

FACILITY LOCATIONS PLANNING FOR THE HANDLOOM SECTOR

8.1 Introduction

In chapter 4, the customer requirements are identified, and they are ranked customer's requirements according to their importance. Chapter 4 also discussed the technical requirements to fulfill the customer requirements. The study suggests that store location is the third important criteria. In Varanasi, most of the weaver houses (comprising of master weavers, independent weavers, and cooperative weavers) are selling their products either to i) the middle man, ii) retailers, or iii) to branded showrooms and so losing their opportunities of earning more profit (Das, 2021; Syukur and Akhmad, 2023). As such, weaver houses are not able to contact customers directly, and there is a need to develop and identify some subsidized stores and their locations. Government support is needed to develop such facilities to be run directly by either the group of weavers or the government. Naik et al. (2023) have indicated that government support is highly needed to create a channel for selling and marketing the products of the handloom sector. Such an effort will uplift the weaver's economic condition as well as help in increasing the customer base of the handloom sector of Varanasi. So, it is high time to develop a network of such stores, especially in Varanasi, to provide a channel to weavers for direct selling. The following objectives were taken up in this chapter.

- Identification of weaver's collection centers ; the selling store locations; and warehouse locations

- Developing facility network design for the handloom industry in order to tap the heavy footfall of tourists in paush areas.

Vlachos et al. (2010) showed that the store location has positively influenced customer purchases and loyalty as customers often form emotional attachments to such stores. Also, in-store shopping has traditionally been considered entertaining, providing consumers with feelings of escapism and adventure (Arnold and Reynolds, 2003). Johnson et al. (2015) highlighted that stores that are loyal to the customers would attract them to visit their stores more frequently for shopping with more money to spend. In a recent study, Kumar (2023) indicated that the customer base can be increased by promoting the handloom sector as a point of tourism in the case city. This idea can also be strengthened by developing a network of such stores which provide not only the means of tourism but also an increment of customer footfall and hence improvement in sales. Naik et al. (2023) have shown the possibility of an Omni channel for this sector for online sales of the products of the handloom sector. The strategic design of systems for locating distribution centers, warehouses, and other important collection centers is impacted by location decisions (Boonmee et al., 2017). This is because poorly situated stores can result in increased capital and inventory costs and a reduction in customer service (Ahmadi-javid et al., 2017). The location of retail stores is a significant challenge for new businesses (Shan et al., 2019). In addition, store location is a critical factor in retailers' long-term success as it can provide strategic advantages that are difficult for competitors to overcome (Arrigo, 2015). Manufacturers should consider redesigning their distribution networks or relocating their distribution centers to reduce supply costs and improve service levels (Liu et al., 2019).

The facility location has become an attraction to the researchers from last couple of decades (Arostegui et al., 2006). Chaudhry et al. (2003) studied the P -median problem to locate the p facilities on a network such that the average distance travelled from the demand points to their nearest facility sites is minimized by using the genetic algorithm approach. Whereas, Javadi and Shahrabi (2014) mentioned that, the p -median problem, known for its NP-hard complexity, is often tackled using Integer Programming, Lagrangian Relaxation, and heuristic methods. However, scalability becomes a significant concern with large databases comprising thousands of points in modern applications. Aydin and Murat (2013) devised an algorithm for solving facility location problems using swarm intelligence principles. Their approach merged particle swarm optimization and sample average approximation techniques. Their findings indicated that as an increase in the dimensions of the problem, their model efficiently produced solutions. Similarly, Jain et al (2002) proposed a greedy approach for solving the uncapacitated facility location problem. Javadi and Shahrabi (2014) proposed a new model for urban facility location, considering geographical obstacles, and introduced three distance functions. they evaluated these functions based on demand point allocation, costs of logistics and response time. Sahraeian and Kazemi (2011) used a fuzzy set covering-clustering algorithm for the facility location problem, where the problem is concerned only with the problem of locating the number of facilities among a finite number of sites. Müller and Haase (2014) proposed a model formulation addressing the maximum capture problem, specifically tailored for retail facility location planning. This formulation incorporates customer segmentation through the multinomial logit model to optimize shopping facility locations. However, a notable limitation of this approach lies in its oversight of segmentation patterns and substitution dynamics between facility locations. Furthermore, the method lacks efficient solution methods suitable for handling larger problem sets. These shortcomings hinder the model's

ability to account for diverse customer preferences accurately and may limit its scalability in real-world retail scenarios. Yücenur and Ipekçi (2021) used the SWARA/WASPAS method for the marine energy plant location by using the criteria and the alternatives. Similarly, Ulutaş et al. (2020), used the fuzzy SWARA and CoCoSo methods for the location selection for the logistics center. Hashemkhani et al., 2020 used the grey-based decision support framework for the location selection for the hospital, with the uncertain nature of the information related to location alternatives.

Accordingly, an effort has been made to develop a network of collection centers, a warehouse, and stores to benefit the weavers and weaving houses directly. Figure 8.1 illustrates the schematic diagram of such a network. The warehouse in Figure 8.1. will be used to check the quality of the products and will work as a store for the Omni channel. A k-means approach was adopted to find the potential location of collection centers, warehouses, and stores. The elbow method was used to get the value of k.

