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The best location selection using analytical hierarchy process method

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ABSTRACT

CHUUO Plain Shirt Factory is a plain shirt manufacturer founded in 2016 and is located at Kaliurang road Km 9, Yogyakarta. They not only sell plain t-shirts but also sell screen printing shirts, receive screen printing services, and orders to make collared shirts (polo). For CHUUO Plain Shirt Factory, business location has an important role in the marketing process related to reaching the customers. One method that can be used to determine the location of a new business is Analytical Hierarchy Process (AHP). This study focuses on selecting the best alternative location by considering seven criteria: geography, cost, population, risk, facilities & infrastructure, availability of human resources, and developer credibility. The research method used was observation and direct interviews using a questionnaire. The result shows that alternative location A (Shop at Gejayan Road No.30) has the highest all weight evaluation value (0.45). Alternative location B (Shop at Kaliurang Road Km 4) has a value of all weight evaluation of 0.3. Alternative location C (Shop at Magelang Road Km 7) has valued all weight evaluations the lowest (0.25). Based on the analytical research conducted, it can be concluded that alternative location A (Shop at Gejayan Road No.30) is the best location to open a branch shop for CHUUO Plain Shirt Factory.

INTRODUCTION

Currently, choosing a strategic location is not easy, it takes a right and appropriate location so that the benefits obtained can be maximized. According to Heizer [1], location is a cost and revenue driver, so location often has the power to make a company's business strategy. The strategic location aims to maximize the benefits of location for the company. Before a company establishes a factory, it is usually planned as well as possible regarding the exact location because the location affects the operating/production costs, selling prices, and the company's ability to compete in the market [2]. Therefore, strategic location is one of the important factors and greatly determines the success of a business.

CHUUO Plain Shirt Factory is a well-known plain t-shirt manufacturer in Yogyakarta and was established in 2016. This MSME sells plain t-shirts as its main product, sells screen-printed shirts, accepts screen printing services, and takes orders to manufacture collared shirts (polo). In developing the production level of CHUOO Plain T-shirt Factory's products, the shop owner has a view to opening branches in other locations. However, the problem was the shop owner did not know the exact location to be used as a branch of the business. According to Kasmir [3], there are two factors in choosing the ideal location, including:

a. Primary Factor
   1. Close to the market.
   2. Close to raw materials.
   3. Available manpower.
   4. There are transportation facilities such as roads, trains.
   5. Infrastructure facilities are available.
   6. People's attitude.
b. Secondary Factor
   1. Location investment costs.
   2. Prospects of price developments or progress at the location.
   3. Possible expansion of the location.
   4. There are supporting facilities such as shopping centers and housing.
   5. Climate and soil.
   6. Tax and regulatory changes in the local area.

To assess the quality of candidates/alternatives, decision-makers use specific measures because in truth no candidate or alternative has better value on each criterion that is used as a measuring tool [4]. Therefore, a Decision Support System (DSS) is used in its implementation. A decision Support System (DSS) is used in decision making and how to solve problems using several problem-solving methods [5]. There are four decision-making phases, namely the intelligence phase (scanning), design, selection, and implementation [6].

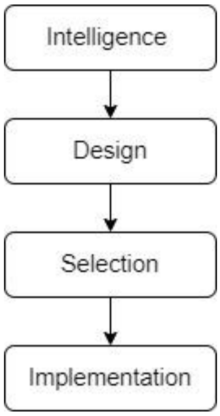

Figure 1. Decision-making phase

In the DSS, there is the concept of Multi-Criteria Decision Making (MCDM). MCDM is a method of selecting the best alternative from several mutually beneficial exclusive alternatives based on general performance in various criteria (or attributes) determined by decision-makers [7]. Several methods are often used in DSS, such as Simple Additive Weighting (SAW), Weighted Product (WP), Technique for Order Preference by Similarity of Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP), and Analytical Network Process (ANP).

