Czech University of Life Sciences Prague

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Diploma Thesis

Deciding which West African country to build automobile plant using Multi criteria Decision Making.

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DIPLOMA THESIS ASSIGNMENT

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Deciding which West African country to build automobile plant Using Multi Criteria Decision Making

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Objectives of thesis

The aim of the thesis is to select the most suitable Country from West Africa for siting Automobile plant Using method of multicriteria analysis of variant.
Four countries within the sub region will be compared, and the most suitable country will be recommended to the stakeholders, and it will be according to the identified preferences and requirements.

Methodology

The theoretical part of the thesis will explain the basic concept and methods of multi-criteria decision making, including those linked to the field of automobile production and management.

The practical part of the work will then focus on determining the criteria and their weights according to basic requirements in setting up production firm, choosing a suitable multi-criteria decision-making method, applying the chosen method to the collected data.

The proposed extent of the thesis

50-60 pages

Keywords

multi-criterial decision-making, multiple attribute analysis, criteria weights, automobile production plant

Recommended information sources

Mu, E. and Pereyra-Rojas, M. (2017)," Practical Decision Making: An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions V2", Springer Cham, ISBN 978-3-319-33860-6

Munier, N. (2011), "A Strategy for Using Multicriteria Analysis in Decision-Making A Guide for Simple and Complex Environmental Projects", Springer Dordrecht, ISBN 978-94-017-8442-9

Olson, D. L. (1996), "Decision Aids for Selection Problems", Springer New York, NY, ISBN 978-0-387-94560-6

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Declaration

I declare that I have worked on my diploma thesis titled "Deciding which west African country to build automobile plant using Multi Criteria Decision Making" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 15Th. March 2023 ______________________________

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Deciding which West African country to build automobile plant using Multi criteria Decision Making

Abstract

West Africa has a very minor presence in the global automotive industry, and many of its small national markets are mostly supplied by importers of used automobiles, with Ghana, Nigeria, and a few other West African nations having small-scale assembly and component manufacture.

Due to the rapidly expanding middle class and rising demand for automobiles, the market is expanding significantly. Encouraging car manufacturing giants to partner with West African governments to construct automobile production and assembling units may result in market expansion and the attraction of both domestic and foreign investment.

Also, the outlook for the automobile manufacturing industry is improved by African governments' resolve to restrict the entry of used and outdated vehicles.

This study seeks to examine which of the West African countries has the highest demand for cars and best business environment.

This is achieved using the Analytical Hierarchy procedure (AHP) and Simple Additive Weighting of Multi Criteria Decision Making methods.

AHP was used in determining the criteria weight of the selected criteria while Simple Additive Weighting was used to rank the variant. Four countries were considered, Cote D'Ivoire, Ghana, Nigeria and Senegal with Ghana immerging as economically viable country in west Africa for citing automobile plant.

Ghana emerges as the best country with overall priority rating of 0.531 followed by Nigeria with 0.506, Cote D'Ivoire with 0.404 and Senegal with 0.351

Keywords: Multi Criteria Decision Making, Multi Attribute Analysis, Criteria Weight, Automobile production plant.

Rozhodování o tom, která západoafrická země postaví automobilový závod pomocí multikriteriálního rozhodování

Abstrakt

Západní Afrika má v globálním automobilovém průmyslu velmi malé zastoupení a mnoho z jejích malých národních trhů je většinou zásobováno dovozci ojetých automobilů, přičemž Ghana, Nigérie a několik dalších západoafrických zemí má montáž a výrobu komponent v malém měřítku. Díky rychle se rozvíjející střední třídě a rostoucí poptávce po automobilech se trh výrazně rozšiřuje. Povzbuzování gigantů vyrábějících automobily, aby se spojili se západoafrickými vládami při výstavbě výroby automobilů a montážních jednotek, může vést k expanzi trhu a přilákání domácích i zahraničních investic.

Vyhlídky pro automobilový průmysl také zlepšuje odhodlání afrických vlád omezit vstup ojetých a zastaralých vozidel. Tato studie se snaží prozkoumat, která ze západoafrických zemí má nejvyšší poptávku po autech a nejlepší podnikatelské prostředí.

Toho je dosaženo pomocí postupu analytické hierarchie (AHP) a metod Simple Additive Weighting of Multi Criteria Decision Making. AHP bylo použito pro stanovení váhy kritérií vybraných kritérií, zatímco Simple Additive Weighting bylo použito pro hodnocení varianty. Byly zvažovány čtyři země, Pobřeží slonoviny, Ghana, Nigérie a Senegal, přičemž Ghana se ponořila jako ekonomicky životaschopná země v západní Africe pro uvedení automobilového závodu. Ghana se ukazuje jako nejlepší země s celkovým hodnocením priority 0,531, následuje Nigérie s 0,506, Pobřeží slonoviny s 0,404 a Senegal s 0,351

Klíčová slova: Rozhodování podle více kritérií, analýza více atributů, hmotnost kritérií, závod na výrobu automobilů.

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LIST OF ABBREVIATIONS

MCDM	Multi criteria decision Making.
MODM	Multi Objective Decision Making.
MADM	Multi Attribute Decision Making
ANP	Analytical Network Problem
AHP	Analytical Hierarchy Procedure
SAW	Simple Additive weighting.
MCMP	Multi Criteria Mathematical Programing
WSM	Weighted Sum Model
WPM	Weighted Product Model
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
ELECTRE	Elimination and Choice Expressing Reality
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
NIS	Negative Ideal Solution
PIS	Positive Ideal Solution
VOP	Vector Optimization Problem
DEA	Data Envelopment Analysis
CI	Consistency Index
CR	Consistency Ratio
RI	Random Index
GDP	Gross Domestic Product
MW	Minimum Wage
IR	Inflation Rate
PT	Profit Tax
CPI	Corruption Perception Index
UR	Unemployment Rate
DE	Demographic Estimate
TRRP	Time Required to Register Property
HDI	Human Development Index
HCI	Human Capital Index

CHAPTER ONE

INTRODUCTION

The global economy benefits greatly from the Automobile sector, both upstream and downstream. It has connections to a wide range of sectors and industries. A wide range of companies and organizations are involved in the conception, creation, production, promotion, and sale of motor vehicles. Forward ties in marketing, shipping, insurance, and services are all quite strong. It is consequently considered to be essential to economic development because of its strong links and large contribution to the overall consumption of a few chosen inputs. Due to the sector's enormous and widespread ties, many African country governments who want to industrialize their countries swiftly consider the automobile industry as one of the best methods to do it. As a result, these governments have given the business sector particular support. Building local manufacturing or assembly capability for vehicles has been attempted on numerous occasions. Unfortunately, not all these countries are appealing for investment due to the high expenditures involved in purchasing real estate and constructing facilities. Choosing the location of the facility thus turns into a long-term investment decision. Given the size of the sector and the continued interest of African governments, this study's goal is to identify the economically viable country in west Africa for automobile business and to propose to automobile investors the investment opportunities in West Africa. The decision of where to locate a factory has a substantial strategic impact on the firm's competitiveness, flexibility, and timeliness because location selection typically entails a long-term commitment of resources and demands a significant amount of investment. The success of the business strategic plans for production objectives, marketing, financing, and human resources must thus be influenced by the final decision regarding the site of a plant. The decision to locate a plant is an example of a multiple criteria decision-making (MCDM) problem, in which there are conflicting possibilities and several opposing criteria. It might not be possible to choose the best option from a small number of possibilities while satisfying all the requirements (attributes). In such cases, MCDM techniques deliver a successful resolution to the issue. Decision-makers use the MCDM techniques as crucial tools to select the optimal alternative after weighing a variety of competing and frequently incompatible criteria.

