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Revitalizing Nepal's Carpet Industry: Strategic Location Planning and Supply Chain Optimization in Special Economic Zones

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Abstract

The lack of proper planning, policies, omitting the domestic market and increased product value has caused drastic downfall of carpet industry in Nepal. Once being the major exported material from the nation, now is surviving solely because of USA, causing a drastic downfall over last decade in terms of quantity demanded. Demand forecasting establishes the declining trend. The major reason for the downfall is noted to be high cost which omits the chances of revival and survival in domestic market. To decrease the cost, the supply of raw materials must be considered through roadways from India and China, replacing expensive airways from New-Zealand. To strengthen the findings, forecasting methods, including Moving Average, Weighted Moving Average, and Exponential Smoothing, were utilized to predict demand trends and assess their implications for strategic planning. The least value of RMSE was obtained for Exponential Smoothing, establishing its accuracy and reliability. The drastic increase in the population of Kathmandu has caused many industries to migrate, leading the Government to plan Special Economic Zones (SEZ) in various locations across Nepal. To meet demand, facilities have been strategically located, focusing on utilizing government-provided resources in SEZ to support the industrial expansion. Additionally, the Center of Gravity (CoG) method was employed using latitude and longitude coordinates in MATLAB, validated through conventional methods, to identify optimal facility locations. Sample calculations demonstrated the applicability of the CoG technique, with Simara and Bhairahawa emerging as favorable SEZs based on varying scenarios. Location planning techniques like Center of Gravity (CoG) and cost modeling helped to identify the most optimal location for the expanding industries based upon the demand of the product across the nation, crucial for the anticipated growth of domestic carpet industries in the years to come.

Keywords

Center of Gravity; cost modeling; forecasting; locating facilities; special economic zones; supply chain management

1. Introduction

Supply Chain is the group of inter-connected participating companies that add values to the stream of transformed inputs from their source of origin to the end product or services that are demanded by the designated end-consumers [1],[2]. Supply chain is a network of

facilities and distribution options that performs the functions of procurement of materials; transformation of these materials into intermediate and finished products; and distribution of these finished products to customers [3]. The supply chain helps to improve product flow, increase production rate, reduce lead time for supply of goods, increase supply reliability, reduce inventory levels leading to reduction in inventory cost, decreased administrative costs, reduce total production cost, and increase the profit of the supplier and the manufacturer [4].

In addition to this SCM also involves location planning to provide the desired product to the consumer at the desired time. Therefore, to achieve this transition of change in different tier of consumers till it reaches the end users, the concept of warehousing becomes essential. Location planning helps to find an optimal or near optimal decision for the location problems over an infinitely long planning horizon [5]. The place or location where the raw materials or goods are stored till it reaches to its final consumer can be termed a warehouse. The long life of warehouse provides a significant advantage by facilitating a response to the market changes [6]. The ideal place for a warehouse should be near to the point where the demand of the product is high. To achieve the best suitable location, location planning needs to be done.

Location planning must be done to find the best location for the different elements of the supply chain. If the location is too far from the consumers, then the cost of material handling/transportation increases. However, the right location does not guarantee the success, but the wrong location surely will guarantee the failure of the organization [7],[8]. Therefore, wrong location will result in poor performance of a company. After the establishment of the company in a particular location, shifting to a new location also costs more. This article aims to find the suitable locations for setting up of carpet industries catering to the domestic market. Hence, if the location is far from the area where the demand weightage is more, then the cost of transport will contribute the rise in the price of the product. Supply chain helps to decrease the cost of the product by a proper planning in various aspect within. Therefore, wrong location is against the principle of supply chain. Also, the location should not be is a densely populated area or highly dense traffic area, which may further add to the complexion to the local movement of the material providing the negative impact on city residents and the environment. If the location is too near to the consumer then the traffic congestion will be high and if the location is too far then the cost of the product will increase[9].

