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Facility Location Selection for Plastic Manufacturing Industry in Bangladesh by Using AHP Method

M. S. Rahman[1*], M. I. Ali[2], U. Hossain[2], T. K. Mondal[2]

[1]Department of Industrial and Production Engineering, Faculty of Engineering and Technology, Jessore University of Science and Technology, Jessore-7408, Bangladesh.
[2]Department of Industrial and Production Engineering, Jessore University of Science and Technology, Jessore-7408, Bangladesh.

ABSTRACT

In present's, the location selection problems play an important role for the top-level manager or entrepreneur for opening a new manufacturing company or relocate or expand their operation. As an engineered material, the plastic is used for manufacturing a wide variety of domestic products. For this reason, the plastic manufacturing industries are growing in Bangladesh through the last two eras. This paper might be helpful to select a new location or expansion of the existing one in Bangladesh for the plastic manufacturing company. In this study, we have taken five commercial districts as location and ten criteria for deep consideration from all promising sites of Bangladesh. For this purpose, data has collected through surveying and questionnaires. Then, the Analytic Hierarchy Process (AHP) has used to make a preference measure to select the best location for plastic manufacturing industries. From the comparison value of the composite weight, it can be found that Mongla is the best alternative location for the decision problems.

Keywords: Facility location, AHP, Multi-criteria decision making.

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1. Introduction

Facility location means the selection of a suitable location where companies can perform their logistics, production, and procurement functions; keep their inventories and sustain their economic benefits. A selected location can cause the growth in production and logistics costs as well as difficulties in finding or reaching key resources such as raw material, human resources, other resources used for processes, governments support, and infrastructure. The selection of facility location also plays a very important role in order to the best use of available resources

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[*] Corresponding author
E-mail address: sumon.just16@gmail.com

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facility. The correctness of a specific location for proposed facility operations depends largely on what location factors are selected and calculated, as well as their possible effect on corporate objectives and processes. Facility location attribute is defined as a factor that influences the selection of facility location for a manufacturing company. In the case of facility location selection for the plastic manufacturing company, the factors chosen include: Skill of the worker, proximity to customers, community attitude, communication network, transportation, land, water, availability of raw materials, infrastructural facilities; government policy, climate condition, political conditions, construction, human resources, and other facilities. Location selection not only is important for the costs and profits or resource accessibility but also has a strategic role in the company's competitive positioning in the global market. So, the decision maker(s) must be conscious about the criteria that affect the selection by considering a long period of time such as practically every real-world problem; location selection problems present a difficult structure that includes both concrete and insubstantial factors. In the various multi-criteria decision, the methods such as ANP, TOPSIS, ELECTRE, and PROMETHEE have been used to select the facility location [1]. In order to take AHP's well-known advantages, this method has been used successfully for various purposes. AHP counts both concrete and insubstantial factors in and this feature fits the subjectivity feature of the real-world problems. Also, the hierarchical structure that includes long-time periods, decision makers, and criteria can be stated as another advantage. However, this kind of hierarchical modeling helps the decision-maker(s) to the solution process and enables of judgments according to their need [2]. In this study, the Analytic Hierarchy Process (AHP) has used to select the best location for a plastic company in Bangladesh. The AHP is one of the most effective tools to deal with complex decision maker to set priorities and make the best decision. The main objective of this study is to provide depositors and administrators with a more effective and competent model for location selection assessments.

2. Literature Review

Several researchers have already applied different methods such as Analytic Hierarchy Process (AHP), TOPSIS, Fuzzy Logic, and Fuzzy TOPSIS, Fuzzy AHP, Analytic Network Process (ANP) [3] to solve the facility location selection problems. These problems have established much attention over the centuries and several methods; both qualitative and quantitative have been recommended. Multiple Criteria Decision-Making (MCDM) have grown-up as a part of operations research, concerned with planning computational and mathematical tools for supporting the subjective evaluation of performance criteria by decision-makers [4]. Researchers mentioned ten criteria and five alternatives project and used the AHP method to identify and evaluate the best project selection [5]. Researchers used a nonlinear programming system to solve the location selection problem with minimum delivery cost [6]. Stochastic functions have integrated with AHP to account for demand and/or supply [7]. Other researchers have recommended various criteria for the facility location problem such as transportation facilities, availability of employ, living cost, availability, nearness to raw resources; closeness to markets, scope of markets, attainment of advantageous economical position, expected growth of markets; income and population developments, cost and availability of industrial plots, closeness to other industries, cost and availability of benefits; government approaches, tax configuration, community related factors, ecological considerations, assessment of risk, and return on properties [8].