CHAPTER TWO

OBJECTIVE AND METHODOLOGY

2.1 Objectives

The aim of the thesis is to select the most suitable Country from West Africa for siting Automobile plant Using Multi Criteria Decision Making. It is an international location selection problem**.** Four countries within the sub region will be compared, and the most suitable country will be recommended to potential investors, and it will be according to the identified preferences and requirements.

Thesis goals is:

I. to determine the economically viable country for automobile business.

II. to locate the best automobile investment destination in West Africa to demonstrate the applicability of Analytical Hierarchy Procedure of MCDM Methods.

2.2 Methodology

The study is organized in two parts, the theoretical part, and the practical part.

The theoretical part brings out the goals, methodology, and introduces the study, pointing out why the study is important. Literature on similar study is also reviewed to achieve the objective of the study stated above. Here, Multi Criteria Decision Making and Multicriteria Decision Making Methods are reviewed with emphasis on Analytical Hierarchy procedure (AHP) and Simple Additive weighting methods. Literature on automobile industries is also reviewed bringing out general ideas where it is beneficial to build an automobile industry, which economic, political, social, infrastructural, and environmental conditions are beneficial. This forms the basis for formulation of the decision criteria in the practical part. The Practical part of the study begins with the description of the decision problem.

The criteria used, the units and who defines them are brought to light in the practical part.

The research employed secondary data. Secondary data collection is made possible by resources like countryeconomy.com, OECD.org, and the World Bank database.

While SAW was used to rate the variant, AHP was utilized to determine the weight of the chosen criteria. In determining the criteria weight, a pairwise comparative matrix was developed where weight was assigned to each criterion using the Saaty's Nine-point scale. The study ended with the results, discussion, conclusions, and recommendations.

CHAPTER 3
LITERATURE REVIEW

3.0 Facility location Decision

Making decisions about where to build and assemble cars is a crucial part of any automobile industry's strategic and logistical decision-making. The best location might provide a competitive edge and might help the industry succeed. Businesses are increasingly exploring locations across the globe (Flaherty, 1996). The choice of a company to locate production facilities abroad may be influenced by a very broad variety of factors. For more than a century, the study literature has focused a lot of emphasis on the important factors that determine where to locate automotive industrial plants (Jungthirapanich and Benjamin, 1995). The major objective of the section that follows is to help readers understand the factors that motivate and affect opinions on foreign countries. It also describes the principles of the criteria used to select one place from among several alternatives.

3.1 Factors that influence international facility location decisions.

In the literature, several strategies have been recommended to assist with choosing an international location when it comes to siting production plant abroad (Brandeau and chiu, 1989). Hoffman and Schniederjans (Hoffman and Schniederjans, 1994), Cancel and Khumawala (Cancel and Khumawala,1996), Jungthirapanich and Benjamin (Jungthirapanich and Benjamin, 1996), Badri (Badri et al. 1995). They presented an overview of research works on general industrial location considerations carried out between 1875 and 1990, organized chronologically. They demonstrated that whereas corporations previously frequently only took a few quantitative elements, such as labor and transportation costs, into account, it has recently been clear that a wide variety of both qualitative and quantitative aspects have become evident. While choosing a foreign location, many factors must be taken into consideration, including potential trade-offs between different costs. Qualitative factors including economic, social milieu, and political climate also have an impact on many international site decisions. political factors (Badri et al. 1995). They claimed that when businesses opt to conduct business abroad, global competition and economic-related considerations are more significant than customary location characteristics like transportation costs and climate. The host governments of different countries may affect or control several variables, including financial incentives and taxation. Over time, the relative importance of the various components could alter dramatically (Epping, 1982). Several classifications and considerations of location elements can be made (Lee and Franz, 1979), (Epping, 1982) (Sule, 1994), (Evans et al., 1990), (Nahmias, 1993). To develop a comprehensive collection of factors and sub-factors that may be significant to decisions about where to locate an organization such as Automobile production plant abroad, a thorough analysis of the literature was conducted (Atthirawong and MacCarthy, 2000), (MacCarthy and Atthirawong, 2001). Table 3.1 provides a summary of these elements. 13 significant factors have been noted. There are several distinct sub-factors discovered for each major factor. This table of determinants and sub-considerations comprises operational, strategic, economic, political, social, and cultural elements as well as quantitative and qualitative factors that are crucial to site decisions (MacCarthy and Atthirawong, 2003). It is important to remember that the factors affecting international location decisions depend on the sector and market type.

Major factors	**Sub-factors**
Costs	Fixed costs, transportation costs, wage rates and trends in wages, energy costs, other manufacturing costs, land cost, construction/leasing costs and other factors.
Labour characteristics	Quality of labour force, availability of labour force, unemployment rate, labour unions, attitudes towards work and labour turnover, motivation of workers and work force management
Infrastructure	Presence of transportation modes (airports, trains, highways, and seaports), as well as the calibre and dependability of utilities (such as water supply, waste treatment, power supply, and telecommunications networks) and means of transportation
Proximity to suppliers	The nature of the supply process (the system's dependability), other suppliers, supplier rivalry, the standard of the providers, and the responsiveness and speed of the suppliers
Proximity to markets/customers	Demand proximity, market size and potential customer expenditure, market responsiveness and delivery times, demographic trends, and the type and variability of demand
Proximity to parent company’s facilities	Close to parent company
Proximity to competition	Location of competitors

Quality of life	Climate, schools, churches, hospitals, recreational options for staff and children, the quality of the environment, community attitudes toward commerce and industry, the education system, and the crime and level of living
Legal and regulatory framework	Laws governing compensation, insurance, the environment, labor relations, the legal system, red tape, requirements for forming local firms, rules governing mergers and joint ventures, and laws governing the export of earnings
Economic factors	Financial incentives, customs charges, tariffs, inflation, the strength of the currency relative to the US dollar, the business environment, the country's debt, interest rates/exchange controls, GDP/GNP growth, and income per capita
Government and political factors	Governmental stability, organizational history, continuity of policy, and stance toward foreign direct investment
Cultural and social aspects	Diverse cultural norms and conventions, languages, and consumer traits
Features of a particular place	Physical conditions (such as weather, proximity to other businesses, parking, appearance, accessibility by consumers, etc.), closeness to raw materials/resources, quality of raw materials/resources, and location of suppliers are all important factors to consider.