Due to its geographical, infrastructural, and socio-financial conditions, location planning in Nepal has always been a challenge. The country's mesmerizing mountainous landscape presents logistical difficulties, compounded by limited connectivity and transportation in rural areas [10]. Additionally, business development has been slow due to infrastructure deficiencies, including limited avenue networks, unreliable delivery options, and poor transportation centers [11]. Industrial activities in Nepal are concentrated in urban areas, as evidenced by the dominance of large-scale industries in terms of investment (86.42% of total capital), leaving rural areas—despite their significant untapped resources—underutilized [12]. The weak and ineffective industrial policy, coupled with inadequate provision of public goods and inefficient transit trade, highlights how bureaucratic challenges and poor policy implementation have created obstacles to industrial development and location decisions in Nepal [13]. Moreover, the difficult political situation further complicates matters, and donors have an important role to play in overcoming these challenges [14]. Additionally, the

pressure to minimize environmental impact and address community displacement concerns often leads to public opposition, causing delays and challenges in the decision-making process for industrial locations [15]. To overcome these challenges, the strategic investments in infrastructure and efficient SEZ management are crucial to make a balanced and sustainable industrial growth.

In present scenario most of the industries in Nepal are located in Kathmandu valley causing high traffic congestion and environmental degradation. To reduce it, the Government of Nepal is trying to shift the industries outside the Kathmandu valley so that the people can be accommodated there and to minimize the pollution caused by the industrial waste. Some industries are shifting out now and among them is the brick industry which had been a major industry in Kathmandu valley. Within a decade, all the kilns might move out of the capital, not for environmental reasons but because of a lack of space [16]. As well as the Government of Nepal has come out with the idea of Special economic zone (SEZ), where the new establishment of the industries can be done with the extra facilities provided by the Government as they are more alluring. Along with better policies for the industries establishment in SEZ, the migrating industries may also move into SEZ. In order to do this shift we need to look for the best possible locations outside Kathmandu. Therefore, SCM will be the best tool to meet the need for shifting industries to best possible alternate locations.

Nepal being an underdeveloped nation it has not seen a proper growth in industrial aspect throughout these years. The various problems restricting the growth of industries like topography, transportation, lack of good quality raw materials, machinery and skilled manpower, lack of proper policies and procedural matters, fluctuation of economic situations, constraints to diversify product due to restriction in import of raw materials, weak Infrastructure, low labour productivity, inadequate marketing network and vision.

Figure 1: Yearly exported quantity for carpets

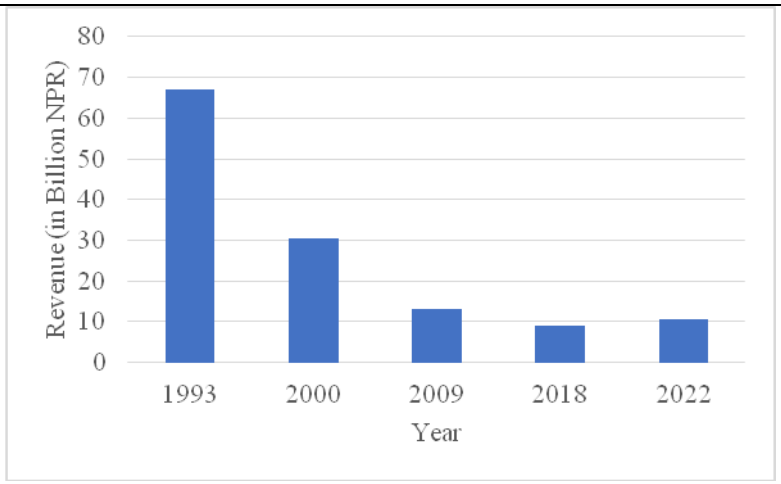

Figure 2: Export earnings from carpet industry (inflation adjusted)

However, among all the industries in Nepal the industry standing out is carpet manufacturing industry which one had the highest export volume in Nepal. Because of its high quality (60 – 150 knots per square inch), the demand for the carpet was high in its initial phase in the international market which has decreased in a drastic manner as shown in Figure 1. The problem of transportation has limited the export quantity as most of the products have to be shipped via airways. Domestic consumption for Nepal carpet industry is negligible as the product price is high for the local market. However, no attempt has been made so far for the locating facilities considering the expected shift in procurement of raw materials and the anticipated growth of domestic market for carpet industry in Nepal, has been looked. As shown in Figure 2, the export earnings from the carpet industry have fluctuated significantly when adjusted for inflation, highlighting the influence of global economic conditions.

