Determination of Realistic Facility Location in Bangladesh by using Center of Gravity Method

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***Abstract* — The facility location plays an important role in an industry's supply chain management to facilitate logistics management requirements, making the sourcing and distribution process smooth and fast. The purpose of this study is to determine the ideal place to determine the location of a garment industry. This research uses the Center of Gravity method to calculate the optimal location that will be considered. This method employs an (X-Y) coordinate system to cover the geographical map of the study areas and identifies the coordinates for the new facility's location. It endeavored to identify the optimal location for the garment industry in Bangladesh. It was pinpointed where the industry can obtain raw materials from various regions of the country and a market, labor force, and energy source. Information was gathered regarding the volume of business activity at existing facilities. From the results of this study, it was found that the selected facility's location at the coordinates (23.68497454, 90.5928119), the arable land of the village of Sreepatir Char, Sonargaon, Narayanganj, which is the centralized position according to the supplier's distance, market distance, and availability of labor. Finally, we have shown that the identified location is appropriate for the facility's placement.**

***Keywords* — Center of Gravity Method, Optimal Location, Logistics Management, Location Coordinates.**

I. Introduction

If an industry or company needs to be set up, then a suitable location or facilities for establishment must be in consideration [1]. It vies with defined the choice of the position for the company or facility. Location or facility settings limn a main part of the strategic dodging techniques of every company or organization. Moreover, albeit most probabilities evolve that location verdicts are one-time factors concerning new organizations or companies which subsist organizations once and again have a bigger trident in some model of selections than new companies. It commences with an in-depth in a very general way of the sakes companies should make facility decisions depending on some models, the characteristics of those selections, and a standard yield of the riving ping and selecting facility other ways.

As the location decisions are very complicated and challenging to analyze, some accessible models could assist with recognizing the fitting location. Location models have been broadly discussed. Production location decision is the interaction that involves a model or part of a model as a device for pursuing choices to decide the best other option. In the model, it is expected to set or decide the variable to restrict the thought. Every variable comes from factors of better places, for example, production framework factors, supply chain factors, or even factors from the product life cycle and fluctuation of demand [2].

Suppose a company or an organization wanted to choose locations, so an organization should envisage certain factors. For instance, a manufacturing organization may elect to have an individual mean plant that spawns all the organization's products. This verdict can aid the organization in gaining economies of balance by decrementing the unit value albeit better utilization of arsenal and smearing of fixed values over exceeding units. Transportation values incurred in knowledge inputs from immensely dispersed suppliers and distributing finished goods from the plant to a highly dispersed market, will be very high. If there is a strike or a catastrophe such as fire or flooding, the ongoing organization's operations can come to a standstill.

Managers can acquire acceptable site choices through specialized location selection models and tactics based on location selection criteria. The specifications of several models are: the Center of Gravity Method of Plant Location, the Cost-Volume-Profit or Break-Even Analysis, the Point Rating Method, the Transportation Method of Linear Programming, and the Analytic Delphi Method.

It is typical for an organization's size and the nature or scope of its operations to influence how it tackles decisions regarding location heavily. When choosing a new site, startups and smaller businesses typically take a more relaxed approach. New businesses frequently shop in an area familiar to the proprietor because that is where they live. Similarly, managers of small businesses typically have a strong desire to keep activities inside their territory. As a result, they tend to focus almost exclusively on opportunities in their area.

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Large, well-established businesses, particularly those that are now being operated in more than one place, tend to take a strategy that is even more formal. In addition to this, they typically take into account a more diverse range of geographical locations. This article's primary topic of discussion is one approach that involves making formal area determinations.

II. Literature Review

Numerous significant geographical variables engaged with the area of individual businesses are of relative importance, e.g., raw materials, power assets, labor, water, markets, and transport facilities. However, other than such geographical elements impacting industrial position, historical, political, human, and economic variables currently tend to outperform the power of geographical benefits [3]. Obtaining materials has become worldwide. Commoditized inputs like steel have been purchased any place; they are generally modest and are delivered to where they are required. The organization will pick whichever source supplier has the least cost, including transport. Assuming that everyone has ever limb something on the web, for the most part, they need to realize which organization has the item with the least general overall cost [4]. There are contrasts in energy costs across space. For energy-concentrated modern exercises, subtle energy is fundamental. China rose from creating next to no steel years and years prior to driving this present reality. It utilizes low labor costs and an extremely modest energy source-huge supply of (highly-polluting) coal [5]. The current location is harmony between material, capital, labor, and markets. The objective is, in general, the least expensive.

