AN AHP APPROACH FOR COLD STORAGE WAREHOUSE SITE SELECTION: A CASE STUDY IN BANGLADESH

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering

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DHAKA, BANGLADESH

OCTOBER 2020

APPROVAL

This Project/internship titled "**An AHP Approach for Cold Storage Warehouse Site Selection: A Case Study in Bangladesh**", submitted by Md.Mehadi Hassan, ID No: 163-15-8399 and Martina Chakma, ID No: 163-15-8354 to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 07 October,2020.

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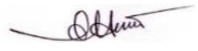

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DECLARATION

We hereby declare that, this project has been done by us under the supervision of **Md. Zahid Hasan, Assistant Professor, Department of CSE** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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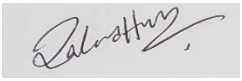

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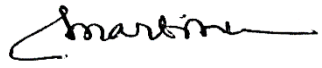

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ACKNOWLEDGEMENT

First, we express our heartiest thanks and gratefulness to almighty God for His divine blessing makes us possible to complete the final year project/internship successfully.

We really grateful and wish our profound our indebtedness to **Md. Zahid Hasan**, **Assistant Professor**, Department of CSE Daffodil International University, Dhaka. Deep Knowledge & keen interest of our supervisor in the field of "*Decision Science*" to carry out this project. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts and correcting them at all stage have made it possible to complete this project.

We would like to express our heartiest gratitude to Dr. Syed Akhter Hossain, Professor, and Head**,** Department of CSE, for his kind help to finish our project and also to other faculty member and the staff of CSE department of Daffodil International University.

We would like to thank our entire course mate in Daffodil International University, who took part in this discuss while completing the course work.

Finally, we must acknowledge with due respect the constant support and patients of our parents.

ABSTRACT

Business investors are frequently faced with complex decisions, such as selecting the location of cold storage warehouse based on multiple inconsistent criteria. An inappropriate site selection imposes excessive effects on both customers and investors of urban areas. Nowadays, multi-attributes decision making approach are recommended to apply to progress exactness of decision making and lessen additional adverse. This work proposes a decision support framework for location selection of cold storage warehouse using analytic hierarchy process (AHP) model. An efficient case study is evaluated in Bangladesh considering several factors using Analytic Hierarchy Process. This paper also describes the necessity for setting up cold storage warehouse. In this study, we have considered 6 attributes and 18 sub attributes among 3 different locations in Bangladesh as alternatives. The alternatives relative importance has been calculated by using AHP. The ultimate decision is prepared based on the arithmetical scores snatched by the alternatives. For finalizing the optimal solution both AHP result and the benchmark deduction have been taken into account. A numerical study is presented to demonstrate the possible alternative of the proposed methodology.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Now a days, site selection process for establishing new company is a challenging issue. It is one of the robust problems if someone is willing to make a new company or business. There are some investors facing same problems who are already well established in the market tries to increase the business and craves for a optimal site [1]. In metropolitan areas, the rapid growth of population and migration need their primary demands (daily essentials) to be fulfilled [2]. The increasing population of urban areas need to fulfill their demand in order to lead a happy life. They need their daily essentials for example -Agricultural products (Vegetables, On-ion, Potato and so on). Any investor can take a chance to establish a new company for fulfilling their demand by providing daily agricultural products. The major problem is that, the agricultural products are easily perishable. The risk of food disease and spoliation will increase if the recent temperature is not moderate and suddenly increases [3]. To overcome this situation the investor needs to establish cold storage warehouse for agricultural products for the long preservation with an ideal temperature. Perishable agricultural products can be preserved for a long time through it. The investor can distribute fresh agricultural products among customers and thus make a profit through his company. Setting up cold storage warehouse may fill the customer demand and it is profitable for both customer and investor. Site selection for a new company depends on different assessment of protocols. It is a multi-attribute decision support system. Before selecting new location of a company, it should analysis different perspectives. The company should analysis the possible problems occurred during site selection. An investor should take into account the surrounding and local conditions. The warehouse should be set up closer to the customer in order to serving fresh agricultural product. Fresh agricultural products can bring huge success and profit on business. It is a multi-standards dynamic methodology for the determination of a best ideal area for setting

up a cold storage warehouse. Different types of decisions and criteria have to be sketched by the decision making team to generate the best alternative among different alternatives .This type of decisions are costly and lengthy process and that is why it is most important for the company to make a decision .They also have an impact on operating costs and revenues[4]. It might cause huge problems such as - excessive transportation cost, shortage of skilled labor force, shortage of security if the decision-making team fails to choose best location. The investor should provide best quality of commodities. The perishable products are being so popular to the customer that it is one of the best business to earn a huge profit by the investor [5]. The investor must also make a background analysis on the current market condition. They should analyze which products are mostly wanted and desired by the customer. The investors also take into account the price rate of that product. To survive with this competitive market requirements the investor must take into account different types of protocols. A productive and laborious investment is the root to attain huge progress on the business while taking multiple criteria decisions and a huge market basket analysis must be ascertained as well as the antagonism and demographics [6-8]. The investors must know the factors for which they are investing [9-10]. A tremendous effect will hit upon the transportation and online based sites for warehouse site selection process if the process for site selection is accomplished in a practical and pragmatic way [11-13]. As for the growing demand of the community and denomination, both local and foreign investors must come forward for the continuous assiduousness for the clients and customers to serve [14].in the hilly regions it is very hard to set warehouse due to land cover disturbance [15-16]. It is immensely rational and significant activity to choose the warehouse location and the feasibility study for the project is costly [17-18]. In this research paper, Analytic Hierarchy Process (AHP) is described properly to derive the solution for warehouse location selection. AHP is a powerful and benign assumption for evaluating and modeling multi criteria decision making problems and it is a multi-criteria approaches used for the assessment of the Achievement which encourages the decision specialist researchers providing great features [19-22].Several researches have been conducted using AHP model and it is a multi-criteria decision making tools since it provides tremendous features

for evaluating optimal solutions by ranking the alternatives based on their criteria weights [23-27].