The challenges faced by Nepal's carpet industry provide a clear view of how the SCM principles can be applied. As one of the country's major export industries, it relies on the complex supply chain that involves the sourcing of raw material, production, and international shipping [17]. However, the supply chain has faced a disturbance by logistical issues, insufficient infrastructures, and lack of regulation in Nepal [18]. The major concern for the air freight is the transportation cost. Air shipping from Nepal is up to five times more expensive than that of sea transportation which has caused a challenge as Nepal is a landlocked nation. The air cargo costs from $1.70 to $4.20 per kilogram, compared to just $0.3 per kilogram for sea transport [19][20]. Besides, road transportation in domestic platform is also costly, averaging around $0.22-$0.36 per kilogram, which is further causing a financial pressure in the business [21]. With around 80% of Nepal's exports, including carpets depend upon air transportation; this cost has impacted the industry's competitiveness in global market. To address these issue SCM strategies must be connected directly with the specific Challenges faced by the carpet sector. This research work attempts to analyze trend of the past data and adopt the best forecast method for the demand and develop a program which gives the best suitable location based upon the varying demand and supply location. It also evaluates the possibilities for the future aspect for the best suitable location in Nepal if the market is shifted away from the current capital Kathmandu.

2. Methodology

In this research, two stage observations for the work have been taken into consideration. Firstly, the forecasting was done using MS Excel for the existing data and secondly, the location planning was done for the setup of the new industry. Forecasting has been done using four different techniques for comparison. The techniques used are: Moving Average, Weighted Moving Average, Exponential Smoothing and Trend Projection. The four forecasting techniques were chosen based on their suitability for analyzing time series data commonly observed in Nepal's carpet industry, their proven effectiveness in similar studies, and their ease of implementation for practical decision-making. To evaluate the accuracy of the forecasting results, we utilized Root Mean Square Error (RMSE), as this metric provides reliable measure of predicting accuracy and error magnitude. This approach ensures the robustness and reliability of the analysis in informing strategic decisions. The least value of RMSE was obtained for exponential smoothing method.

Also, for the location planning the Center of Gravity (COG) method was taken into consideration for which the latitude and longitude of the earth is taken while writing the program in MATLAB instead of x and y co-ordinates from the map and after the program is executed certain output are known. To validate the output, the conventional method of COG was taken into consideration using the map.

However, the latitudes and longitudes are not simple coordinates but directions from the center of the sphere. The adoption of Cartesian coordinates is to account for the Earth's curvature, which ensures greater accuracy when determining optimal locations over large geographical areas like Nepal. This approach is particularly critical in this study as ignoring the curvature could lead to distortions in distance and area calculations, which are vital for supply chain efficiency and special economic zone planning. After expressing the latitudes as x and longitudes as y, three dimensional Cartesian coordinates for the earth (x, y, z) were obtained using equation 1. To do that, the degree values of coordinates should be expressed in radians [22]. Figure 3 gives the basic idea for the three-dimensional Cartesian coordinates (x, y, z). Cartesian coordinates (x, y, z) can be determined for each coordinate point by using the formulas:

$$x = cos(lat)\ x\ cos(lon) \quad (1)$$

$$y = cos(lat)\ x\ sin(lon) \quad (2)$$

$$z = sin(lat) \quad (3)$$

where,

lat = latitude point in the radian

lon = longitude point in the radian

Once the three-dimensional Cartesian co-ordinates are found they are used in the COG formula as shown below:

$$x^* = \frac{\sum l_i x_i}{\sum l_i} \qquad y^* = \frac{\sum l_i y_i}{\sum l_i} \quad (4)$$

where,

x* = actual latitude coordinate for the optimal location

y* = actual longitude coordinate for the optimal location

l_i = load of each location

x_i = x coordinate of the load point

y_i = y coordinate of the load point.