This research chooses the AHP as the supporting tool to solve the mentioned problems among the methods. According to Ditdit [8], AHP is a concept for multicriteria-based decision making (many criteria). Several criteria are compared with each other (level of importance) is the main emphasis on this AHP concept. Saaty [9,10] proposed the analytical hierarchy process (AHP) as a strong decision-making technique. This is a pairwise comparison method based on

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Eigen values. AHP enables the decision-maker to compare options based on a variety of factors using his or her judgment. These requirements may or may not be quantified.

Based on the literature review, many things must be considered in choosing a location, as one of the fundamental factors, which greatly influences income and costs, location also affects the convenience of buyers and also comfort as a business owner [11]. There are seven criteria to consider in determining the location: geography, cost, population, risk, advice and infrastructure, human resources (HR), and developer credibility. From these criteria, five criteria have sub-criteria. The sub-criteria are geography (proximity to suppliers, close to settlements, road conditions), costs (rental fees, cleaning fees, electricity costs), population (population (age of residents, lifestyle of residents, and economic level of residents), risk (criminality). , business competitors, disasters), and the last is facilities and infrastructure (internet coverage, kiosk area, parking lot). There are three alternatives in choosing this location, namely a shophouse on Gejayan Street No. 30 (around the Yogyakarta State University (UNY)), a shophouse on Kaliurang Street Km.4 (around the Gajah Mada University (UGM)), and a shophouse on Magelang Street Km. 7 (around the Multi Media College (MMTC)).

Therefore, the aim of the study was to select the best location for the CHUOO Plain Shirt Factory business branch by considering various factors. The results of this study are expected to be the basis for choosing a business location.

1. Multi Criteria Decision Making (MCDM)

Multi Criteria Decision Making (MCDM) is one method that can help decision-makers on several alternative decisions that must be taken with several criteria that will be considered [12]. One thing that becomes a problem is if the importance of each criterion and the degree of suitability of each alternative to each criterion contain uncertainty. Usually, the assessment given by decision-makers is carried out qualitatively and represented linguistically [13].

The MCDM method refers to viewing, prioritizing, ranking, and choosing alternatives with independent, incommensurate or conflicting criteria [14]. MCDM is appropriate for implementation in cases where all alternatives have several criteria. Each has a nominal value, and each criterion has a weight that can be used to compare. Some of the methods included in MCDM are Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), TOPSIS, etc.

2. Analytical Hierarchy Process (AHP)

According to Saaty [10], the complexity in making decisions is due to the diversity of criteria. He developed a decision analysis method called the Analytical Hierarchy Process (AHP) to eliminate this complexity. AHP is a general theory of measurement that is used to find ratio scales, both discrete and continuous pairwise comparisons that describe complex problems into a hierarchy [15]. According to Saaty [10], hierarchy is a representation of a complex problem in a multi-level structure where the first level is the goal, followed by the criteria level, sub-criteria, and so on, down to the last level, namely the alternative. While a complex problem can be interpreted that the problem has so many criteria (multi-criteria), the structure of the problem is not clear, the opinion of the decision-maker is uncertain, the decision-maker is more than one person, as well as the inaccuracy of the available data [16].

The following three ideas underpin this method: problem identification and model structure development, the comparative judgment of criteria and options, and relative weight assessment. The criteria are usually broken down further into sub-sub criteria, and so on, in as many levels as the situation requires [17] (see Figure 1). The hierarchy can be represented graphically as seen below, with the aim at the top, alternatives at the bottom, and criteria in the middle.

After constructing the hierarchy, the decision-makers analyze its many aspects in pairs, meticulously evaluating them. The decision-makers can utilize either concrete data about the elements or their judgments about the elements' relative significance and importance when making the comparisons. The AHP is built on the idea that human judgments may be employed to do evaluations rather than only the underlying data. A pairwise comparison scale is utilized for this. The evaluations are then converted to numerical values that may be processed and compared over the entire problem range by AHP. Each element of the hierarchy is assigned a numerical weight or priority, allowing disparate and frequently incommensurable elements to be compared rationally and consistently. Global priority refers to an attribute's importance about the ultimate purpose. The priorities specify how much weight each item in a collection of nodes is given. Weight can refer to importance, preference, likelihood, or any other aspect that the players consider, depending on the problem. This feature sets the AHP apart from other decision-making methods. For each alternative, numerical priority is determined in the final step of the procedure. These statistics, which represent the alternatives' relative capacity to meet the chosen goal, enable for a simple comparison of the various options.