Table 3.1 Summary of factors that influence international location selection. (MacCarthy and Atthirawong, 2003)

It is important to remember that the factors affecting international location decisions depend on the sector and market type.

3.2 Mathematical Methods.

Both the global financial crisis and the level of market rivalry have significantly increased. Owners of vehicle businesses have been compelled by this to review their processes to become more responsive, adaptable, and efficient. In this situation, applying mathematical techniques to the solution of strategic choice problems may show to be a crucial step in achieving these goals. one of the mathematical methods used to support decision-making which has proven to be effective is Multi Criteria Decision Making (MCDM). It is a subfield of operation research that deals with issues involving the most prevalent type of decision-making and multiple selection criteria (Triantaphyllou et al, 1998).

3.2.1 MCDM

MCDM is a formal quantitative approach to assist in decision-making. It deals with problems involving numerous selection criteria and most common sort of decision making (Triantaphyllou et al, 1998). MCDM approach to decision-making is normative and involves a single decision-maker and several criteria. Its objective is to consider the decision-maker's perspective on the complex situation. Since there is too much information in a multi-criteria problem for a human to process, it is necessary to build a mathematical model to accomplish that. The best way to accomplish this is to let the decision-maker concentrate on more manageable aspects of the issue. The decision maker's method of approaching the multi-criteria problem is known as decision maker specific data. (Keyser and Springael, 2010).

The fundamental driving force for the establishment of MCDM is the recognition that human judgment can be constrained, skewed, and subject to prejudice, particularly when dealing with issues that call for processing and analysing vast amounts of complicated information (Dodgson et al. 2000).

Researchers began devoting their time to creating MCDM methodologies and approaches in the 1960s. This was done to get around the constraints placed on human judgment. Because to its importance, MCDM developed swiftly and became a thriving research area in the 1970s.

The proposed strategies aimed to improve the organization, transparency, and effectiveness of the decision-making process. In addition to MCDM being used to solve real-world problems, MCDM also helps decision-makers feel more confident in their choices. It aids people in arriving at a decision that is consistent with their preferences and guiding principles.

The application of such methodologies to real-world scenarios may prove to be a challenging and time-consuming undertaking due to the interactive and iterative character of the MCDA process, which demands a major effort from both analysts and decision makers. Hence, MCDM is better suited to supporting issues that are complicated and may have long-term effects (Brito et al., 2010). The decision maker is viewed as the person who is responsible for the decision and analysts as those who assist and guide the decision makers throughout the process of arriving at a satisfactory decision (Belton and Stewart, 2002).

A decision maker is provided a cogent overall view of the problem by using the problem-solving process known as MCDM to organize and synthesize the information related to a particular decision problem. When there is multiple, complex, incommensurable, and frequently conflicting objectives (e.g., maximize quality and minimize costs), measured in terms of various evaluation criteria, MCDM methods help decision maker (DM) in the process of choosing the most preferred action from a set of possible alternative actions.

Since none of the alternatives often performs well for all objectives, the alternative actions are distinguished by how well they achieve the objectives (Dodgson et al., 2000). Depending on the type of MCDM problem at hand, the options can either be explicitly known or implicitly derived through solving a mathematical model. (Lu et al., 2007).

The DM ranks the criteria according to their perceived relevance before taking them all into account while evaluating the options. Criteria are performance metrics (qualitative or quantitative), often known as attributes or objectives.

MCDA procedures inevitably result in more effective and well-informed judgments since they openly evaluate the performance of various alternative actions based on the fusion of quantitative measurement with subjective value judgment. The purpose of MCDA is not to dictate the "optimal" course of action, but rather to assist decision-makers in choosing one option—or a small number of excellent options—that best meets their requirements, is consistent with their preferences, and advances their understanding of the issue at hand (Brito et al., 2010). Most of the time, the preferred option is the best.

Choosing a compromise solution over the best one. Researchers' opinions, like those of (Belton & Stewart, 2002), (Seydel, 2006), and (Dooley et al. 2009), concur that MCDM encourages learning and greater understanding of the viewpoints of the DM themselves and of the other remaining important actors in the decision-making process.

The most effective way to learn and grasp the issue at hand is to encourage introspection, idea sharing, and conversation about it.

This inadvertently increases decision-making transparency and could speed the formation of agreement. MCDM can therefore be used as a tool to record, support, and defend judgments. The advantages of MCDM approaches in assisting decision making are reflected in both the academic focus given to the topic of MCDM and the implementation of its methods in real-world choice problems.

3.2.2 MCDM Classification

multi-attribute decision-making (MADM), which is comparatively more common, and multi-objective decision-making (MODM) are two categories into which multi-criteria decision-making can be classified, according to numerous writers. Difficulties with MODM can be broadly categorized as "mathematical programming problems," whereas problems with MADM are "selection problems." Choosing the best option from a limited number of predetermined options is the foundation of MADM. The term multiple criteria approach for finite options may also be used to describe it. A pay-off table is a common way to visualize MADM.

MODM issues based on developing an alternative when there are a lot of options and not all of them are pre-set. The MODM problem, also known as the multiple criteria mathematical programming (MCMP) problem or a vector optimization problem, is used to determine the optimum option in an MCMP. (Abu, 2009)

3.2.2.1 Multi Objective Decision-Making

Multi Objective Decision-Making (MODM) Problem deal with decision problems in which the decision space is continuous (Triantaphyllou et al., 1998). Because of this, a multi-objective decision-making problem typically presupposes that the decision-maker should choose an option from an infinite list that includes decision variables, restrictions, and an objective function. Alternatives for deciding are not disclosed or predetermined.

MODM problem is about using mathematical programming to discover the best solution. Once an alternative has been identified, it is determined whether the alternative comes near to achieving the goal.

In MODM, many of the algorithms, non-linear mathematical programming problems, and multiple objective linear integer problems are used to formulate the problems (Dyer et al;1992).

Finding the optimum solution, which can encompass and accomplish several objective functions at once, is the main goal of MODM, which focuses on continuous decision space. Different interactions within the limitations must meet the required thresholds of quantifiable goals to determine the optimum solution. Due to the deterministic nature of the model's data, it is unable to assist the decision-maker in dealing with ambiguities, uncertainties, and ambiguity. The fuzzy technique in this situation enables the decision-maker to incorporate unquantifiable data, partial information, unattainable information, and some uninformed facts into the decision model. (2008) Kahraman

A few typical mathematical programming techniques that can be used in the selection of a facility's site include dynamic programming, linear programming, goal programming, the shortest-route problem, the minimal spanning tree problem, the transportation problem, the assignment problem, and goal programming. (Schniederjans 2000).

