

Georgise, Fasika Bete; Jarso, Boru Bedeya; Mindaye, Alemayehu Tesfaye

Article

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*Corresponding author: Fasika Bete Georgise, Department of Industrial Engineering, Faculty of Manufacturing, Hawassa University, Institute of Technology(IoT), Ethiopia
E-mail: fasialem@gmail.com

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Albert W. K. Tan, Education,
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OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

Model development for coffee processing plant location selection by using AHP method: Case of Guji Zone, Ethiopia

Fasika Bete Georgise^{1*}, Boru Bedeya Jarso² and Alemayehu Tesfaye Mindaye¹

Abstract: It is very difficult to find a suitable location for a coffee processing plant from many alternatives. This research developed a model by Analytic hierarchy pairwise that gives full information for a coffee processing plant to select a suitable location from alternatives as its objective. The main location factors were analyzed by the Analytic Hierarchy Process (AHP) pairwise method to rank candidate alternative locations. The questionnaire analysis mainly used Statistical Packaging Social Software (SPSS) and AHP method for weighting and ranking alternative locations according to the evaluation of location criteria priority values. The discussion addressed as the misallocation has an impact on selecting a suitable location before, and it is good to follow this developed model. It is inevitable for the society to update with the growth model and generally pre-coffee processing plant owners are facing problems in selecting a suitable location from alternatives in a Guji Zone. The proposed model has three main sequential stages that focus on reducing the time to decide on a new suitable location. Thus, it reduces the effort for searching



Fasika Bete Georgise

ABOUT THE AUTHORS

Fasika Bete Georgise was awarded his doctorate in Production Engineering at the University of Bremen, Bremen, Germany, in 2015. Georgise received his master's degree in Mechanical Engineering specializing in Industrial Engineering at Addis Ababa University, Addis Ababa, Ethiopia. He is serving as an Assistant Professor in Industrial Engineering. Additionally, he has been appointed as Deputy Director for Academic Affairs since 2018 at Hawassa Institute of Technology, Hawassa, Ethiopia.

Boru Bedeya Jarso was awarded his Master of Science Degree in Industrial Engineering and Logistics Management from Hawassa University. He is currently working as a lecturer at Bole Hora University. Recently, he has been appointed as Dean of the College of Engineering.

Alemayehu Tesfaye Mindaye is currently working as a lecturer at Hawassa University, Institute of Technology, and Department of Industrial Engineering. He has done his MSc degree in Industrial Engineering from Addis Ababa University with a key area of interest in manufacturing waste identification and measurement for productivity improvements.

PUBLIC INTEREST STATEMENT

Quality is the most important parameter in the World coffee trade. The quality of Ethiopian coffee is determined by two main factors, namely, the geographic origin and the post-harvest processing techniques. In order to enhance the quality and market value of Ethiopian coffee, improved site selection for the processing plant is a prerequisite. Site selection is a crucial strategic decision that should be made with due attention since it involves consideration of multi-criteria that have a great impact on future plant performance. This paper tried to assess the traditional way of site selection made in the case region. Finally, we have proposed an appropriate model to suit for optimal site selection that solves associated problems.

and deciding the best location for pre-coffee processors. The result is summarized in the framework model that can lead users to understand the current status and the trend concerning the models and factors used in the primary coffee processing plant location selection decision. This research has proposed a suitable solution for the location problems. Finally, the recommendation was given to coffee processing actors and responsible government offices.

Subjects: Industrial Design; Plant Engineering; Manufacturing & Processing

Keywords: coffee; coffee processing plant; location; location factors; AHP method; model

1. Introduction

The study of location selection for coffee processing plant has a long and extensive history. The challenges were driven by the changes in trends and criteria to decide suitable locations from the alternatives. The world economy rule, technology, and environment have affected the currently existing models used in the production location decision. This modeling process used the previous-developed models as benchmark or references to propose a new model for coffee processing plants. There are strong policy and legislative rationales behind establishing an Industrial site (Ermias, 2019).

The quality coffee supplied to the international market from the Guji zone is very low, which is less than one-third (1/3) of this zone total coffee production (Guji Zone Coffee and Tea Authority Office Report, 2014–2019). The unsuitability of coffee processing plant location vastly exists in this zone as many evidences indicated. Unsuitable location decision leads most of the primary coffee processing owners challenged to produce the required amount of coffee production. This problem is not limited to Guji Zone only, as a recent report of International Coffee Organization (ICO, 2017) Ethiopia is the birthplace of coffee and it was discovered earlier. But still, as this report indicated Ethiopian coffee export is lower when compared with coffee trade as world-leading countries: Brazil, Vietnam, Colombia, and Indonesia. This is due to highly local consumption, misallocation of pre-processing plants, and the quality fail of huge coffee production tons/year. The selection of a coffee shop or plant location is crucial for its success or failure. It should be decided in a strategically and comprehensive way (Lin & Zu, 2013).

Hence, the motivation of this research was to fill the gap that was not included by many researchers as an unsuitable location selection for coffee primary processing plant challenges to produce the required amount of coffee. The problem of suitable location selection vastly exists and required solution in the Guji Zone. This research focuses on the identified problem in the case of Guji Zone, Oromia Regional State, Ethiopia. Before any technical process within the coffee processing plant, the suitable location selection by considering criteria, weighting, and ranking the alternative locations, and selecting from alternative locations is possible. Then, by depending on the rank of location factors an alternative location was ranked. The alternative location that fit the first rank can be selected as a suitable location for new location selection (Gebermedin, 2015).

1.1. Challenges of coffee processing plant location

Most of the coffee processing plant owners nowadays having a problem of selecting a suitable location, especially during the best location selecting for coffee pre-processing processing plants like wet or washing and drying processes. The processing plant owners in this research area normally simply bought the land for their plant without considering many location factors and there is no scientific approaches they follow to decide the suitable location from alternatives. This causes challenges during coffee processing and some of the coffee processing in Guji Zone enforced to stop their operation (Guji Zone, 2013). Therefore, this research has carried out to analyze and propose a suitable selection model for the coffee processing plant owners to decide the suitable location, save time, and less extravagancy during searching the new or

expansion branch for their business by following the proposed model. Nowadays, most of the world coffee business is widely on expansion and a number of models were developed. But, in Ethiopia, Oromia, Guji Zone no such types model was utilized to decide the suitable location. However, coffee processing plant owners are in a challenge to decide the suitable location for their plant. The side effect of this problem is serious and needs a better solution to handle it. The objective of this paper is to assess and propose a model for the coffee processing plant location selection process by using the AHP method for ranking the candidate locations.