The profitability of the facility does not depend on only the location, it also depends on the proper functioning of the equipment and its utilization. Such overall equipment's utilization factor calculation and improvement was shown in the Ready Made Garments (RMG) sector in Bangladesh. Some articles Proposes enhancing Overall Equipment Effectiveness (OEE) through a hybridized Total Maintenance (TPM) scheme, laying the foundation for implementing the TPM model in the plant to achieve sustainability and world-class benchmarking [6]

In some cases, they were pushing down one class, similar to labor, and incrementing different expenses, similar to transportation. Hoag (1980) likewise brings up that a region with much modern land and adequate region for the foundation of a manufacturing plant is helpful for the modern turn of events. Many of these should be provincial explicit, for instance, on account of raw materials unevenly circulated worldwide [7]. If someone wants a coal mine shaft, situating it in a spot with coal is brilliant. This is the most outrageous type of limitation; however, remember that many spots have mineral riches, yet not everyone is currently separating that abundance. Many spots that would be contenders for asset extraction are not being utilized now because the assets cannot be removed and sold for a benefit [8]. The proximity of sources of raw material is the fundamental significance to distinguishing the area of industry. Closeness to the sources of raw substances would minimize the industry's manufacturing cost [9].

One more component affecting the location of an industry is the accessibility of modest power. Water, wind, coal, gas, oil, and electricity are the central wellsprings of power. Both water and wind power were broadly looked for at wellsprings of the power supply before the development of the steam motor. During the nineteenth century, closeness to coal fields became the chief finding effect on setting up new ventures, especially for severe businesses [10]. Promising chances to go electric can be likewise tracked down on the planet's plants and modern parks. The financial and natural advantages of utilizing electricity rather than fossil fuels are expanding for modern organizations. Today, around 20% of the energy consumed in the industry is electricity [11]. Most ventures buy electricity from electric utilities or free power makers. A few modern offices likewise create electricity for their utilization utilizing fuels they buy or potentially the buildups from their current cycles. For instance, many paper factories have consolidated intensity and power establishes that might consume bought natural gas or coal and dark alcohol created in their plants to process heat and produce electricity [12]. Combined Heat and Power (CHP) is an exceptionally productive interaction that catches the overabundance of heat and steam created during the assembly system and feeds it back into the framework [13]. Laborer mentality toward turnover, non-appearance, and comparable variables might contrast among possible areas - laborers in massive metropolitan places might display unexpected perspectives compared to laborers in modest communities or rural areas [5], [14]. Alfred Weber (1868-1958) was a significant supporter of geographic reasoning regarding modern areas. Weber extended the idea of involving the most reduced, generally speaking, expense for the location of industry. He created models that held many contributions to assembling consistently to exhibit the significance of transportation in deciding the most minimal expense [7], [15]. Sea transport represents over 90% of the world's exchange economy. Contrasted with air transportation, ships are fit for conveying monstrously heavier burdens for a negligible portion of the expense. Air transportation likewise has an immense degree contrasted with rail and ship freight. It is a consistently growing industry with a few thousand air terminals and runways in activity across the globe [16]. Air transport is more costly than truck transport because of the more significant expense of fuel and extra costs like tickets, upkeep, designated spots, and unique dealing with charges for specific materials, steel trailers, and that is just the beginning. At the point when ground coordinated factors are a choice, and reliable, fast conveyance is not needed, trucks are, in many cases, the more affordable choice. Air transport is excellent for organizations that can bear the cost of the expense and depend on quick shipments [14], [15]. A location that has better banking offices and insurance are the most ideal for the establishment of industries. There is a consistent feeling of dread toward harm to machines and men in industries for which insurance offices are severely required [16].

III. Methodology

A. Critical Factors in Facility Location Decision-Making

1) Proximity to sources of supply

To reduce transportation costs, firms that process bulk raw materials typically locate close to the supply source. The proximity of paper mills to forests, canneries to agricultural regions, and fish processing plants to the harbors where fishing vessels dock is typical.

2) Proximity to customers

There are numerous reasons why a business would choose to locate close to its customers. As with supermarkets, gas stations, fast food restaurants, and hospitals, service businesses must be close to customers to be convenient. Transportation costs can also necessitate proximity to customers, as in concrete production. Producing perishable goods close to their final market is typically necessary.

3) Labor factors

According to research, most location decisions are primarily influenced by labor factors, as labor is a crucial variable for many businesses. Labor factors include the prevailing wage rate for similar jobs in a community, the availability of qualified workers, and the average education level of the local population (percentage of high school graduates, etc.). Other labor factors can include the level of unionization, the general work ethic of a community, and other measures of absenteeism. Worker tenure can play a significant role in a company's location decision.

B. Steps Involved in the Study

We determined the coordinates of the existing facilities on a two-dimensional plane or grid. Then, we collect information regarding the volume of business activity at existing facilities.

After that, the new coordinates are computed using the formulas.

1) Sensitivity analysis

- Natural resources,
- Power supply,
- Transportation routes,
- Political issues,
- Government policies,

2) Banking facilities

Result and discussion: Finally, we determine a facility's optimal location based on our data analysis findings and recommendations.

C. Model Formulation of Center of Gravity Method

The center of gravity method is employed for locating single facilities considering existing services, the distances among them, and volumes of products becoming sent among them. To calculate a load distance for just about any area that is possible we make use of either of the distance actions and simply boost the loads moving to and from the facility by the distances traveled.