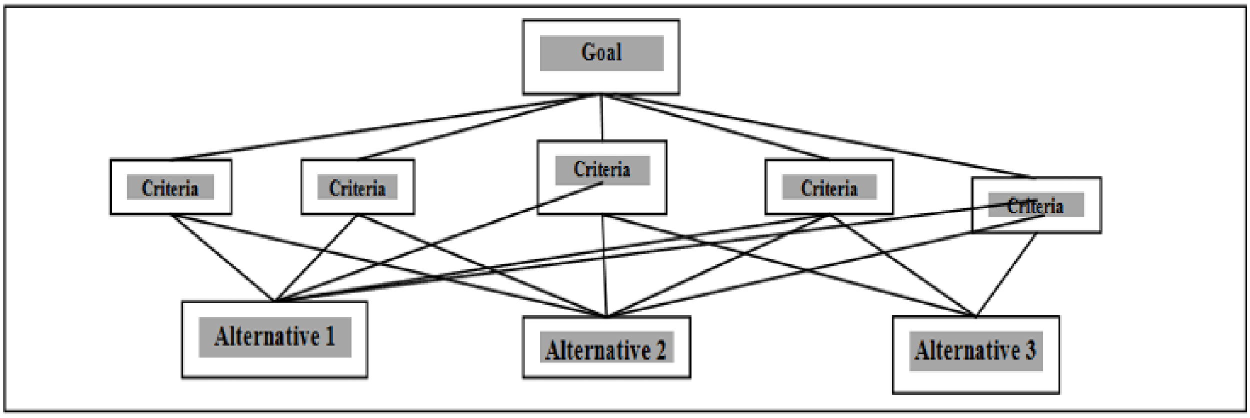

Figure 2. Decision Making Phase Hierarchical Structure for AHP [9]

In short, there are several steps involved in the AHP process. The following are the stages in the AHP method [7]:

a. Determine the pairwise comparison matrix, describing an expert's opinion regarding the level of importance of each aspect to other aspects. The comparison is based on the Saaty comparison scale [9], as shown in the following Table 1:

Table 1. Pairwise comparison scale

Intensity of Interest	**Information**
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is much more important than the other
9	One element is absolutely more important than the other elements
2,4,6,8	The values between the two values of adjacent considerations

b. Normalize the pairwise comparison matrix
c. Finding the priority of pairwise comparisons
d. Finding the priority of interest (Eugen Vector) with the formula:

$$Eugen\ Vector = \frac{TWM_a}{n} \tag{1}$$

e. Calculating Eugen Value

$$Eugen\ Value = \frac{EVe_a}{M_a} \tag{2}$$

f. Calculating λ_{max}
g. Calculating *Consistency Index* (CI)

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h.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (3)$$

i. Calculating *Consistency Ratio* (CR) value

$$CR = \frac{CI}{RI} \quad (4)$$

with the value of A as in Table 2 and N is the number of orders of pairwise comparison matrices. This step is carried out to test the consistency of the expert. If it is not consistent (indicated by the CR value > 0.1) then take the data again, which is to return to the previous step.

Table 2. Ratio index value

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

Recently, the AHP has been used by many researchers to solve many problems. For instance, AHP has been applied to identify and evaluate the effective criteria for detecting congestion in a smart city in India [18]. In this research, AHP can be used to help the decision-maker through a pairwise comparison in a matrix-based. Furthermore, Sharma et al. [17] implemented AHP-TOPSIS-based approach to prioritize the assembly line balancing (ALB) solution methods (heuristics) and to choose the best of them. A benchmark assembly line balance problem is solved using five distinct heuristics, and the value of the line's objectives criteria (performance measurements) is calculated.