1.2. Scope and significance of the research

This research covers the assessment of the current trend of location selection for coffee processing plants, location factors, and their challenges during collecting and transporting their coffee to the processing center. Among coffee potential producer Wereda: Odo Shakisso Wereda was covered and most fieldwork was done in this Wereda. The farmers and ownership of the coffee processing plant was conducted and questionnaire was distributed for them. The research data were collected from Eastern Guji Zone Administration Offices; Coffee and Tea Authority Office, Investment Office, and Rural Land Management Office (Guji Zone, 2013). The current location selection management practice was assessed. It had proceeded up to develop model for coffee processing plant location selection with the help of analyzed questionnaires by SPSS and AHP method to select a suitable location from alternatives. As limitations of research, the coffee quality test experimentally, Geographical Information System (GIS) for location selection, the location factor impacts on coffee quality experimentally were not included.

This research output would be useful as guidelines for the investors, cooperatives, associations, private-limited company, and Coffee and Tea Authority Office. Therefore, it is hoped that the result of this research has practical uses mainly to location selection for the primary coffee processing plant and other similar areas. It can serve as a base for any further studies to be conducted in other areas in this line of study.

2. Literature review

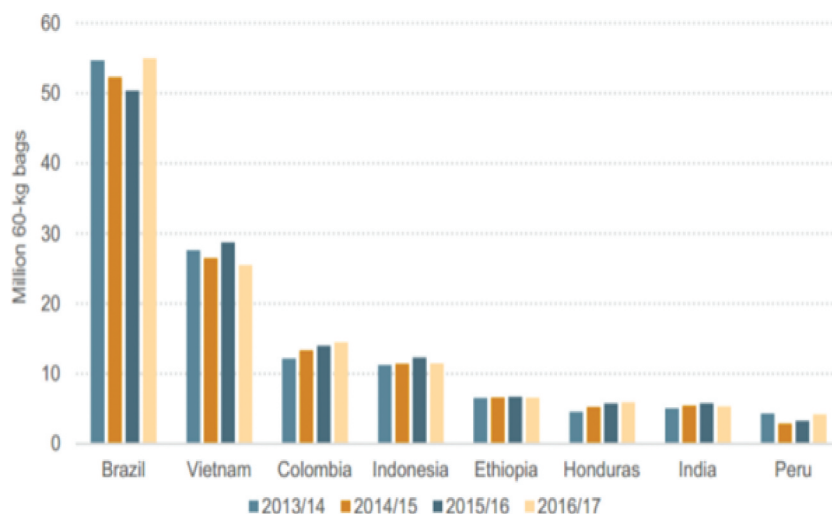
2.1. Background of processing plant

Nowadays, coffee processing plants were widely on expanding all over the world. Mostly, it is the oldest industry in African countries than others. As many researchers presented, Ethiopia is the origin center for coffee Arabica and other types are also widely produced (Weinberg & Bonnie, 2001). But still, the misallocation challenges many coffee investors to operate their business as their wish. Even if Ethiopia is the origin center for coffee Arabica and others vastly produced in different areas, it can not prepare huge numbers of first quality and specialty coffee per tons for international coffee trade when compared with other world countries like Brazil, Vietnam, Colombia, and Indonesia as reported (ICO, 2014). Figure 1 shows major coffee-producing countries.

Production industry site selection is one of the key vital decisions in the process of starting, expanding or changing the location of industrial systems of all kinds. Structural complexity of the industrial system and the relationship with the environment, changes in market demand, conditions providing inputs, the characteristics of the production programs, economic conditions, and working conditions, environmental and other impacts determine the new location. While changes in production programs, the characteristics of the work process, the frequency of technological changes and the effect of disorder requires adjustment of the existing site industrial systems (Debelo, 2017).

Construction of a new industrial or processing plant is a major long-term investment. One of the main goals of industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. In the process of industrial site selection, seeks to optimize the number of goals in determining the suitability of a specific location for a defined industrial system. The selection of an industrial site involves a complex array of critical factors involving economic, social, technical, environmental issues (Johan, 2011).

Figure 1. Coffee production report for eight main countries: 2013–2017 (ICO, 2014).



2.2. Coffee harvesting and transporting to processing plant

Coffee processing is the method of converting the raw fruit of the coffee cherry into the green (dried) coffee beans. Coffee is either processed by wet or dry methods. When the coffee is harvested before the beans are ripe or at an immature stage, the end product will show the color defect and will be because of uneven roasts. The coffee picking and collection are the primary process that operates by coffee farmers and daily collector workers. An available location is best to reduce labor effort and quality effect (Walker, 2011).

2.3. Previous-developed models for location selection

The process of site selection includes managing the risks involved in selecting a new industrial or production location is one of the most critical factors in determining the ultimate success of a business. To keep risks at a minimum, investors should first be familiar with the stages of the site or location selection process and what are the key risks that need to be considered and managed during each of these stages. One of the most important and far-reaching decisions faced by operation managers is deciding where to locate new industrial facilities. There are many location models and factors that have developed so far. Some models are powerful tools used in the past but not today. The factors considered in the models have changed as the global business conditions changed over time. It is imperative to examine several different sources to understand the current status concerning models and factors where are overlapped or where are falling short. This review aims to critically reviewing the current status concerning models and factors used in location selection decisions.

From our literature, the researchers have summarized seven different models. The first model is (Urška & Branko, 2011). Mostly this model is used in Germany to decide the potential industry site selection. The second location selection is a Pongpanich model(1999). This model is used for project site selection. It has five horizontal steps and four down steps. The production location decision process for the case study related to four phases is operated by this model (Pongpanich, 1999). The third location selection model is Veerayuth and Lu (2006). This model is used in Sweden to decided a suitable production site location. As a result, the AHP location model with a view to dynamic, which is involved to rank importance of objectives, preference, and factors with a pair of candidates. This model is similar to Yang and Lee (1997) model for production location selection. The fourth type of location selection model is the Weber and Moses Model (2006). Plant location selection term in literature is first defined by German economist Alfred Weber. Weber defined plant location factors as “the advantage obtained as a result of an occurrence to any place of an economic activity at one point or at some specific points” Weber (1929). This model is used in Indonesia and California. Checherenkova (2008) is the fifth type of location selection model. This model was developed to select a suitable location for

production firms. All the steps was discussed one by one. According to this model the steps in production location decisions are introduced by dividing into different parts. The sixth type of location selection model is Thai et al. (2005). According to the model developed by Thai et al. (2005) in Lahti University Applied Science. The researchers in Vietnam, location selection for any business to be fruitful it is assumed as the basic and primary for many criteria. This method is also called the preference matrix or the factor-rating method. The method is utilized in multiple parts in different steps, so it is described here to understand how it is to be interpreted. The last location selection model is Eldin and Sui model (2003). This model is used in Arabian countries, most of the time for industry site selection. The integration capabilities of these tools are crucial to the feasibility of reaching a final solution. Therefore, developing efficient integration strategies became a high priority for many researchers (Eldrandaly et al., 2005).