3.2.2.2 Multi Attribute Decision Making

Multi Attribute Decision Making Problem MADM is a well-known branch of decision-making. In contrast to MODM problems, which determine the best course of action by weighing the trade-offs within a set of limitations, MADM problems determine the best course of action by weighing a variety of frequently at odds factors (Kahraman, 2008). With a limited number of alternatives that are explicitly known at the outset of the process, discrete decision space problems are the focus of MADM (Triantaphyllou et al., 1998). Both quantitative and qualitative features are taken into consideration for several MADM concerns.

In many cases, only human judgment—which is susceptible to error—can be used to evaluate the qualitative traits (Guo et. al., 2009). To solve a MADM, sorting and ranking are necessary. Using MADM techniques, input from the decision maker and the information from the problem-solving matrix can be combined to create a final ranking, sorting, screening, and selection among several possibilities. (Kahraman, 2008). MADM problem can be easily expressed in matrix/table format. A decision matrix A is an (M × N) matrix in which element a_{ij} indicates the performance of alternative A_i when it is evaluated in terms of decision criterion C_j, (for i = 1,2, 3..., M, and j = 1,2, 3, N). Additionally, it is expected that the decision-maker has chosen the relative performance weights for the choice criterion. alternatives (denoted as W_j, for j = 1,2, 3..., N). These weights are often normalized so that their sum equals one($\sum_{j=1}^{n}$ wj= 1). (Triantaphyllou, 1991). Figure 3.1 Shows the summary of this information. A benefit or a cost might be represented by the criterion. A benefit criterion should be maximized, meaning that the higher an alternative score in relation to this criterion, the better the alternative is, on the other hand, lower values are preferred for cost criterion (Ceballos et al., 2016).

$$A = \begin{bmatrix} & C_1 & C_2 & C_3 & C_4 & . & . & CM \\ & (W1) & (W1) & (W3) & (W4) & . & . & (Wm) \\ A_1 & a_{11} & a_{12} & a_{13} & a_{14} & . & . & a_{1N} \\ A_2 & a_{21} & a_{22} & a_{23} & a_{24} & . & . & a_{2N} \\ A_3 & a_{31} & a_{32} & a_{33} & a_{34} & . & . & a_{3N} \\ . & . & . & . & . & . & . & \\ . & . & . & . & . & . & . & \\ A_N & a_{M1} & a_{M2} & a_{M3} & a_{M4} & . & . & a_{MN} \end{bmatrix}$$

Fig 3.1 Typical decision matrix Sources: (E. Triantaphyllou,1998)

A = Decision matrix

A_i = alternatives, (for i = 1, 2, ..., N),

C_j = attributes, (for j = 1, 2, ..., M),

w_j = weights of attributes, (for j = 1, 2, ..., M) and

x_{ij} = measures of performance of alternatives, (for i = 1, 2, ..., N; j = 1, 2, ..., M).

It may be necessary to normalize the table to compare all types of attributes. (Rao, 2007)

3.2.2.3 Classification of Multi Attribute Decision Making

There are numerous options for categorizing MADM approaches, and they can be categorized based on the data they employ. They can be a mix of deterministic, stochastic, fuzzy, or fuzzy MADM approaches. The number of decision-makers involved in the decision-making process is the basis for another classification method. For instance, the WSM, AHP, improved AHP, WPM, and TOPSIS procedures are single decision maker deterministic MADM techniques.

A thorough analysis of multiple attribute decision-making techniques and applications was published by Hwang and Yoon. Evaluation difficulties and design problems are two sorts of issues that are typical in project management, such as siting automobile industry, and which are best matched by MCDM models. (Steuer, 2003). The evaluation of discretely defined alternatives and potential choices between them are at the heart of the evaluation problem. Finding a preferable alternative from a group of possibly infinite alternatives that are implicitly defined by several constraints is the focus of the design issue (Al. Harbi,2001). (Hwang and Yoon,1981) provided 14 MADM approaches in their book, and

(Kahraman ,2008) added five additional ways in his book. Those are Dominance Method, maximin Method, Maximax Method, Minimax (Regret) Method, Conjunctive (Satisfying) Method, Compromise Programming, Disjunctive Method, Lexicographic Method, Lexicographic Semi-order Method, Elimination by Aspects, Linear Assignment Method, Simple Additive Weighting (SAW) Method, Weighted Product Method, Non-traditional Capital Investment Criteria, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), Distance from Target, Analytic Hierarchy Process (AHP), Outranking Methods (ELECTRE, PROMETHEE, ORESTE), Multiple Attribute Utility Models, Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Multi Attribute Fuzzy Integrals.

3.3 Multi Criteria Decision Making Methods

With the continual development of these strategies and their modifications, it is essential to understand the relative usefulness of decision procedures. Each strategy employs numerical methods to help decision-makers choose from a constrained set of viable possibilities. This is done by thinking about how the options would impact a specific criterion and, consequently, how helpful the decision-makers would be overall.

Multi-dimensional approaches have drawn criticism, although some of them are still frequently utilized. The earliest and arguably most used method is the weighted sum model (WSM). The weighted product model (WPM), which has been proposed to address some of the WSM's shortcomings, can be seen as a variant of the WSM. In a subsequent development, the analytic hierarchy process (AHP), which has lately gained popularity was proposed (Saaty, 1980, 1983, 1990, and 1994). The AHP was modified by Professors Belton and Gear (Belton and Gear, 1983), and this change seems to be more effective than the original strategy. Other commonly used techniques include TOPSIS (Hwang and Yoon, 1981) and ELECTRE (Benayoun, et al., 1966). These techniques are given in greater detail in the subsequent subsection.

The figure shown in Fig 3.2 represents hierarchical picture of MCDM approaches and its types.

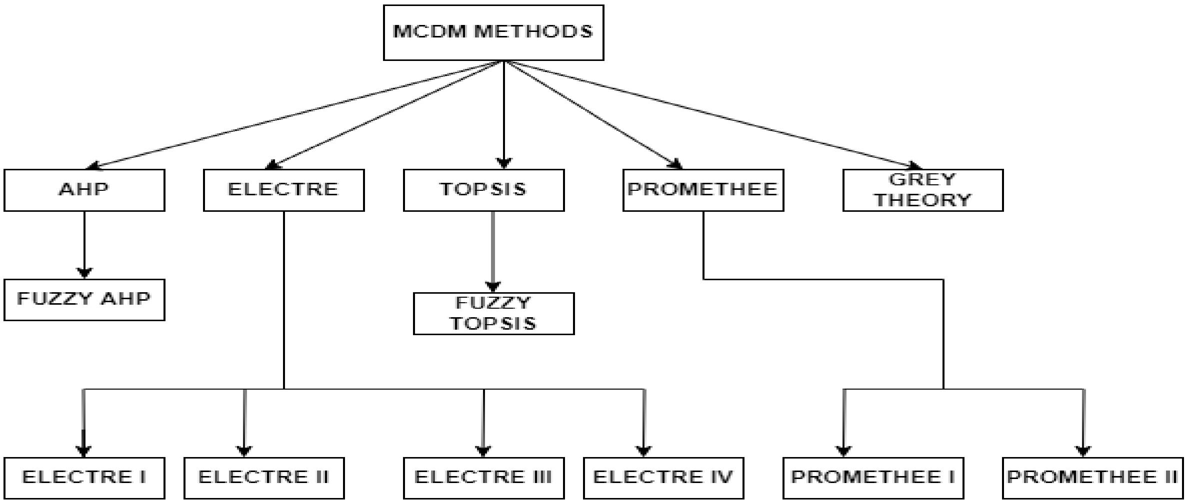

Fig 3.2 The hierarchical picture of MCDM approaches Sources: (Aruldoss et al. 1988).