Recently the need for constructing warehouse in Bangladesh has been increased for solving several food related problems. In Bangladesh, many farmers are producing potatoes in Bogra, Kishoreganj and Rangpur district. Although the production is good enough but the local rural market is not so perfect to sell the potatoes at a best price. The farmers do not get desired profit by selling potatoes in their local market. Beside that robust amount of potato is being rotten for the lack of preservation. As a result, some investors from the farmers' society decided to take some necessary steps to be beneficial on their potato production site. So, they have decided to set up cold storage warehouse to the urban area for the perishable agricultural food that will enlarge the preservation time of perishable food. They have decided that their warehouse must be far away from the production area. They have chosen three different locations for setting up cold storage warehouse. Among these three locations, they will finally select only best optimal location. If there is 1% chance to be successful, we must do it for 100 times to achieve our goal. This research study is based on the perspective of Bangladesh.

The main contributions of this research are given below:

1. This research describes the concept of AHP for implementing cold storage site selection process for the investors to the manufacturing and industrial field. According to the expert's opinion, 6 main criteria and 18 sub-criteria that are helpful for evaluating the cold storage warehouse location.

2. This study provides the solution to select the best location with the help of miscellaneous inference. We finalize the objectives and construct different decision tables that generates the optimal and decisive dimension of the substitutes.

3. The ranking for each of the alternatives calculated with the help of the equations formatted on this research. The AHP method is helpful for finding the best location.

After all this paper describes about the details of business startup scheme along with best selection way for evaluating the maximum profit.

1.2 Motivation

For the enlightenment to demographics, scientific and numerical research is the root to come out from the darkness. Scientific investigation on any problem lead to a perfect and an optimal solution. Recently several problems are raising related to perishable products. One of the best solutions is to set up cold storage warehouse to preserve these products for a long time. This research paper basically proposes an optimal framework to solve this problem. This paper is essential for providing continuous inspiration among the people who wants to contribute themselves on the scientific field. Two types of people will be motivated through this research paper since various numerical and scientific aspects have been discussed for evaluating optimal solution from multi criteria decision making problems. These two types are farmers and investors. This paper discusses briefly about various decision-making problems. This paper focuses on the decision science field. Many farmers are getting stuck on their profession and livelihood since perishable products (potatoes, vegetables, onions) are getting rotten easily. The farmers who are producing perishable products have the opportunity to overcome this problem getting involved themselves with scientific research. This paper discusses how to overcome this problem easily using Analytic Hierarchy Process. The people who wants to be successful in the agricultural site can be motivated a lot through this research paper because this paper describes about different factors and aspects which should be experimented by the farmers. Brief scientific and numerical experiment have been performed to solve perishable product rotation problem. Another group of people who will be motivated a lot is the investors. Because investment process on the agricultural site has been discussed on this paper. This paper helps to take several multi criteria decisions and to handle problems which summarizes the optimal success on the field on investment and production for both investors and farmers. Young generation can be inspired mostly by this research paper as this paper describes both investment site as well as production site.as this paper is based on setting up cold storage warehouse to save the perishable products, so young generation will be enlightened enough about the process to start a business .Young people will contribute themselves in the business sites without any failure after being motivated

analyzing this scientific and numerical research paper .So any people can start their own business being supported by this research paper.

1.3 Expected Outcome

1) To evaluate the consistency ratio.
2) To determine criteria weights
3) To determine the best optimal alternative among different alternative.
4) To make the rank of the alternatives according to their priority scores.
5) To find out the best location for warehouse site selection.
6) Knowledge for Investment policy is gathered
7) Different factors for decision related problems are evaluated.

1.4 Report Layout

This paper is containing a total of five chapters named as Introduction, Background, Research Methodology, Numerical Experiment and Result Analysis and Conclusion and Future Works.

Chapter 1: Introduction; This chapter describes about Introduction, Motivation, Expected Output, Report Layout.

Chapter 2: Background; This chapter includes Introduction, Related Works, Scope of the Problem, Challenges.

Chapter 3: Research Methodology; It is containing Introduction, Research Model, Data Collection Procedure, AHP Methodology

Chapter 4: Numerical Experiment and Result Analysis; This chapter helps to evaluate Problem Statement, Numerical Experiment, Result Analysis.

Chapter 5: Conclusion and Future Works; Finally, the total Conclusion, Future Works is evaluated and shown in this chapter.

CHAPTER 2
BACKGROUND

2.1 Introduction

Different people take different decisions in their everyday life. Decision taking and handling is a serious problem to the people who don't have any knowledge in decision science. To take a right decision is not easy at all since different attributes are playing vital role for the selection of the alternatives. Moreover, it is a complex and time-consuming task to take a right decision. Any success depends on the proper and logical decision taking. A wrong decision can lead to a destruction. So, this paper is based on the decision taking and handling. This paper describes about the Analytic Hierarchy Process to take right decision and to select the best alternatives. AHP is a tremendous decision-making approach which lets the decision maker to take right decision. AHP is widely used to make a rank of all the alternatives according to their scores. So, to know details on decision taking, different multi criteria decision making model are used all over the world. AHP describes about the factors and attributes and sub-attributes related to any decision. It provides the exact overview on any decision related problem to the decision maker.

2.2 Related Works

For the increasing demographics several decisions and problems are emerging. It is more necessary to have knowledge on the decision fields. It is a stubborn and troublesome errand to choose the best other options among thousands of alternatives. So, to choose the right decision and to choose best alternative, different decision-making approaches are widely used. Some multi criteria decision making approaches are-Analytic Hierarchy Process (AHP), Fuzzy AHP, Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and so on. All these approaches sort all the alternatives according to their score. So, the decision maker can easily find the best solution according to the score level. This paper describes deeply about the Analytic Hierarchy Process (AHP). This research