There are so many factors which are needed to evaluate because there is no one set of solution for a company with the combination of various types of criteria and alternatives. Some common factors/criteria for location selection are cost of the land, rents, energy costs, transportation, proximity to raw materials and other production resources; infrastructure, costs of resources, workforce proximity and cost, proximity to white-collar personnel and/or technicians; proximity to the market or customers, government policies, initiatives and incentives, tax rates; close industries, water, electricity, surrounding facilities, environmental limits or opportunities [9]. To select the facility location, the AHP method was used with fuzzy [10]. For finding out the best site for the hospital, the AHP method was also used and showed that the cost of land, population density, and proximity to public transport evolved as the three most significant sub factors [11]. Considering both qualitative and quantitative factors, a model for the location-allocation problems was proposed [12]. Weighting model was used to determine the relative prominence with improbability in 29 criteria [13]. A multi-disciplinary study accompanied to select a site for a nuclear power facility [14]. Fuzzy TOPSIS method was used to make location choices [15]. The AHP enables the judgment to structure a composite problem in the form of a simple hierarchy and to estimate a large number of quantitative and qualitative factors in a methodical way with different multiple criteria [16]. The AHP method was also used to prioritize the needs of the customer for their study of ‘Miniature Circuit Breaker’ [17]. Then they used the fuzzy logic system to eliminate imprecision between what and how room precisely. They also used ANN technique to make the judgment between case study firm and its modest firm. The results were similar computational models comprised of densely interrelated adaptive dispensation units.3.

3. Study Methodology

Mainly our study purpose has two-fold aims. The first aim determines the relative importance or weight of various criteria and its selected alternatives in the location selection problems. The second aim of this study is to apply the AHP method for estimating the facility location and to determine the best location for facility based on the various criteria and alternatives. Five districts of Bangladesh such as Rangpur, kustia, Narayongong, Chittagong, and Mongla were selected in this study. The data of facility location was taken from public and stakeholders through questionnaire from respondents, and the special people from the selected site were accessed over a period of time. The aim of this study has explored the application of the Analytic Hierarchy Process (AHP) to select a new location among five alternatives for a plastic product manufacturing company in Bangladesh.

3.1 AHP Method

The AHP developed by Saaty addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem [18]. The AHP method is based on three principles: first, the structure of the model; second, the comparative judgment of the alternatives and the criteria; third, synthesis of the priorities.

Step 1. A complex decision problem is structured as a hierarchy. With the AHP, the objectives, criteria, and alternatives are organized in a hierarchical structure like to a family tree in where, an overall goal of the problem at the top, a multiple criteria that define alternatives in the middle, and a decision alternatives at the bottom is shown in the Figure 1, where A= Alternatives, C= Criteria.

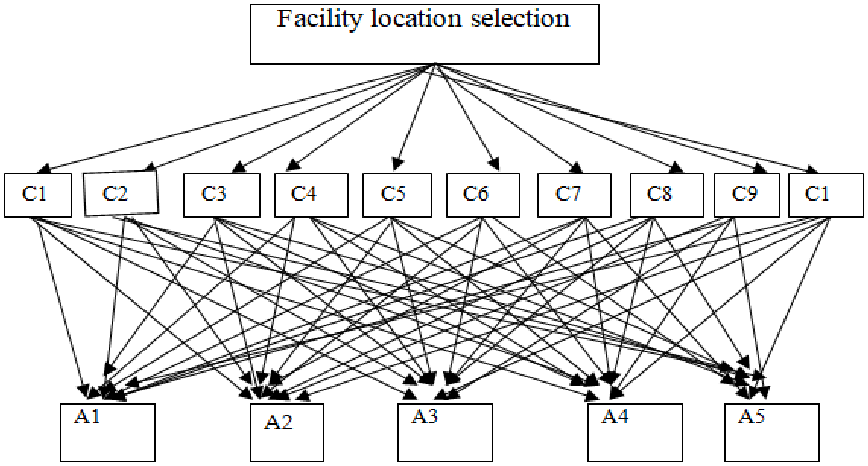

Figure 1. Hierarchy for the Facility Location Selection.