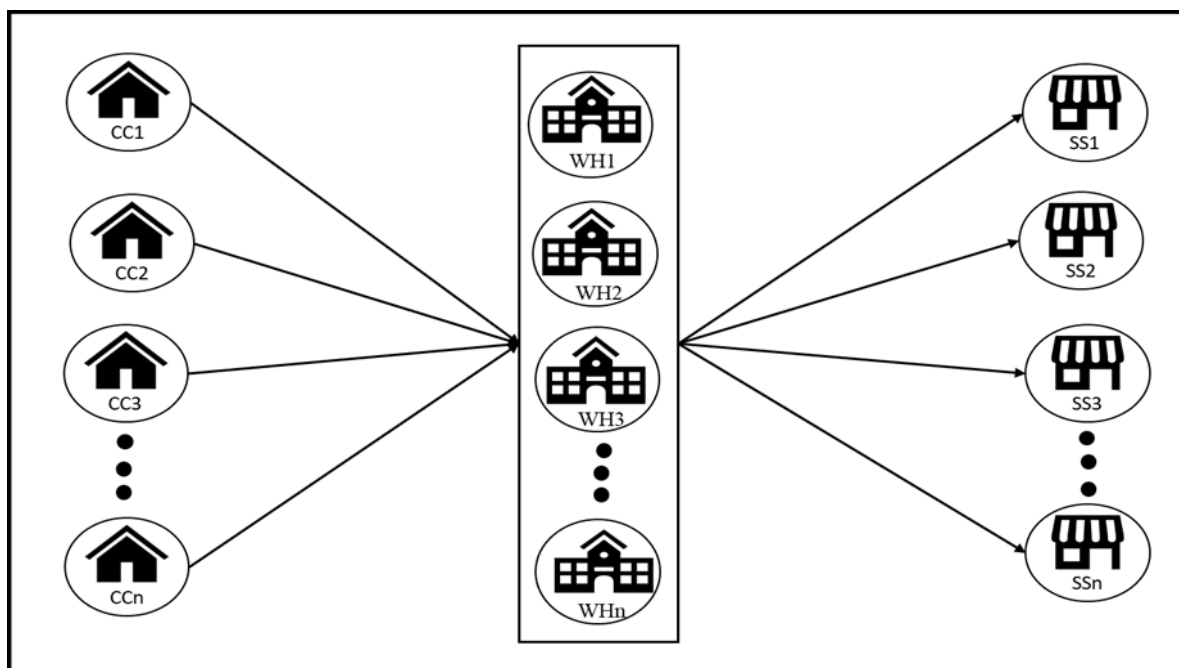


Figure 8.1: Illustrative design of network

*CC: Collection centres; SS: Selling stores; WH: Warehouse

8.2 Methodology

The study was carried out in three steps. Figure 8.2 illustrates the detailed methodology adopted in this study to assess a facility located in the Varanasi handloom sector. In the first step, collection centers are decided by using Weaver's location data. In the second step, tourist locations were clustered, and centroids were identified for the store location. In step three, the k-mean method was applied to the weaver's clusters centroid (i.e., collection centers) and tourist cluster centroid (i.e., store locations) to identify potential warehouse opening sites.

8.2.1 *k-means clustering*

The MacQueen James first introduced the "k-means" term in 1967 (MacQueen, 1967). The k-mean clustering algorithm is unsupervised (Sinaga and Yang, 2020) and consists of two phases. In the first phase, k centroids are computed, and in the second phase, each data point is assigned to the cluster with the nearest centroid. The Euclidean distance method is commonly used to define the distance between a data point and its nearest centroid (Dhanachandra et al., 2015). The k mean method performs the best when compared to the other methods, like Canopy and EM, in terms of accuracy and speed. Similarly, Velmurugan (2012) compared the K-Medoid and K-Mean algorithms for the clustering of arbitrary data points; the results show that k-mean yields the best results. According to Ikotun et al. (2023), the K-means clustering algorithm is credited with flexibility, efficiency, and ease of implementation, making it among the top ten clustering algorithms in data mining for its wide acceptance across many domains in solving clustering problems. So, for this network design, we used the k-mean method. The objective function of the k-means algorithm is to minimize the square error function. The steps of the k-means method are reproduced below (Li et al., 2022).

Step 1: Calculation of Euclidean Distance

The k-means clustering algorithm uses the Euclidean distance calculation formula to measure the distance between two data locations, which can be expressed as Equation 8.1.

$$D(X_i, X_j) = \sqrt{\sum_{a=1}^m (x_{ia} - x_{ja})^2} \quad (8.1)$$

Where $X_i = (x_{i1}, x_{i2}, \dots, x_{im})$, $X_j = (x_{j1}, x_{j2}, \dots, x_{jm})$ represent the attribute values of two data locations, which contain m-dimensions. In this work, we are considering geographical data containing only two attributes.

$$L_i = (l_{i1}, l_{i2}) \quad \forall i \in N \quad (8.2)$$

In this work, the locations are denoted as Equation 8.2, where l_{i1} and l_{i2} are the x and y coordinates of the i^{th} of location expressed in longitude and latitude, respectively, and N represents the number of locations in this category.

$$Z_k = (z_{k1}, z_{k2}) \quad \forall k \in K \quad (8.3)$$

$$D(L_i, Z_k) = \sqrt{(l_{i1} - z_{k1})^2 + (l_{i2} - z_{k2})^2} \quad \forall i \in N, k \in K \quad (8.4)$$

Additionally, the coordinates of the k^{th} cluster centroid are represented by Equation 8.3, where z_{k1} and z_{k2} are the x and y coordinates of the k^{th} cluster center, respectively. Thus, the formula for calculating the Euclidean distance between the i^{th} location and the k^{th} cluster centroid is given by Equation 8.4.