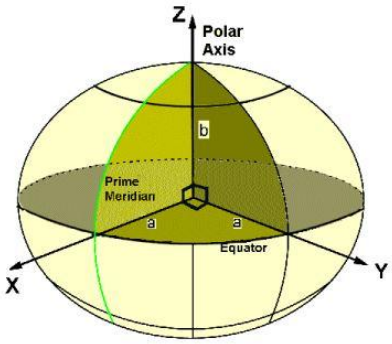

Figure 3: Three dimensional cartesian coordinates [22]

Therefore, the points of the earth's surface were taken into consideration by using the above steps which further can be used with defined weightage to find the COG for the varying demand over various periods. To find COG, MATLAB was used. Similarly, cost modelling was done by creating a database of the entire supplier to SEZ distance and by using following formula:

$$\sum C = \sum l_i * d_i \quad (5)$$

Here, l_i = load of the given site and d_i = the distance of a site from a given supplier's location.

Then $\sum C$ for all the given sites were found and the minimum value for $\sum C$ is selected as the best location. The distance between two places was found by using the google map. The road distance between two points was also taken into consideration using the google map distance. The weightage was assigned by the MATLAB programming on the random basis. Random weightage was considered just to ensure the fair location based upon the weightage i.e. the demand. It illustrates that the location planning will mainly depend upon the demand of quantity and availability of the supplier or material. In terms of Nepal as it is highly depended upon imports the importing custom points will exert the load. Hence the optimal location can be selected based upon the upstream supplier's location.

3. Results and discussion

Based upon the data provided by Nepal Carpet Exporters Association (NCEA) from Figure 1, forecast was done using four different methods as shown in Figure 4. It was seen that the demand forecast from the year 2008/09 to the year 2009/10 the forecast and actual volume differences is very high. Unlike 2 year moving average, the 4-year moving average method takes the average of past 4 year demanded value. Hence if the drop is high in a year, the average value will be significantly high as per the others data. The trend projection forecast analysis is not a fit for this sort of data characterized with a huge fall in demand. The drastic fall and deviation in demand forecasting shows that it will be ineffective in this sort of varying and drastic changed data and cannot be relied solely based upon the forecasting of past few years. No exact trend can be seen in the above data structure implying that data fluctuates if a year's demand changes in a high volume. From the figure 4 it can be concluded that the carpet industry has experienced a huge fall in past decade. Owing to the

competitive market, high raw material cost and lack of proper planning and policy. In order to attend a better planning, location planning should be done.

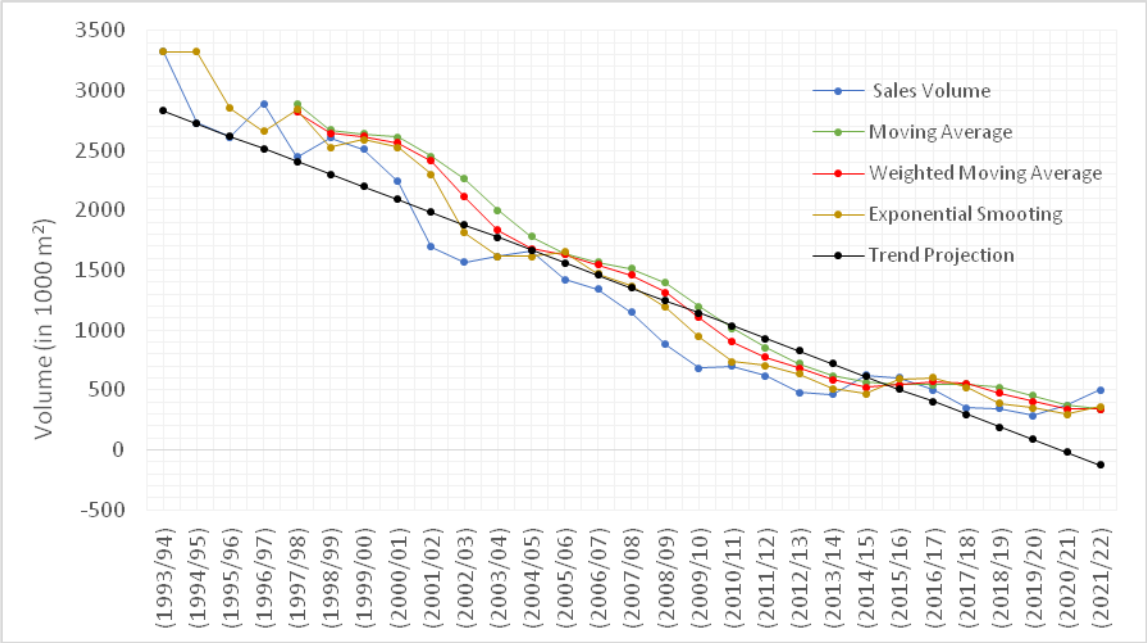

Figure 4: Forecasts using various techniques

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To do the location planning COG was found using the MATLAB program and to validate it, conventional method from graph was also done. For the graph the x and y co-ordinates (the co-ordinates plotted from the graph) are found from the Figure 5. And the values from Figure 5 are tabulated in Table 1 and 2.