describes the step wise procedure to sort out the best cold storage warehouse location according to the highest scores. Several researches have been performed worldwide based on this topic. Several methodologies have been applied on for site selection. So, now for multi criteria decision making, there are several methodologies for the warehouse location selection. This work is carried out with AHP method. Analytical Hierarchy Process (AHP) is developed by Thomas L. Saaty in 1980 [38]. It is one of the best methodologies for solving multi criteria decision making problems since it offers various aspects like Attributes, sub-attributes, pairwise comparison matrix and different alternatives [28,29]. Au et.al [30] used FAHP for country site selection. He made a decision model to find the best solution. AHP is used for the software selection by the pairwise comparison of the attributes and alternatives by Lai et al [31]. Garcia et al. [1] used the Analytic Hierarchy Process for the warehouse site selection. A compact relationship for selection the warehouse is emerged using AHP by Korpela and Tuominen [12]. A unified framework is proposed using AHP by Shang and Sueyoshi [32] for the selection of a tremendous manufacturing system. Tummala et al. [33] used AHP for evaluating concurrent engineering in the industry. Armacost et al. [34] applied AHP. They used AHP for the housing selection based on customer requirements. A manufacturing system is proposed by Abdi and Labib [35]. AHP approach is implemented in different decision-making sectors. But the main drawback of the AHP approach is uncertainty. It does not talk about the existing uncertainty moreover Beynon [36] describes to his proposed model about the uncertainty level with the help of both Dempster-Shafer theory as well as AHP model.so, DS/AHP basically used in his paper calculates the possible uncertainty created by AHP model. A combined fuzzy multi criteria decision making approach is used by Onut et al. [7] to select the best location for shopping mall. Chen [10] used the desired AHP approach for convention site selection. Nuclear power plant location is set using AHP with GIS environment by Abudeif et al. [9]. Geographic Information System is used for the industrial site selection by Rikalovic and Lazarevic [11]. Vlachopoulou et al. [13] also used GIS for warehouse site selection. An organic farming site is selected using AHP and GIS by Mishra et al. [15]. Chen and management [17] proposed the field depot location selection model based on AHP. Solar plan thermal plant which is an investment project developed by

Aragones-Beltran et al. [18]. They made the model which is implemented under multi criteria decision making approach. Neissi et al. [19] used AHP in a semi-arid region for site selection. Sure service terminal location is modeled by AHP framework and derived by Hegde and Tadjkamalla[22].The decision scientist find an efficient feature using AHP method. Any decision can be taken using AHP approach. It provides rational results. It uses Thomas L. Saaty (1-9) scale point for making the pairwise correlation framework which is the main framework for the initialization of the process. Another technical way to solve MCDM issues is TOPSIS manifested by Hwang and Yoon in 1981[37]. It helps to rank the set of alternatives as like as AHP method. Saaty [28,29] designed his own proposed model AHP for solving critical decision related issues and relative measurement. For the decision-making purposes, scientific researches on decision science helps by providing continuous knowledge which enlighten us for being successful while taking any critical decision.

2.3 Scope of the Problem

As described briefly about various aspects why this work is committed, it will be lovely to inform once again that this research is about taking and handling several multi criteria decision related problems. This research defines the stepwise process to select the best optimal alternative among many alternatives. It describes about multiple attributes, sub-attributes. It shows the final ranking according to scores as well as the benchmark result. All these works are done using Analytic Hierarchy Process which will be implementing over next three chapters. Besides these some obstacles and problems arises while working with this project. It is compulsory to handle and reduce the mistakes occurred during warehouse site selection process. Actually, a new location is selected analyzing the various MCDM approach as well as applying previous knowledges and researches. So, the chance to occur any mistakes remains generally. Some common mistakes that AHP approach should reduce are given as follows:

1) Taking decision without analyzing huge data of research.

2) short term aspects, factors, criteria should be eliminated while selecting a new location.

3) site selection on a very remote and uncertain area is another obstacle.

2.4 Challenges

One of the major challenges while writing this research paper is to select the suitable attributes and sub-attributes. Another challenge is to select the alternatives. Because before selecting alternatives, attributes and sub-attributes, a vast knowledge must be gathered since any error while taking decision may cause huge destruction. Another most terrific challenge is to calculate the criteria and sub-criteria weights. Analyzing various research papers and with the help of AHP model the weights are assigned. So, it also one of the crucial challenges for the researchers. Alternatives choosing is also very difficult since numerous factors must be inspected. After finding criteria weights the next challenge is to check the consistency ration. Consistency Ration must be less than 0.10. So, if the consistency ration is less than 0.10 then only the calculated criteria weights are accurate to work for the research otherwise not. So, these are the challenges while writing a research paper.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

Any investor should first background analysis and identify the problem. Then second task is to make a plan. The third task is to re-evaluate and fix the plan so that he or she can go for the next step. Fourth task is to research on various attributes, sub-attributes and alternatives according to his or her plan. This will provide him or her huge knowledge on the particular topic which he or she planned. It is necessary to tell that the overall success depends on the efficient thoughts and framework. It is more important to perpetuate the consistency ratio less than 0.10 while working with several critical attributes and sub-attributes. Otherwise the researchers will not be able to evaluate the best alternative appropriately. If the consistency ration is more than 0.10 then the researchers must go back to the previous step and again find out new possible and accurate value for attributes and sub-attributes for rechecking of the consistency ratio. A felicitous model and sketch for a research implementation is very indispensable for the optimization of the problem. Applying previous knowledge and researches and various MCDM approach any problem can be handled.