3.3.1 AHP

AHP's main goal is to record specialists' knowledge about the phenomena being investigated. For the alternative selection and justification problem, a systematic approach is used, drawing on the ideas of fuzzy set theory and hierarchical structure analysis. Decision-makers typically find that giving interval judgments rather than fixed value judgments gives them more confidence. This approach can be used when a user preference is ambiguous and not expressly stated. AHP comprises expert opinions and a multi-criteria evaluation; it is unable to capture the hazy ideas of a human being. The fuzzy set theory makes the comparison process more adaptable and capable of elucidating experts' preferences because the traditional AHP only considers the precise judgements of decision makers. The Analytic Hierarchy Process is used to break down a difficult MCDM challenge into a methodical hierarchy technique (Buttle, 2002). The final stage of the AHP technique deals with the structure of a m*n matrix, where m is the number of options and n is the number of criteria. The relative relevance of the options is used to generate a matrix that considers each criterion. The Analytic Hierarchy Process is built on the principles of priority theory (AHP). It handles with complex challenges that call for simultaneously assessing several factors and options.

3.3.2 Fuzzy AHP

In typical market surveys, etc., the Fuzzification of Analytic Hierarchy Process (Fuzzy AHP) is applied. Through pairwise comparisons, the weight of each item evaluated and the evaluation values for each product and alternative are discovered for each item evaluated in the AHP. However, the outcome of the pairwise comparison is not 0.1, the degree is rather provided by a numerical number (Business Credit, 2006). In Fuzzy AHP, the weight is expressed by a necessary measure or possibility measure, as well as the traditional requirement that the sum of the possible weights can be lowered to 1.

3.3.3 ELECTRE

ELECTRE Which is one of the MCDM techniques, enables decision-makers to select the alternative that satisfies the greatest number of requirements while posing the fewest conflicts (Roy, 1978). The ELECTRE method, later referred to as ELECTRE I, is used to choose the best course of action from a list of alternatives. Electre has been built in several iterations, including Electre I, II, III, IV, and TRI. Although all techniques share the same conceptual underpinnings, they differ in terms of how they operate and how the choice problem is structured (Yusuf TanselIç, 2012).

Electre I, Electre TRI, Electre II, III, and IV are specifically designed for selection problems, assignment difficulties, and ranking problems, respectively. The right use of "outranking relations" is the main concept. The use of coordination indices to model a decision-making process is made possible by ELECTRE. Concordance and discordance matrices make up these indices. The decision-maker analyzes outranking relationships between many alternatives using concordance and discordance indices, and then uses the crisp data to select the optimal alternative.

3.3.4 TOPSIS

The TOPSIS technique assumes that each criterion tends to monotonically increase or decrease utility, which makes it simple to define the ideal solutions that are both positive and negative (Hwang and Yoon, 1981) The Euclidean distance approach is suggested to assess how closely the alternatives resemble the ideal solution. The preferred order of the alternatives will be determined by a series of comparisons of their relative distances. The TOPSIS approach, like the ELECTRE method, first transforms the numerous criteria dimensions into non-dimensional criteria (Taghipourian et al, 2009). According to TOPSIS, the preferred option should be the one that is both the furthest away from the negative ideal solution and the closest to the positive ideal solution (PIS) (NIS).This technique is used to achieve the best results in multi-criteria decision-making as well as for ranking purposes. All the criteria have been rated according to region after being evaluated using the FUZZY TOPSIS approach in each region.

3.3.5 PROMETHEE I and II

is a system for ranking. In an outranking procedure, no alternative is eliminated in a pairwise comparison; rather, the alternatives are ranked in accordance with the decision-preferences maker's and the criteria. This approach has the benefits of being straightforward, stable, and simple (Brans and Vicke, 1986). This technique can be used to achieve a partial preorder (PROMOTHEE I) or a full one (PROMOTHEE II) with a finite number of actions (Brans and Vicke, 1986). The PROMOTHEE approach consists of five basic steps, as claimed by Mateo (Mateo, 2011) and Brans et al (Brans and Vicke, 1986). A preference function outlining the decision-preference makers for one course of action (action a) over another (action b) will be defined independently in the first stage.

The second phase involves comparing the recommended alternative to the preference function in pairs. The results of these comparisons are then displayed in an evaluation matrix as the estimated value of each criterion for each alternative as the third step. The two final phases are where the ranking is done: the fourth step applies the PROMOTHEE I method for partial ranking, and the fifth step applies the PROMOTHEE II method for full ranking of the alternatives. The key benefit of this approach is that there is no requirement for score normalization. Nevertheless, as this method does not include weighting procedures, weight must be defined independently (Fulop, 2005)

3.3.6 Grey Theory

The term "insufficient data" and "poor knowledge" are used to describe the systems that have a high mathematical analysis and are defined as being both known and unknown to some extent. When the decision-making process is obscure, Grey Theory looks at the interactional analysis because there are many distinct and insufficient inputs. Many decision-making issues have successfully used the Grey Theory methodology in recent years (TuncayOzcan and NumanCelebi, 2011). When there are many options and strict criteria, the MCDM approaches mentioned above have been used extensively to discover the optimal option. These techniques were chosen based on the type of decision-making. TOPSIS, which selects the best, has been used for ranking, ELECTRE, which selects the best, and grey theory, which selects the best in cases where complete data is unavailable.

3.3.7 SAW

The SAW method is often known as the weighted addition method. The fundamental idea behind the SAW technique is to find a weighted sum of the performance ratings for each alternative across all criteria (Fishburn, 1967). (MacCrimmon, 1968). The decision matrix must be normalized for the SAW technique to a scale that can be compared to all currently accessible alternative ratings (Mude, 2016). In this SAW approach, the decision-maker must select the weight for each attribute. The total score for the alternatives is the sum of all the multiplication results between the rating (which can be compared across attributes) and the weight of each attribute. Each attribute rating must be dimension-free, i.e., have through the previous matrix normalization process, successfully (Helilintar, 2016).