Step 2. The pairwise comparison table is mathematically expressed in the form of square matrix n x n, where n is the number of alternatives or criteria. The elements of the matrix are pairwise comparisons based on the AHP scale and the relative importance among alternatives or criteria which are as follows.

Comparison Matrix Geometric mean Normalized weight

$$\begin{array}{cc|cccccccc} & & & & & & j & & & \\ & & 1 & 2 & \cdots & \cdots & k & \cdots & \cdots & n \\ \hline & 1 & 1 & a_{12} & \cdots & \cdots & a_{1k} & \cdots & \cdots & a_{1n} \\ & 2 & a_{21} & 1 & \cdots & \cdots & a_{2k} & \cdots & \cdots & a_{2n} \\ & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ i & k & a_{k1} & a_{k2} & \cdots & \cdots & 1 & \cdots & \cdots & a_{kn} \\ & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ & n & a_{n1} & a_{n2} & \cdots & \cdots & a_{nk} & \cdots & \cdots & 1 \\ \hline \text{Sum} = & & y_1 & y_2 & \cdots & \cdots & y_k & \cdots & \cdots & y_n \end{array} \qquad \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ \vdots \\ b_k \\ \vdots \\ \vdots \\ b_n \end{bmatrix} \qquad \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_k \\ \vdots \\ \vdots \\ x_n \end{bmatrix}$$

Here, i and j are alternatives or criteria to be compared and a_{ij} is a value which represents the comparison between alternatives/criteria i and j. In the matrix,

$$y_k = \sum_{i=1}^{n} a_{ij} \tag{1}$$

where, k = 1, 2…n and j = 1,2 ….n.

Each of these judgments is then assigned as an integer on a scale. In these studies, the original definition of scale given by Saaty [18] was adopted. The scale and their relative importance are explained in Table 1.

Table 1. The Saaty Rating Scale.

Scale	The Relative Importance of the Element	Explanation
1	Equally important	i and j are equally important
3	Moderately important	i is moderately more important than j
5	Strongly important	i is strongly more important than j
7	Very strongly important	i is very strongly more important than j
9	Extremely important	i is extremely more important than j
2,4,6,8	Intermediate values	used when a compromise is needed

As shown in Table 1, the ranking in comparisons must be as follows; 1 for equal importance, 3 for importance, 5 for strong importance, 7 for very important, and 9 for extremely importance.

Step 3. Geometric mean is calculated as follows:

$$b_k = [(a_{k1})\cdot(a_{k2})\cdot\cdots\cdot(a_{kn})]^{1/n} \tag{2}$$

Step 4. Normalized weights are calculated as follows:

$$x_k = \frac{b_k}{\sum_{k=1}^{n} b_k} \tag{3}$$

Step 5. Consistency Index (CI) is calculated as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{4}$$

where $\lambda_{\max} = y_1x_1 + y_2x_2 + \cdots\cdots + y_nx_n = \sum_{k=1}^{n} y_kx_k$.

Step 6. Determine Random Index (RI) as following Table 2.

Table 2. Random Index (RI).

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 7. And then Consistency Ratio (CR) is found by using the following equation:

$$CR = \frac{CI}{RI} \tag{5}$$

If C.R. ≤ 10%, then the degree of consistency is acceptable; otherwise, pairwise comparisons should be revised.

4. Data Collection and Analysis

For this research work, five alternatives/towns were identified as Rangpur (A1), Kustisa (A2) Narayongong (A3), Chittagong (A4), and Mongla (A5). During the evaluation, ten (10) main criteria/factors as C1: Human resource, means cost, and availability of labor; C2: Transportation facilities; C3: Land which means cost of land; C4: Water, here this term means supply of water and transportation facility through water; C5: Construction cost; C6: Skill of the worker, means the availability of skill workers; C7: Customer proximity, this term defines the availability of customers; C8: Community attitude, means political condition; C9: Communication, means IT facility; C10: Other facilities included the labor health, government policy, climate condition, child education facilities, etc. have been identified. We constructed a questionnaire to tap perception of public and stakeholders near factors related to facility location selection problem. The relative comparison between criteria and the relative comparison between alternatives needs to judge with respect to criterion in linguistic scales. An integer scale was used to assign these judgments. In this scale and their relative importance for the AHP, the method is explained in Table 3. Finally, the best location among the five alternatives was identified. The details of the returned questionnaires were summarized in the pairwise comparison matrices from Table 3.