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i}; \qquad C_y = \frac{\sum d_{iy} V_i}{\sum V_i}; \tag{1}$$

where,
C_x = X coordinate of center of gravity,
C_y =Y coordinate of center of gravity,
d_{ix} =X coordinate of the i'th location,
d_{iy} =Y coordinate of the i'th location,
V_i= Demand / Volume of goods moved to or from i'th location.

TABLE I: Data on Raw Material Collection

S/N	Supplier	Supplies	Factory Location	X-Y Coordinate	Demand (%)		
1	Alltex Fabrics Limited	Fabric	Ariabo, Rupganj, Narayangonj	23.74785, 90.54333	7	8	4
2	Asian Fabrics Mills Ltd.	Fabric	Shashongaon, Fatullah, Narayangonj	23.65678, 90.48449	9	11	10
3	Fair Trade Fabrics Ltd.	Fabric	Shafipur, Kaliakoir, Gazipur	24.07159, 90.22229	13	8	11
4	H. H. Textile Mills Ltd.	Fabric	Rupshi, Rupgonj, Narayangonj	23.73921, 90.52706	5	5	7
5	A. G. Textile Mills Ltd.	Fabric	Gorai, Mirzapur, Tangail	24.10010, 90.16048	3	3	5
6	Newtop Textile BD. Ltd.	Fabric	Adamjee EPZ, Narayangonj	23.67805, 90.52476	4	5	6
7	AB Textile Mills (BD.) Ltd.	Fabric	Madhabdi, Narsingdi	23.84891, 90.67052	2	3	7
8	Regent Textile Mills Ltd.	Fabric	Charkhidipur East Kalurghat Bandar, Chittagong	22.35235, 91.89389	10	8	7
9	Ring Shine Textiles Ltd.	Fabric	DEPZ, Ganakbari, Savar, Dhaka	23.94757, 90.28175	12	14	8
10	Saad Musa Fabrics Ltd.	Fabric	Kulgaon, Jalalabad, Chittagong	22.40417, 91.82476	13	11	3
11	Envoy Textiles Ltd.	Fabric	Jamirdia, Bhaluka, Mymensingh	24.30684, 90.38625	7	9	10
12	NZ Fabrics Ltd.	Fabric	Vulta, Rupgonj, Narayangonj	23.78078, 90.56486	6	8	9
13	Paramount Textile Ltd.	Fabric	Gillarchala, Sreepur, Gazipur	24.19131, 90.42422	9	7	13
14	Shasha Denims Ltd.	Denim	DEPZ, Savar, Dhaka	23.94757, 90.28175	8	8	3
15	Nice Denim Mills Ltd.	Denim	Mawna, Sreepur, Gazipur	24.21154, 90.44107	14	21	9
16	Ha-Meem Denim Ltd.	Denim	Mawna, Sreepur, Gazipur	24.21154, 90.44107	7	9	17
17	Square Denims Ltd.	Denim	Olipur, Habiganj	24.28462, 91.37685	32	25	26
18	Amber Denim Mills Ltd.	Denim	Rajendrapur, Gazipur	24.09317, 90.37547	31	28	35
19	Argon Denims Ltd	Denim	Sreepur, Gazipur	23.83328, 90.41883	8	9	10
20	Simtex Industries Ltd.	Thread	Savar, Dhaka	23.88131, 90.38419	14	16	10
21	Texus Accessories Ltd.	Thread	Halishahar, Chittagong	22.32716, 91.77339	9	11	10
22	BHT Industries Ltd	Thread	Nowjoor, Kadda, Gazipur	24.07344, 90.35996	20	18	17
23	Apex Yarn Dyeing Ltd.	Thread	Gulshan, Dhaka	23.78853, 90.41624	17	15	15
24	Fabian Thread Ltd.	Thread	Kalurghat, Chittagong	22.45164, 91.85625	9	9	8
25	Global Premium Accessories Ltd.	Thread	Rupnagar, Mirpur Dhaka	23.87249, 90.36348	18	14	22
26	R.S.S Thread & Accessories	Thread	Shantinagar, Dhaka	23.89176, 90.42203	13	17	18
27	Amin Associates Limited	Accessories	Dakhian Khan, Uttara, Dhaka	23.87984, 90.40938	8	8	13
28	Auko-Tex Ltd.	Accessories	Northern Rd, Dhaka	23.81863, 90.41134	13	12	11
29	S.A. Thread & Accessories Ltd.	Accessories	Gacha Road, Tongi, Dhaka	23.94292, 90.36945	9	8	7

S/N	Supplier	Supplies	Factory Location	X-Y Coordinate	Demand (%)		
30	Biswas Accessories Limited	Accessories	Kawran Bazar, Dhaka	23.81358, 90.42579	5	6	12
31	Masco Accessories Limited	Accessories	New Market, Dhaka	23.74689, 90.39326	8	10	3
32	N.M. Accessories Industry Ltd.	Accessories	Khilgaon, Dhaka	23.76531, 90.36885	10	11	7
33	Vertex Accessories International	Accessories	Rampura, Dhaka	23.91512, 90.37339	9	11	8
34	Import	Machinery/Accessories	Chittagong Port	22.30976, 91.80185	18	16	22
35	Import	Machinery/Accessories	Mongla Port	22.54756, 89.59161	20	18	17

IV. Data Analysis and Findings

Center of Gravity analysis is a technique for determining the optimal location for a centralized distribution center. In Bangladesh, we have endeavored to identify the optimal location for the garment industry. We have pinpointed where the industry can obtain raw materials from various regions of the country, as well as a market, labor force, and energy source. Using these attributes, we have added several points with X-Y coordinates to the map.