Among the above location selection models, all models have their contribution to select a suitable location from these alternatives. But, from these models that interrelated with a coffee processing plant to developing the coffee processing plant location selection model were selected. To specifically select from seven discussed models and to develop a suitable model, the following main criteria were considered. These were: the goal of models, stages or steps of the models, and the location criteria, or location factor. Some parts of these models were included in this paper to develop a model for coffee processing plant location selection. Table 1 shows the key information about selected models for the adaptation: how many steps they were included for each of them, the main goal of the developed model. From seven discussed models this research mainly uses the two of them those more related to the coffee processing plant location selection.

2.3.1. Location selection model by Weber and Moses

This model is used in Indonesia and California. There are many factors affecting the plant location selection of companies. The plant location factors are not static and they are not the same for each work branch (Weber and Moses, 2006).

- (i) The location factors and alternative locations are listed. In these clues, attribute means the location factors or key criteria those required to decide the optimal location.
- (ii) At this stage evaluation and ranking of locations must be accomplished. Analytic Hierarchy Process method has been utilized to do this evaluation and ranking of locations have. Consistency test and selecting an optimal location from listed alternatives were done.

Table 1.: Site selection model summarized information

No.	Model	Adapted country	Steps (Stage) to complete decision	Goal of developed model (Decision)
1	Brando and Milo, (2010)	German	Five steps	Potential industry location selection
2	Pongpanich, (2000)	Sweden, UK	Five Steps	Relocation production plant
3	Veerayuth and Lu (2006)	Sweden	Six steps	Suitable production location selection
4	Weber and Moses Model, (2006)	Indonesia, California	Three main stages	Optimum processing plant location selection
5	Checherenkova (2008)	Malardalem (Sweden)	Five steps	Production location selection
6	Thai et al., (2005)	Vietnam	Three steps	Specific site selection
7	Eldin and Sui (2003)	Arabian	Two Main phases	Industry site selection

(iii) After all the required location factors weighed and calculated, the ranking of locations takes place. Then, after the negotiation with the government and multi-lateral negotiation has been conducted. Multi-lateral negotiation is the negotiation which takes place with different parts at more than two stages of negotiation between two decision-making parts. Depending on negotiated attribute values optimal location can be selected. Figure 2 demonstrates the process of location selection.

2.3.2. Location selection model by Eldin and Sui

Decision-making processes such as industrial site selection usually involves not only technical requirements but also economic, social, environmental, and political dimensions. This model is used in Arabian countries mostly for industrial site selection. Therefore, developing efficient integration strategies became a high priority for many researchers (Eldin and Sui, 2003). Figure 3 shows the characteristic of the Elden and Sui model.

The selection of plant location is a multi-person and multi-criteria decision problem. AHP is an effective tool for dealing with the complex decision-making process and may aid the decision-maker to set priorities and make the best decision. From two methods of Multi-criteria Decision Making (MCDM): Multi-Objectives Decision Making (MODM) and Multi-Attributes Decision Making (MADM) is the main. From MADM the AHP method is best to weigh and rank alternative locations (Suman & Saha, 2015).

3. Research methodology

The framework of this research demonstrates the purpose of the research up to the proposed model to solve the existing problem in the area. Figure 4 shows the general framework. The total population size for this research is found between 501 and 1200 population interval as zone statistical data reported in 2018. By depending on the method developed by Carvalho (1984) as cited in Malhorta (2007) improved sample size selection table from the total population the medium sample size 80 for data gathering by questionnaire was selected.

In order to assess and examine the coffee processing plant location factors, the Coffee and Tea Authority Office Management current practices and valuable data were gathered both from primary and secondary sources. Hence, efforts were garnered to gather as many data as possible. The questionnaire respondent's values were analyzed by Statistical Packaging Social Software (SPSS) version 20 and the Analytical Hierarchy Process matrix was used to give the weight and ranking for location factors and alternative locations to select a suitable location.

Figure 2. Location selection model according to (Weber and Moses, 2006).

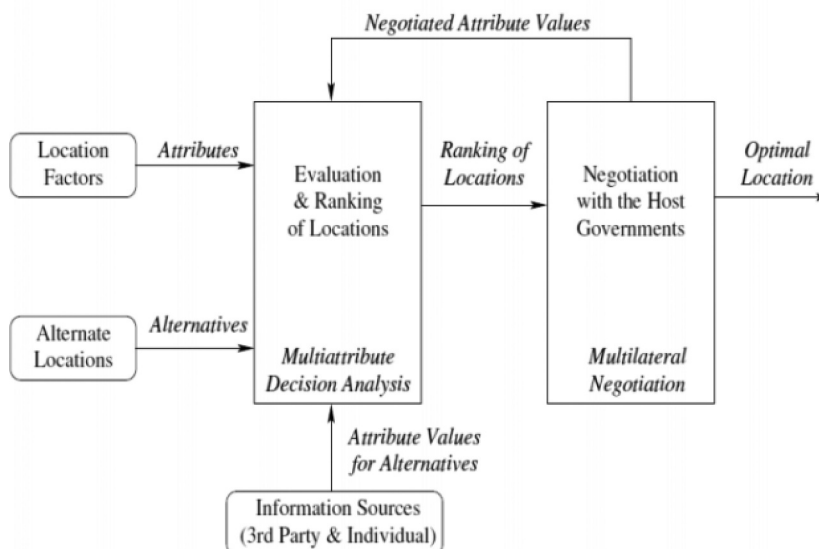


Figure 3. Optimal location selection model (Eldin and Sui, 2003).