Table 3. Pairwise Comparison Matrix for Criteria with respect to Objectives.

Criteria	1C	C2	3C	4C	5C	6C	7C	8C	9C	C10
1C	1	0.5	0.25	2	0.33	0.14	4	5	0.33	7
2C	2	1	0.12	2	0.33	0.2	7	4	0.5	8
3C	4	8	1	5	4	2	9	9	5	9
4C	0.5	0.5	0.2	1	0.14	0.25	3	5	0.33	6
5C	3	3	0.25	7	1	2	5	6	4	7
6C	7	5	0.5	4	0.5	1	6	5	2	5
7C	0.25	0.14	0.11	0.33	0.2	0.17	1	2	2.	2
8C	0.2	0.25	0.11	0.2	0.17	0.2	0.5	1	0.12	2
9C	3	2	0.2	3	0.25	0.5	5	8	1	4
10C	0.14	0.12	0.11	0.17	0.14	0.2	0.5	0.5	0.25	1
sum	21.09	20.51	2.85	24.70	7.06	6.66	41	45.5	13.73	51

The geometric mean and the normalized weight for all criteria with respect to objectives are represented in Table 4.

Table 4. The Matrix of Geometric Mean and Normalized Weight for all Criteria.

Criteria	Geometric mean	Normalized weigh
1C	0.9391	0.0651
2C	1.1350	0.0786
3C	4.6439	0.3219
4C	0.0744	0.0051
5C	2.6859	0.1862
6C	2.5241	0.1750
7C	0.3579	0.0248
8C	0.2918	0.0202
9C	1.5336	0.1063
10C	0.2366	0.0164
sum	14.4223	
n = 10		CI = 0.1393
λ_{max} = 11.254		CR = 9.35% < 10%
Consistency Ratio (CR) is less than 10%, so is accepted.		

The comparison among alternatives and criteria's are shown in Table 5 to Table 14.

Table 5. Comparison Matrix of Alternatives with respect to C1.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.25	2	3	0.14	0.7318	0.1083
2A	4	1	4	5	0.5	2.019	0.2988
3A	0.5	0.25	1	3	0.33	0.6584	0.0974
4A	0.33	0.2	0.33	1	0.17	0.3263	0.0482
5A	7	2	3	6	1	3.021	0.4471
sum	12.83	3.7	10.33	18	2.14	6.7565	
n =5			CI= 0.0813				
⋋_max =5.3255			CR= 7.25% < 10%				
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 6. Comparison Matrix of Alternatives with respect to C2.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.33	0.11	0.11	0.12	0.2168	0.0271
2A	3	1	0.17	0.14	0.33	0.4725	0.0592
3A	9	6	1	2	6	3.650	0.4578
4A	9	7	0.5	1	4	2.6307	0.3298
5A	8	3	0.17	0.25	1	1.003	0.1258
sum	30	17.33	1.95	1.28	1.628	7.9723	
n =5		CI = 0.08625					
⋋_max =5.345		CR = 7.7% < 10%					
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 7. Comparison Matrix of Alternatives with respect to C3.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	2	7	4	0.25	1.695	0.2214
2A	0.5	1	6	3	0.14	1.047	0.1367
3A	0.14	0.17	1	1	0.11	0.304	0.0397
4A	0.25	0.33	1	1	0.2	0.440	0.0574
5A	4	7	9	5	1	4.169	0.5446
sum	5.89	10.5	24	14	1.7	7.655	
n =5		CI = 0.0895					
⋋_max =5.358		CR = 7.99 % < 10%					
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 8. Comparison Matrix of Alternatives with respect to C4.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.33	2	9	0.33	1.1440	0.1902
2A	3	1	2	7	0.5	1.184	0.1967
3A	0.5	0.5	1	7	0.5	0.9736	0.1618
4A	0.11	0.14	0.14	1	0.11	0.1883	0.0313
5A	3	2	2	9	1	2.5508	0.4240
sum	7.61	3.97	7.14	33	2.44	6.0147	
n =5		CI = 0.0765					
⋋_max =5.306		CR = 6.83 % < 10%					
		Consistency Ratio (CR) is less than 10%, so is accepted.					