Here, the two stage observation for the work is taken into consideration. Firstly, the forecasting is done using MS Excel for the existing data and secondly, the location planning is done for the setup of the new industry as shown in Figure. 6.

Two outputs were obtained for COG for two different input conditions and verified the results from the MATLAB program which used the concept of COG with the result of conventional method of locating facilities. The results shown in Table 3 and Table 4.

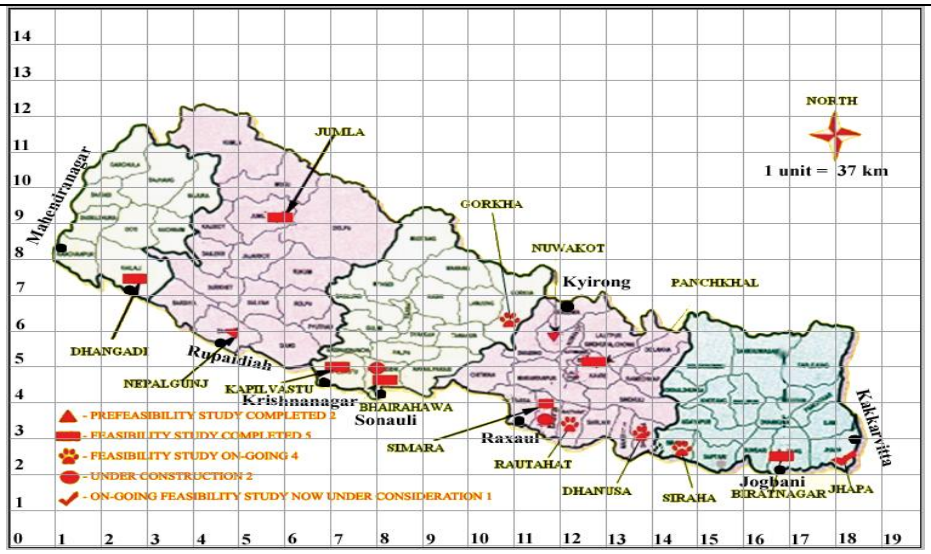

Figure 5: Map of Nepal showing the supplier's and SEZ location in the grid (Ministry of Industry Commerce and Supply, Government of Nepal, 2014)

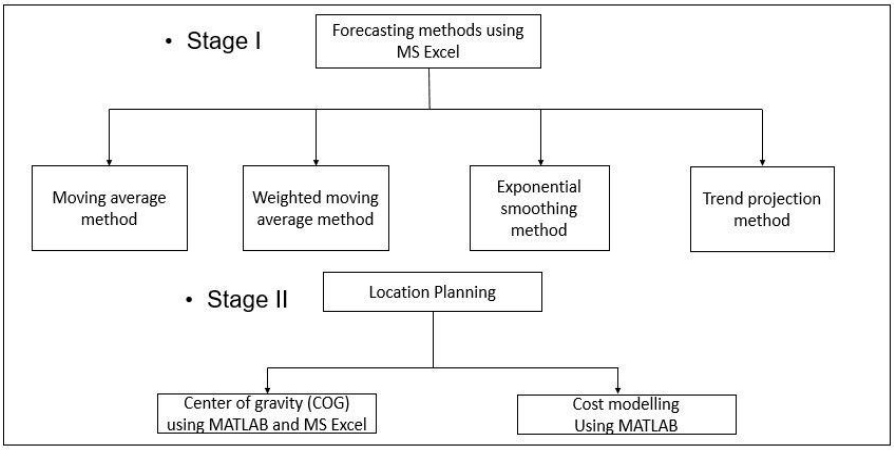

Figure 6: SCM tools used for forecast and location planning

Table 1: x and y co-ordinates of supply points

Supply point	*x*	*y*
Kakkarvitta	18.4	3.0
Jogbani	16.8	2.2
Raxaul	11.2	3.5
Kyirong	12.2	6.8
Sonauli	8.0	4.2
Krishnanagar	6.8	4.6
Rupaidiah	4.6	5.6
Mahendranagar	1.2	8.4