3.2 Research Model

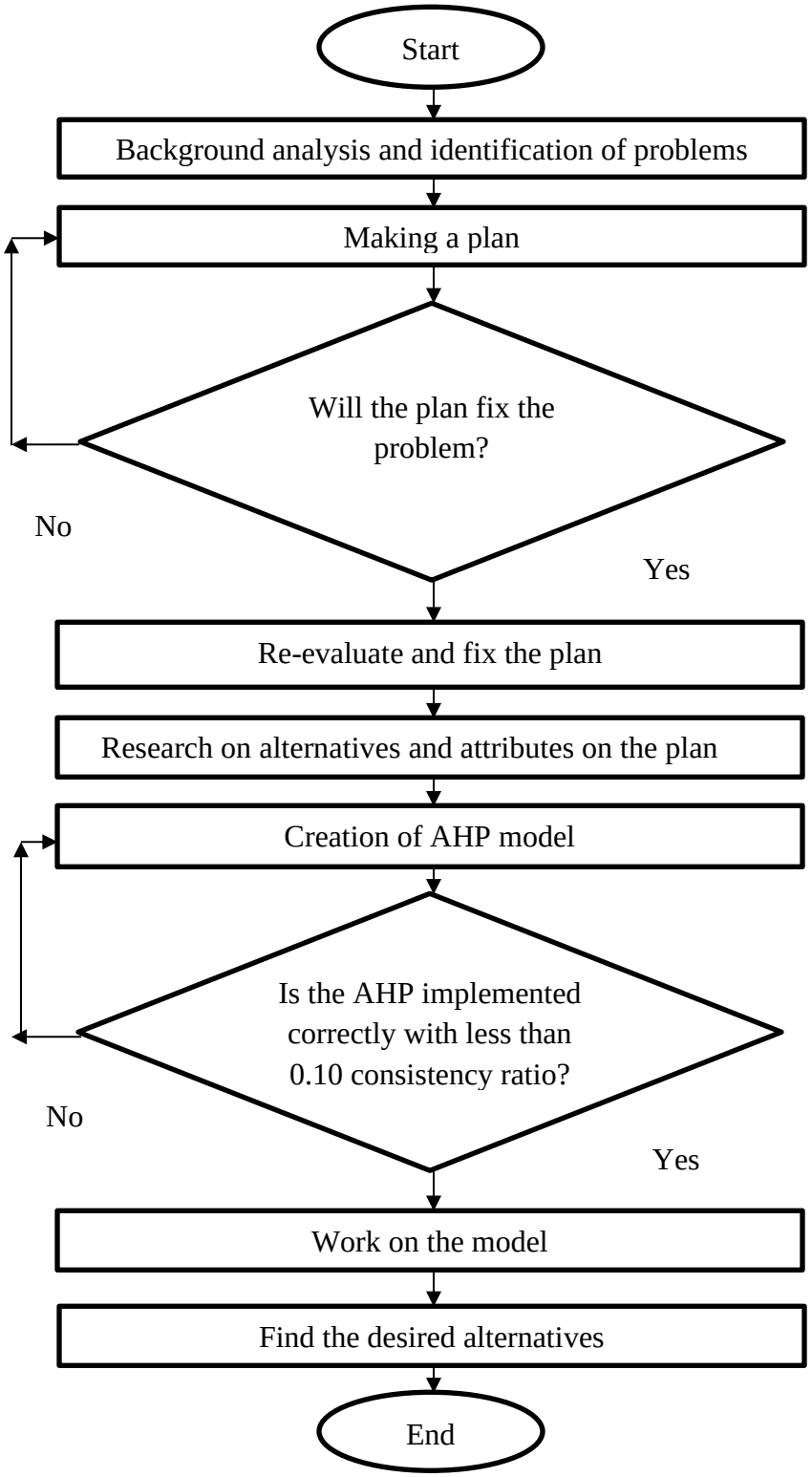

Figure 3.1: Basic proposed model for warehouse site selection

3.3 Data Collection Procedure

Figure 3.1: represents the model of data collection steps to accomplish the warehouse site selection problem. Based on the proposed research model stated above all information and data are sorted and emerged together. Miscellaneous attributes, sub-attributes, alternatives are accumulated which satisfy the research experiment. Different factors are collected for research purpose. The data about the production sites are compiled. And the data about various alternatives are also compiled simultaneously. There is a sequence of data collection procedure stated below based on our research model.

3.3.1 Background Analysis and Identification of Problems

The first and foremost duty for an entrepreneur is to find out the problems for which he or she is going to set up the business in order to solve that problems of the custom-er and their own. The investor should background analysis and find the issue for which he or she can establish company. This paper describes the agricultural food problem issue of Bangladesh. The agricultural foods are easily perishable. This is a major problem for Bangladesh. Huge amount of potato, onion and other vegetables are being rotten because of the critical weather and other bad situation. So, this a major problem for Bangladesh. So, anyone can make a business to make profit on this sector. Onions and potatoes are being damaged easily. In some states of Bangladesh such as Bogra, Kishoreganj and Rangpur district, farmers are having problems on agricultural food damaging. They detect that the main problem for getting spoiled of potato and onion is excessive heat.

3.3.2 Making a Plan

The association of farmers have decided to make a plan to fix their problems. They realized that, if they can preserve their foods in an optimal temperature the food will be saved for long time. Different types of criteria and sub-criteria must be considered while setting up

a warehouse in the desired location and thus it is a complex process for selecting a warehouse location since there are so much objectives that have to take into account to the Decision makers. After all they decided to set up cold storage warehouse to preserve their foods. Now they are thinking whether their plan can fix the problem or not.

3.3.3 Re-evaluate and Fix the Plan

Several researches have been made on that problem by the investors who are willing to set up cold storage warehouse. They have studied details on that problem. They have studied on the advantages and disadvantages of cold storage warehouse. So, the best selection of the warehouse location will make a great effect between customer and investors. If the warehouse is set up closer to the densely populated area then the business will be profitable. The capacity of the cold storage must be large enough to preserve different types of perishable agricultural food [39]. The cold storage ware-house must be well air conditioned to ensure the better preservation of agricultural food. Based on previous experience and with the help of different company owners, the farmer's team has finalized their plan and want to work on that.

3.3.4 Research on the Alternatives and Attributes Based on the Plan

As the plan is fixed, the farmer's association can make a special decision-making team whose main work is to research on the alternatives and attributes that match to their goal. This team is composed with the agricultural shareholders and the farmers who actually are willing to start this business. Strength, weakness, opportunities and possible threats are also measured by the decision-making team. The decision-making team must ensure the best alternatives with their best attributes and sub-attributes to research for the solution on that problem.

There must be some threats while taking various decision which the decision-making team must overcome. Decision making team must find out the alternatives and at-tributes which they must occupy. This research paper shows that they have chosen three different

locations for setting up their cold storage location. The locations are- Cumilla, Narsingdi and Laksham which are denoted by X, Y and Z. These three locations are chosen by the decision-making team based on some protocols. The team has chosen three locations which are far away from the production area. As the local market near production area are not so good to sell the product so they have taken this decision. Actually, they want to set up their cold storage warehouse in the metropolitan area so that they can sell their products easily and earn a profit. Their idea will help a lot because they will preserve perishable agricultural food for a long time and will serve to the nearest customer and the food will not get spoiled. The question may arise -why not to set up cold storage beside the production area? The answer is that, if the local market is good enough so that the producer can sell all his products at the best price then it must be taken into account, otherwise not. Then another question may arise-why to set up cold storage warehouse in the metropolitan area? The simple answer is that, the metropolitan area has many people to sell the product at a high rate which is not possible in the rural area. Criterion should be taken into account before the assessment of the alternatives [40]. Criteria and sub-criteria satisfy the best location strategy. They describe the details about any alternatives.

Now different types of criteria are described on the next sub-section which satisfies the best alternative to choose.

3.3.4.1 Accessibility (AC)

It denotes the best routes by which the product is brought to warehouse from the production area. There are two types of routes we usually use to transport the product to warehouse from the growing area. They are:

• Land Route (LR)

• Railways (RW)

The product can be brought through land route or railways.