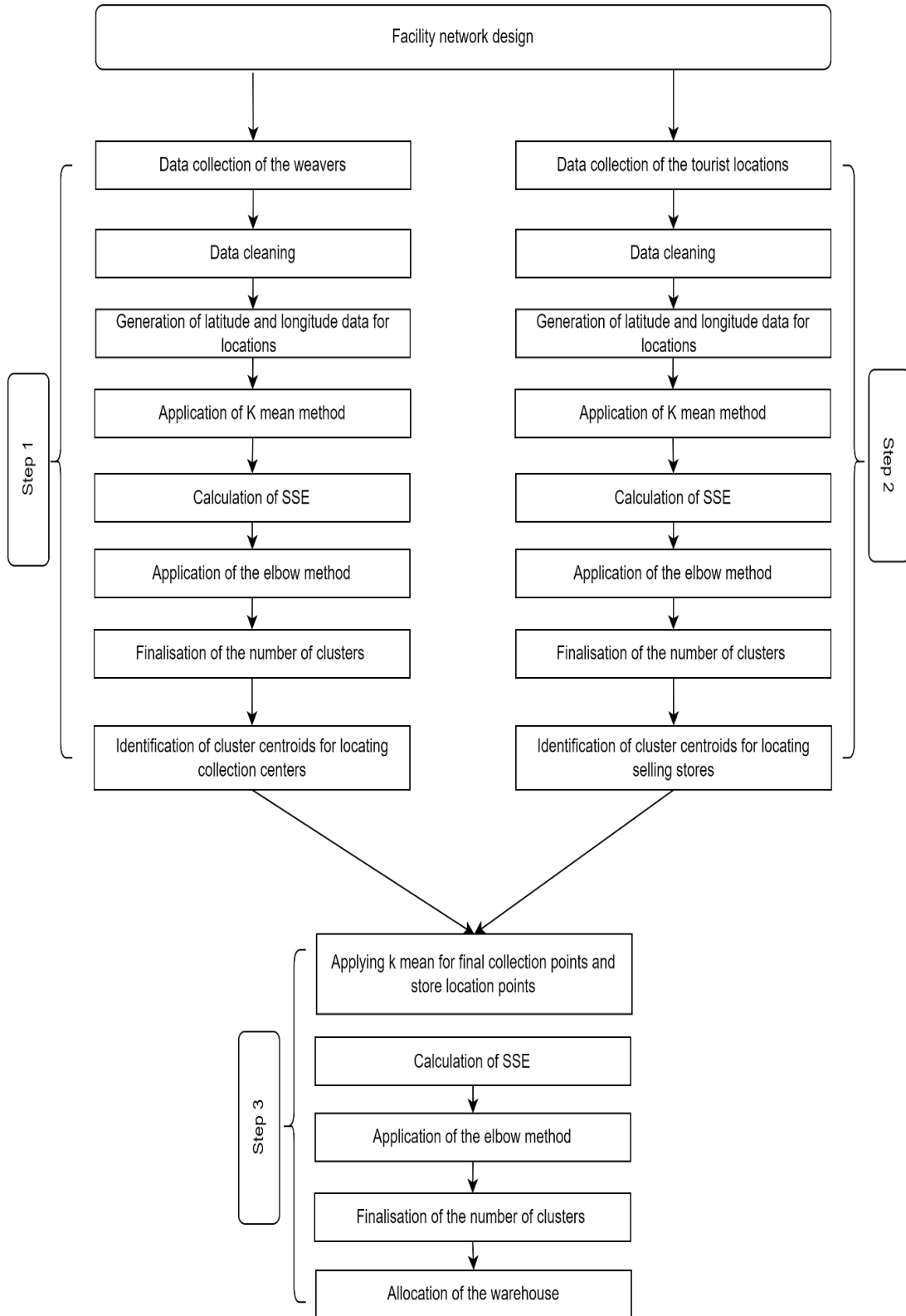


Figure 8.2: Methodology adopted for the study

Step 2: calculation of the SSE.

The formula for calculating the degree of distortion in the k-means clustering algorithm is calculated from Equation 4.5

$$SSE = \sum_{k=1}^K \sum_{i=1}^N [D(L_i, Z_k)]^2 \quad (8.5)$$

Where SSE represents the sum of squared errors, K is the number of clusters, N is the set of location numbers in a category, L_i represents the position of the i^{th} location, and Z_k represents the position of the k^{th} cluster center.

8.2.2 Elbow method

In this study, the optimal number of clusters was determined using the elbow method (Li et al., 2022) and the expert's opinion (Lopez-Martinez-Carrasco et al., 2021). The Elbow method is a visual method to test the consistency of the best number of clusters by comparing the difference of the sum of square error (SSE) of each cluster (Umargono et al., 2020). So, there is a chance of ambiguity in selection (Hassan et al., 2021). Therefore, we used an expert's opinion to decide the number of clusters. The elbow rule number of the cluster is identified by plotting the SSE as a function of the number of clusters K. The plot typically shows a decreasing SSE with an increasing number of clusters. The point where the rate of decrease slows down significantly is called the elbow point. Further, increasing the number of clusters does not significantly improve clustering performance.