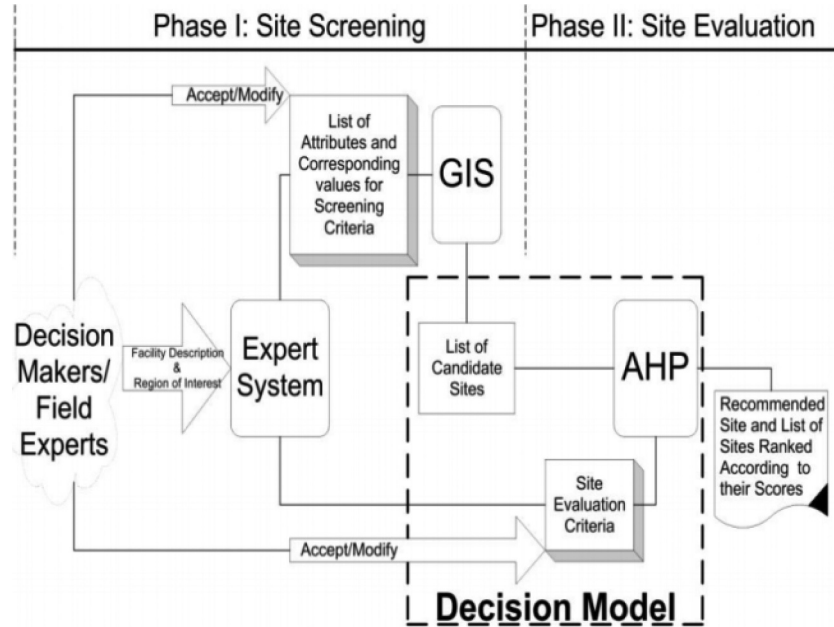
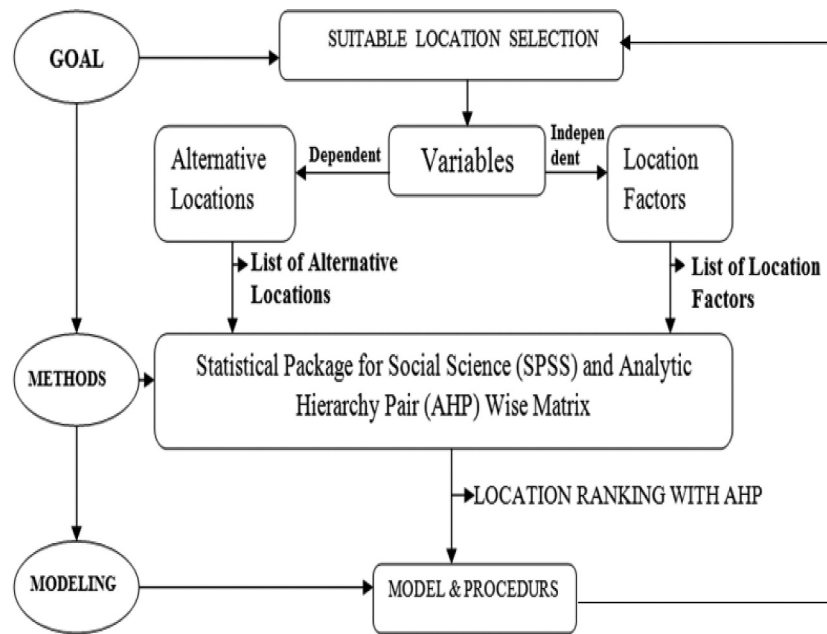


Figure 4. Framework of research.

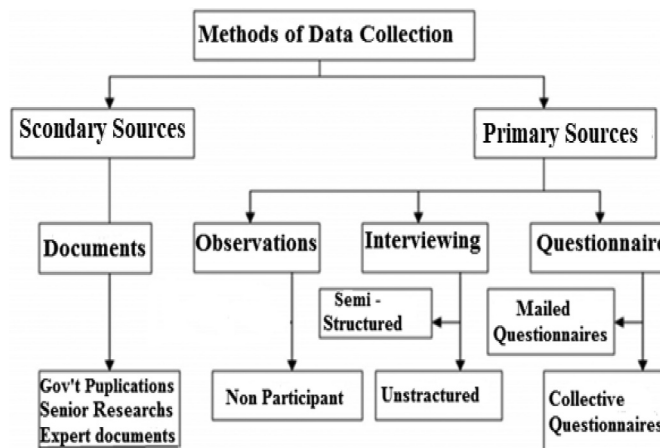


Questionnaires, interviews, and official report document recording the interviews, photographs from selected parties are the detailed way of gathering data. Figure 5 showed the way data was collected for this research success.

3.1. Questionnaire response coding by likert's Scale

The questionnaire is the appropriate instrument to collect data from a relatively large sample size. The questionnaire direction was depending on five points. Likert's scale to show the level of agreement: 5 = strongly agree (SA), 4 = agree (A), 3 = moderately agree (MA), 2 = disagree (DA), and 1 = strongly disagree (SD). Such type of questionnaire provides a great uniformity of respondent's responses which shows the level of agreement was prepared. After data collection, the result of respondents' SPSS value

Figure 5. Methods of data collection by framework developed by (Kumar, 2005).



regression equation was developed to determine the contribution of each location criterion to select a suitable location from alternatives.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 \dots \dots \dots \text{(Eqn.1)}$$

Where Y is represent dependent variable,

X represents independent variables, while beta values used to know the contribution of each location factors to decided one location. X₁ represent factor one which similar in name with criteria one (C₁). X₁=C₁, X₂=C₂ ... similar for all up to C₈ = X₈

3.2. Data analysis and Likert's scale criterion response

Likert's Criterion response the five points scale methods for a range of mean values and the standard deviation were used (Al-Sayaad et al., 2006). Table 2 presents five-point Likert criterion responses.

3.3. Analytic hierarchy process (AHP) method scale

Analytic Hierarchy Process is one of the most famous methods of multi-stage decision-making for ranking and weighting location, and to select a suitable location. It was developed by Saaty, 1980. This method builds a hierarchy of decision items using comparisons between each pair of items expressed as a matrix. Paired comparisons produce weighting scores that measure how much importance items and criteria have with each other (Al-Sayaad et al., 2006). Table 3 shows the Analytic Hierarchy Process scale.

3.4. Methods of processing and data analysis

Data analysis and processes were used primary and secondary source of data to answer the research question and attain the research objective. The primary data through the questionnaire was categorized in to a way that suits to address the research question raised in study. The categorization of analysis includes two main variables to select the suitable. Location was dependent variable, while location factors assumed as independent variable.

