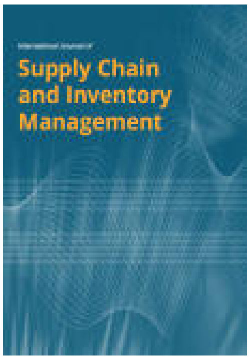

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Warehouse location selection using AHP: a case of third-party logistics provider in India

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Abstract: In developing economies with dynamic market conditions, building a new facility is one of the firm's biggest challenges. The location of the warehouse has a considerable impact on revenues, cost, and level of service. There is always a trade-off between inventory and distribution cost, and location plays a vital role in bridging the gap between the two costs. Thus, warehouse site selection is one of the critical decisions for any company. For a third-party logistics provider housing products of different companies belonging to various industries, the major challenge is selecting a location of the new warehouse to fulfil the requirements of all. Thus, the study's objective is to identify critical factors for optimal location selection for the warehouse. The paper presents a real-life problem (in the Indian context) of consolidating four warehouses of third-party logistics (3PL) providers to reduce cost. The study adopts the Delphi method, followed by the analytical hierarchy process.

Keywords: warehouse location; third-party logistics; 3PL; analytical hierarchy process; AHP; Delphi method; India.

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1 Introduction

A third-party logistics (3PL) provider business is growing due to the evolving demand for advanced logistics services. In the current business world, firms prefer to concentrate on their core competencies and outsource the enabling activities to specialised companies. Globalisation with intense competition, need for reduction in lead time (LT) and cost (both the logistic and capital expenditure), and focus on customer orientation are forcing firms to transfer their logistics activities to a third-party vendor known as '3PL' provider (Sahu et al., 2015; Baruffaldi et al., 2020). A 3PL is a logistics service provider that focuses on the supply chain's specific elements to optimise the physical movement of goods from the point-of-origin to the end-user and the customer return of defective products to their supplier (Meade and Sarkis, 2002). It includes logistics activities to other companies, such as transportation, warehousing, inventory management, distribution, and other value-added services (for example, pick-and-pack, assembly, repairs, and re-conditioning). Globalisation, reduction in LT, customer orientation, and outsourcing are fundamental changes leading to this interest in logistics. They optimise logistics services to provide the right product to the customer in a given timeline at an optimised cost without compromising quality (Zacharia et al., 2011). 3PL providers have progressed a lot since their dawning in the 1980s (Baruffaldi et al., 2020). Initially, transportation and storage operations services were the only entrusted services to 3PL providers. However, in the last decades, with the increase in outsourcing trend, the offer of value-added logistic services such as optimisation of cross-docking operations, reduction in waiting times for drivers, tracking and tracing, and improvement of stock management has exponentially grown adapting to different client specific requirements (Baruffaldi et al., 2020; Lu et al., 2013). 3PL providers must manage a relationship with its customers efficiently and effectively for their strategic edge on the market. It has been found that the use of 3PL services has contributed to overall logistics cost reductions and enhanced customer service (Third-Party Logistics Study, 2017). The geographical placement of facilities such as factories, warehouses, distribution centres, sourcing points, and stocking points is the first step in creating the supply chain. The warehouse is a storage facility that collects products for eventual distribution to consumers and forms a critical part of 3PL.

Warehouse location selection is a challenging task as the warehouse is generally built or leased for a substantial period of time-based on-demand centres, and any incorrect decision can lead to high logistics costs for the firm. Today, given the substantial growth in India's organised retail and manufacturing activities, the warehousing market has gradually gained steam within the supply cycle. It has been observed that in developing countries such as India, and other south Asian countries, the share of warehousing cost is more than in developed countries. The cost of warehousing in India is 29% of the total logistics cost (Singh et al., 2018). Hence, the warehouse location is strategically important while designing and maintaining a supply chain network (View et al., 2014). The logistics company, which is into the business of moving products timely, efficiently, and cost-effectively needs to strategically select a warehouse's location considering multiple parameters to satisfy customer needs. A 3PL most of the time acts as an aggregator to take advantage of volumes from its numerous customers, create more extensive storage facilities with technological benefits and shared resources, and provide best in class services at an affordable cost. One of the exceptional cases of warehouse location selection is deciding upon the location of a multi-client site, i.e., when numerous companies storing their products under one roof but may or may not have specific requirements. A better-placed warehouse not only reduces the number of lines and items per order but also optimises the average distance to customers and lessens the average transit LTs to the customer. Unfortunately, sometimes businesses face partial visibility on their customers' operations, on the variation of the turnover of the inventory mix as well as on the products characteristics. This limits the selection of optimal location also in the 3PL warehousing operations (Lu et al., 2013). Selecting a profitable warehouse from a number of potential warehouses is challenging as future profitability is unpredictable and needs both subjective and objective data to be looked upon (Chai et al., 2013). Thus, the objective of the paper is to identify the optimal location of a multi-client warehouse for a 3PL operating in India. A Delphi method followed by the analytical hierarchy process (AHP) was adopted as a decision support system. AHP was developed to deal with both tangible and intangible criteria (Saaty, 2011). In this approach, at each level, the decision-makers are asked to measure a comparison matrix by comparing enough of criteria where the alternatives at the bottom level are compared against the standards to develop overall priorities for ranking the options. AHP is absolute as it has been acclaimed to be robust and consistent (Ertay et al., 2006; Sharma et al., 2020a) and at the same time, AHP is flexible in such a way that it integrates different techniques like linear programming, quality function deployment (QFD), fuzzy logic, etc. to achieve the desired goal in a better way (Vaidya and Kumar, 2006; Sharma et al., 2020b). Gao et al. (2009) designate AHP, a systematic way for subjective decision processes, better understanding and participation among the members of the decision-making group and hence a commitment to the chosen possibility.