3.3.4.2 Distance (DS)

• Distance of the warehouse from the growing area (DW)

• Distance of the customer from the warehouse (DC)

Warehouse distance from the customer must be as close as possible. To be successful in the business the distance between customer and warehouse must be very close.

3.3.4.3 Acceptance (AE)

Acceptance means how the local people and government will conduct with our product and services and company. Acceptance is one of the major criteria for setting up a warehouse. Below are some acceptance sub-criteria

- Government Acceptance (GA)
- Local Acceptance (LA)
- Product Acceptance (PA)

Government issue is one of the most issue in recent time to start a new business. If there is no Government license for your business then you cannot start a business. So, government License is must needed to start a company. The investor must take into account that their product should be good and fresh according to customer will. Their service should be much user friendly. The investor should also take into account whether their product is locally accepted or not.

3.3.4.4 Cost (CO)

Cost criteria is one of the best criteria. It must be taken into account before starting a new company. The investor has to calculate the cost before establishing a company. To set a cold storage warehouse there are several types of cost associated are given below

- Product transportation cost (PC)
- Salaries and wages cost (SC)
- Energy Cost (EC)
- Insurance Cost (IC)
- Depreciation Cost (DC)

Product transportation cost is the cost for product transportation from one place to other. Monthly salary is paid to the employee. The best location should consider the lowest energy cost. So before selecting any company location, energy cost is justified. Depreciation cost

is the cost deduced by everyday asset uses. For example, every day we use office equipment and machineries.so this thing is losing its value by everyday uses.

3.3.4.5 Security (SC)

Security is also a major attribute for location selection in decision support system.

• Recent local crime on the state (RC)

• Security System (SS)

Before choosing any company location, the investor must take into account the re-cent local crime on the state. If the selected location is associated with crime and another violation then the business will be crashed. The decision-making team should select such a place for setting up cold storage warehouse so that there are plenty of security system available.

3.3.4.6 Essentials for Warehouse (EW)

• Experienced qualified labor force (QF)

• Machinery and Equipment (ME)

• Land or Terrain (TR)

• Electric or generator Energy (ER)

Qualified labor force must be available to the desired company area. Otherwise the business will be crashed. Land or terrain is needed for setting up a warehouse.

3.4 AHP Methodology

Thomas L. Saaty developed the Analytical Hierarchy Process in 1980 which is an effective method for complex decision making. This method is highly used to set priorities of the alternatives, criteria, sub-criteria. AHP decides the inclinations among the arrangement of choices by utilizing pair-wise correlations of the chain of command components at all levels [41]. The following steps of the AHP methodology is explained as follows.

3.4.1 Identification of Problems, Criteria, Sub-Criteria, Alternatives and Objectives

Identification of problems, objectives, main criteria, sub-criteria, alternatives are set in order to making the hierarchy structure. An Analytical Hierarchy process describes all the issues related to our problem. Fig: 2 shows the hierarchy structure of location selection for cold storage decision making process.

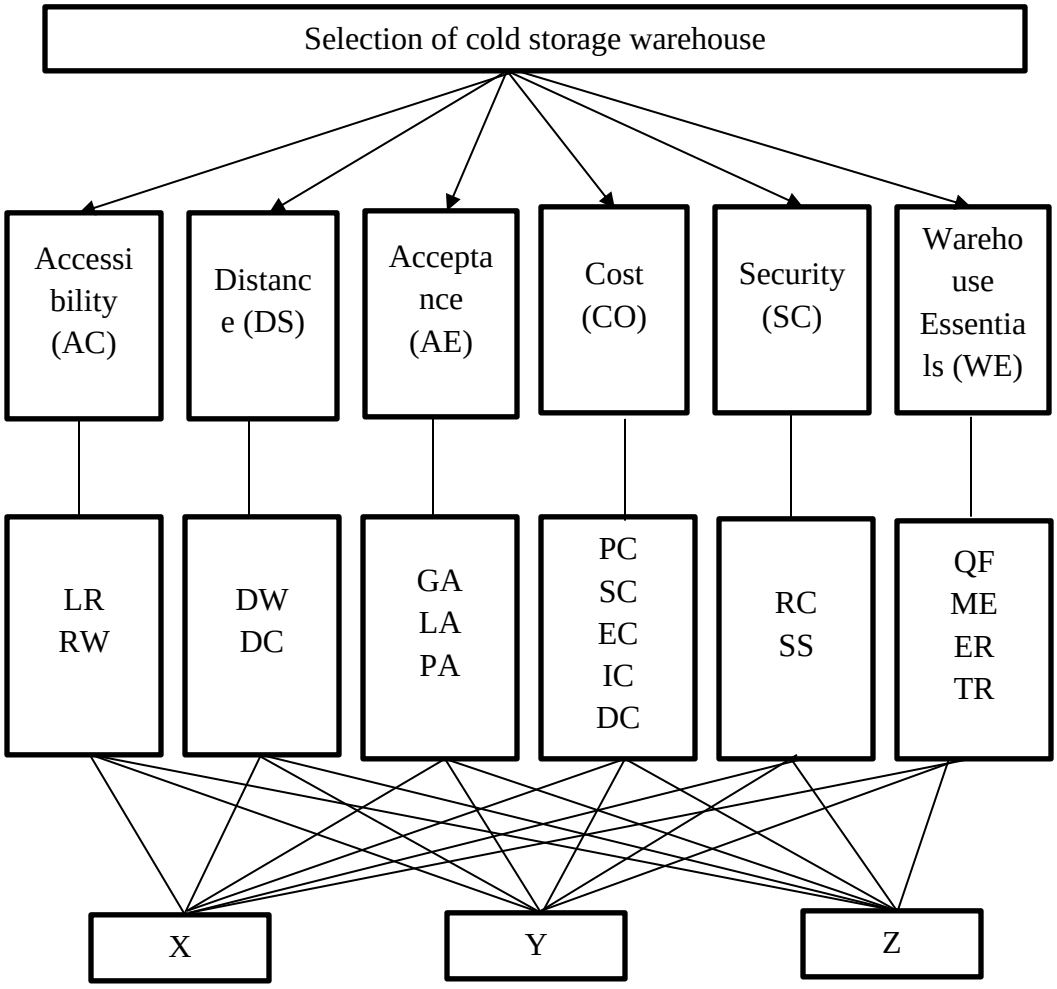

Figure 3.2: Hierarchy structure for cold storage selection.