Table 2. Five-point scale Likert's criterion response		
No	Mean range	Response Option
1	[1.00–1.80)	Strongly (SDA)
2	[1.80–2.60)	Disagree (DA)
3	[2.60–3.40)	Moderate (M)
4	[3.40–4.20)	Agree (A)
5	[4.20–5.00)	Strongly Agree (SA)

Table 4. Multi-collinearity test

Model	B	Collinearity Statistics	
		Tolerance	VIF
(Constant)	0.164		
Average of coffee production potential question mean value	.292	.899	1.112
Average of water questions mean value	.315	.913	1.096
Average of land availability question mean value	.207	.823	1.215
Average of distance question mean value	.188	.948	1.055
Average of infrastructure question mean value	.216	.701	1.427
Average of market question mean value	.495	.659	1.517
Average of transportation question mean value	.233	.952	1.051
Average of environment question mean value	.310	.887	1.127
Average of question of labor availability mean value	.302	.873	1.145

Table 5. Linear multiple regression model (Model of Fitness)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.962 ^a	.925	.914	.03596

Substituting the values of respondents from the output of SPSS in equation (2)

$$Y = 0.292X_1 + 0.315X_2 + 0.207X_3 + 0.188X_4 + 0.216X_5 + 0.495X_6 + 0.310X_7 + 0.302X_8 \dots \dots \dots \quad (\text{Eqn.3})$$

Y represents the dependent variable which is location of coffee processing plant and **X** represents the location criteria those assumed as independent variables. The value of $\beta_1 = .495$ indicates the market proximity to planned coffee processing plant contributes about 49.5% of contribution.

The coffee existence has a contribution of 29.2% on the success of the primary coffee processing plant. The water availability contributes 31.5%. The land availability for construction of the coffee processing plant is 20.7% and the distance of each other factors from the expected location contributes 18.8% to the success of the selected location. The next beta values similarly reflect the contribution of labor, environmental, transportation condition contribution, and infrastructure. Of 76 respondents most of them agreed (A) and strongly agreed (SA) as values between ((4.20–5.00) and (3.40–4.20)) as the problem of misallocation exist in the research district area.

4.3. Supportive data from field observation and reports

In Guji Zone, even if there is an increment of total coffee production per year exist, the supply to the international market is less than one-third (1/3) of the total coffee production of Guji Zone Coffee and Tea Authority Office Nagele (2009 E. C). This challenge is due to misallocation of the coffee processing plant is vastly existed in this zone (Figure 6).

4.4. Current trend conceptual framework for location selection

The framework is drawn ideally after expert and researcher was discussed how the ownership of coffee processing plant mostly selects or decide the location in the research area. This conceptual model was explained by the number and arrow direction to understand the step to decide the location for their coffee processing plant (Figure 7) that included from number 1 up to six.

Figure 6. Dry and wet-processed coffee report (Guji Zone, 2013).

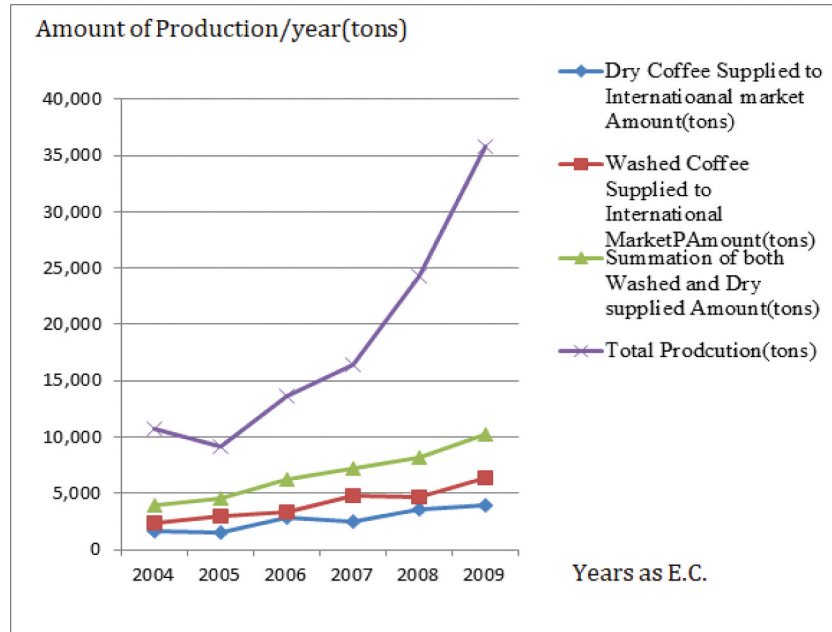
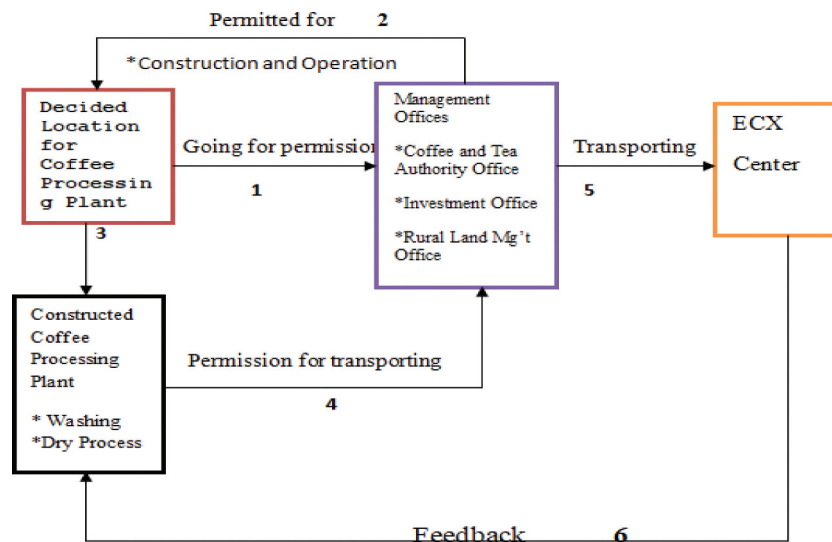


Figure 7. Current trend conceptual framework (field survey).