8.3 Data collection and assumption of model

The collection of the data was carried out in three phases. In the first phase, the location data of 4001 weavers were collected from the Weavers Service Centre (WSC),

Varanasi. In the second phase, 82 tourist location data was collected from the tourist travel agencies and filed study.

Assumption of the model:

- I. The collection center and selling store can be located anywhere within the cluster;
- II. The number of the cluster need to be optimal
- III. there is no constraint on the budget and space availability for allocating facilities.

8.4 Results and discussion

This study aims to identify the weavers' collection centers to collect the handloom products, identify the potential tourist location for opening the stores, and allocate the warehouse to manage the products. The following subsections show stepwise results.

8.4.1 Allocation of the weaver's collection centres

Step 1: The 4001 Varanasi handloom weavers' data was collected from Weaver's Service Centre (WSC), Varanasi. The data was cleaned by sorting, removing duplicate locations and missing area information. In data cleaning, all the addresses of the weavers were merged by the name of the area/colony. This reduced the data points significantly. Finally, 404 locations were identified and marked on maps, shown in Figure 8.3.



Figure 8.3: Geographical position of weaver's area.

Step 2: The weaver area's latitude and longitude were collected by using Google Maps. The illustrative data of the longitude and latitude is shown in Table 8.1. The plot of weaver's geographical coordinates in latitude and longitude is shown in Figure 8.4.

Table 8.1: The example of the input data for the k-means clustering algorithm for weavers' location.

Weaver area location number	Latitude	Longitude
5	25.37957	83.02347
22	25.28864	83.00676
32	25.29834	83.00734

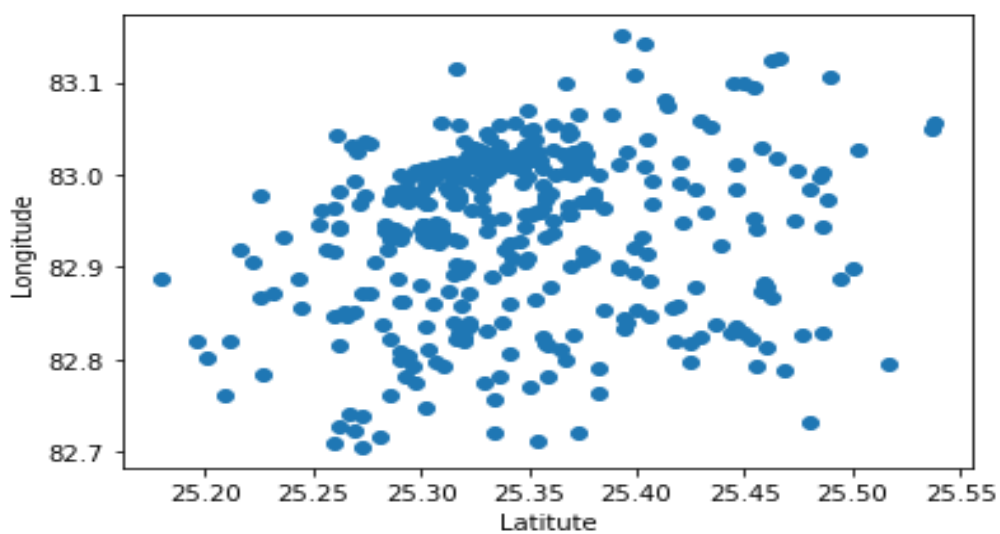


Figure 8.4: Plotting geographical coordinates for various weavers' locations

Step 3: The k-mean method was applied as discussed in Section 8.2.1, and the value of the sum of squared error (SSE) with respect to the number of clusters (k) was recorded. The graph of the SSE Vs k was plotted as shown in Figure 8.5.

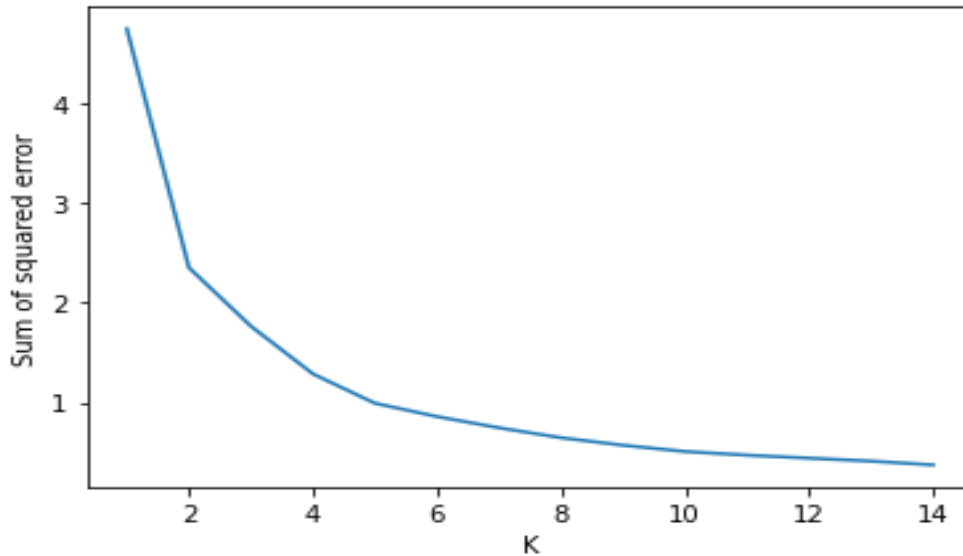


Figure 8.5: Plot between the sum of square error (SSE) and number of clusters (k) of weavers' data

