar | Maharashtra Government*. [Online]. Retrieved October 13, 2023, from https://aurangabad.gov.in/

https://www.maharashtra.gov.in/Site/1529/Districts. (2023d). *Nanded District, Government of Maharashtra| India*. [Online]. Retrieved October 14, 2023, from https://nanded.gov.in/en/about-district/

https://www.maharashtra.gov.in/Site/1529/Districts. (2023e). *Nashik District, Government of Maharashtra | India*. [Online]. Retrieved from https://nashik.gov.in/

District Domestic Product of Maharashtra. Directorate of Economics and Statistics Planning Department, Government of Maharashtra, India. (2023). [Online]. *https://mahades.maharashtra.gov.in*, pp. 29-38. [Online]. Retrieved October 22, 2023, from https://mahades.maharashtra.gov.in/surveySubSIESReports.do?reptName=DISTRICT&&repCatId=SISS

International Scorecard Page | Logistics Performance Index (LPI). (2023). [Online]. *lpi.worldbank.org*. [Online]. Retrieved July 11, 2023, from https://lpi.worldbank.org/index.php/international/scorecard/radar/C/IND/2023

Iyer, K. C., & Nanyam, V. P. S. N. (2021). Technical efficiency analysis of container terminals in India. *The Asian Journal of Shipping and Logistics*, *37*(1), 61-72. doi:https://doi.org/10.1016/j.ajsl.2020.07.002

Kapoor, A., & Singh, S. (2023). *Export preparedness index 2022* (pp. 224, 225, 247-248). NITI AAYOG, Government of India. [Online]. Retrieved October 5, 2023, from https://niti.gov.in/report-and-publication

Munjal, P., & Pohit, S. (2023). *Report on logistics cost in India, assessment and long-term framework*. [Online].

Retrieved January 4, 2024, from https://www.ncaer.org/publication-category/books-reports

Nasir, S., & Kalirajan, K. (2016). Information and communication technology - Enabled modern services export performances of Asian economies. *Asian Development Review*, *33*(1), 1-27. doi:https://doi.org/10.1162/adev_a_00059

Park, S. (2020). Quality of transport infrastructure and logistics as source of comparative advantage. *Transport Policy*, *99*, 54-62. doi:https://doi.org/10.1016/j.tranpol.2020.07.016

pib.gov.in. (2021). *Top export districts in the country*. [Online]. Retrieved June 22, 2023, from https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1780245

Rehman, F. U., Noman, A. A., & Ding, Y. (2023). Does infrastructure increase exports and reduce trade deficit? Evidence from selected South Asian countries using a new global infrastructure index. *Journal of Economic Structures*, *9*(1). doi:https://doi.org/10.1186/s40008-020-0183-x.

shipmin.gov.in. (2022). *Basic port statistics 2021-2022 | Ministry of Ports, Shipping and Waterways*. [Online]. Retrieved June 22, 2023, from https://shipmin.gov.in/content/basic-port-statistics-2021-2022

Telangana State Statistical Abstract. (2022). https://telangana.gov.in, Government of Telangana, India, pp. 20, 69. [Online]. Retrieved July 11, 2023, from https://telangana.gov.in/downloads/reports/

Wahab, S. N., Ahmed, N., & Ab Talib, M. S. (2023). An overview of the SWOT analysis in India's pharmaceutical supply chain. *Arab Gulf Journal of Scientific Research*. doi:https://doi.org/10.1108/agjsr-03-2023-0102

Worldbank.org. (n.d.). *India trade statistics | WITS*. [Online]. Retrieved July 13, 2023, from https://wits.worldbank.org/CountryProfile/en/IND

www.census2011.co.in. (2023). *Bid (Beed) district population census 2011*. [Online]. Retrieved October 28, 2023, from https://www.census2011.co.in/census/district/361-bid.html

Sudan, T., & Taggar, R. (2021). Recovering supply chain disruptions in post-COVID-19 pandemic through transport intelligence and logistics systems: India's experiences and policy options. *Frontiers in Future Transportation, 2,* 5-6. [Online]. doi:https://doi.org/10.3389/ffutr.2021.660116

Veerappan, M., Sahu, P. K., Pani, A., Patil, G. R., & Sarkar, A. K. (2020). Analysing and modelling the relationship between air freight movement and airport characteristics in India. *Transportation Research Procedia, 48,* 74-92. doi:https://doi.org/10.1016/j.trpro.2020.08.007

Eriksson, V., Dubois, A., & Hulthén, K. (2022). Transport in supply networks. *The International Journal of Logistics Management*, *33*(5), 85-106. doi:https://doi.org/10.1108/ijlm-06-2021-0350.

pib.gov.in. (2023). *Multi-modal logistics parks*. [Online]. Retrieved September 19, 2023, from https://pib.gov.in/newsite/pmreleases.aspx?mincode=46

Arvis, J.-F., Wiederer, C., Raj, A., Dairabayeva, K., & Kiiski, T. (2018). Connecting to *compete 2018: Trade logistics in the global economy.* © World Bank, Washington, DC, License: CC BY 3.0 IGO. Retrieved from http://hdl.handle.net/10986/29971

Dang, V. L., & Yeo, G. T. (2018). Weighing the key factors to improve Vietnam's logistics system. *The Asian Journal of Shipping and Logistics, 34*(4), 308-316.

Google Maps. (2023). *Geolocations data* [Map]. Retrieved from https://www.google.com/maps

Survey of India, Ministry of Science and Technology. Retrieved December 11, 2023, from onlinemaps.surveyofindia.gov.in website: https://onlinemaps.surveyofindia.gov.in/Digital_Product_Show.aspx