The rest of the paper is organised as follows: the literature review on warehouse/ facility location selection is presented in Section 2. In Section 3, the objective and rationale of the study while in Section 4 research methodology is discussed. Section 5 shows the analysis, findings, and discussions. Section 6 provides the conclusion of the research, while Section 7 discusses the implications, and Section 8 presents the limitations and scope of future research.

2 Review of literature

The concept of 3PL has attracted great interest, especially in academia (Cui et al., 2009). Lieb (1992) is the pioneering study in the context that highlighted the situation of 3PL services by large manufacturers in the USA. Few researchers have used Lieb's instrument to investigate the 3PL in various countries such as Dapiran et al. (1996) reported the result in the Australian context; Bhatnagar et al. (1999) presented their findings in the context of Singaporean firms; Sohal et al. (2002) conducted a longitudinal study over a period of four years (1995 and 1999) by Australian firms. Further, Sohail and Sohal (2003) studied Malaysian firms; Sohail and Al-Abdali (2005) reported findings with firms in Saudi Arabia; Sahay and Mohan (2006) investigated in India and Cui et al. (2009) examined Sweden manufacturing firms. Further, cross-country studies have been conducted by Lieb et al. (1993) (USA and Europe); Millen et al. (1997) (Australia, America and Western Europe); and Sohail et al. (2006) (Singapore and Malaysia).

Facility location problems have attracted researchers with diverse backgrounds such as economics, industrial engineering, and geography (Ghosh and Harche, 1993). Different researchers have studied the location problem in a different context.

Yang and Lee (1997) proposed three sites location problems for the organisations seeking a site for a new facility or relocation of an existing facility considering nine major facility location factors. They indicated that the non-availability of a proper road or rail siding facility has a serious impact on the location and operations of a warehouse. Vlachopoulou et al. (2001) focused on developing a geographic decision support system for warehouse site selection, enabling the manager to use quantitative criteria to classify an alternative warehouse or visualise the best one. Drezner et al. (2003) considered the transportation cost from local warehouses, inventory, and service cost for selecting the location of the central warehouse. They indicated that ignoring inventory costs in modelling location models may lead to inferior location solutions. Partovi (2006) constructed a new analytic model for facility location that considers both external (customer wants, the status of the competition, and characteristics of location) and internal (critical internal processes) criteria that sustain competitive advantage using QFD. Sharma and Berry (2007) considered the single-stage capacitated warehouse location problem (SSCWLP) with minimum transportation cost. Korpela et al. (2007) proposed an approach for selecting the warehouse operator network by combining AHP and the data envelopment analysis (DEA) and analysed the service capabilities of the five alternate warehouses. Yang et al. (2008) proposed a measurement model for evaluating three locations by application of the hybrid AHP/analytic network process (ANP) approach through questionnaire from the experienced marketing and sales managers. Their study reflected that market attraction, consumer characteristics, and location qualifications play an essential role in evaluating a profitable shop location for the service industry. Demirel et al. (2010) used Choquet integral approach to determine warehouse location with criteria such as costs, labour characteristics, infrastructure, markets, and macro environment for a leading Turkish logistics firm. Gupta et al. (2010), applied the Delphi method to shortlist the most important criteria and most probable 3PL providers in northern India. Chen and Wu (2011) developed a decision-making method by combining the Delphi method and ANP to help the electronic companies evaluate and select the logistics service provider type. Mousavi et al. (2011) applied the two-step AHP-vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) to determine the best potential sites for a plant location problem for a home appliance manufacturer. For this purpose, the Delphi method as a pre-step was adopted to select the most influential criteria via experts. Ashrafzadeh et al. (2012) proposed fuzzy AHP (FAHP) in determining the weights of the main criteria and sub-criteria for selection of the best alternative for a big company in Iran. Seven criteria – costs, labour characteristics, geographical location, infrastructure, market, macro environment, and economic factors were identified. Dey et al. (2016) proposed a hybrid fuzzy technique for the selection of warehouse location in a supply chain under a utopian environment. In disaster relief, Rath and Gutjahr (2014) proposed a math-heuristic model for a three-objective warehouse location problem encompassing medium-term strategic costs (the fixed cost of opening the depot and the procurement and operative cost of the vehicle fleet located at the depot), short-term operative costs (transportation cost of the goods from the plants to the depots and the warehousing cost in a depot) and uncovered demand (the total supply that is actually delivered to the customers) objectives. Gothwal and Saha (2015) implemented AHP to select the best locations for the manufacturing industry. Koç and Burhan (2015) applied AHP methodology for the warehouse selection for the Carglass Turkey, an auto glass company and investigated more than 40 criteria out of which five were chosen for evaluation namely sectorial factors, environmental factors, investment cost, labour potential, and regional potential. The regional potential (with sub-criterion-number of cars in the region, regional automobile insurance rate) was identified as the most critical factor. Dey et al. (2016) proposed three fuzzy multi-criteria decision making (MCDM) methodologies – fuzzy technique for order preference by similarity to the ideal solution (FTOPSIS), fuzzy simple additive weighting (FSAW) and fuzzy multi-objective optimisation on the basis of ratio analysis (FMOORA) considering criterion such as cost, labour characteristics, infrastructure, markets and macro environment. Further, Mangalan et al. (2016), in their research, utilised a case study presented by Özcan et al. (2011) on a retail sector and considered – cost, capacity to hold stock, the distance to the supplier and shops, and flexibility to move goods for selecting the warehouse. Momeni et al. (2015) measured 3PL reverse logistics using DEA with a leading Iranian automaker with headquarters in Tehran. Lu and Koufteros (2013) focused on transport logistics security practices. The authors examined the institutional pressures to improve the ability to deal with natural disasters. Vanichchinchai and Apirakkhit (2018) conducted a study to select a warehouse location among the different provinces in Thailand considering the distance from the origin to destination, freight rate, and demand at the destination. Singh et al. (2018) focused on the selection of most optimal location for a warehouse in Iran (in various special economic zones and free trade zones) for an Indian auto manufacturing firm using FAHP. They considered nine criteria grouped under three categories – infrastructure, government, and market. Recently, with the growing importance and varied role of 3PL, researchers have studied various aspects of 3PL such as – providing integrated logistics and financial services to a budget-constrained manufacturer (Wang et al., 2019), providing customisation in warehouse management (Baruffaldi et al., 2019), pro-silience framework for 3PL supply chain network (Gkanatsas and Krikke, 2020), facility location-routing problem (Tayebi-Araghi et al., 2020). The managerial competencies of 3PL in Indonesian business have been investigated by Sangka et al. (2019). The results indicated that both the local and multinational 3PL providers emphasise logistics as the ‘most important’ competency category. Jovčić et al. (2019) used fuzzy approach to evaluate criteria for 3PL provider selection and found the total cost of logistics outsourcing, reliability and connection with other transport modes as the three most critical criteria. Logistics service quality and customer satisfaction for 3PL has been investigated for an Italian food company and highlighted the role of B2B relationships and 3PL service providers (Gaudenzi et al., 2020).