4.5. Suitable location selection from alternatives by AHP method

4.5.1. Obtaining the percent of importance for location factors

Eight (8) primary coffee processing plant location criterion and four (4) alternative locations were evaluated. Alternative locations were selected from Odo Shakisso Wereda: Alternative location one (A₁) is **Sawana**, Alternative location two (A₂) is **BantiKorbo**, Alternative location three (A₃) is **Taro** and Alternative location four (A₄) is **Diba Bate**. Table 6 demonstrates eight criteria and thier abbreviation. Figure 8 presents the used location criteria and abbreviations. Then, draw tree structure for the AHP method; build a hierarchical form of goal, criteria, and option.

4.5.2. Pair wise comparison matrix of the location factors (criteria)

Pair-wise comparisons are made of elements of each hierarchy by means of a ratio scale. Comparison of criteria has done one-to-one and mutually according to the importance values they own. Table 7 demonstrates pair-wise comparison matrix of criteria.

Table 6. Eight location criteria's and their abbreviations

No.	Name of location Criteria	Abbreviation of Criteria's
1	Potential of coffee production	C1
2	Water supply availability	C2
3	Land availability	C3
4	Distance	C4
5	Infrastructures	C5
6	Labor availability	C6
7	Market proximity	C7
8	Environmental condition	C8

Figure 8. Alternative locations and location factors.

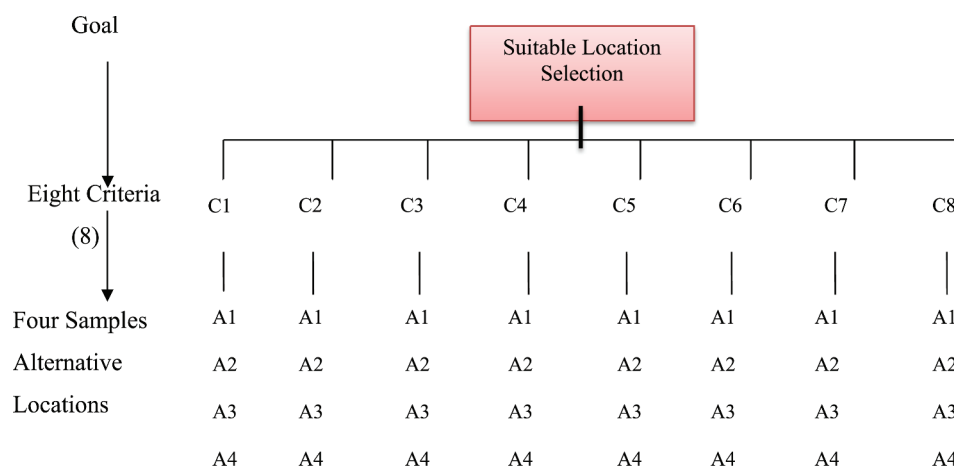


Table 7. Pair-wise comparison matrix of the criteria or location factors

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	5	4	7	6	8	3	5
C2	1/5	1	5	6	4	2	1/5	1/2
C3	1/4	1/5	1	3	2	1/4	1/5	6
C4	1/7	1/6	1/3	1	8	5	7	1/5
C5	1/6	1/4	1/2	1/8	1	3	7	1/2
C6	1/8	1/2	4	1/5	1/3	1	4	1/4
C7	1/3	5	5	1/7	1/7	1/4	1	1/5
C8	1/5	2	1/6	5	2	4	5	1
Total	2.4178	14.1166	20.00	22.4678	23.4761	23.500	27.400	13.650

4.5.3. Normalized criteria comparisons

After obtaining a comparison matrix, it is followed by a normalization process and the normalized matrix is formed by dividing each element of the matrix by the column total where it belongs. Table 8 demonstrates the normalized matrix.

$$1/[1 + (1/5) + (1/4) + (1/7) + (1/6) + (1/8) + (1/3) + (1/5)] = 1/2.4178 = 0.41$$

Then, priority vectors given in Table (9) at the next were obtained by averaging of a total of each row of Table 8 .

0.41	0.354	0.2	0.3115	0.255	0.34	0.109	0.366
0.083	0.0708	0.25	0.267	0.17	0.085	0.0073	0.037
0.103	0.0142	0.05	0.1335	0.085	0.0106	0.073	0.44
0.059	0.0118	0.0166	0.0445	0.341	0.212	0.255	0.0147
0.0689	0.0177	0.025	0.00556	0.0425	0.1276	0.255	0.037
0.0518	0.035	0.2	0.0089	0.014	0.04255	0.159	0.0183
0.1378	0.354	0.25	0.0089	0.0061	0.0106	0.0365	0.015
0.0827	0.142	0.00833	0.2225	0.085	0.1712	0.183	0.0733

criteria's	Priority		criteria's	Priority	
C ₁	P1	0.293	C ₅	P5	0.072
C ₂	P2	0.121	C ₆	P6	0.066
C ₃	P3	0.105	C ₇	P7	0.102
C ₄	P4	0.119	C ₈	P8	0.121

$$\text{Priorityone}(P1) = \frac{(0.41 + 0.354 + 0.2 + 0.3115 + 0.2555 + 0.34 + 0.109 + 0.366)}{8} = \mathbf{0.29325}$$

Listing of factors affecting location preference is provided. With respect to the obtained priority vector, the coffee potential existence criterion (C1) has the first-degree importance with a 29.325 % ratio. Labor availability is in the last place with a 6.6% ratio.

In order to test the consistency, **CI** and **CR** calculation steps with the help of the first comparison matrix values and priority vectors are shown in detail as follows.

$$(1 * 0.29325) + (5 * 0.1212625) + (4 * 0.10545) + (7 * 0.119325) + (6 * 0.7241) + (8 * 0.066168) + (3 * 0.1023625) + (5 * 0.12119) = \mathbf{4.03906}$$

After calculating all eight calculations like the above formula the consistency index (**CI**)

$$CI = \left[\frac{\frac{4.0039}{0.2933} + \frac{2.0054}{0.1213} + \frac{1.0047}{0.1055} + \frac{0.091}{0.12} + \frac{1.00195}{0.07241} + \frac{0.07355}{0.0662} + \frac{1.035}{0.1024} + \frac{0.096}{0.1212} - 8}{8} \right] / (8 - 1) = \mathbf{0.0408}$$

$$CI = \mathbf{0.0408}$$

By depending on the Random index (RI) for eight (8) number of locations criterion can be used **1.41** random of the index.

$$CR = \frac{CI}{RI} = \frac{0.408}{1.41} = \mathbf{0.02}$$

This value is less than the upper values of the consistency ratio value which is **0.10**. So, it is consistent and the operation process can proceed to the next step. The ratio is below 0.10 means that the judgment of decision-maker is consistent.