3.4 AHP DETAILED

Between 1971 and 1975, The AHP, a thorough decision-making method, was created by Thomas L. Saaty. (Triantaphyllou, 2000).

Making decisions frequently involves comparing a constrained range of options to a finite set of criteria. AHP can be used to determine a comprehensive ranking of the options by splitting the decision issue into pairwise comparisons (Saaty, 1971,1975). In other words, the AHP weighs each specified criterion differently for the decision-makers when it compares each alternative to the others. The problem can be made simpler through this method, and more importantly, a ranking of the alternative solutions can be generated, allowing for the selection of the best option.

AHP decision makers may consider and voice opinions on both relevant qualitative criteria and quantifiable criteria (Saaty 1980). The AHP serves as a tool for selecting the best option as well as providing a clear and logical orientation to the decision-making process (Saaty 1980).

It is crucial to remember, for instance, that each ranking determined by the AHP contains a consistency metric. The Analytic Hierarchy Method has generally been used extensively. The following stands out among them:

- multicriteria decisions, which entail selecting one option from a group of options and are frequently based on many decision criteria. The choice of a site, a product, a supplier, and a policy are examples of classic dilemmas.
- Strategic planning: AHP can help a company choose between various missions and strategies (Facco, 2019).
- Resource allocation: distributing few resources among a range of options. For example, in times of shortage, power might be given to industry based on that sector's contribution to national security, employment, welfare, and other factors (Saaty, 2008).
- Conflict resolution: resolving conflicts between parties holding seemingly conflicting agendas or perspectives (proposed resolutions to the Israeli-Palestinian conflict and the Northern Ireland conflict are two examples) (Saaty, 2008).

3.4.1 AHP METHODOLOGY

The steps for application of the AHP can be formulated as follows (Enrique Mu and Milagros Pereyra-Rojas, 2017).

Step 1: Model Development and Problem Formulation.

To prioritize the alternatives, the AHP has various steps. The decision problem is broken down into a hierarchy of objectives, criteria, sub-criteria, and alternative or variant standards in the first stage. The hierarchical structure places the problem's objective at the top, followed by criteria, sub-criteria, and alternatives.

The process of creating a hierarchical structure based on the objective, criteria, sub-criteria, and alternative is known as decision modelling. Figure 3.1 shows a typical AHP decision model. These hierarchical decomposition's benefits are evident. By organizing the issue in this manner, the decision to be taken, the standards to be used, and the selection criteria can all be better understood.

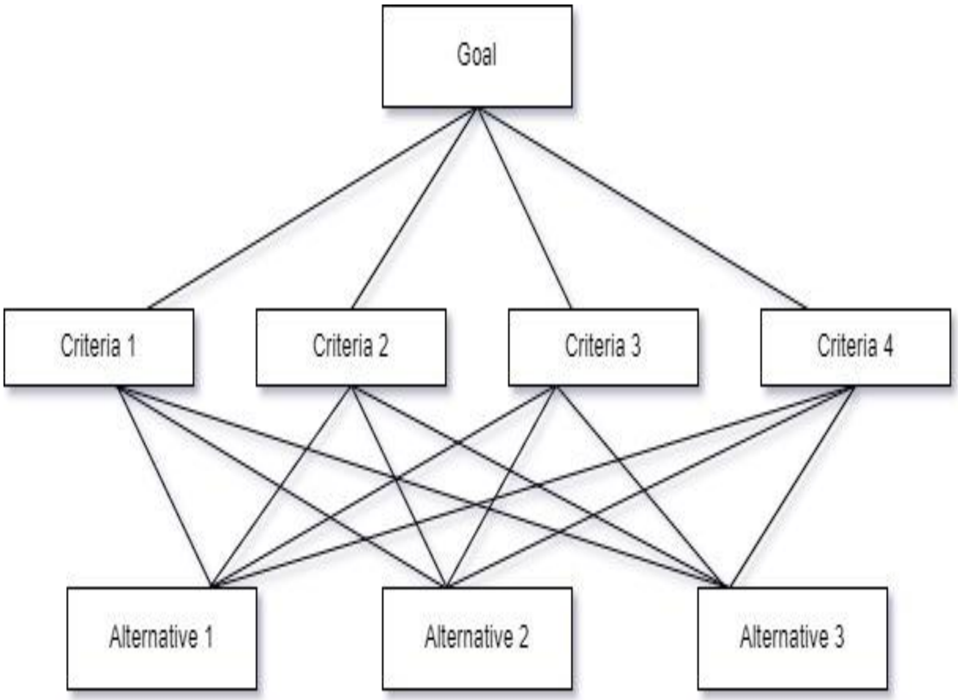

Figure 3.3 AHP decision model.   Sources: **(Dean, 2022)**

Step 2: Pairwise Comparison and Attribute Weighting

The weights of the criteria are to be determined in the second stage. Weights are determined by comparing the criteria in pairs regarding the decision problem's goal (**Table 3.2**).

This approach builds a ratio matrix via pair-wise comparison. To compare the significance of two traits at once, the decision-maker can be posed with a number of comparison questions, like: “Which one of these two attributes is more important, and how much more important?” In the AHP, comparisons are done with the Saaty-developed numerical nine-point scale (**Table 3.3**).

The outcomes of the pairwise comparison of n criteria can be summarized using a (M x N) assessment matrix A with every member aij expressing the significance of the criterion in the row I compared to the criterion in the column j.

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & . & . & a_{1N} \\ a_{21} & 1 & a_{23} & a_{24} & . & . & a_{2N} \\ a_{31} & a_{32} & 1 & a_{34} & . & . & a_{3N} \\ . & . & . & . & . & . & \\ . & . & . & . & . & . & \\ a_{M1} & a_{M2} & a_{M3} & a_{M4} & . & . & a_{MN} \end{bmatrix}$$

Fig 3.3 Evaluation matrix

$$a_{ji} = \frac{1}{a_{ij}} \quad \text{Eqn 3.1}$$

$$a_{ij} \neq 0$$

A basic consistency requirement states that the obtained matrix A must be reciprocal; otherwise, the decision-maker may have misunderstood the issue. It is also obvious that all the members in the matrix's major diagonal have values of 1, as they represent the situation in which a criterion is compared to itself.

The weights of the criterion can be calculated from the generated matrix using the normalized Perron-Frobenius eigenvector, which provides relative weights (v). As a result, the total of all criteria weights will equal 1. Consistency is the only concept that directly affects the output quality of the AHP.