Table 1 Factors influencing warehouse location selection

Author, year	*Factors are taken*	*Methods/ techniques used*	*Context*
Yang and Lee (1997)	• Market: Market growth potential, proximity to market, proximity to raw materials • Transportation: Land, water, and air transportation • Labour: Cost of labour, availability of skilled workers, availability of semi-skilled workers • Community: Housing, education and business climate	AHP	Three random sites
Vlachopoulou et al. (2001)	• Customer population of the surrounding area • Spending power of this population • Time, cost, availability, and capability of transport mode • Competition • Possible store size • Parking facilities • Proposed in-store facilities • Warehouse management cost (rent and utilities) • Distribution cost	Pairwise comparison, geographic information systems (GIS) and decision support system (DSS)	Greece
Drezner et al. (2003)	• Total inventory • Transportation costs	Weiszfeld algorithm	Three local warehouses
Partovi (2006)	• Customers and their wants • Competitors • Characteristics of various location • Critical processes in the manufacturing organisation	Quality function deployment (QFD), AHP and ANP	ABC Inc., digital mass measurement manufacturer
Sharma and Berry (2007)	• SSCWLP where goods are shipped from plants to warehouses and from warehouses to markets		100 SSCWLP problems

Source: Prepared by the author

Table 1 Factors influencing warehouse location selection (continued)

Author, year	*Factors are taken*	*Methods/ techniques used*	*Context*
Korpela et al. (2007)	• Reliability: Delivery time, quality, quantity • Flexibility: Urgent deliveries, frequency, special requests, capacity	AHP and DEA	Europe process industry
Yang et al. (2008)	• Market attraction: Passer-by flow security issue, clustered market, public transit • Consumer characteristics: Consumer populations, density, disposable income, purchasing power, brand loyalty • Location qualifications: Rent, flexibility of lease term, shop size, manpower, expected revenue, shop visibility, shop accessibility, synergy between each branch • Competition	AHP/ANP	Three shop locations
Demirel et al. (2010)	• Cost • Labour characteristics • Infrastructure • Market • Macro environment	Choquet integral	A Turkish logistics firm
Mousavi et al. (2011)	• Skilled worker • Expansion possibility • Availability of material • Investment cost • Risk imposed	Delphi's method, VIKOR and AHP	A home appliance manufacturer, Tehran
Ashrafzadeh et al. (2012)	• Costs: Labour costs, transportation costs, handling costs, and land cost • Labour characteristics: Availability of qualified labour • Geographical location: Land availability and climate	Fuzzy AHP	Iran

Source: Prepared by the author

Table 1 Factors influencing warehouse location selection (continued)

Author, year	*Factors are taken*	*Methods/ techniques used*	*Context*
Ashrafzadeh et al. (2012)	• Infrastructure: Modes of transportation, telecommunication, quality and reliability of modes of transportation and quality and reliability of utilities • Market: Proximity to customers, proximity to suppliers or producer, lead times and responsiveness • Macro environment: Policies of government, industrial regulations laws, zoning, and construction plan • Economic factors: Tax incentives and tax structures, financial incentives	Fuzzy AHP	Iran
Sharma et al. (2014)	• Demand • Transportation cost between plant to warehouse • Transportation cost between warehouse to market • Fixed cost of setting warehouse	Branch and bound and branch and cut	India
Dey et al. (2016)	• Costs – Labour costs, transportation costs, tax incentives and tax structure, financial incentives, handling costs • Labour characteristics – Skilled labour, availability of labour force • Infrastructure – existence of modes of transportation, telecommunication systems, quality and reliability of modes of transportation • Markets – Proximity to customers, proximity to suppliers or producers, lead times and responsiveness • Macro environment – Policies of government, industrial regulations, laws, zoning and construction plans	FTOPSIS, FSAW and FMOORA	South East Asian company

Source: Prepared by the author

Table 1 Factors influencing warehouse location selection (continued)

Author, year	*Factors are taken*	*Methods/ techniques used*	*Context*
Koç and Burhan (2015)	• Sectoral factors: Proximity to warehouse and market, regional commercial activity, customer potential • Subjective factors: Competitors, availability of carglass franchises, sales and performance of franchises • Environmental factors: Climate, transportation, urbanisation rate, land size, and security • Regional potential: Number of cars in the region, regional automobile insurance rate • Investment cost • Labour potential	AHP	An auto glass company, Turkey
Mangalan et al. (2016)	• Unit price • Stock holding capacity • Average distance to shops • Average distance to main suppliers • Movement flexibility	Multi-objective optimisation on the basis of ratio analysis (MOORA)	Retail sector case study, India
Singh et al. (2018)	• Transport and connectivity • Electricity and water supply • IT and telecommunication setup (ITS) • Cost of land • Taxation policy • Incentive • Market size • Proximity to main market • Scope for market growth	FAHP	Auto manufacturing firm, Iran
Jovčić et al. (2019)	• Total cost of logistics outsourcing • Delivery • Reliability • Flexibility • Professionalism	FAHP	Logistics and supply chain, Czech Republic