4.6. Alternative comparison matrix and priority vectors for the criterion

This part contains one by one location criteria with respect to alternative locations to prioritize and ranking to select a suitable locations and the consistency ratio (**CR**) must be tested. From [Table 10](#) upto [Tables 11–17](#) shows the results of each alternative location respect to selected criteria.

I. Potential of coffee production

Table 10. Potential of coffee production

Coffee Production Potential	A1	A2	A3	A4	Priority Vector
A1	1	1/6	¼	2	0.092
A2	6	1	2	8	0.528
A3	4	½	1	7	0.33
A4	1/2	1/8	1/7	1	0.053

CR = 0.01

II. Water supply availability

Table 11. Water priority value with respect to alternatives

Water Availability	A1	A2	A3	A4	Priority Vector
A1	1	5	9	7	0.66
A2	1/5	1	4	2	0.182
A3	1/9	¼	1	2	0.087
A4	1/7	½	½	1	0.073

CR = 0.08

III. Land availability

Table 12. Land Priority Value With Respect to Alternatives

Land Availability	A1	A2	A3	A4	Priority Vector
A1	1	½	3	¼	0.150
A2	2	1	5	½	0.280
A3	1/3	1/5	1	1/7	0.059
A4	4	2	7	1	0.510

CR = 0.01

IV. Distance

Table 13. Distance priority value with respect to alternatives

Distance	A1	A2	A3	A4	Priority Vector
A1	1	1/3	¼	3	0.134
A2	3	1	2	6	0.450
A3	4	½	1	7	0.360
A4	1/3	1/6	1/7	1	0.055

CR = 0.05

V. Infrastructures

Table 14. Infrastructure priority value with respect to alternatives

Infrastructures	A1	A2	A3	A4	Priority Vector
A1	1	1/8	1/3	1/5	0.050
A2	8	1	5	6	0.630
A3	3	1/5	1	2	0.170
A4	5	1/6	1/2	1	0.150

CR = 0.09

VI. Labor availability

Table 15. Labor availability priority value with respect to alternatives

Labor Availability	A1	A2	A3	A4	Priority Vector
A1	1	1/6	1/4	1/8	0.123
A2	6	1	2	1/3	0.251
A3	4	1/2	1	1/4	0.151
A4	8	3	4	1	0.477

CR = 0.024

VII. Market proximity

Table 16. Market proximity priority value with respect to alternatives

Market Proximity	A1	A2	A3	A4	Priority Vector
A1	1	1/3	3	1/5	0.1303
A2	3	1	4	1/2	0.288
A3	1/3	1/4	1	1/6	0.0667
A4	5	2	6	1	0.5164

CR = 0.029

VIII. Environmental condition

Table 17. Environmental priority value with respect to alternatives

Environmental Condition	A1	A2	A3	A4	Priority Vector
A1	1	1	1/3	1/2	0.1712
A2	3	1	5	3	0.485
A3	1/2	1/5	1	1/5	0.0716
A4	2	1/3	5	1	0.2733

CR = 0.023

The next steps in the process is multiplying preference matrixes according to alternative locations and location criteria or factors. Ranking for alternatives was shown in (Table 18) and the calculation process of the first one (**Sawana (A1)**) is explained in detail as an example below.

Table 18. Calculation of priority vector for the entire alternative location and location factors

Alternative Locations/Priority Vectors	Location Factors										Priority vector for the entireGoal
	Coffee production	Land availability	Water availability	Distance	Infrastructures	Labor availability	Market Proximity	Env, Condition			
Sawana (A1)	0.2932	0.1213	0.1055	0.1193	0.072	0.0662	0.1024	0.1212			
Bantikorbo (A2)	0.091	0.660	0.150	0.1340	0.05	0.123	0.1303	0.1712			0.230
Taro (A3)	0.530	0.182	0.300	0.450	0.63	0.251	0.288	0.485			0.413
Diba Bate (A4)	0.330	0.087	0.060	0.360	0.17	0.151	0.0667	0.0716			0.218
	0.053	0.073	0.510	0.055	0.15	0.477	0.5164	0.2733			0.213

$$[(0.091 * 0.29325) + (0.660 * 0.1213) + (0.150 * 0.1055) + (0.134 * 0.1193) + (0.05 * 0.0724) + (0.123 * 0.0662) + (0.1303 * 0.1024) + (0.1712 * 0.1212)] = 0.230$$

After the last priority vector calculated for selected alternative locations, the ranking of alternative locations can be known. The values of priority of location criteria Table 19 and the priority of each location factors were used to get the goal or end priority of locations. After the ranking of alternative locations, the suitable location was selected (see Table 19) .

According to the obtained values of the column priority vector, 0.230 shows the importance level of A1, 0.413 is the importance level of A2 alternative, 0.218 is the importance level of A3 alternative, and 0.213 shows the importance level of A4 alternative. Finally when the results are analyzed alternative location (A2) or **Bantikorbo** received the highest score and alternative location (D) or **Diba Bate** received the lowest score.

4.7. Proposed model for coffee processing plant location selection

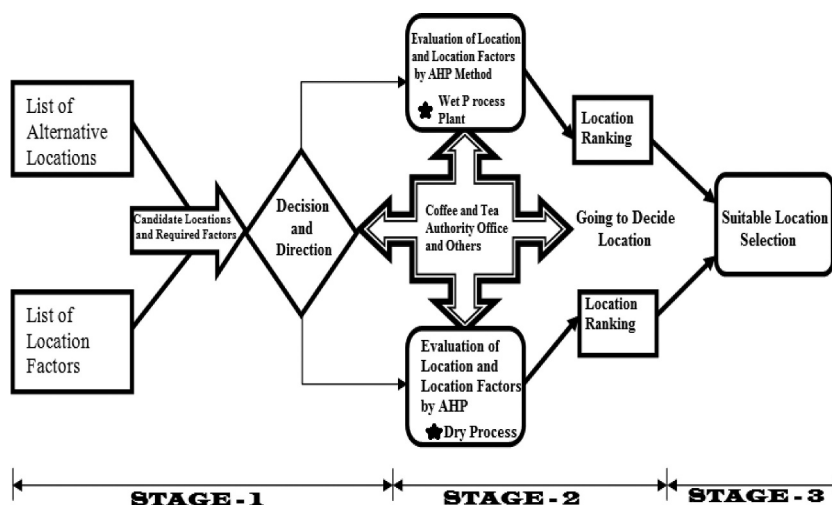
The model is dynamic and specifically assumed to solve the real problem of the research area to select a suitable location from different alternatives. The results of the collected data from the primary source and secondary source, questionnaire respondent values. Alternative location ranking by AHP method indicates as the problem of location deciding for coffee processing plant exists in the Guji zone. So, this model was developed to solve the misallocation of deciding the coffee processing plant in three sequential stages. Figure 9 shows the proposed model stages.