A. Raw Material Collection

Proximity of sources of raw material is the fundamental significance to distinguish the area of industry. Closeness to the sources of raw substances would minimize the cost of manufacturing in the industry. Here we found out the different suppliers of fabric, denim, thread, and accessory in Bangladesh for locating a garment manufacturing industry.

B. Distance to Market

Transport and distribution expenses can be limited by be nearer to the market. We put out the possible markets of garment to different districts in Bangladesh, X-Y coordinate, and the demand value for each location according to current scenario of market.

C. Labor Availability

Labor is accordingly vital for the assembling area. The labor needs of the plant will fluctuate contingent upon the idea of the creation interaction. In circumstances where a lot of gifted or semi-prepared labor is required, it could be favorable to find a region close to suburbia since it is more open to laboring suburbia and the cost of land is more affordable. In this manner, the businesses nearest to suburbia could be sold at a greater cost. As before we found out the densely populated areas for different districts in Bangladesh where labors are available with low cost.

D. Data Calculation

In the data analysis part, we created appendix tables by putting all X-coordinates (d_{ix}), Y-coordinates (d_{iy}), and demands (V_i) got from data analysis tables for raw material collection, distance to market, and labor availability. We have calculated $d_{ix}.V_i$ and $d_{iy}.V_i$ in Excel. Finally, we calculated the X coordinate of center of gravity (C_x) and Y coordinate of center of gravity (C_y) based on three fluctuating demands.

E. Discussion

For calculation, three fluctuating demands have been taken; here, three different calculations were done varying on those demands. The value of the X coordinate of the center of gravity and the Y coordinate of the center of gravity depends on demand. Three locations were found for those three different demand samples, which will be examined under sensitivity analysis in the next step.

TABLE II: Data on Distance to Market

S/N	District Name	Division	X-Y Coordinate	Demand (%)		
1	Dhaka	Dhaka	23.764649, 90.360750	25	23	22
	Gazipur		24.000098, 90.419786	12	14	17
	Narayanganj		23.615809, 90.50161	6	5	3
	Narsingdi		23.921906, 90.719442	3	4	2
	Tangail		24.252824, 89.915055	1	1	3
2	Chattogram	Chattogram	22.336708, 91.832084	18	16	16
	Cumilla		23.456793, 91.187830	2	4	6
3	Jamalpur	Mymensingh	24.924877, 89.948955	1	1	3
	Mymensingh		24.924877, 89.948955	4	3	1
	Netrokona		24.885768, 90.730201	1	1	2
4	Natore	Rajshahi	24.410158, 88.977154	3	3	3
	Pabna		24.022750, 89.249319	1	2	4
	Rajshahi		24.364620, 88.603150	4	4	1
5	Jessore	Khulna	23.177068, 89.212430	1	1	2
	Khulna		22.844631, 89.538658	4	3	3
6	Barishal	Barishal	22.702686, 90.368490	3	3	4
	Patuakhali		22.357717, 90.341227	2	2	1
7	Moulvibazar	Sylhet	24.490496, 91.771534	1	2	2
	Sylhet		24.891553, 91.870255	3	3	2
8	Dinajpur	Rangpur	25.644021, 88.647090	2	2	1
	Rangpur		25.752355, 89.253395	3	3	4

TABLE III: DATA ON LABOR AVAILABILITY

S/N	District	Areas	X, Y Coordinate	Demand (%)		
1	Dhaka	Savar	23.88445, 90.26136	9	8	7
		Keraniganj	23.68892, 90.33582	3	3	4
		Dohar	23.61751, 90.11889	4	4	3
		Nawabganj	23.67017, 90.17563	3	3	6
		Dhamrai	23.918156, 90.21570	6	5	5
2	Gazipur	Gazipur Sadar	23.98057, 90.40649	6	6	8
		Kapasia	24.16423, 90.60495	1	2	3
		Tongi	23.91072, 90.37442	6	6	2
		Sreepur	24.20212, 90.49342	2	3	5
		Kaliganj	23.96828, 90.56160	1	1	2
		Kaliakior	24.06852, 90.22127	2	2	1
3	Narayanganj	Bandor	23.64437, 90.54758	5	4	5
		Rupganj	23.88599, 90.51874	7	6	6
		Araihazar	23.79466, 90.65420	3	3	4
4	Narsingdi	Narsingdi Sadar	23.87660, 90.70590	2	2	3
		Palash	23.98032, 90.64634	4	3	2
		Monohardi	24.17079, 90.71570	2	2	3
5	Mymensingh	Bhaluka	24.40471, 90.38688	6	6	5
		Trishal	24.57554, 90.41223	2	3	3
		Ishwarganj	24.69270, 90.59798	2	3	2
6	Chittagong	Anwara	22.23269, 91.85188	3	3	6
		Mirsharai	22.77657, 91.56979	8	6	5
		Lohagara	21.98898, 92.10469	2	3	3
		Patiya	22.29467, 91.97396	2	3	1
7	Cumilla	Cumilla Sadar	23.46201, 91.12759	2	2	1
		Chandina	23.49034, 91.00713	1	1	2
		Muradnagar	23.64394, 90.91506	1	1	1
8	Khulna	Phultala	22.97696, 89.45806	1	2	1
		Rupsha	22.82420, 89.63461	3	3	1
		Mongla	22.18283, 89.61488	1	1	3