Moreover, Dmytrów and Gnat [19] applied the AHP method to assess the influence of attributes on value in real estate valuation. Experts conducted pairwise comparisons of the importance of qualities based on this information (valuers). The weights of each attribute have been determined using the AHP approach, and the impact of each attribute on real estate value will then be examined. The study has been based on 318 real estate properties in Szczecin. In addition, Kim et al. [20], in their research regarding the promotion of environmental management in the South Korean health sector, analyzed hospital staff members' responses to a questionnaire about the relative importance and performance of individual environmental management tasks using the AHP, and also identified environmental management tasks that should be prioritized by using those questionnaire responses to create an importance-performance analysis (IPA) matrix. This study found that the top priorities are “establishment of vision and strategy for environmental management” and “organization of task team for environmental management and task assignment”. Aprilianto et al. [21] also applied the AHP to analyze the criteria to determine the locations of 5G implementation. There are a lot of factors to consider when deciding where to put 5G technology in place. An AHP is a helpful tool for determining criteria based on expert evaluation. To examine the criteria and deliver the weighted value, AHP created a hierarchy. As stated in the procedure, there are 12 parameters to examine in determining the locations of 5G technology development in Indonesia. Experts analyze and assess criteria data gathered through interviews and questionnaires to obtain accurate primary data relevant to the issue under research.

METHOD

3.1 Object of research

The object of this research is about choosing the best location for the CHUUO store branch, Polos Shirt Factory, Kaliurang Road Km 9 Yogyakarta.

3.2 Research Flow

Procedures outlined in this study were divided into three phases: Preliminary Stage, Data Collection and Processing Stage, and Discussion and Conclusion Stage as shown in Figure 2.

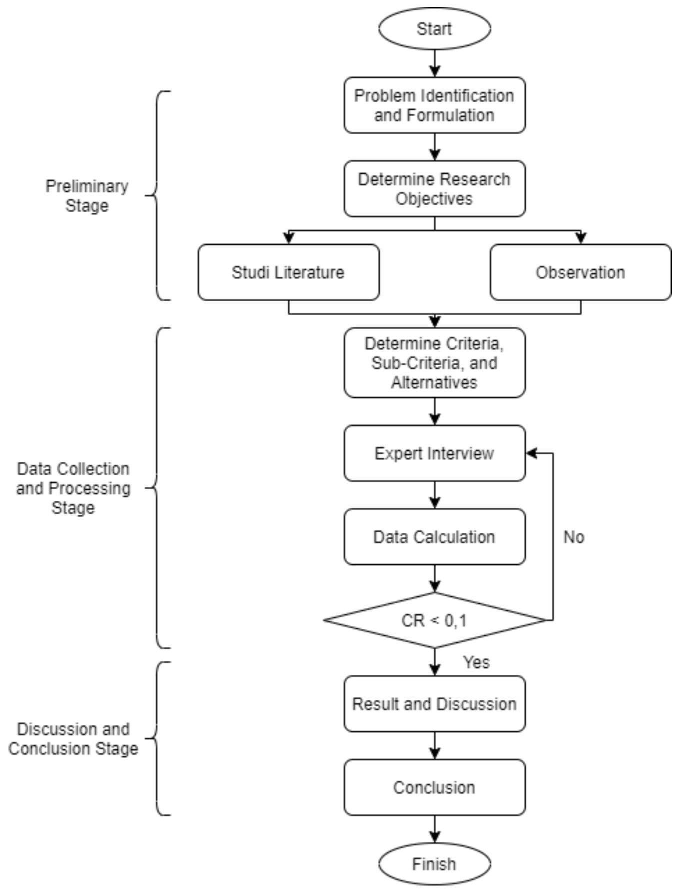

Figure 2. Research flow

3.3 Hierarchy AHP

The hierarchy in AHP is divided into four levels. The first level is located at the very top, which describes using AHP. The second level below it defines the criteria, the third level shows the sub-criteria, and the last level at the bottom shows the alternatives. The following is a hierarchy in this research:

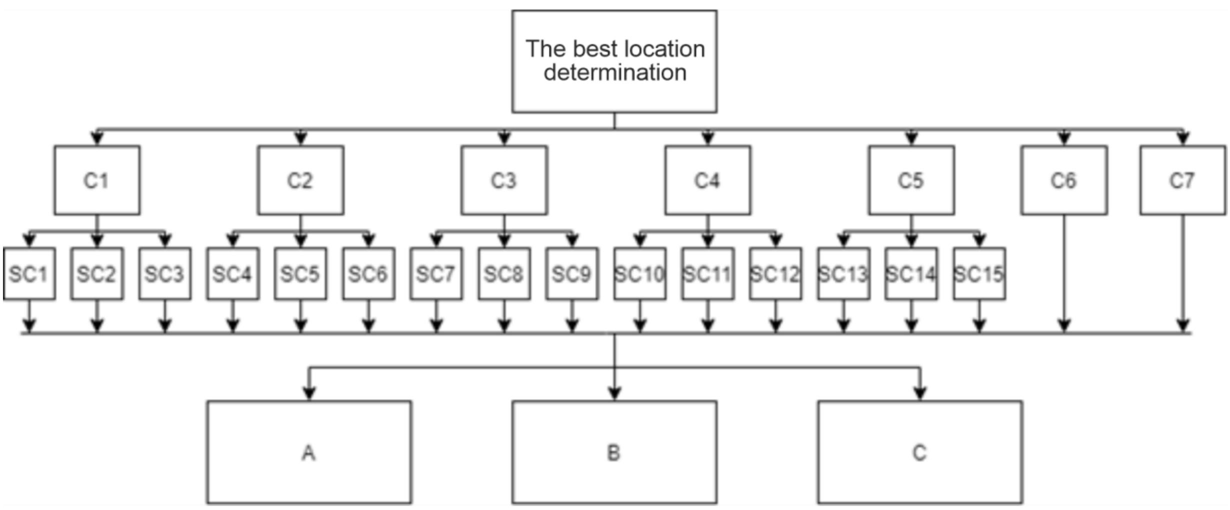

Figure 3. Problem hierarchy

In this case there are seven criteria and 15 sub-criteria were considered. In addition, there are 3 alternative locations. The criteria, sub-criteria and alternatives in this study are shown in Table 3, 4, and 5.

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Table 3. Criteria

Criteria	Code
Geographical	C1
Cost	C2
Population	C3
Risk	C4
Facilities and infrastructure	C5
Human Resources	C6
Developer Credibility	C7

Table 4. Sub-criteria

Sub-Criteria	Code
Close to Supplier	SC1
Close to Settlement	SC2
Road Condition	SC3
Rental costs	SC4
Cleaning Fee	SC5
Electricity cost	SC6
Age	SC7
Lifestyle	SC8
People Economic Level	SC9
Crime	SC10
Business Competitors	SC11
Disaster	SC12
Internet Reach	SC13
Shop Area	SC14
Parking Area	SC15

Table 5. Alternatives

Alternatives	Code
Shophouse on Gejayan Street No.30 (around the UNY Campus)	A
Shophouse on Kaliurang Street Km.4 (around the UGM Campus)	B
Shophouse on Magelang Street Km.7 (around the MMTC Campus)	C

RESULTS AND DISCUSSION

The data used in calculating the priority importance of the criteria and sub-criteria in choosing the location were obtained from a questionnaire addressed directly to the owners of MSME. The questionnaire given is a pairwise comparison questionnaire. This questionnaire is used to compare each criterion with homogeneous properties in pairs so that it will be easier and more objective to determine the criteria that have a better value [22]. The following are the stages in the weighting of criteria, sub-criteria, and alternative selection using the AHP method:

3.1. Pairwise Comparison Matrix

The results of the questionnaire that have been obtained will be made a paired matrix. The results of the paired matrix in the site selection process are shown in Table 6.