	Criteria 1(C1)	**Criteria 2(C2)**	**Criteria 3(C3)**	**Criteria 4(C4)**
Criteria 1(C1)	C1 compared. with C1	C1 compared. with C2	C1 compared. with C3	C1 compared. with C4
Criteria 2(C2)	C2 compared. with C1	C2 compared. with C2	C2 compared. with C3	C2 compared. with C4
Criteria 3(C3)	C3 compared. with C1	C3 compared. with C2	C3 compared. with C3	C3 compared. with C4
Criteria 4(C4)	C4 compared. with C1	C4 compared. with C2	C4 compared. with C3	C4 compared. with C4

Table 3.2 Pairwise comparison table **Sources: Own elaboration**

Verbal Judgement	Numerical Value	Description
Equally important	1	The two choices are equally important
moderate	3	One choice is comparatively slightly more important
Strong	5	One choice is comparatively more important.
Very strong	7	One choice is comparatively much more important
Absolutely strong	9	One choice is more important.
Middle ground values	2, 4, 6, 8	Represents intermediate values.

Table 3.3 Saaty’s pairwise comparison scale

Step 3: Normalization

Normalization in MCDM is often a transformation step that produces numerically equivalent input data by using a same scale (N. Vafaei et al ,2015).

After data collection, some pre-processing must be done to ensure criteria comparability to make input data useful for decision modelling. Furthermore, normalization processes in A common practice of MCDM is to convert criteria (attributes) with various measurement units to a single scale with a (0–1) range (Pavlicic et al. 2011). Many research investigating how normalization approaches affect the ranking of options in MCDM situations show that some strategies perform better when employed with decision-making procedures. (Chakraborty, 2017).

In the normalization procedure, pairwise comparisons outlined in step 2 are used to determine the weight of each alternative. Equation 3.2 below shows how to achieve this by dividing each column value in the matrix by the sum of its columns, which normalizes the matrix with the total of each column in the normalized matrix being 1. (Triantaphyllou, 2000).

$$a_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad \text{...} \quad \textbf{Eqn 3. 2}$$

The criteria weight is then calculated by averaging the values for each row.

$$Cw_{ij} = \frac{\sum_{i=1}^{n} a_{ij}}{n} \quad \text{...} \quad \textbf{Eqn 3.3}$$

Stage 4: Consistency Ratio

Consistency measures the quality of the AHP's output, as was described in the preceding section. In other words, consistency ensures that there are no logical inconsistencies when making decisions. By requiring that matrix A be reciprocal, some consistency in the AHP is imposed (Saaty,1971). Despite this, explicit transitivity may not always be proven. For instance, it is crucial to confirm that a random decision maker prefers alternative 'a' to alternative 'c' in addition to preferring alternative 'b' to alternative 'a'. This makes sense mathematically, yet the decision-makers are frequently influenced by irrational behaviour, which leads to distorted results and inconsistent outcomes. Consistency requires careful adoption of accurate estimations of preference intensity in addition to adherence to the preferences' logical basis, as the use of disproportionate values may potentially skew the results. The decision-maker favours option an over option b, but in other situations or under other conditions, prefers option b over option a. This is an illustration of a preference paradox. Inconsistency can, more broadly, be caused by a variety of distinct and occasionally combined factors, such as a lack of understanding of the subject, significant degrees of ambiguity when determining preferences, intransitivity, a cheating mentality, etc.

In each of these situations, further knowledge about the issue is required to help decision-makers eliminate discrepancies. Because numerical values are based on the arbitrary decisions of individuals, significant error in AHP analysis is not only expected but also permitted (Saaty, 1971). The T. L. Saaty-proposed Consistency Index (CI) is used to measure consistency.

CI = $\frac{\lambda max - n}{n-1}$ **……………………………......................................…… Eqn 3.4**

The maximum eigenvalue of matrix A should be n, the total number of choices for completely reciprocal and transitive comparison matrices (or criteria). Low values of CI often indicate little inconsistency, however high values of CI point to a problem. To calculate consistency ratio (CR), which contrasts the CI of the in-question matrix with the consistency index of a random-like matrix, Saaty specified the acceptable value of (in)consistency (Saaty,1971).

RI: Table 3.4 provides a summary of the values.

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

Table 3.4 Saaty’s Radom Index

The consistency ratio must be defined as

$$CR = \frac{CI}{RI} \text{ ....} \textbf{Eqn 3.5}$$

According to Saaty, the AHP analysis can be deemed to have given consistent results when the appropriate consistency ratio is 0.10 or lower (Saaty,1971). If the CR is larger than 0.10, To find and address the inconsistent source, the evaluation process must be repeated.

Step 5: Overall Priority

The fifth stage aims to determine the alternatives' relative weights and overall priorities about each criterion independently. The technique is the same as the previous phase, and it entails a pairwise comparison of the alternatives with respect to each criterion. A consistency check is necessary, as before. The weighted sum of all the derived alternative priorities is combined to determine the overall priorities of the alternatives after taking into consideration the significance of each criterion.

. The option with the highest overall priority is the best one. Sensitivity Analysis is also required to understand the reasoning behind the results that were obtained. A study is done to determine the potential effects of changing the weights of the criteria on the result. The sixth and final process involves making the ultimate choice based on the findings of the synthesis and the sensitivity analysis.

3.5 Simple additive Weighting (SAW) Methods

One option for resolving MADM problems is the SAW method. The SAW methodology is also known as the weighted sum approach. The core idea of SAW is to weight the performance scores for each alternative across all parameters (Fishburn, 1967). The SAW approach requires a decision matrix normalization process to a scale that can be compared with all currently accessible alternative ratings (Mude, 2016). In this SAW approach, the decision-maker must select the weight for each attribute. The total score for the alternatives is the result of adding up the results of multiplying each attribute's rating by its weight. Each attribute must have a rating. dimension-free, meaning it must have successfully undergone the preceding matrix normalization process (Helilintar, 2016). The steps for completing the SAW are as follows:

The appropriate rating of each alternative is derived once the criteria that will be used as a guide in making judgments are established. Following the creation of a decision matrix based on the criteria, the matrix is normalized using an equation modified for the kind of attribute, benefit attribute, or cost attribute to produce matrix $\mathbf{a_{ij}}$. The normalized matrix $\mathbf{a_{ij}}$ is added to and multiplied by the weight vector to get the greatest value being selected as the best alternative (Ai) as a solution.

3.5 .1 NORMALIZATION IN SAW

Eqn 3.3 can be used to implement the SAW normalization approach for benefit and cost criteria, ensuring that the decision objective is logically sound at the end.

Simple Additive Weighting (SAW) is standardized using the following equation throughout the normalization process:

$$\mathbf{a_{ij}} = \frac{\mathbf{x_{ij}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{x_{ij}}} \quad \textbf{Eqn 3.6}$$

Criteria values are changed when they have many dimensions or different units.

They can be a benefit criterion or cost criterion.

The values of the benefit criteria are calculated according to the formula.

$$a_{ij} = \frac{x_{ij}-D_j}{|H_j-D_j|} \quad \textbf{Eqn 3.7}$$

The values of the cost criteria are calculated according to the formula.

$$a_{ij} = \frac{x_{ij}-D_j}{|D_j-H_j|} \quad \textbf{Eqn 3.8}$$

That is the absolute value of the difference between the smallest value of the criteria (**Di)** and the biggest value of the criteria (**Hi**) is used.

a_{ij} is a normalized performance rating, Xij is the attribute value of each criterion.