Table 2: The co-ordinates of Special Economic Zones

SEZ	*x*	*y*
Jhapa	18.2	2.4
Biratnagar	16.8	2.5
Siraha	14.8	2.6
Rautahat	12.2	3.3
Dhanusha	13.8	3.0
Simara	11.7	3.8
Bhairahawa	8.2	4.6
Nuwakot	11.8	5.8
Gorkha	10.8	6.2
Kapilvastu	7.0	5.0
Nepalgunj	4.8	6.0
Jumla	6.0	9.2
Dhangadhi	2.8	7.4
Panchkhal	12.7	5.2

Table 3: Result for COG for input 1

SEZ	***Weightage (ton)***	***Method 1***			***Method 2***		
		CoG latitude	***CoG longitude***	***Distance from CoG***	***CoG x***	***CoG y***	***Distance from CoG***
Jhapa	0	27.3504	85.2049	2.87	12.11	4.46	6.432
Biratnagar	14			2.25			5.086
Siraha	0			1.42			3.273
Rautahat	0			0.55			1.166
Dhanusha	0			0.96			2.236
Simara	26			**0.29**			**0.778**
Bhairahawa	28			1.78			3.911
Nuwakot	40			0.5			1.373
Gorkha	0			0.9			2.175
Kapilvastu	13			2.28			5.136
Nepalgunj	6			3.66			7.468
Jumla	12			3.63			7.730
Dhangadhi	31			4.77			9.761
Panchkhal	41			0.51			0.946

The output in Table 3 shows Simara as the nearest SEZ from COG stating that the latitude of COG is 27.3504 and longitude is 85.2049. The supplier with highest weightage is Jogbani and the highest weightage for SEZ is in Panchkhal which is also in the central part of Nepal. Due to the weightage demand all over the Nepal, Simara emerges as the nearest SEZ location to the COG. To validate the results of the program, facility location was also done using the conventional method using MS Excel and the obtained result validated that the best location is Simara.

Similarly, the output in Table 4 shows Bhairahawa as the nearest SEZ from COG stating that the latitude of COG is 27.3504 and longitude is 85.2049. The results of the program were validated by conventional method as obtained result for best location was Bhairahawa.

Table 4: Result for COG for input 2

SEZ	*Weightage*	*Method 1*			*Method 2*		
		CoG latitude	*CoG longitude*	*Distance from CoG*	*CoG x*	*CoG y*	*Distance from CoG*
Jhapa	0			4.64			10.290
Biratnagar	7			4			8.917
Siraha	0			3.17			6.991
Rautahat	0			2.04			4.321
Dhanusha	32			2.66			5.914
Simara	0			1.61			3.667
Bhairahawa	31	27.6886	83.4622	**0.18**	8.26	5.09	**0.496**
Nuwakot	0			1.66			3.603
Gorkha	0			1.08			2.764
Kapilvastu	9			0.56			1.271
Nepalgunj	0			1.88			3.585
Jumla	19			2.18			4.693
Dhangadhi	20			3.01			5.935
Panchkhal	2			2.15			4.434

Similarly, to plan the location, cost modelling was also done. In the cost modelling method, the distance from each supplier to the SEZ is multiplied with the weightage giving the most efficient SEZ location based upon the distance. Here, the nearest SEZ point from all the supplier's location was be taken to the consideration provided that the transportation cost throughout is the same.

Consideration of the consumer demand was done beforehand and the location list was taken. The location list is the SEZ list provided by the Government of Nepal. Hence the weightage of supply and distance from supplier to SEZ was considered and multiplied. The location which had the least cumulative value for the product was selected as the best location.

In Table 5 for cost model, the supplier's weightage from the western part is higher than that of the eastern part of Nepal. Based upon the selected SEZ and Supplier data with the distance and weightage consideration Kapilvastu was found to be the optimal location for the above given scenario.