Table 8.2: The value of SSE with respect to the number of cluster k of weavers' data

K	SSE Value
1	4.78
2	2.35
3	1.76
4	1.28
5	0.99
6	0.85
7	0.74
8	0.64
9	0.57
10	0.50
11	0.47
12	0.44
13	0.41
14	0.37



From Figure 8.5 and Table 8.2, it is observed that with the increase in the number of clusters, the value of SSE is decreasing. The maximum k value considered for the study is 14. By analyzing the Figure 8.5, the number of clusters (K) was decided as four. The

value of SSE at K=4 is 1.28. The weavers' latitude and longitude graph, the four cluster areas, and their centroids as collection centers are shown in Figure 8.6.

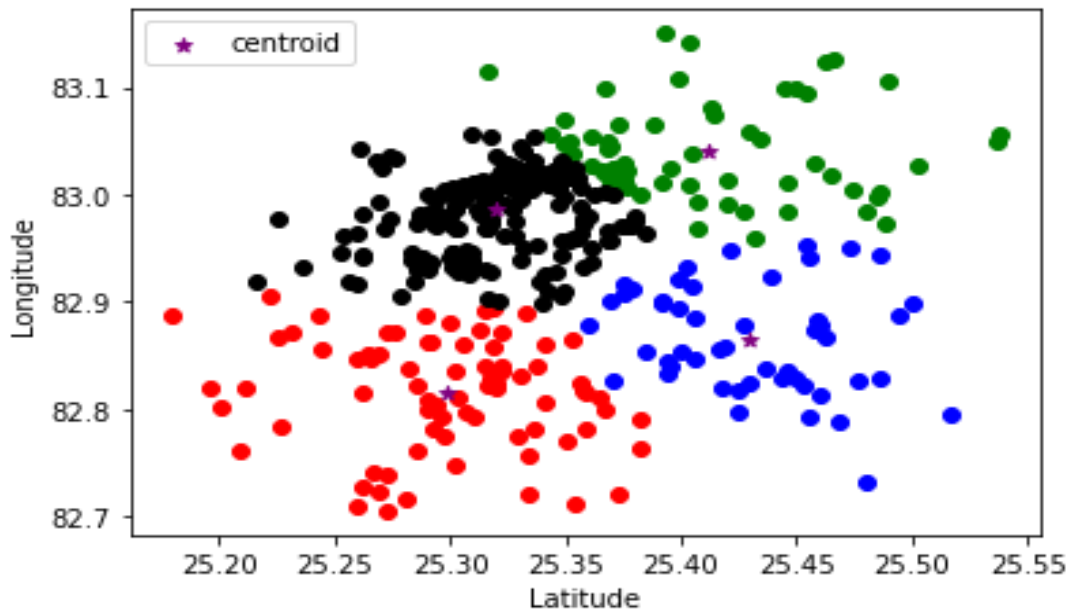


Figure 8.6: Marking of weaver's clusters and their centroids

8.4.2 Allocation of store location

Identification of selling stores was also made with the help of the k-means clustering approach using tourist location data. Following steps present the application of the k-mean method to find the cluster.

Step 1: Eighty-two tourist locations were identified in Varanasi through field visits and tourist travel agencies. The tourist locations consist of temples, ghats, forts, and museums. The graphical representation of the tourist location on the map is shown in Figure 8.7.

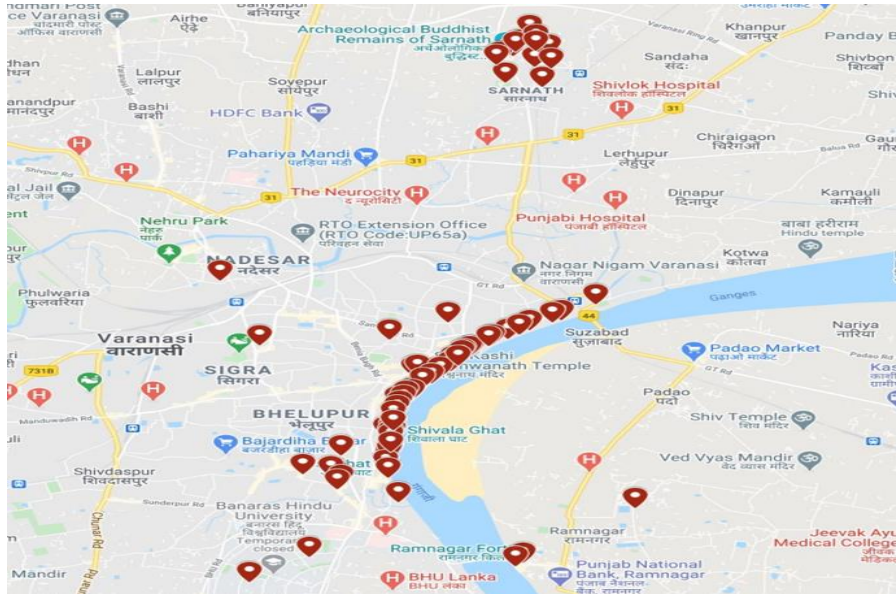


Figure 8.7: Geographical position of tourist locations in Varanasi

Step 2: The tourist location's latitude and longitude data were collected using Google Maps.