Source: Prepared by the author

Table 1 Factors influencing warehouse location selection (continued)

Author, year	*Factors are taken*	*Methods/ techniques used*	*Context*
Jovčić et al. (2019)	• Connection with other transport modes • Social responsibility • Reputation • Information and equipment system • Quality	FAHP	Logistics and supply chain, Czech Republic
Van Kien Pham and Tran (2020)	• Cost structure • Workforce ability • Supporting industry • Government policy	AHP	Vietnam, Thailand, Indonesia and The Philippines
Yan et al. (2020)	• Turnover level • Cost level • Demand level • Supply level	Integrated data mining and TOPSIS	Non-governmental top chains – China (Shanghai and Shenzhen)

Source: Prepared by the author

The systematic literature methodology as indicated by Sharma et al. (2020c) has been followed to shortlist the related work. Table 1 summarises the factors considered in different contexts for warehouse selection, along with the methodology adopted The literature revealed that the location factors that have been widely used in are grouped into the various categories: market, transportation, labour, site considerations, raw materials and services, utilities, governmental regulations, and community environment.

Many quantitative models especially MCDM techniques including AHP, FAHP, TOPSIS, and VIKOR have been proposed to investigate the complexity of the supply chain and its solution using 3PL, especially in the field of logistics (Yan et al., 2020). The quantitative methods have been used for finding solutions like the assessment of the efficiency and operational capacity of 3PL for selecting trustworthy suppliers (Jovčić et al., 2019); ranking factors to prioritise 3PL selection criteria (Gupta et al., 2010; Singh et al., 2018). With the evolving demands and market changes, businesses are in a continuous process of assessing and improving the performance of the 3PL in order to get maximum benefits (Gupta et al., 2010; Lu et al., 2013). These studies provide a list of factors such as service quality, business strength, management success that need to be adjusted when constructing the 3PL evaluation model. However, prior literature lacks a detailed approach that can help in the identification and prioritisation of comprehensive factors for warehouse location selection for 3PL in the Indian context.

3 Research gaps

The literature highlights that the selection of warehouse location for a multi-client site for a 3PL is crucial to reduce cost and increase the efficiency of an organisation. However, warehouse location selection has been studied in a limited way, especially in the context of a developing country like India.

The Indian companies are moving towards the acquisition of new logistics capabilities and complex solutions from the 3PL service providers for managing supply chain processes successfully, thereby bringing down costs. Logistics cost in India accounts for 13–17% of the gross domestic product (GDP), which is nearly double (6–9%) the logistics cost to GDP ratio in developed countries such as the US, Hong Kong, and France. Also, the Indian logistics market is fragmented and unorganised. Recently 3PL companies are growing and hold significant importance in logistics offering value-added services as well. 3PL is 4% of the total logistics market in India and is growing at 19–21% CAGR (https://www.edelweiss.in/ewwebimages/WebFiles/Research/b05dc6dc-e7e0-43be-9ae4-56fc3cdc8702.pdf) for the year 2020. Thus, the location of the warehouse selection becomes critical.

India being a developing economy, can enjoy various benefits from the implementation of 3PL. However, such implementation needs a comprehensive decision-making approach that includes consideration of all critical factors. Hence, there is a need for research on identifying factors and subfactors that influence the selection of warehouse. Further, only a handful of studies are conducted on prioritising factors using MCDM techniques. This research contributes in three primary areas

a this is one of the primary work that focuses on such an extensive list of criteria and sub-criteria

b the study uses Delphi method and strongly emphasises the need of discussion with experts for the selection of criteria relevant to the research topic which can help in assortment of appropriate and pertinent factors to work upon

c provides weights to all criteria and sub-criteria to detect the most optimal warehouse location.

4 Methodology

The practice-oriented approach through a real-life case has been considered to analyse the warehouse location selection. A 3PL provider wanted to consolidate their four warehouses in a metropolitan city of India to reduce the manpower and maintenance cost to sustain the efficiency of operations. The metropolitan city is well connected through roads and railways to all other metropolitan parts of the country that forms golden quadrilateral, as shown in Figure 1. One of the significant services provided by the selected organisation for the study is express delivery of spare parts to end customers within 2–4 hours, specifically for technology customers. The research is conducted with a mixed methodology approach using a sequential design (Sharma et al., 2020a). To identify critical factors for location decision and select the optimal solution, the study was carried out in two phases:

1 Phase 1 – qualitative

2 Phase 2 – quantitative.

Figure 1 Map of India: golden quadrilateral in India (see online version for colours)

Source: Map of India, prepared by the author

Since the literature on warehouse location selection in the Indian context is very sparse and did not address the same level of detail, an exploratory approach was adopted. Further, as warehouse selection is a long-term investment, inputs from multiple stakeholders (having different perspectives) become essential. For example, the business development manager would look at the customer base and hotspots for customers; the finance manager would try to optimise cost; the transportation executive would try to manage logistics cost at the same time efficiently meet turn-around time. Thus, in view of this, for the first phase of the present study, a Delphi method was adopted to identify important factors in location selection. Delphi method is an anonymous, iterative and independent technique for facilitating and structuring communication among a group of experts with the objective of either transforming individual opinions into group consensus or identifying systematic dissent among participants on a specific real-world issue (Rowe and Wright, 2001; Loo, 2002). Delphi has been widely accepted and applied in the domains of logistics (Gossler et al., 2019), warehouse management (Hassan et al., 2015), supplier selection (Luzon and El-Sayegh, 2016; Lin et al., 2018) across different industries. The heterogeneous panel in Delphi ensures that the full spectrum of views is represented (Loo, 2002) and encourages experts to express their true opinions (Fischer, 1978). In addition, the successive rounds in Delphi enables to build upon earlier results and maintain focus in the study (Loo, 2002). The first round of Delphi method focused on in-depth interviews with executives, managers, directors, and experts from various departments like supply chain solutions, strategy, business development, logistics, operations, legal and real estate who were the key stakeholders. The team members who have more than 15 years of experience were interviewed. The panel was selected to have representatives from academia also to gain rich insights. The questions focussed on capturing the business requirement, need for consolidation, short-term and long-term growth strategy for that region, motivation of firms that seek specific locations for warehouse selection, key steps that are generally involved in the location decision process, parameters used in industries as decision factors, and the significant obstacles in the location decision-making process.