Table 9. Comparison Matrix of Alternatives with respect to C5.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.25	1	3	0.25	0.7154	0.1072
2A	4	1	2	5	0.25	1.584	0.1736
3A	1	0.5	1	8	0.5	1.1486	0.1722
4A	0.33	0.25	0.12	1	0.14	0.2681	0.0402
5A	4	4	2	7	1	2.9515	0.4426
sum	10.33	6	6.12	24	2.14	6.6676	
n =5		CI = 0.103					
⋋_max =5.412		CR = 9.19 % < 10%					
		Consistency Ratio (CR) is less than 10%, so is accepted.					

Table10. Comparison Matrix of Alternatives with respect to C6.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.12	0.11	0.11	0.12	0.1771	0.0248
2A	8	1	0.33	0.5	0.5	0.920	0.1291
3A	9	3	1	3	0.5	2.096	0.2942
4A	9	2	0.33	1	0.33	1.440	0.2021
5A	8	2	2	3	1	2.491	0.3496
sum	35	8.12	3.77	7.62	2.45	7.1241	
n =5		CI = 0.0865					
⋋_max = 5.3465		CR = 7.7 % < 10%					
		Consistency Ratio (CR) is less than 10%, so is accepted.					

Table 11. Comparison Matrix of Alternatives with Respect to C7.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.33	0.17	0.25	0.11	0.2739	0.0336
2A	3	1	0.11	0.5	0.17	0.4893	0.0601
3A	6	9	1	5	0.33	2.4545	0.3019
4A	4	2	0.2	1	0.12	0.7188	0.0884
5A	9	6	3	8	1	4.1929	0.5157
sum	23	18.33	4.48	14.75	1.73	8.1294	
n =5			CI = 0.103				
⋋_max = 5.412			CR = 9.19 % < 10%				
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 12. Comparison Matrix of Alternatives with respect to C8.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	5.	6	4	33.	1.3168	0.2042
2A	2	1	6	33.	25.	0.9979	0.1547
3A	17.	17.	1	2	17.	0.3967	0.0615
4A	25.	33.	5.	1	17.	0.3708	0.0575
5A	3	4	6	6	1	3.3658	0.5219
sum	6.42	6	19.33	13.33	1.92	6.448	
n =5			CI = 0.10375				
⋋_max =5.415			CR = 9.26% < 10%				
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 13. Comparison Matrix of Alternatives with respect to C9.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	5.	25.	14.	11.	0.2863	0.0369
2A	2	1	17.	25.	11.	0.3927	0.0507
3A	4	6	1	2	2.	1.5720	0.2031
4A	7	4	5.	1	33.	1.3580	0.1754
5A	9	9	5	3	1	4.1391	0.5347
sum	23	20.5	6.92	6.39	1.75	7.740	
n =5			CI = 0.079				
⋋_max =5.316			CR = 7.05% < 10%				
Consistency Ratio (CR) is less than 10%, so is accepted.							

Table 14. Comparison Matrix of Alternatives with respect to C10.

Alternatives	1A	2A	3A	4A	5A	Geometric mean	Normalized weight
1A	1	0.25	3	5	0.2	0.9440	0.1298
2A	4	1	4	7	0.5	2.2368	0.3076
3A	0.33	0.25	1	4	0.25	0.6071	0.0834
4A	0.2	0.14	0.25	1	0.11	0.2383	0.03277
5A	5	2	4	9	1	3.2453	0.4463
sum	10.53	3.64	12.25	26	2.06	7.2715	
n =5			CI = 0.07975				
λ_max =5.319			CR = 7.12% < 10%				

Consistency Ratio (CR) is less than 10%, so is accepted.