Table 8.3 shows a few data points of such longitude and latitude. The plots of latitude and longitude are shown in Figure 8.8.

Table 8.3: The example of the tourist locations input data for the k-means clustering algorithm.

Tourist location number	Latitude	Longitude
9	25.37958	83.02347
25	25.26608	82.98790
35	25.27029	83.02486

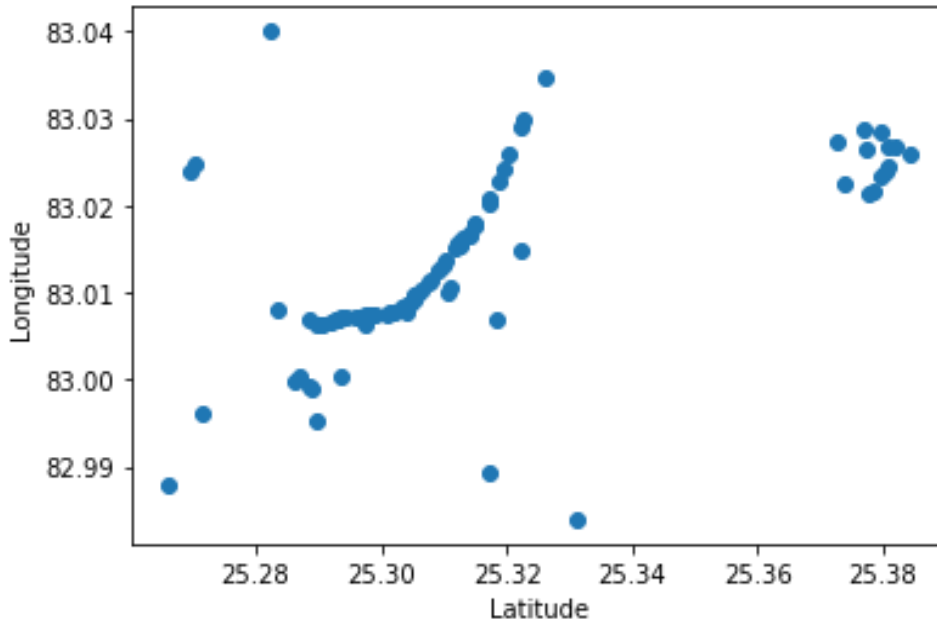


Figure 8.8: Plotting geographical coordinates for various tourist locations

Step 3: The k-mean method was applied as discussed in Section 3.1, and the values of the sum of squared error (SSE) with respect to the number of clusters (k) were recorded. The graph of the SSE Vs. k graph was plotted as shown in Figure 8.9 and Table 8.4.

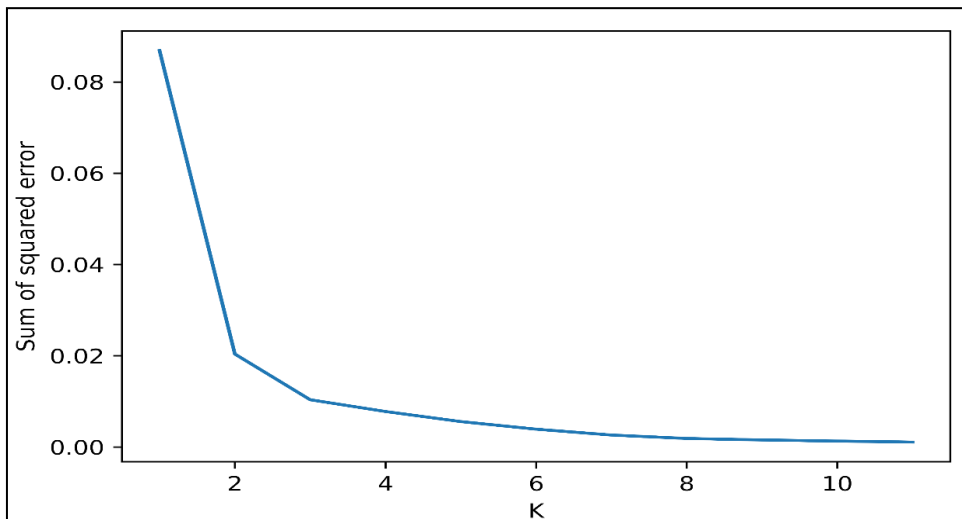


Figure 8.9: Plot between the sum of square error (SSE) and number of clusters (K) for tourist location data

Table 8.4: The value of SSE with respect to the number of cluster K for tourist location data

K	SSE Value
1	0.086
2	0.020
3	0.010
4	0.007
5	0.005
6	0.003
7	0.002
7	0.001
8	0.001
9	0.001
10	0.001



The maximum k value was considered as 10 for the study. Based on the elbow plot of Figure 8.9, the number of clusters (k) was decided as 4. The value of SSE at k=4 is 0.007. The marking of these four tourist cluster areas and their centroids are shown in Figure 8.10.