The questions were designed as open-ended and allowed participants to provide and express their opinions or add information freely and independently. Based on literature review and results from the first round of the Delphi method, eight major criteria and 21 sub-criteria were identified for consideration in the second round of the Delphi method. In the second round, the questionnaire focused on the assessment of the relative importance of major criteria and their sub-criteria for warehouse location decisions (phase 2 of the study). The experts from the different departments were asked to provide their inputs on the relative importance of various criteria and sub-criterion. These experts had the knowledge of, the experience of and interest in warehouse selection and the ability to take a broad cross-sectorial view of the issues involved in warehouse location selection in the city under consideration.

Then quantitative phase using AHP, a MCDM technique is applied to prioritise the criteria and sub-criteria and select the best location from the location alternatives identified in the city (Prakash and Barua, 2016). The AHP is one of the extensively used MCDM methods. The primary advantage of AHP is handling multiple criteria with relative ease, along with the ability to effectively manage both qualitative and quantitative data. Hence, AHP has been applied to select the best location from the location alternatives identified in the city. AHP is more predominant among other MCDM techniques, mainly for two purposes,

a its simplicity in application

b its comprehensibility in theory (Sharma et al., 2021).

AHP method allows qualitative parameters in gauging and arranging several decisional choices and has been widely utilised in various field for decision-making such as information technology (Sharma et al., 2020a), healthcare (Sharma and Sehrawat, 2020a), warehouse (Jovčić et al., 2019), and manufacturing (Sharma and Sehrawat, 2020b; Sharma et al., 2020d).

There are two approaches of AHP which can be applied for decision-making: pairwise AHP and rating wise AHP. In rating wise approach instead of comparing the alternatives, fixed ratings like high, medium, and low are given, and thus, several alternatives can be dynamically changed. The pair-wise approach, in combination with rating wise approach, offers a flexible and standard model. Pairwise comparison matrices are done using Saaty (2008) scale, as shown in Table 2 and were adopted for phase 2.

Table 2 Pairwise comparison scale of attributes

Degree of importance	*Definition*
1	Equal importance
3	Moderate importance of one factor over another
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate value between two adjacent judgments

Source: Saaty (2008)

5 Analysis and discussion

5.1 Findings from qualitative approach-Delphi method

Maximum number of the panellists identified operations feasibility as the most important parameter for location selection of the warehouse, which is in line with the objective of maintaining similar operations efficiency (Baruffaldi et al., 2020). LT of delivery from the desired connectivity with other parts of the country for inbound and outbound logistics, entry of truck and parking facility are identified as critical factors. Further interaction with legal departments revealed some macro factors like government policies, industrial laws, and city development plans of the government. Tax and incentives [like goods and service tax (GST), Octroi, etc.], custom bonds and special economic zones are also revealed as important factors. The analysis revealed that competitor proximity is considered painstaking to business. Regional factors such as availability of qualified labour within that region, union issues, and proximity of customers are also highlighted.

The present and future industrial pockets, as well as infrastructure facility (such as mode of transport along with quality and reliability of road, railways, air, ocean/river and distance from national highways, railways, and terminal ports), are critical when responsiveness is desirable. Further, geographical locations, along with the probability of flooding, earthquakes, market/economic analysis, and feasibility studies in that region are essential for locations' consideration. Some panellists revealed that the building completion certificate, high power connection is vital and could lead to significant problems. Also, storage license and trade license make the process of decision-making complex. It was highlighted that the city had got moderate connectivity with other parts of the country due to ongoing infrastructure projects by government, which is also one of the essential criteria enabling the transportation of goods. The criterion and sub-criterion identified are presented and defined in Table 3. Further, the top six locations (L1, L2, L3, L4, L5 and L6) out of 14 proposed areas of the metropolitan city are identified after a feasibility study and expert opinion.

Table 3 Definitions of the criteria and sub-criteria

Criteria	*Sub-criteria*	*Definitions*
Operations feasibility (OF)	Regional distribution	The lead time of delivery should be met from the desired location
	National distribution	The location should be well connected to other parts of the country for inbound and outbound logistics
	Other operations	Feasibility of other operations like the entry of truck, parking facility, etc.
Geographical location (GL)	Land cost (rentals) (RT)	The rent of the space required
	Land availability (LA)	The probability of getting land for built-to-suit warehouse
	Climatic conditions	Weather conditions which may affect stock keeping units (SKUs) in a warehouse, considering hazards like the probability of flooding, earthquakes, etc. in the region where the land is low-line
Human resource (HR)	Easy availability of labour (EAL)	Easy availability of qualified labour within that region
	Union issues (UI)	The issues related to workforce
	Transportation of labours (TL)	Transporting labours from one region to other or within the region
Market presence (MP)	Proximity to customer (PC)	The present and future industrial pockets affect the location when responsiveness is desirable
Infrastructure facility (IF)	Connectivity with other parts of city	Ease of connectivity with different parts in city and other regions
	Mode of transport	Road, railways, air and ocean/river
	Quality and reliability of transport	Current conditions of roads, existing railway terminals, and route, future developments, etc.
	Distance from important landmarks	National/state highways, railway terminals, ports, transportation hubs, logistic centres, etc.
Macro environment (ME)		Government policies, industrial laws, city development plans of the government. It also takes into account the effect of tax and incentives (like GST, Octroi, etc.), custom bonds and special economic zones
	Land legality for warehouse	The land is legal for a warehouse building
	Fire no objection certificate	There are no fire-related issues, and government certifies the building is safe for operation
	Building completion certificate	Government certifies the building is complete and safe for operation
	Permission for high power connection	Government certifies the power is legalised with high power connection
	Storage license	Government certifies the building has storage license
	Trade license	Government certifies the warehouse has a legal trade license
Competitors (CPT)		Leverage upon competitor proximity and presence of logistics hubs and parks