Figure 3.4.1: describes about the various types of criteria and sub-criteria. It is more important for the investor to design a Hierarchy structure for their own business plan that

will evaluate the essential objectives to be initiated by the investor. Hierarchy model can describe huge information about any business plan. To set up a cold storage warehouse it is much more important for the investor to design a Hierarchy mod-el to evaluate the best alternatives. Identification of problem is also a major challenge for the business man. If someone willing to start a new business he/she must find out the recent problems of the customer.

3.4.2 Pairwise Comparison Matrix of Criteria

The AHP method creates a comparison matrix D (m × m real matrix) to calculate the various criteria weights by using 1-9 scales in AHP method (see Table 3.1). The matrix is given below:

$$D = \begin{bmatrix} d_{11} & d_{12} & d_{13} & \cdots & d_{1m} \\ d_{21} & d_{22} & d_{23} & \dots & d_{2m} \\ d_{31} & d_{32} & d_{33} & \dots & d_{3m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ d_{m1} & d_{m2} & d_{m3} & \dots & d_{mm} \end{bmatrix} \quad (1)$$

TABLE 3.1: AHP 1-9 SCALE

Value	Meaning	Description
1	Refers to same importance	When two elements are same while comparing or judgements.
3	Refers to moderate importance	Judgement tolerably select one component over another component
5	Strongly importance	If one element is given strong importance over other while comparing
7	Very strong importance	If one is chosen with very strong importance over other.
9	Absolute or extreme importance	When one element extremely dominates other.
2,4,6 and 8	Intermediate value	At the point when bargain is required between contiguous required decisions
1/2, 1/3, 1/4, 1/5,1/6, 1/7, 1/8, 1/9	Inverse comparison	They are placed in the transposed positions

In D_{ij}matrix, if d_{12} is given strong importance 5, then the d_{21} will be 1/5. In matrix D_{ij} where i defines the row number and j defines the column number. So, if importance is given to any element, then the inverse values are placed in D_{ji} position. For example, if absolute importance is given to d_{13} then the inverse value will be set to d_{31} position. If d_{32} position is set with a value 7 (very strong importance), then the corresponding transposed position of d_{23} will be set to 1/7 which defines the inverse value. When two criteria or attributes contribute equally, then they both set 1. If d_{13} is given 1, then the d_{31} must be 1. Beside this, equal importance (value 1) is set along to diagonal direction. d_{11}, d_{22} , d_{33} will be 1.

After creating the matrix D, the weights of each criteria (w_i) is calculated by applying the following rules –

1) Calculating the geometric mean of the i^{th} row.

$$GM_i = \left[\prod_{j=1}^{n} d_{ij}\right]^{1/n} \quad (2)$$

Where n=no of criteria. i=1, 2, …, m and j=1,2, …, n

2) The summation of geometric mean for all rows is represented as.

$$\sum_{i=1}^{m} GM_i \quad (3)$$

Where i denotes the row.

3) Then dividing GM_i by $\sum GM_i$ we obtain w_i

$$w_i = (GM_i) \Big/ \left(\sum_{i=1}^{m} GM_i\right) \quad (4)$$

Where i=1, 2… m. And thus, we can find the criteria weight.

3.4.3 Consistency Check

If the weights for criteria are not assigned properly, the consistency ratio will increase. The best ideal acceptable consistency ratio should be less than 0.10. To calculate the consistency ratio (CR), the following rules should be maintained.

1) Multiply criteria weights (w_i) matrix (named E) with the matrix D and thus a new matrix is created named F. So,

$$F = D \times E \tag{5}$$

Where, E refers to criteria weight matrix and D refers to pairwise comparison matrix

2) Dividing matrix F by criteria weight matrix E and the new matrix created is K. so

$$K = \frac{F}{E} \tag{6}$$

3) Finding the average of K matrix and the average of K matrix is defined as λ_{max}
4) Then calculating the consistency index (C.I) by maintaining the following rules.

$$C.I = \frac{\lambda_{max} - n}{n - 1} \tag{7}$$

5) At last, the consistency ratio is calculated by applying the following formula:

$$C.R = \frac{C.I}{R.I} \tag{8}$$

Where, C. I= Consistency Index, C. R=Consistency Ratio and R. I=Random Index.

C.R must be less than 0.10.

If C.R < 0.10 then we can go for next step.
If C.R < 0.10, the data is consistent.
If C.R ≥ 0.10, the data is inconsistent.
R.I for different values of n is defined in Table 3.2

TABLE 3.2: RANDOM INDEX LIST

Criteria no (n)	Random index (RI)	Criteria no (n)	Random index (RI)
1	0.00	9	1.45
2	0..00	10	1.49
3	0.52	11	1.52
4	0.89	12	1.54
5	1.11	13	1.56
6	1.25	14	1.58
7	1.35	15	1.59
8	1.40		

3.4.4 Finding Comparison Matrix of each Sub-Criteria

The comparison matrix for each sub-criterion is calculated and then calculating the weights of each sub-criteria.

3.4.5 Calculation of Global Weights

Global weight (GW_i) is calculated by multiplying the criteria weight and sub-criteria weight. So, Global weight (GW_i) = criteria weight × sub-criteria weight

3.4.6 Pairwise Comparison of Alternatives with respect to sub-criteria and to find the weights of alternatives

The pairwise comparison of the alternatives create matrix T (n × m) matrix. Where, m = no of sub-criteria and n = no of alternatives.

$$T = \begin{bmatrix} t_{11} & t_{12} & \dots & t_{1m} \\ t_{21} & t_{22} & \dots & t_{2m} \\ \vdots & \vdots & \dots & \vdots \\ t_{n1} & t_{n2} & \dots & t_{nm} \end{bmatrix} \quad (9)$$

3.4.7 Calculation of Priority Vector, V

So, V = global weight for sub-criteria × T matrix

If the global weight of each sub-criteria is defined as, $w_1, w_2, w_3, \dots w_m$

Then the matrix V is,

$$V = \begin{bmatrix} w_1 t_{11} & w_2 t_{12} & \dots & w_m t_{1m} \\ \vdots & \vdots & \dots & \vdots \\ w_n t_{n1} & w_n t_{n2} & \dots & w_n t_{nm} \end{bmatrix} \quad (10)$$

3.4.8 Overall Priority Calculation

Overall Priority is calculated by adding all the elements of **ith** row where i=1,2, 3…n

$$Alternative\ 1 = w_1 t_{11} + w_2 t_{12} + \cdots + w_m t_{1m} \quad (11)$$

For the other alternatives, the same rule is used and thus the overall priority of all alternatives is determined.