Table 5: Results of cost modelling

Supply point	*SEZ*				
	Bhairahawa	*Biratnagar*	*Kapilvastu*	*Panchkhal*	*Dhanusha*
'Mahendranagar'	12880	26404	10752	20972	21896
'Sonauli'	455	33085	5135	20475	22620
'Rupaidiah'	25470	68940	18630	51480	54450
'Kakkarvitta'	29450	5350	32000	33400	12950
'Krishnanagar'	7332	55554	3102	37412	40514
'Jogbani'	9576	152	10545	11077	3306
'Raxaul'	2332	3465	3333	3641	1826
Total	87495	192950	**83497**	178457	157562

4. Conclusions

Owing to the drastic downfall of the demand over the past years and dependence on the USA as the main customer the market may collapse if the demand ceases to exist. To run the existing industry, it is very essential to find the domestic market for the product and develop the product that can be sold in domestically. Nepal being the nation with low per capita income the consumer will not be able to invest much in the carpet for household. Hence, the cost of manufacturing must be decreased. To decrease the manufacturing cost the raw materials should be imported from India and China using land transport rather than from New-Zealand and China through airways. Also, owing to the increase in population of Kathmandu Valley the industries existing in Kathmandu is not being able to expand and outward movement of product from Kathmandu valley is causing congestion in traffic.

Hence it is advisable to expand the existing industries or start new industries in the SEZ itself. To get the best location for the SEZ based upon the demand from various places of the nation location planning methods like COG and Cost modelling can be successfully used. The cost plays the significant role in the product cycle as the increase in transportation cost will increase the overall price of the product. Both the methods are only applicable efficiently whenever the transportation cost throughout is same.

Hence there were certain limitations in these methods:

1. The value of the weightage was generated randomly as no real value was there for the supply of carpet in domestic market, owing to the point that carpet industries has been focusing in the export rather than the domestic market.
2. The cost considerations for the transportation were not taken which can be a huge factor to plan the location. As, the transportation cost from a location to another will have huge significance in the overall cost of the product.
3. The distance found in the program was based upon the latitude and longitude which considers the aerial distance of two point and the real distance from the road will differ.
4. Utilization of GIS-based tools was not done, which can be done in future works owing to the topographic conditions of Nepal.

The adjusted COG method may be used so that it considers the cost of the movement of the material from one place to another. Also, the network analysis may also be considered if the cost for movement of product is known. Furthermore, the alternate location can be developed using factor rating as well as evaluation for the location may be done using break even analysis and cost-volume-profit analysis. A framework has been developed to enable future researchers for locating facilities shown in Figure 7.

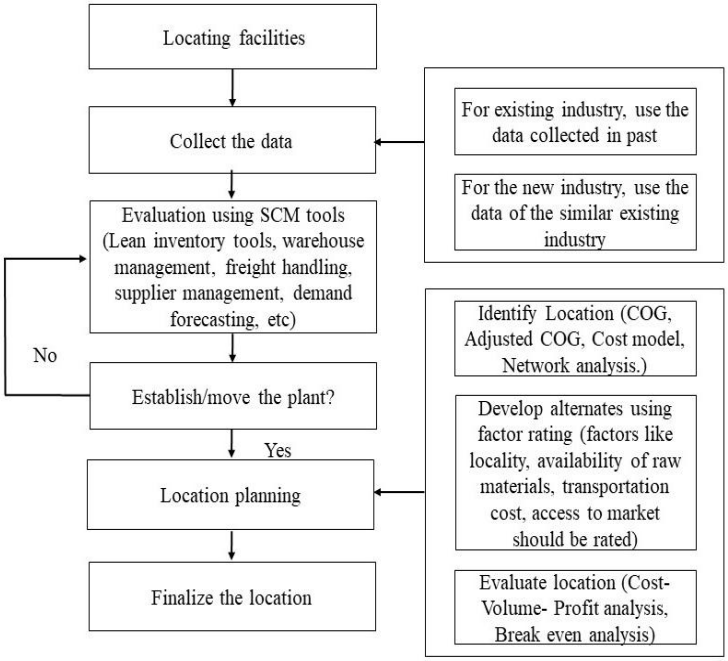

Figure 7: Framework for locating facilities

Conflicts of Interest Statement

The authors declare no conflicts of interest for this study.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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