Source: Prepared by the author

5.2 Findings from quantitative approach-AHP

Top six locations (L1, L2, L3, L4, L5 and L6) out of 14 proposed locations of the city were identified according to a feasibility study based on analysis of Delphi technique and the industries located in the area. Then rating as per the scale is given by experts for the criteria (listed in Table 2). The goal for the selection of appropriate location for the warehouse is on the highest level of the hierarchy and the criteria on the second level. Each criterion is further divided into sub-criteria on the third level of the hierarchy, as shown in Figure 2.

Following steps were conducted for AHP analysis:

1 To create ($n * n$) pairwise comparison matrix for multiple factors, let A_{ij} the extent to which we prefer factor 'i' to factor 'j'. Let $A = (a_{ij})_{n \times m}$ be a Pairwise comparison judgments of criteria; where $a_{ij} = 1/a_{ij}$ therefore is a positive reciprocal matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix}$$

2 Normalised pairwise comparison matrix is calculated. For this:

  a First, the sum of each column is computed.

  b Then, the division of each entry in the matrix is done with the column sum.

  c Finally, a mean of rows is done to get the relative weights.

Table 4 Random CI value for 'n' numbers

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.51	1.54	1.56	1.57	1.59

Source: Saaty (2008)

Let a_{ijk} where $i, j = 1, \dots, n$; $k = 1, \dots, m$ represents the pairwise judgments in comparing alternative i with alternative j expressed by the k^{th} member in the group decision making process, and w_{ik} represents the i^{th} priority weight for the k^{th} member in the group. Composite priority weight W_i^G (El Hefnawy and Mohammed, 2014) is then calculated as

$$W_i^G = \left(\sum_{k=1}^{m} w_{ik} \right)^{(1/m)} \quad (1)$$

Priority weights of the major criteria are obtained from the geometric mean method (GMM) as it is appropriate and widely used method in many aspects. GMM is the only mathematically valid way that preserves the reciprocal property of the comparison matrices as well as acceptable inconsistency level. Also, when equal importance is given to all the policymakers, GMM provides a proper way of synthesising judgments.

Table 5 Local weights and pairwise comparison matrix for criteria

Department 1	*OF*	*GL*	*HR*	*MP*	*IF*	*ME*	*CPT*
OF	1	2	3	4	2	5	6
GL	0.5	1	2	3	1	4	5
HR	0.33	0.5	1	2	0.5	3	4
MP	0.25	0.33	0.5	1	0.5	2	3
IF	0.5	1	2	2	1	2	3
ME	0.2	0.25	0.33	0.5	0.5	1	2
CPT	0.16	0.2	0.25	0.33	0.33	0.5	1
Local weights	0.32	0.20	0.12	0.08	0.16	0.05	0.03

Notes: OF – operational feasibility, GL – geographical location, HR – HR perspective, MP – market presence, IF – infrastructure facility, ME – macro environment, CPT – competitors.

Source: Prepared by the author

3 For controlling the consistency of the estimated weight values, the consistency ratio (CR) is calculated to ensure the appropriateness of comparisons:

a First, the eigenvector and the maximum eigenvalue for each matrix is computed.

b Then, an approximation to the consistency index (CI) is computed.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

where $\lambda_{\max}$ is the largest eigenvalue of the pairwise comparison matrix and, 'n' is the dimension of the matrix.

c Finally, the consistency judgment must be checked using the CR. The CR is calculated by dividing the CI by the random index (RI). The RI values for different numbers of 'n' are presented in Table 4. If $CR \leq 0.10$, the degree of consistency is satisfactory.

$$CR = \frac{CI}{RI} \tag{3}$$

where 'RI' is the random CI.

Table 6 Local weights and pairwise comparison matrix of sub-criteria under operational feasibility

Department 1 (operational feasibility)	*Lead time delivery (existing customer)*	*Width of truck for easy truck movement*	*Distance from NH/SH*
Lead time delivery (existing customer)	1	2	3
Width of truck for easy truck movement	0.5	1	2
Distance from NH/SH	0.33	0.5	1
Local weights	0.54	0.29	0.16

Source: Prepared by the author

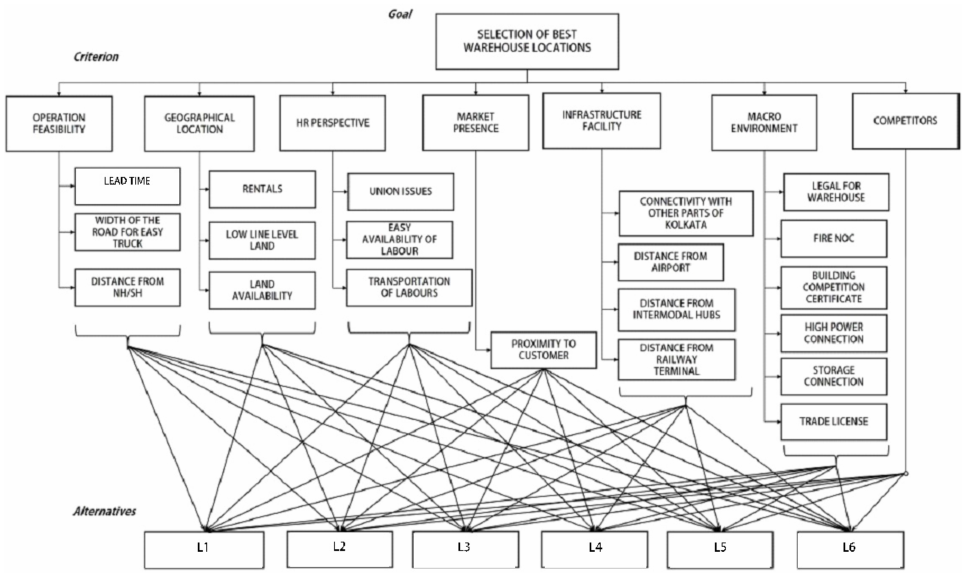
Table 7 Priority weights and pairwise comparison matrix of criteria and sub-criteria