V. COMPUTATIONAL RESULTS

A. Identified Locations

The accumulated data was calculated from the data analysis and identified realistic facility locations. Three locations were found, and their (X, Y) coordinates are (23.66854636, 90.6060552), (23.68497454, 90.5928119), and (23.70186785, 90.5897). Those locations are appropriate for locating a garment factory and finding a centralized position based on the raw material collection, distance to market, and availability of labor. It will make it possible to optimize the overall cost and supply chain. The sourcing and distribution will become more accessible through locating the facility in those locations.

TABLE IV: IDENTIFIED LOCATIONS

No. of Location	Cx, Cy	Geographical Location
1	23.66854636, 90.6060552	Hamchadi, Sonargaon, Narayanganj
2	23.68497454, 90.5928119	Sreepatir Char, Sonargaon, Narayanganj
3	23.70186785, 90.5897	Kanda Para, Sonargaon, Narayanganj

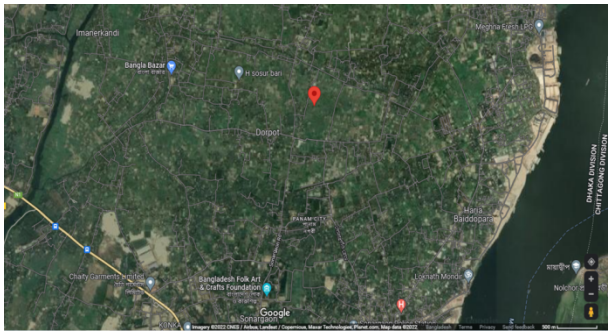

Fig. 1. Google map view of identified first location.

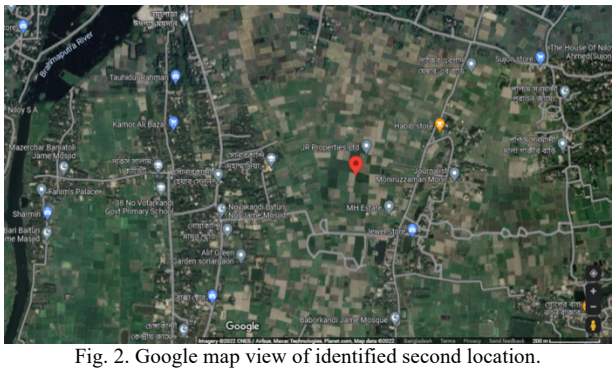

Fig. 2. Google map view of identified second location.

Fig. 3. Google map view of identified third location.

VI. CONCLUSION

The Center of Gravity method has been used to identify the centralized location for a garment industry in Bangladesh based on supplier distance, market distance, and labor availability. This paper's first objective is to determine the optimal location for locating a facility. The optimal location was identified for the garment industry in Hamchadi, Sreepatir Char, and Kanda Para in Sonargaon, Narayanganj. The finding locations have been discussed, and it has been concluded that Sreepatir Char is the most appropriate location

for locating the garment facility based on sourcing raw materials and garment accessories, distribution of goods to market, and workforce availability. Finally, this paper reveals the acceptability of this location as most appropriate because of its ease of accessing the routes by using roads and waterways for the supply chain, excellent availability of natural resources, power supply, and overall its location in an industrial area which will add a great value and advantages for production and distribution. Though the research goals have been achieved, there were also some limitations. This work is developed adequately through a theoretical process. In this process, it can be different in the practical field. Another area for improvement is that we use the Center of Gravity method, but several methods can be used as efficiently in locating the facility.

The data we used for selecting the facility location can vary on factors like factorized's product types, market demand, order quantity, buyer's recommendations, and variables like political environment, natural disasters, economic environment, and overall conditions.

There are some recommendations for future work. Only the location was identified in this paper, but sensitivity analysis can be done to make it more appropriate and acceptable. Secondly, there is a huge chance of using different tools like IncenTrac, Geocision, and LaborCast for better prediction through deriving more accurate forecasts.

Finally, the exact result can be found by implementing actual demands in the Center of Gravity equation. The study can be conducted on other organizations, i.e., the Cement industry, automobile industry, furniture manufacturing industry, electronics showroom, restaurants, etc.