CHAPTER 4
NUMERICAL EXPERIMENT AND RESULT ANALYSIS

4.1 Introduction

This research focuses on the tremendous optimal solution for the perishable agricultural crops which are being rotten every year in Bangladesh. This paper emphasizes on the protection of the perishable agricultural crops. In recent times, Agricultural crops are getting damaged and rotten in some area of Bangladesh (Bogra, Kishoreganj, Rangpur) which is creating perturbation and menace among the farmers of these particular region which lead to a huge attenuation on the production sites. And another concerning issue is that the local market is diminishing because the prize is getting low. This paper focuses on these two problems. The farmers are trying to find out an optimal solution to prevent the agricultural products from being rotten. So, this paper is focusing to help them and to provide them the best methods and approaches by solving their problems. This research analyzed that to solve the agricultural food rotation problem, it is most necessary to set up a cold storage warehouse so that perishable agricultural foods do not get rotten. Moreover, the benefit of setting up cold storage is to preserve the perishable crops for a long time. The second problem is that the local market is not good enough to sell these products as their expectation rate. As a result, the farmers are being loosed because no profit by selling their crops. So, this paper provides the best solution to the farmers. It describes for selecting an industrial urban area so that they can earn a huge profit. This paper selects three different locations and they are-Cumilla, Narsingdi, and Laksham denoted as X, Y and Z. Among these three different locations the best alternatives are selected using the AHP model implemented through this research to set up cold storage warehouse. So, this research paper describes the tentative methodology implemented for the various site selection problems based on multi criteria decision making problems. And the method which is used to solve the farmers problems is Analytic Hierarchy Process which was developed by Thomas L.Saaty in 1980 for solving several decision related problems. So, the key purpose of this research work is to prevent the perishable foods from being rotten and to make the best investment on the farming site.

4.2 Numerical Experiment

Pairwise comparison matrix (D) for main criteria is created in order to calculating the weight or priority for each main criterion by using AHP method. Since there are six main criteria observed, the decision maker first takes into account the priority or weight. The decision makers analyzed that they should give the highest priority to criteria accessibility. According to their observation on market basis experimentation, they sorted the criteria weight as follows –

Accessibility (AC) > Security (SC) > Distance (DS) > Acceptance (AE) > Ware-house Essentials (EW) > Cost (CO)

Accessibility and security are much more important than cost. Beside that Distance and Acceptance both are important. The criteria weights are sorted according to the background detail analysis. Three suitable alternatives are selected by the decision makers. Table 4.1: describes Pairwise comparison made by using equation (1) for finding the criteria weight that describe the priority.

TABLE 4.1: PAIRWISE COMPARISON MATRIX(D) FOR CRITERIA

Attributes	DS	EW	AC	SC	CO	AE
DS	1	7	1/3	1/3	5	3
EW	1/7	1	1/9	1/7	3	1/3
AC	3	9	1	1	7	7
SC	3	7	1	1	7	9
CO	1/5	1/3	1/7	1/7	1	1/5
AE	1/3	3	1/9	1/9	5	1

Now the Geometric mean is calculated by using equation (2) and represented in Table 4.2: For instance, Distance (DS),

The Geometric Mean (GM) = $(1 \times 7 \times \frac{1}{3} \times \frac{1}{3} \times 5 \times 3)^{1/6}$

= 1.506

Similarly, for EW = 0.362, AC = 3.313, SC = 3.313, CO = 0.255, AE = 0.656

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TABLE 4.2: GEOMETRIC MEAN FOR ALL CRITERIA

Criteria	Geometric mean	Sum
DS	1.506	9.422
EW	0.362	
AC	3.313	
SC	3.313	
CO	0.255	
AE	0.656	

Criteria weight is obtained by dividing the geometric mean by the sum (using equation 4) shown in Table 4.3:

TABLE 4.3: CRITERIA WEIGHT MATRIX(E)

Criteria	Criteria weight (w_i)
DS	0.160
EW	0.038
AC	0.352
SC	0.352
CO	0.027
AE	0.070

Multiplying criteria weights matrix (E) with the pairwise comparison matrix (D), we obtain new matrix F using equation (5).

$$F = \begin{bmatrix} 1 & 7 & \frac{1}{3} & \frac{1}{3} & 5 & 3 \\ \frac{1}{7} & 1 & \frac{1}{9} & \frac{1}{7} & 3 & \frac{1}{3} \\ 3 & 9 & 1 & 1 & 7 & 7 \\ 3 & 7 & 1 & 1 & 7 & 9 \\ \frac{1}{5} & \frac{1}{3} & \frac{1}{7} & \frac{1}{7} & 1 & \frac{1}{5} \\ \frac{1}{3} & 3 & \frac{1}{7} & \frac{1}{9} & 5 & 1 \end{bmatrix} \times \begin{bmatrix} 0.160 \\ 0.038 \\ 0.352 \\ 0.352 \\ 0.027 \\ 0.070 \end{bmatrix} = \begin{bmatrix} 1.005432 \\ 0.254598 \\ 2.205 \\ 2.269 \\ 0.186326 \\ 0.461688 \end{bmatrix}$$

Now dividing the matrix F by criteria weight matrix (E), we obtain matrix K Using equation (6). So,

$$K = \begin{bmatrix} 1.005432 \\ 0.254598 \\ 2.205 \\ 2.269 \\ 0.186326 \\ 0.461688 \end{bmatrix} \Big/ \begin{bmatrix} 0.160 \\ 0.038 \\ 0.352 \\ 0.352 \\ 0.027 \\ 0.070 \end{bmatrix} = \begin{bmatrix} 6.28395 \\ 6.69994 \\ 6.26420 \\ 6.44602 \\ 6.90096 \\ 6.59554 \end{bmatrix}$$

Now finding the average of K matrix which is known as $\boldsymbol{\lambda_{max}}$.

So, $\boldsymbol{\lambda_{max}}$ =(6.28395 + 6.69994 + 6.26420 + 6.44602 + 6.90096 + 6.59554)/6=6.5318

Now, consistency index and Ratio is obtained using equation (7) and (8).