On the basis of the result of above matrices, an overall evaluation is performed using the calculated weights of the alternative five locations and ten measuring criteria as follows:

Table 15. Evaluation of Location.

Alternative location	Criteria and their weights										Composite weights ($\sum x_k$ of criteria × x_k of alternative)	Overall ranking
	human resource	transportation	land	water	constriction	skill of labor	customer	community	communication	all others		
	0.0651	0.0786	0.3219	0.0051	0.1862	0.1750	0.0248	0.0202	0.1063	0.0164		
Rangpur	0.1083	0.0271	0.2214	0.1902	0.1072	0.0248	0.0336	0.2042	0.0369	0.1298	0.1867	3
Kustia	0.2988	0.0592	0.1367	0.1967	0.1736	0.1291	0.0601	0.1547	0.0507	0.3076	0.1734	4
Narayongong	0.0974	0.4578	0.0397	0.1618	0.1722	0.2942	0.3019	0.0615	0.2031	0.0834	0.2011	2
Chittagong	0.0482	0.3298	0.0574	0.0313	0.0402	0.2021	0.0884	0.0575	0.1754	0.0327	0.1531	5
Mongla	0.4471	0.1258	0.5446	0.4240	0.4426	0.3496	0.5157	0.5219	0.5347	0.4463	0.2857	1

5. Result and Discussion

According to the AHP method, that location is best which have the highest composite weight score and rank 1. In accordance with the results generated by Mongla, it has the highest composite weight value and its rank is 1 comparatively with other alternatives. Here, the relative composite weights for the selected locations are shown in the Figure 2.

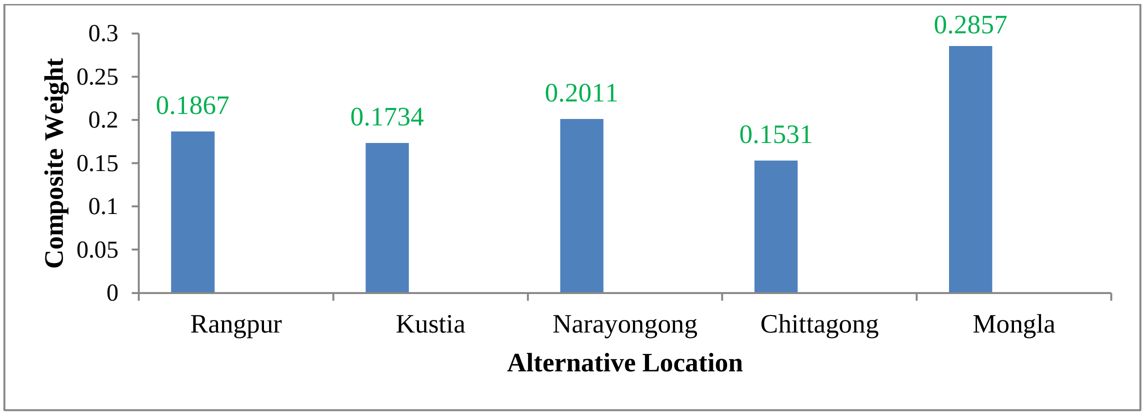

Figure 2. Composite Weight According to AHP.

From results obtained, according to the AHP method, the highest composite weight is 0.857 for the site Mongla in comparison with the rest of the locations. So, the Mongla (A5) is the best alternative to be selected for the facility location, and Narayongong is considered as a second best location. The lowest composite weight is 0.1531 for Chittagong, so it is the less important site for plastic industry in Bangladesh. This case study has developed considering five alternative location and ten criteria only in accordance with the plastic manufacturer company.

6. Conclusion

The sharing facility location choice is a more multifaceted problem due to the uncertainty and instability of sharing environments. The location selection process comprises qualitative as well as quantitative factors. The AHP has been engaged successfully to provide steady estimation (weighting and ranking) of location options. This paper showed the application of AHP approach to select the best location for the plastic manufacturing company in Bangladesh to set a new factory or to extend existing one among a number of alternatives considering various criteria. The application presented in this study had clarified how multiple decision factors can be estimated with the AHP method to permit the more flexible and inclusive use of existing information about alternative locations in a facility location problem. The proposed decision model offered an efficient approach to solve the facility location problem.

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