APPENDIX

TABLE V: DATA CALCULATION IN EXCEL BASED ON FIRST SAMPLE DEMANDS

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
23.74785	90.54333	7	166.23495	633.80331
23.65678	90.48449	9	212.91102	814.36041
24.07159	90.22229	13	312.93067	1172.88977
23.73921	90.52706	5	118.69605	452.6353
24.1001	90.16048	3	72.3003	270.48144
23.67805	90.52476	4	94.7122	362.09904
23.84891	90.67052	2	47.69782	181.34104
22.35235	91.89389	10	223.5235	918.9389
23.94757	90.28175	12	287.37084	1083.381
22.40417	91.82476	13	291.25421	1193.72188
24.30684	90.38625	7	170.14788	632.70375
23.78078	90.56486	6	142.68468	543.38916
24.19131	90.42422	9	217.72179	813.81798
23.94757	90.28175	8	191.58056	722.254
24.21154	90.44107	14	338.96156	1266.17498
24.21154	90.44107	7	169.48078	633.08749
24.28462	91.37685	32	777.10784	2924.0592
24.09317	90.37547	31	746.88827	2801.63957
23.83328	90.41883	8	190.66624	723.35064
23.88131	90.38419	14	334.33834	1265.37866
22.32716	91.77339	9	200.94444	825.96051
24.07344	90.35996	20	481.4688	1807.1992
23.78853	90.41624	17	404.40501	1537.07608
22.45164	91.85625	9	202.06476	826.70625
23.87249	90.36348	18	429.70482	1626.54264
23.89176	90.42203	13	310.59288	1175.48639
23.87984	90.40938	8	191.03872	723.27504
23.81863	90.41134	13	309.64219	1175.34742
23.94292	90.36945	9	215.48628	813.32505
23.81358	90.42579	5	119.0679	452.12895
23.74689	90.39326	8	189.97512	723.14608
23.76531	90.36885	10	237.6531	903.6885
23.91512	90.37339	9	215.23608	813.36051
22.30976	91.80185	18	401.57568	1652.4333
22.54756	89.59161	20	450.9512	1791.8322
23.764649	90.36075	25	594.116225	2259.01875
24.000098	90.419786	12	288.001176	1085.037432
23.615809	90.501612	6	141.694854	543.009672
23.921906	90.719442	3	71.765718	272.158326
24.252824	89.915055	1	24.252824	89.915055
22.336708	91.832084	18	402.060744	1652.977512
23.456793	91.18783	2	46.913586	182.37566
24.924877	89.948955	1	24.924877	89.948955
24.924877	89.948955	4	99.699508	359.79582
24.885768	90.730201	1	24.885768	90.730201
24.410158	88.977154	3	73.230474	266.931462
24.02275	89.249319	1	24.02275	89.249319
24.36462	88.60315	4	97.45848	354.4126
23.177068	89.21243	1	23.177068	89.21243
22.844631	89.538658	4	91.378524	358.154632
22.702686	90.36849	3	68.108058	271.10547
22.357717	90.341227	2	44.715434	180.682454
24.490496	91.771534	1	24.490496	91.771534
24.891553	91.870255	3	74.674659	275.610765
25.644021	88.64709	2	51.288042	177.29418
25.752355	89.253395	3	77.257065	267.760185
23.88445	90.26136	9	214.96005	812.35224

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
23.68892	90.33582	3	71.06676	271.00746
23.61751	90.11889	4	94.47004	360.47556
23.67017	90.17563	3	71.01051	270.52689
23.918156	90.2157	6	143.508936	541.2942
23.98057	90.40649	6	143.88342	542.43894
24.16423	90.60495	1	24.16423	90.60495
23.91072	90.37442	6	143.46432	542.24652
24.20212	90.49342	2	48.40424	180.98684
23.96828	90.5616	1	23.96828	90.5616
24.06852	90.22127	2	48.13704	180.44254
23.64437	90.54758	5	118.22185	452.7379
23.88599	90.51874	7	167.20193	633.63118
23.79466	90.6542	3	71.38398	271.9626
23.8766	90.7059	2	47.7532	181.4118
23.98032	90.64634	4	95.92128	362.58536
24.17079	90.7157	2	48.34158	181.4314
24.40471	90.38688	6	146.42826	542.32128
24.57554	90.41223	2	49.15108	180.82446
24.6927	90.59798	2	49.3854	181.19596
22.23269	91.85188	3	66.69807	275.55564
22.77657	91.56979	8	182.21256	732.55832
21.98898	92.10469	2	43.97796	184.20938
22.29467	91.97396	2	44.58934	183.94792
23.46201	91.12759	2	46.92402	182.25518
23.49034	91.00713	1	23.49034	91.00713
23.64394	90.91506	1	23.64394	90.91506
22.97696	89.45806	1	22.97696	89.45806
22.8242	89.63461	3	68.4726	268.90383
22.18283	89.61488	1	22.18283	89.61488
-	-	**600**	**14201.12782**	**54363.63313**
-	-	**$\sum V_i$**	**$\sum$dix.Vi**	**$\sum$diy.Vi**