STAGE1: This stage is the primary stage at which the parties that required selecting the location for the coffee processing plant gather the information from different parties. At this stage the ownership gathers information to propose the new location he/she required. The two main things in this stage are alternative locations and location factors required to give rank for alternative locations by the selected method. Next, to these candidate locations, location factors present to

Table 19. Ranking of alternative locations (source: AHP output)

Alternative Locations	Priority Vector Values	Ranking of Locations
Bantikorbo (A2)	0.413	1
Sawana(A1)	0.230	2
Taro (A3)	0.218	3
Diba Bate (A4)	0.213	4

Figure 9. Proposed model for coffee processing plant location selection.



directly responsible office (Coffee and Tea Authority Office and others). As drawn in the model this office has four main arrows (left and right, top and bottom), the left arrow has the responsibility to make tentative decisions and direction to transfer alternative locations and criteria to the evaluation stage. At this stage decision-making is more focused on how much candidate locations are available to evaluate and ranking.

STAGE 2: This stage is the second stage in this model that contains mainly evaluation of candidate locations by depending on the percent of importance of required location factors. Evaluation of location factors and alternative locations was depending on the Analytic Hierarchy Process method. At this stage the Coffee and Tea Authority Office plays a great role. The upper and bottom arrow indicates, at this stage the evaluation and ranking of location both wet and dry coffee processing. Importance-based scale of values given for each factors. Evaluation for ranking alternative locations to select suitably will be calculated at this stage. An arrow to the left side of the Coffee and Tea Authority Office shows the last step to select a suitable location from alternatives. If the comparison matrix is not consistent means the value is greater than 0.01 the process of hierarchy location criteria will be adjusted again until the value of the comparison matrix will be consistent, which means less than 0.01 values of consistency ratio.

STAGE3: This stage is the third stage according to this model for coffee processing plant location selection. After all steps were completed the ranking of alternative locations that depending on end values of priority vector correctly address which location is suitable than others. At this stage, all the steps were summarized and specifically address which location is suitable from listed candidate locations. Then, put their priority vector value in importance or suitability ranking. In this stage the chance to adjust the hierarchy process of location factors to test the consistency of the location criteria is impossible. Because this stage is the last stage only we can select a suitable location from alternatives for the required coffee processing plant.

5. Conclusions & recommendations

The location selection of a coffee shop or plant is crucial for its success or failure. It should be decided in a strategically and comprehensive way (Lin & Zu, 2013) and failure to do so will lead to a potential loss. This paper confirmed that the above thought is correct in relation to the Guji Zone. In the case area, almost all the coffee processing plants were located in a traditional way even without taking into consideration the average distance from farm place to processing areas which lead to a high distance travel of cherry which directly affected the quality of coffee being marketed from the area.

The location decisions till now were carried out by investors simply by considering the availability of enough space for the plant and ignoring other location selection criteria's and even it was done without the consultation of Coffee and Tea Authority Office and Experts. Such practices let to locate the wet processing plants very far from the farm places that lead to the majority of household farmers and suppliers to transport their coffee beans/cherry long distance which creates unfavorable conditions to them. On the one hand they are forced to travel long distances, on the other hand, they are not obtaining enough returns since damage happened to cherry due to improper transportation facilitation along with the distances that degrade the coffee beans quality. This also directly affected the competitiveness of investors in the areas and forced to supply less volume of quality coffee to the international market which is not attractive as compared to the production volume of the area. This reality not only discouraged attraction of new investors in wet processing plant but also affected the already established plants and forced to shift their mind towards dry processing plant which relatively degrades the natural quality/grade of the coffee as compared to wet-processed and washed coffee beans. Generally, the traditional ways of site selection practice for wet processing coffee plants in this zone has affected household farmers, suppliers, investors, and even the region and the country at large by degrading the quality and volume of coffee beans to the international market and consequently lowering the income generated.

To overcome the problem of suitable location selection as one factor that challenged the production of quality in the research area of the Guji zone, the data was gathered from both primary and secondary sources of data. The respondent's answer was analyzed by Statistical Packaging Social Science Software and Likert's mean range values were used to specifically know as respondents addressed as the problem is existed. Among the 80 respondents, 76 of them were participating in questionnaire responses and response values were summarized by Likert's mean scale which was found between (3.50–4.20) and (4.20–5.00) that was addressed as the challenge of selecting a suitable location is existed in the research area.

From field observation, most of the coffee processing plants have their own challenge as per the impact of location criteria due to misallocation. The analytic hierarchy process method was used as the main method to develop the model. Also, many developed models were used as input and has integration with this model for coffee processing plant location selection. Four alternative locations with eight location factors were included in this thesis and the ranking of alternative locations was done. Alternative location Bantikorbo (A2) was selected with 0.413 highest priority vector value as a suitable location for the required coffee processing plants from listed locations. Diba Bate Location (A4) from alternatives had the lowest priority vector value 0.213 when compare with others. The number of alternative locations is not limited to some numbers; it is based on a decision-maker list them for the required purpose. But most of the time the location factors or criteria is listed and limited by the management group, professional, Institute of research, skillful persons, and others.

Generally, rather than a simple selection scientific approach to the suitable location selection for the coffee processing plant is best when it is based on the research-based model to specifically decide the fruitful location among many alternatives. Likewise, this model and techniques employed can be adapted to other areas to aid in optimum site selection to benefit all role players in the economy and also to promote the natural coffee aroma of the area.

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Author details

Fasika Bete Georgise¹

E-mail: fasialem@gmail.com

Boru Bedeya Jarso²

E-mail: borubedeyagb@gmail.com

Alemayehu Tesfaye Mindaye¹

E-mail: alex.tesfaye46@gmail.com

¹ Department of Industrial Engineering, Faculty of Manufacturing, Hawassa University, Institute of Technology(IoT), Ethiopia.

² Department of Industrial Engineering and Logistics Management, College of Engineering and Technology, Bule Hora University, Ethiopia.

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