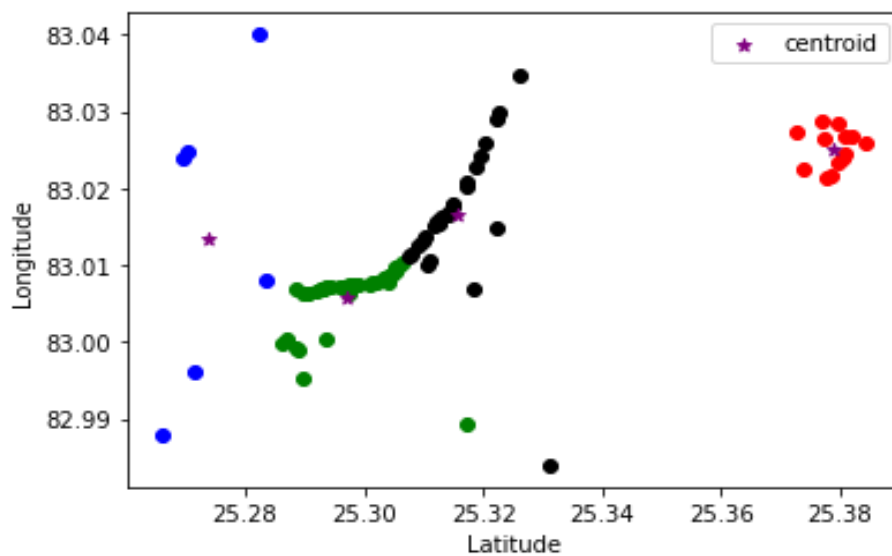


Figure 8.10: Marking of tourist clusters and their centroids

8.4.3 Allocation of warehouse

The warehouse is located on the basis of the locations of selling the stores and weaver's collection centers. Such a warehouse is used to check the quality of the material and for inventory management and online sales. The handloom products collected from the weavers' collection centers are checked with the quality standards and transported to the stores with demand. The allocation of the warehouse is done by using the k-mean method. In this, the centroids of the weavers (i.e., collection centers) and the tourist location in the cluster (i.e., store location for sales) are considered. The latitude and longitude coordinates (identified through Google Maps) were used in the k-mean method to find the cluster centroid to open a warehouse. The k-mean method was applied as discussed in Section 3.1, and the values of the sum of squared error (SSE) with respect to the number of clusters (k) were recorded. The graph of the SSE Vs. k for the warehouse is shown in Figure 8.11 and Table 8.5.

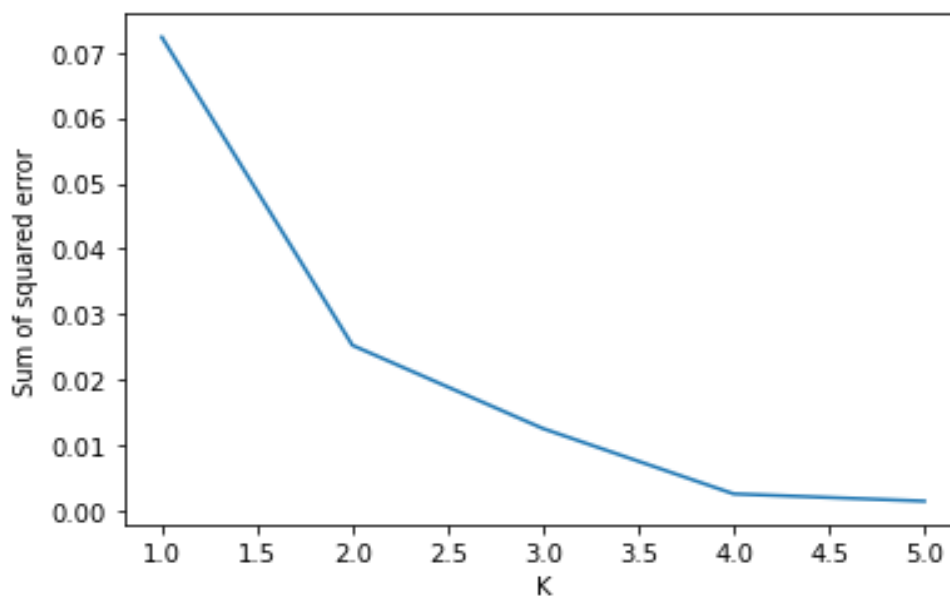


Figure 8.11: Plot between the sum of square error (SSE) and number of clusters (K)

Table 8.5: The value of SSE with respect to the number of cluster K

K	SSE Value
1	0.072
2	0.025
3	0.012
4	0.002
5	0.001



The maximum k value was considered as five for the study. Based on the elbow plot, the number of clusters (k) was decided as two. The value of SSE at k=2 is 0.025. The marking of these two warehouse location areas and their centroids are shown in Figure 8.12.