Criteria	*D1*	*D2*	*D3*	*D4*	*Geomean (a)*	*Sub-criteria*	*D1*	*D2*	*D3*	*D4*	*Geomean (b)*	*(a * b)*	*Rank*
Operational feasibility	0.32	0.24	0.19	0.21	0.23	Lead time delivery (existing customers)	0.54	0.50	0.50	0.54	0.51	0.12	1
						Width of road for easy truck movement	0.30	0.25	0.25	0.30	0.27	0.06	5
						Distance from NH/SH	0.16	0.25	0.25	0.16	0.20	0.05	6
Geographical location	0.20	0.15	0.31	0.21	0.21	Rentals	0.31	0.49	0.54	0.31	0.40	0.08	2
						Low line level land	0.49	0.31	0.16	0.49	0.33	0.07	4
						Land availability	0.20	0.20	0.30	0.20	0.21	0.05	6
HR perspective	0.13	0.15	0.23	0.13	0.15	Union issues	0.40	0.54	0.54	0.33	0.44	0.08	2
						Easy availability of labour	0.20	0.30	0.30	0.33	0.27	0.04	9
						Transportation for labours	0.20	0.16	0.16	0.33	0.20	0.03	10
Market presence	0.09	0.10	0.09	0.08	0.08	Proximity to customer	0.67	0.67	0.67	0.50	0.62	0.05	6
						Responsiveness	0.33	0.33	0.33	0.50	0.36	0.03	10
Infrastructure facility	0.17	0.07	0.08	0.25	0.12	Connectivity with other parts of city	0.47	0.02	0.20	0.47	0.16	0.02	15
						Distance from airport	0.16	0.14	0.14	0.16	0.15	0.02	15
						Distance from intermodal hubs	0.26	0.27	0.28	0.26	0.26	0.03	10
						Distance from railway terminal	0.11	0.42	0.39	0.11	0.20	0.03	10
Macro environment	0.06	0.24	0.05	0.08	0.09	Legal for warehouse	0.28	0.38	0.38	0.33	0.34	0.03	10
						Fire NOC	0.06	0.15	0.15	0.06	0.09	0.01	18
						Building completion certificate	0.29	0.24	0.24	0.20	0.23	0.02	15
						High power connection	0.17	0.10	0.10	0.20	0.13	0.01	18
						Storage license	0.98	0.06	0.06	0.07	0.12	0.01	18
						Trade license	0.98	0.06	0.06	0.07	0.12	0.01	18
Competitors	0.04	0.05	0.05	0.05	0.04								

Notes: D1 – supply chain department 1, D2 – logistics department 2, D3 – business development department 3, D4 – legal department.

Source: Prepared by the author

Figure 2 Hierarchy of criteria, sub-criteria, and alternatives



Source: Prepared by the author

One sample calculation of the criteria and sub-criteria are presented in Tables 5 and 6, respectively. Here, Table 5 shows how the local weights are calculated for criteria based on the pairwise comparison for one department where the CR is 0.023, and the principal eigenvalue is 7.188. Table 6 shows how sub-criteria (under operational feasibility) are calculated for one department where the CR is 0.01, and the principal eigenvalue is 3.009. All the calculations are done in a similar manner for all other criteria and sub-criteria. Table 8 shows the local as well as global weights and final ranks of locations.

The analysis revealed that for operational feasibility and geographical locations are the most critical criteria which is inline with Sangka et al. (2019), Baruffaldi et al. (2020) and Gkanatsas and Krikke (2020). This indicates that while selecting optimal warehouse location, its necessary to first prioritise how much time does the transportation will take to ship goods from selected location to the desired location. The LT delivery for existing customers is found to be the most crucial sub-criterion under operational feasibility (Gaudenzi et al., 2020). This indicates that it is essential to provide on-time delivery for existing customers, thereby having good business relationships and increasing chances of re-order. Rental of locations are also found to be the critical, decisive sub-criterion under geographical location (Tayebi-Araghi et al., 2020). It highlights that the land cost (rentals) plays a vital role while selecting the location. It is because if the rent is too high, it will impact the overall cost of goods, thereby affecting the business inversely. Union issues are found to be the critical, decisive sub-criterion under HR perspective. It is indispensable to have a competent working manpower. If there are any issues in the workforce, then it will cause a delay in the overall functionality of the business, i.e., it will impact everything from picking, packing, and shipping (Lieb and Lieb, 2016). Further, low-line land and width of the road for easy truck movements are also found to be important sub-criteria. This justifies that if the warehouse area is earthquake or flood-prone, it will lead to loss of goods, manpower, machinery, and business (Meethom and Koohathongsumrit, 2018). Further, if the area has congested or ill-maintained roads, it will delay in transportation and can also cost on the maintenance of trucks additionally. Surprisingly, fire no objection certificate (FNOC), high power connection, storage license, and trade license are found to be the less essential sub-criteria as compared to others which is in contrast with Kmiecik (2020). However, this may be because once the location is chosen, the approvals become the necessity for operational reasons and can be acquired through appropriate processes. Table 8 presents the normalised scores and the consolidated priority weights of the warehouse locations – L1, L2, L3, L4, L5 and L6 obtained against all criteria and sub-criteria. L6 outperforms in all criteria and sub-criteria for warehouse location selection whereas L1 is identified as the second most preferred location for the warehouse with weights 0.61 and 0.52, respectively. L6 depicted good operational feasibility while L5 depicted good market presence than L6.