Table 6. Criteria interest priority assessment matrix

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	1	2	2	1	1/4	4	3
C2	1/2	1	4	3	1/3	5	2
C3	1/2	1/4	1	2	1/4	3	3
C4	1	1/3	1/2	1	1/5	1	1/2
C5	4	3	4	5	1	5	3
C6	1/4	1/5	1/3	1	1/5	1	1/2
C7	1/3	1/2	1/3	2	1/3	2	1

3.2. Normalization

The value of the priority assessment matrix will then be normalized. Paired matrix normalization is the result of the value of each criterion divided by the total value of each column. The normalization results are shown in Table 7.

Table 7. Result of normalization of pairwise comparison of criteria

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	0.13	0.27	0.16	0.07	0.10	0.19	0.23
C2	0.07	0.14	0.33	0.20	0.13	0.24	0.15
C3	0.07	0.03	0.08	0.13	0.10	0.14	0.23
C4	0.13	0.05	0.04	0.07	0.08	0.05	0.04
C5	0.53	0.41	0.33	0.33	0.39	0.24	0.23
C6	0.03	0.03	0.03	0.07	0.08	0.05	0.04
C7	0.04	0.07	0.03	0.13	0.13	0.10	0.08

3.3. Interest Priority Calculation

This calculation is to determine the order of priority of interest in each pairwise comparison. The criterion that has the greatest value indicates that the criterion is considered the most in decision making. Table 8 presents the order of importance criteria.

Table 8. Order of importance criteria

Criteria	Total Weight Matrix	Eugen Vector	Order of Interest
C1	1.16	0.17	3
C2	1.25	0.18	2
C3	0.79	0.11	4
C4	0.45	0.06	6
C5	2.46	0.35	1
C6	0.32	0.05	7
C7	0.58	0.08	5
Total	7	1	

Based on the calculation of the Eugen vector, the criteria most considered by business owners in choosing a branch location is C5 (Facilities and Infrastructure) with a value of 0.35.

Total Weight Matrix (TWM) is the sum of the normalized values for each criterion. Next, the total weight matrix values are added up to be used for the next calculation.

$$Eugen\,Vector = \frac{TWM_a}{n} \tag{5}$$

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Eugen Vector is the result of dividing the total weight matrix on element a with the number of elements being compared (n). This value shows the importance of the criteria in decision making. From the calculation results show that the criteria in choosing a location, the first priority is facilities and infrastructure with a weight of 0.35, the second priority is cost with a weight of 0.18, the third priority is geographical with a weight of 0.17, the fourth priority is the population with a weight of 0, 11, the fifth priority is developer credibility with a weight of 0.08, the sixth priority is risk with a weight of 0.06 and the last is HR criteria with a weight of 0.05.

3.4. Matrix Multiplication

The next process is the Matrix multiplication process. In this process, the multiplication between the pairwise comparison matrix and the Eugen vector matrix is calculated. To simplify the calculation, you can use the MMULT formula in Microsoft Excel. The results of the calculation of the matrix multiplication criteria in this case are shown in Table 9.

Table 9. Multiplication of criteria comparison matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	*EV*	Result
C1	1	2	2	1	1/4	4	3	0.17	1.33
C2	1/2	1	4	3	1/3	5	2	0.18	1.41
C3	1/2	1/4	1	2	1/4	3	3	0.11	0.84
C4	1	1/3	1/2	1	1/5	1	1/2	0.06	0.50
C5	4	3	4	5	1	5	3	0.35	2.79
C6	1/4	1/5	1/3	1	1/5	1	1/2	0.05	0.34
C7	1/3	1/2	1/3	2	1/3	2	1	0.08	0.60

3.5. Eugen Value Calculation

The Eugen Value is the result of the Eugen vector of element a divided by the matrix multiplication value of element a. The results of the calculation of the Eugen value in pairwise comparisons between criteria are shown in Table 10.