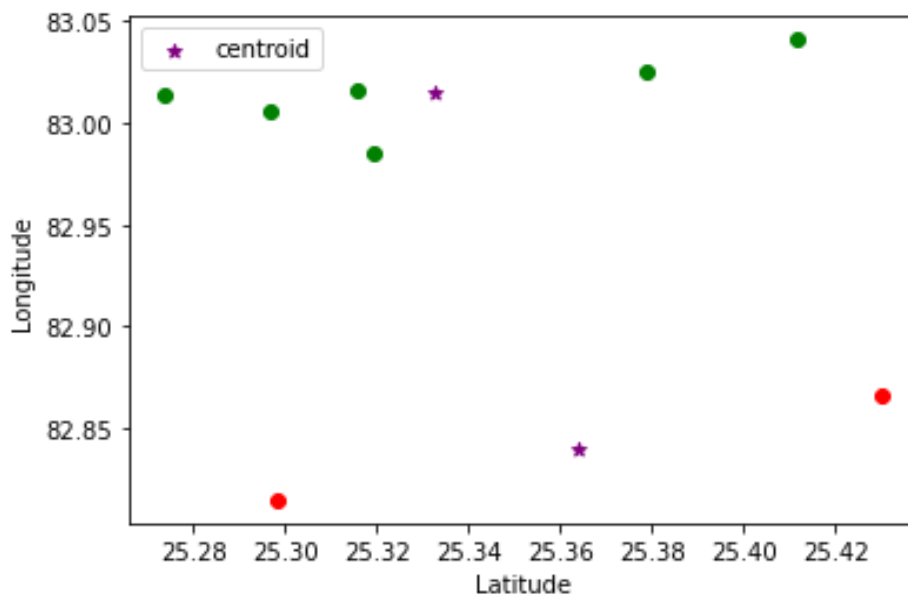


Figure 8.12: Marking of warehouse clusters and their centroids

The designated positions for the establishment of the Varanasi handloom sector's facility network have been indicated on Google Maps. The store locations are denoted by blue points, collection centers by green points, and warehouse locations by red points, as illustrated in Figure 8.13.

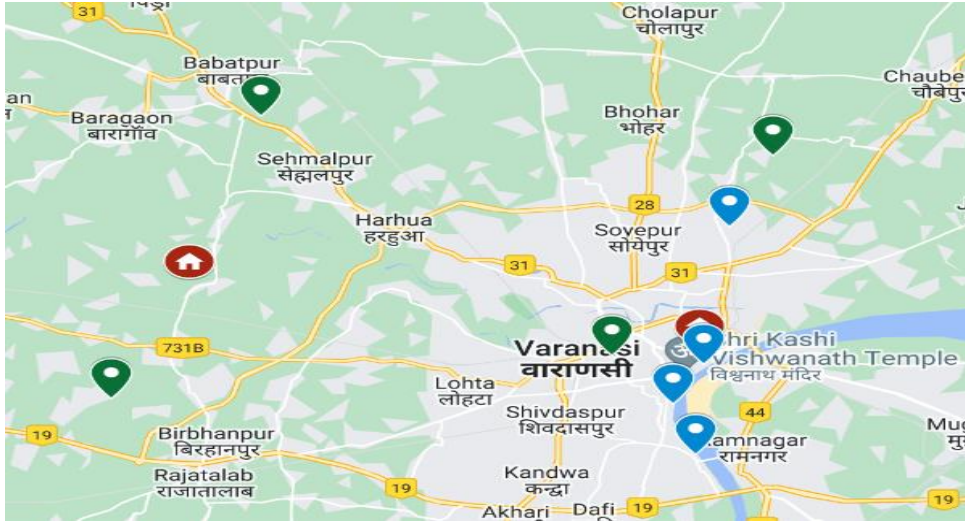


Figure 8.13: Marking of facility location of Varanasi handloom sector

*Blue- selling store locations, Green-Collection centers, Red- warehouse locations

8.5 Conclusion

The Indian handloom sector is creating livelihood for most of the rural people of India. The weavers of this sector are facing a decrease in the demand for the products, and this is because of the lack of proper customer interaction, involvement of mediators, and other factors. The weavers have to have access to some stores near the tourist location to increase footfall and enhance turnover. This study is useful for all types of weavers (like cooperative weavers, Master Weavers, and Independent Weavers) and policymakers to improve the health of the handloom sector. The collection centre location, warehouse location, and store location will provide basic infrastructure to this extent. The study suggests that the handloom sector policymaker should design a policy that can deal with the development of such a network to deal with customer reachability. The store location and weaver's collection centres can also have a social impact on the weavers. Store locations near tourist places will increase reachability for handloom products, leading to an increase in demand for products and availability of work and ultimately increasing the profit of weavers. A warehouse can serve the dual purpose of checking quality and inventory management as well as online selling by providing an omnichannel

This research explored the facility location to install handloom stores, weavers' collection centres, and warehouses in the Varanasi handloom sector. Weavers' location data was collected from WSC, while field surveys identified tourist locations. The location of the weavers and the tourist places were used to generate the geographical location. The k-mean method was applied to the geographical location data, and appropriate clusters were formed. Four number of clusters were decided based on the elbow method. Weaver's cluster centre is supposed to be used as a product collection centre. Simultaneously, the Varanasi tourist locations were also clustered. The number of clusters is decided in the same fashion as four. The store locations and Weaver's collection centre locations were used in K-mean to allocate the warehouse. Two warehouses were identified based on the elbow method. This result can be used to develop a network to facilitate the weavers for direct selling through the warehouse, either through physical selling in the selling store or online in the warehouse.

This k-mean and elbow technique is based on the case study of the Varanasi handloom sector in India, and this model may be biased and limited to this Varanasi city only. However, this model can be generalized in other sectors, which may require modifications in the geographical locations. In this present work, various geographical locations are considered to locate the collection centers, warehouses, and selling stores. An effort is required to extend this work to find the actual cost of developing such a network and towards the implementation of the same.