Table 8 Ranking to warehouse locations as per effective priority weights

Major criteria	*Weights*	*Sub-criteria*	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*
Operations feasibility	0.23	Lead time delivery (existing customers)	0.42	0.20	0.19	0.08	0.05	0.05
		Width of road for easy truck movement	0.21	0.12	0.10	0.09	0.26	0.21
		Distance from NH/SH	0.09	0.01	0.18	0.13	0.39	0.19
Geographical location	0.21	Rentals	0.25	0.26	0.17	0.10	0.10	0.12
		Low line level land	0.05	0.05	0.19	0.08	0.20	0.42
		Land availability	0.08	0.05	0.42	0.19	0.05	0.20
HR perspective	0.16	Union issues	0.20	0.42	0.05	0.08	0.05	0.19
		Easy availability of labour	0.13	0.24	0.07	0.07	0.23	0.23
		Transportation for labours	0.19	0.10	0.13	0.09	0.24	0.24
Market presence	0.09	Proximity to customer	0.10	0.33	0.13	0.26	0.13	0.05
		Responsiveness	0.05	0.05	0.19	0.08	0.20	0.42
Infrastructure facility	0.12	Connectivity with other parts of city	0.34	0.13	0.09	0.16	0.13	0.14
		Distance from airport	0.04	0.06	0.32	0.10	0.07	0.40
		Distance from intermodal hubs	0.11	0.20	0.13	0.14	0.19	0.23
		Distance from railway terminal	0.42	0.20	0.19	0.08	0.05	0.05
Macro environment	0.09	Legal for warehouse	0.08	0.05	0.19	0.42	0.05	0.20
		Fire NOC	0.09	0.01	0.18	0.13	0.39	0.19
		Building completion certificate	0.20	0.42	0.05	0.08	0.05	0.19

Notes: L1 – location 1, L2 – location 2, L3 – location 3, L4 – location 4, L5 – location 5 and L6 – location 6.

Source: Prepared by the author

Table 8 Ranking to warehouse locations as per effective priority weights (continued)

Major criteria	*Weights*	*Sub-criteria*	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*
Macro environment	0.09	High power connection	0.05	0.05	0.19	0.08	0.20	0.42
		Storage license	0.25	0.26	0.17	0.10	0.10	0.12
		Trade license	0.21	0.12	0.10	0.09	0.26	0.21
Competitors	0.04	CPT	0.42	0.20	0.19	0.08	0.05	0.05
		Total	0.52	0.44	0.50	0.35	0.49	0.61
		Priority	2	4	5	6	3	1

Notes: L1 – location 1, L2 – location 2, L3 – location 3, L4 – location 4, L5 – location 5 and L6 – location 6.

Source: Prepared by the author

6 Conclusions

The study began with the motivation to find the most suitable warehouse location for a 3PL in India based on various criteria and sub-criteria. This study commenced with the assertion that facility location determination is a strategic decision, which is critical for any sector as it involves a lot of capital expenditure and it directly affects business (workers, transportation, market, and competition). Be it a manufacturing location, warehouse, or office setup, many factors are considered, and the decision making is complex and has a long-term impact. Delphi, along with AHP, was used for analysing the real-life problem of warehouse selection for a 3PL. Delphi method was used to capture the requirements of all stakeholders and to prioritise the decision parameters. As the number of stakeholders is more in case of facility location determination and accountability is high, AHP combined with Delphi's method gives a scientific approach, which ensures that all the requirements of the stakeholders are met. The study considers eight criteria and twenty-one sub-criteria for warehouse location by 3PL in an Indian context.

The contribution of this study is multifold:

a this is the first study that works on such an extensive list of criteria and sub-criteria, thereby providing future researchers detailed list to explore

b the study strongly emphasises the need of having opinions from experts for the selection of criteria relevant to the research topic which can help in an assortment of appropriate and pertinent factors to work upon

c provides weights to all criteria and sub-criteria thereby paving path for practitioners to concentrate on critical criteria and sub-criteria to improve the selection of warehouse location.

7 Implications

The Delphi analysis highlighted that LT of delivery from the desired connectivity with other parts of the country for inbound and outbound logistics, entry of truck and parking facility are identified as important factors. It was also highlighted the city had got moderate connectivity with other parts of the country due to ongoing infrastructure projects by government, which is also one of the essential criteria enabling transportation of goods. The study contributes by identifying critical criteria – *operational feasibility* and *geographical location* and sub-criteria – *LT delivery with an existing customer*, *rentals of location* and *union issues in the Indian context for selecting warehouse location*. The analysis will help firms' top management to think about critical factors before selecting a warehouse location for better investment and returns. With the recent changes in the tax structures in India, all the companies are looking forward to warehouse consolidation opportunities to leverage the cost and other resources (such as rent, manpower, IT systems, facility maintenance, equipment's, and electricity). Also, with the changing infrastructure in India, warehouse consolidation will help to achieve a balance between efficiency and responsiveness.

The findings of this study present significant implications for both academics and practitioners involved in the implementation of 3PL and the selection of appropriate warehouse location. We propose the following three practical implications based on the present review.

1. Companies must determine logistics goals and requirements prior to taking on a 3PL.
2. It is critical for practitioners and managers to rethink their value propositions and select the appropriate criteria before making a decision related to the optimal location selection.
3. Not only financial factors but other factors like proven track record of supplier, scalability, flexibility, regularity of service should be taken into account to bring objectivity to decisions via an analytical approach.

8 Limitations

The study has been conducted in India with a single case that limits the generalisability of results in developed economies. Also, the methodology is based on expert judgments which is specific to the sector, so results can vary with different sectors. However, this provides scope for the future study where researchers can extend the present work by analysing other criteria and sub-criteria across other Indian 3PL as well as for manufacturing locations. Also, a similar study for warehouse location problem in other countries can confirm the factors studied.

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