Table 10. Eugen value inter-criteria

Criteria	*Eugen Vector*	Matrix Multiplication	*Eugen Value*
C1	0.17	1.33	8.05
C2	0.18	1.41	7.89
C3	0.11	0.84	7.47
C4	0.06	0.50	7.82
C5	0.35	2.79	7.95
C6	0.05	0.34	7.38
C7	0.08	0.60	7.31
	Total		53.86

3.6. λ_{max} Calculation

The value of λ_{max} is the result of the total value of the eugen value divided by the number of elements in a pairwise comparison as in the following formula:

$$\lambda_{max} = \frac{\Sigma EVe}{n} \tag{6}$$

$$\lambda_{max} = \frac{53,86}{7}$$

$$\lambda_{max} = 7,69$$

3.7. Consistency Index (CI) Calculation

Consistency Index or consistency index is a measurement of the value of deviation from consistency. The CI value is calculated using the following equation:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{7}$$

$$CI = \frac{7{,}69 - 7}{7-1}$$
$$\mathrm{CI} = 0{,}12$$

3.8. Consistency Ratio (CR) Calculation

The consistency ratio value was obtained from the CI values divided by the Random Index (IR) value. The random index value is a provision value based on the number of elements in a pairwise comparison. There are 7 elements/criteria in this pairwise comparison, so the IR value is 1,32. The CR value is obtained from the following equation:

$$CR = \frac{CI}{IR} \tag{8}$$

$$CR = \frac{0{,}12}{1{,}32}$$
$$CR = 0{,}09$$

Because the value of CR <0.1 means that the expert's preference is consistent. Consistency for paired comparisons is shown in table 11. It shows that all pairwise comparisons have been consistent, so that it can be continued to the next process, namely the calculation of the final weight.

Table 11. Expert consistency

Pairwise comparison	CR	Information
Inter-Criteria	0.09	Consistent
Inter-Sub-Criteria C1	0.046	Consistent
Inter-Sub-Criteria C2	0.016	Consistent
Inter-Sub-Criteria C3	0	Consistent
Inter-Sub-Criteria C4	0.016	Consistent
Inter-Sub-Criteria C5	0.047	Consistent
Inter-Alternatives to C6	0	Consistent
Inter-Alternatives to C7	0.0079	Consistent
Inter-Alternatives to SC1	0.016	Consistent
Inter-Alternatives to SC2	0.0079	Consistent
Inter-Alternatives to SC3	0	Consistent
Inter-Alternatives to SC4	0	Consistent
Inter-Alternatives to SC5	0	Consistent
Inter-Alternatives to SC6	0	Consistent
Inter-Alternatives to SC7	0.075	Consistent
Inter-Alternatives to SC8	0.047	Consistent
Inter-Alternatives to SC9	0.075	Consistent
Inter-Alternatives to SC10	0	Consistent
Inter-Alternatives to SC11	0.064	Consistent
Inter-Alternatives to SC12	0	Consistent
Inter-Alternatives to SC13	0	Consistent
Inter-Alternatives to SC14	0.046	Consistent
Inter-Alternatives to SC15	0	Consistent

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3.9. Alternative Weight Calculation

The weight of each alternative is obtained from the sum of the global values for each alternative. The following is the weighting result for each alternative:

Table 12. Alternative final weight

Alternative	Final Weight	Priority
Location A	0.45	I
Location B	0.3	II
Location C	0.25	III

Based on the final weight, location A (Ruko Jalan Gejayan No. 30) has the largest final weight of 0.45. So that location A is the best location for a business branch based on the factors considered.

CONCLUSION

This research implemented the Analytical Hierarchy Process (AHP) method for selecting the best location for the CHUUO business branch of the Polos Shirt Factory. The research result was the alternative location A (Shophouse on Gejayan Street No. 30) has the highest all weight evaluation value compared to the value of location B and location C with a value of 0.45, which means this alternative is the best location to open a CHUUO Plain Shirt Factory store branch. Furthermore, The criteria for selecting the location of business branches that have been ranked based on the assessment in order of priority are the criteria for Facilities and Infrastructure (C5), Cost (C2), Geographic (C1), Population (C3), Developer Credibility (C7), Risk (C4), Human Resources (C6).

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