Now, Consistency Index (C.I) = $\frac{\boldsymbol{\lambda_{max}} - \boldsymbol{n}}{n-1} = \frac{6.5318-6}{6-1}$ = 0.10636

So , Consistency Ratio (C.R) = $\frac{Consistency\ Index\ (C.I)}{Random\ Index\ (R.I)} = \frac{0.10636}{1.25}$ = 0.08

So, C. R= 0.08 and C. R<0.10

Consistency Ratio is 0.08 that means criteria weights are correct to work.

All the global and local weights of both the main-criteria and sub-criteria are summarized in Table 4.4.

Global weights are calculated in Table 7 by using below equation:

Global weight $(GW_i) = criteria\ weight\ \times\ sub\ criteria\ weight$

TABLE 4.4: LOCAL AND GLOBAL WEIGHTS FOR CRITERIA AND SUB-CRITERIA

Criteria (weight)	Sub-criteria	Local weight	Global weight	Criteria (weight)	Sub-criteria	Local weight	Global weight
AC	LR	0.667	0.235	CO	PC	0.265	0.007
	RW	0.333	0.117		SC	0.412	0.011
DS	DW	0.167	0.027		EC	0.045	0.001
	DC	0.833	0.133		IC	0.035	0.001
AE	GA	0.073	0.005		DC	0.243	0.007
	LA	0.835	0.058	EW	QF	0.060	0.002
	PA	0.092	0.006		ME	0.360	0.014
SC	RC	0.578	0.203		ER	0.356	0.014
	SS	0.422	0.149		TR	0.224	0.009

Global weights are necessary for the calculation of overall priority. Global weight is

Consisted with the multiplication of local Weight of sub-criteria and main criteria Weight. Pairwise comparison of alternatives for sub-criteria is shown in Table 4.5:

TABLE 4.5: PAIRWISE COMPARISON OF ALTERNATIVES FOR LAND ROUTE(LR)

	X	Y	Z	Weight
X	1	6	3	0.678
Y	1/6	1	1	0.142
Z	1/3	1	1	0.179

Similarly weights for alternatives for all sub-criteria and total summary is obtained in Table 4.6. Using table 4.4 and 4.5 the total summary is evaluated in Table 4.6

TABLE 4.6: SUMMARY OF SITE SELECTION USING AHP

Sub attribute	GW_i	X	Y	Z	Sub attribute	GW_i	X	Y	Z
LR	0.235	0.678	0.142	0.179	EC	0.001	0.445	0.382	0.173
RW	0.117	0.726	0.172	0.102	IC	0.001	0.416	0.458	0.126
DW	0.027	0.528	0.333	0.14	DC	0.007	0.410	0.460	0.13
DC	0.133	0.275	0.128	0.597	RC	0.203	0.165	0.372	0.463
GA	0.005	0.165	0.290	0.545	SS	0.149	0.265	0.527	0.208
LA	0.058	0.709	0.06	0.231	QF	0.002	0.377	0.464	0.159
PA	0.006	0.712	0.03	0.258	ME	0.014	0.582	0.239	0.179
PC	0.007	0.584	0.184	0.232	ER	0.014	0.154	0.566	0.28
SC	0.011	0.25	0.684	0.066	TR	0.009	0.664	0.120	0.216

Now the overall priority is calculated using the equation (11).

So, X = 0.442

Similarly, Y = 0.265 and Z = 0.292

4.3 Result Analysis

On this research the Decision makers obtain a result that shows that Alternative (X) has the highest AHP score 0.442. The second position takes place by Alternative (Z) having score 0.292 and the third position takes place by Alternative(Y) having score 0.265. So, Cumilla > Laksham > Narsingdi. A graphical representation is simulated based on the AHP score and Benchmark score in Figure 4.1.

Figure 4.1: Graphical overview for site selection scores

Figure 4.1 summarizes the scoring of both Analytic Hierarchy Process and Benchmark result. AHP system obtained “Cumilla “as the best optimal location to select to set up cold storage warehouse. Besides that, the Benchmark result shows that “Cumilla” is the best location to choose for setting up cold storage warehouse. So, this research is now able to select the best location and thus it now will be able to solve the farmers problems. Table 4.7 finalizes the scores for both AHP and Benchmark.

TABLE 4.7: FINAL VALUE OBTAINED USING AHP

Warehouse site selection final score				
Alternatives	Priority (AHP Score)	Priority (Benchmark Score)	AHP Rank	Benchmark Rank
X	0.442	0.432	1	1
Y	0.265	0.274	3	3
Z	0.292	0.287	2	2

CHAPTER 5
CONCLUSION AND FUTURE WORKS

5.1 Conclusion

To find the optimistic solution in any decision related problems, scientific information is most necessary as well as different parameters. Lack of the information on the attributes, sub-attributes and alternatives may cause failure on decision making. Without proper knowledge on different parameters, any business can crack down. However, this paper shows the best way for making decision on any field. It applies the AHP methodology for selecting the best alternatives. A Benchmark result is also obtained in order to compare with the main score calculated by AHP method. This research has now come to a situation that it has the capability to handle any decision related problem. This work makes a sequence of rank of AHP scores for all alternatives and according to this rank of score the optimal alternative is selected by the decision maker. AHP provides the best process to select the optimal solution. Three different location was selected by the decision makers and finally among these three locations only one best optimal location is selected by using the AHP approach. The three location or alternative were Cumilla, Narsingdi and Laksham. And the final optimal location selected to set up cold storage warehouse is “Cumilla”. So,this work has come to a solution that the best alternative for setting up cold storage warehouse is “Cumilla” having the highest AHP score . However, this work defines the substantive and tangible scenario of selecting the best optimal alternatives as well as handling the multi criteria decision related problems using Analytic Hierarchy Process narrated before.

5.2 Future Works

This research has extracted the optimal alternative using AHP methods. For the multi-criteria decision problems, AHP method will be using extensively in future by the decision makers as this paper describes how to implement the Analytic Hierarchy Process (AHP) for making decision under a problem. This paper helps the farmers, the investors, and the entrepreneur a lot to take decision to any problem. So, this research provides continuous knowledge to those people who wants to work with this research. This paper creates an opportunity for future works for the decision makers by creating a scope of the solution. It also ensures that in future people can make and handle any complex decision applying extended multi criteria decision making tools. This work also emphasizes about developing an extended version of MCDM solving tool which will help people extremely while taking decision as well as to achieve the sustainable goal.

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