TABLE VI: DATA CALCULATION IN EXCEL BASED ON SECOND SAMPLE DEMANDS

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
23.74785	90.54333	8	189.9828	724.34664
23.65678	90.48449	11	260.22458	995.32939
24.07159	90.22229	8	192.57272	721.77832
23.73921	90.52706	5	118.69605	452.6353
24.1001	90.16048	3	72.3003	270.48144
23.67805	90.52476	5	118.39025	452.6238
23.84891	90.67052	3	71.54673	272.01156
22.35235	91.89389	8	178.8188	735.15112
23.94757	90.28175	14	335.26598	1263.9445
22.40417	91.82476	11	246.44587	1010.07236
24.30684	90.38625	9	218.76156	813.47625
23.78078	90.56486	8	190.24624	724.51888
24.19131	90.42422	7	169.33917	632.96954
23.94757	90.28175	8	191.58056	722.254
24.21154	90.44107	21	508.44234	1899.26247
24.21154	90.44107	9	217.90386	813.96963
24.28462	91.37685	25	607.1155	2284.42125
24.09317	90.37547	28	674.60876	2530.51316
23.83328	90.41883	9	214.49952	813.76947
23.88131	90.38419	16	382.10096	1446.14704
22.32716	91.77339	11	245.59876	1009.50729
24.07344	90.35996	18	433.32192	1626.47928
23.78853	90.41624	15	356.82795	1356.2436
22.45164	91.85625	9	202.06476	826.70625
23.87249	90.36348	14	334.21486	1265.08872
23.89176	90.42203	17	406.15992	1537.17451
23.87984	90.40938	8	191.03872	723.27504
23.81863	90.41134	12	285.82356	1084.93608
23.94292	90.36945	8	191.54336	722.9556
23.81358	90.42579	6	142.88148	542.55474
23.74689	90.39326	10	237.4689	903.9326
23.76531	90.36885	11	261.41841	994.05735
23.91512	90.37339	11	263.06632	994.10729
22.30976	91.80185	16	356.95616	1468.8296
22.54756	89.59161	18	405.85608	1612.64898
23.764649	90.36075	23	546.586927	2078.29725
24.000098	90.419786	14	336.001372	1265.877004
23.615809	90.501612	5	118.079045	452.50806
23.921906	90.719442	4	95.687624	362.877768
24.252824	89.915055	1	24.252824	89.915055
22.336708	91.832084	16	357.387328	1469.313344
23.456793	91.18783	4	93.827172	364.75132
24.924877	89.948955	1	24.924877	89.948955
24.924877	89.948955	3	74.774631	269.846865
24.885768	90.730201	1	24.885768	90.730201
24.410158	88.977154	3	73.230474	266.931462
24.02275	89.249319	2	48.0455	178.498638
24.36462	88.60315	4	97.45848	354.4126
23.177068	89.21243	1	23.177068	89.21243

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
22.844631	89.538658	3	68.533893	268.615974
22.702686	90.36849	3	68.108058	271.10547
22.357717	90.341227	2	44.715434	180.682454
24.490496	91.771534	2	48.980992	183.543068
24.891553	91.870255	3	74.674659	275.610765
25.644021	88.64709	2	51.288042	177.29418
25.752355	89.253395	3	77.257065	267.760185
23.88445	90.26136	8	191.0756	722.09088
23.68892	90.33582	3	71.06676	271.00746
23.61751	90.11889	4	94.47004	360.47556
23.67017	90.17563	3	71.01051	270.52689
23.918156	90.2157	5	119.59078	451.0785
23.98057	90.40649	6	143.88342	542.43894
24.16423	90.60495	2	48.32846	181.2099
23.91072	90.37442	6	143.46432	542.24652
24.20212	90.49342	3	72.60636	271.48026
23.96828	90.5616	1	23.96828	90.5616
24.06852	90.22127	2	48.13704	180.44254
23.64437	90.54758	4	94.57748	362.19032
23.88599	90.51874	6	143.31594	543.11244
23.79466	90.6542	3	71.38398	271.9626
23.8766	90.7059	2	47.7532	181.4118
23.98032	90.64634	3	71.94096	271.93902
24.17079	90.7157	2	48.34158	181.4314
24.40471	90.38688	6	146.42826	542.32128
24.57554	90.41223	3	73.72662	271.23669
24.6927	90.59798	3	74.0781	271.79394
22.23269	91.85188	3	66.69807	275.55564
22.77657	91.56979	6	136.65942	549.41874
21.98898	92.10469	3	65.96694	276.31407
22.29467	91.97396	3	66.88401	275.92188
23.46201	91.12759	2	46.92402	182.25518
23.49034	91.00713	1	23.49034	91.00713
23.64394	90.91506	1	23.64394	90.91506
22.97696	89.45806	2	45.95392	178.91612
22.8242	89.63461	3	68.4726	268.90383
22.18283	89.61488	1	22.18283	89.61488
-	-	**600**	**14210.98472**	**54355.68717**
-	-	**$\sum V_i$**	**$\sum$dix.Vi**	**$\sum$diy.Vi**

TABLE VII: DATA CALCULATION IN EXCEL BASED ON THIRD SAMPLE DEMANDS

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
23.74785	90.54333	4	94.9914	362.17332
23.65678	90.48449	10	236.5678	904.8449
24.07159	90.22229	11	264.78749	992.44519
23.73921	90.52706	7	166.17447	633.68942
24.1001	90.16048	5	120.5005	450.8024
23.67805	90.52476	6	142.0683	543.14856
23.84891	90.67052	7	166.94237	634.69364
22.35235	91.89389	7	156.46645	643.25723
23.94757	90.28175	8	191.58056	722.254
22.40417	91.82476	3	67.21251	275.47428
24.30684	90.38625	10	243.0684	903.8625
23.78078	90.56486	9	214.02702	815.08374
24.19131	90.42422	13	314.48703	1175.51486
23.94757	90.28175	3	71.84271	270.84525
24.21154	90.44107	9	217.90386	813.96963
24.21154	90.44107	17	411.59618	1537.49819
24.28462	91.37685	26	631.40012	2375.7981
24.09317	90.37547	35	843.26095	3163.14145
23.83328	90.41883	10	238.3328	904.1883
23.88131	90.38419	10	238.8131	903.8419
22.32716	91.77339	10	223.2716	917.7339
24.07344	90.35996	17	409.24848	1536.11932
23.78853	90.41624	15	356.82795	1356.2436
22.45164	91.85625	8	179.61312	734.85
23.87249	90.36348	22	525.19478	1987.99656
23.89176	90.42203	18	430.05168	1627.59654
23.87984	90.40938	13	310.43792	1175.32194
23.81863	90.41134	11	262.00493	994.52474
23.94292	90.36945	7	167.60044	632.58615
23.81358	90.42579	12	285.76296	1085.10948
23.74689	90.39326	3	71.24067	271.17978
23.76531	90.36885	7	166.35717	632.58195
23.91512	90.37339	8	191.32096	722.98712
22.30976	91.80185	22	490.81472	2019.6407
22.54756	89.59161	17	383.30852	1523.05737
23.764649	90.36075	22	522.822278	1987.9365
24.000098	90.419786	17	408.001666	1537.136362
23.615809	90.501612	3	70.847427	271.504836

X-Coordinate, d_{ix}	Y-Coordinate, d_{iy}	Demand, V_i	$d_{ix}.V_i$	$d_{iy}.V_i$
23.921906	90.719442	2	47.843812	181.438884
24.252824	89.915055	3	72.758472	269.745165
22.336708	91.832084	16	357.387328	1469.313344
23.456793	91.18783	6	140.740758	547.12698
24.924877	89.948955	3	74.774631	269.846865
24.924877	89.948955	1	24.924877	89.948955
24.885768	90.730201	2	49.771536	181.460402
24.410158	88.977154	3	73.230474	266.931462
24.02275	89.249319	4	96.091	356.997276
24.36462	88.60315	1	24.36462	88.60315
23.177068	89.21243	2	46.354136	178.42486
22.844631	89.538658	3	68.533893	268.615974
22.702686	90.36849	4	90.810744	361.47396
22.357717	90.341227	1	22.357717	90.341227
24.490496	91.771534	2	48.980992	183.543068
24.891553	91.870255	2	49.783106	183.74051
25.644021	88.64709	1	25.644021	88.64709
25.752355	89.253395	4	103.00942	357.01358
23.88445	90.26136	7	167.19115	631.82952
23.68892	90.33582	4	94.75568	361.34328
23.61751	90.11889	3	70.85253	270.35667
23.67017	90.17563	6	142.02102	541.05378
23.918156	90.2157	5	119.59078	451.0785
23.98057	90.40649	8	191.84456	723.25192
24.16423	90.60495	3	72.49269	271.81485
23.91072	90.37442	2	47.82144	180.74884
24.20212	90.49342	5	121.0106	452.4671
23.96828	90.5616	2	47.93656	181.1232
24.06852	90.22127	1	24.06852	90.22127
23.64437	90.54758	5	118.22185	452.7379
23.88599	90.51874	6	143.31594	543.11244
23.79466	90.6542	4	95.17864	362.6168
23.8766	90.7059	3	71.6298	272.1177
23.98032	90.64634	2	47.96064	181.29268
24.17079	90.7157	3	72.51237	272.1471
24.40471	90.38688	5	122.02355	451.9344
24.57554	90.41223	3	73.72662	271.23669
24.6927	90.59798	2	49.3854	181.19596
22.23269	91.85188	6	133.39614	551.11128
22.77657	91.56979	5	113.88285	457.84895
21.98898	92.10469	3	65.96694	276.31407
22.29467	91.97396	1	22.29467	91.97396
23.46201	91.12759	1	23.46201	91.12759
23.49034	91.00713	2	46.98068	182.01426
23.64394	90.91506	1	23.64394	90.91506
22.97696	89.45806	1	22.97696	89.45806
22.8242	89.63461	1	22.8242	89.63461
22.18283	89.61488	3	66.54849	268.84464
-	-	**605**	**14339.63**	**54806.7695**
-	-	**∑Vi**	**∑dix.Vi**	**∑diy.Vi**

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the author(s).

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