H_j is the greatest value of each criterion, D_j is the smallest value of each criterion.

Benefit is when the greatest value is the best, Cost is when the smallest value is the best.

$u(a_i)$ is the normalized performance rating of the alternatives Ai on attribute Cj.

(i = 1, 2…m) and (j = 1, 2…, n)

The preference value for each alternative (Vi) is given as:

$$u(a_i) = \ldots \sum_{j=1}^{k} v_j a_{ij} \quad \textbf{Eqn 3.9}$$

Where $u(a_i)$ is the ranking for each alternative, v_j is the weighted value of each criterion; a_{ij} is the normalized performance rating value. A larger $u(a_i)$ value indicates that the alternative Ai is preferred.

CHAPTER 4
METHODS APPLIED IN THE PRACTICAL PART

4.1 Decision problem

One of the major industrial sectors in the world is the automotive sector and it has been crucial to regional and national growth. It combines a variety of industrial processes, such as those involving metals, plastics, and electronics, and is commonly seen as a symbol of national industrialization. In the global automotive sector, West Africa has a very modest presence, and many of its small national markets are mostly supplied by old cars importers with Ghana, Nigeria and few other West African countries having small scale assembly and component production.

The market is expanding quickly, as the middle class is growing quickly and the demand for cars increasing. Encouraging car manufacturing giants to collaborate with West African governments to establish automobile production and assembling plants may result in market expansion and the attraction of both domestic and foreign investment.

In addition, with African Governments' determination to limit importation of used and overaged cars, automobile manufacturing business look brighter.

Which of these West African countries has the highest possible demand for cars and at the same time has the best condition for business is the problem this study seeks to address.

The Analytical Hierarchy model of Multi Criteria Decision Making approach is used to provide a solution to this query.

4.2 Decision goals and targets

The main goal of the study as stated in section 2.1 is to select and propose the most suitable Country from West Africa for siting Automobile plant Using Multi Criteria Decision Making

The target for this study is to identify the most economically viable country for automobile business.

4.3 Selecting Relevant Decision Criteria for the study.

A comprehensive set of criteria that may influence the decision process were determined through literature review backed by support from automobile production expert who has experience in the auto industry and a consultant who is well verse in international auto business.

Two primary criteria and a total of 10 sub-criteria, as shown in Fig. 4.2, were determined to be appropriate based on the extensive set of variables suggested by the literature and the experts.

Availability of secondary data was considered when making the selection.

A more extensive list of criteria had initially been defined, however some of them were eventually dropped for lack of data since there is no use in choosing variables for which there is no data at all or only incomplete data.

Criteria	**SUB-CRITERIA**	**CODE**	**UNITS**
Economic & Political	Gross Domestic Product	GDP	USD ($)
	Minimum Wage	MW	USD ($)
	Inflation Rate	IR	Percentage (%) Annual
	Profit tax	PT	Percentage (%) Annual
	Corruption Perception Index	CPI	SCORE (0 – 100)
Social and Amenities	Unemployment Rate	UR	% Of Total labour force
	Demographic Estimates	DE	In thousands
	Time Required to Register Property	TRRP	In Days
	Human Development/Capital Index	HDI/HCI	Scale (0 – 1)
	Access To Electricity	ATE	% Of population

Table 4.1 Relevant decision criteria and units. Sources: Own elaboration

Gross Domestic product: GDP used to measure the economic performance of a country (Rahman, 2013). GDP also defined as total market values of all final goods and services produced in a country each year and it measures the growth in the economy (Mallett and Keen, 2012). GDP was developed by Dr. Simon Kuznets in 1934 for used as the basis for some derivative statistics. It has a positive relationship with the car sales (Sivak and Tsimhoni, 2008). They conducted their study in 25 developing countries. They applied multiple regression method to analyse by using the data in the year 2006 on the current sales of the new cars on current GDP and population.

Minimum wage: Minimum wage has been defined by international labour organization as the minimum amount of remuneration that an employer is required to pay wage earners for the work performed during a given period, which cannot be reduced by collective agreement or an individual contract. The purpose of minimum wage is to protect workers against unduly low pay. When large company wants to invest in other country, among the elements checked is Salary and wages, whether it is favourable or not for their business. Auto industry just like every business organization wants to minimize as much as possible labour cost.

Minimum wage is not a desirable criterion and therefore automobile companies may prefer countries with lower minimum wage.

Inflation Rate: Inflation is broadly defined as a rise in the general price level of goods and services in a country or an economy without a corresponding rise in the value of those commodities. It is also defined as the sustainable and continuous rise in the general price level or a fall in the value of money (Makinen, 2003). Inflation poses serious economic hitches to businesses. When there is high inflation, the effect is that there is loss of consumer buying power, social instability, and loss of confidence in the currency (Gershman and Howitt, 2013). Therefore, siting a plant in an economy where there is high inflation rate will have adverse effects on the industry which makes it undesirable criterion.

Profit Tax: Taxation is the compulsory levy by the government on the income or consumption of various items (Hassert and Hubbard,1976). corporate tax is defined as tax levied on the profits of corporates (Alworth and Arachis, 2001). The corporate investment decision is the decision of the company to invest its profits in various long-term assets with an anticipation of future income flows. Taxes have various effects on corporate investment decisions. Profit taxes will have a big impact on the amount of income that automobile company wishes to reinvest in various investment portfolios. Corporate taxes significantly reduce the number of earnings by shareholders. The company is under obligation to pay its shareholders more especially those who ought to be paid regardless of the financial health of the company.

Therefore, automobile company just like any other will want to invest in a country with less profit tax.

Corruption Perception Index: Index for Perceived Corruption According on how much public officials and politicians are thought to be corrupt, CPI assigns a ranking to each country. It is a composite index, a survey of surveys, drawing corruption-related data from expert and corporate surveys conducted by several independent and renowned entities. Transparency International is an example of such a group. The misuse of public office for personal benefit is defined as corruption by Transparency International (Lambsdorff, 2007).

The surveys used to calculate the CPI include questions about the abuse of official authority for personal gain. Public official bribery, kickbacks in public procurement, theft of public funds, and inquiries into the strength and efficacy of anti-corruption initiatives are a few examples that cover both the administrative and political facets of corruption. The CPI rates nations on a scale of zero to ten, with a score of zero denoting extremely serious corruption. When a government or official changes, there is a chance of having to pay again, which makes a country with high levels of corruption unfavourable for the auto industry.

Unemployment Rate: The unemployed are people of working age who are without work, are available for work, and have taken specific steps to find work. The uniform application of this definition results in estimates of unemployment rates that are more internationally comparable than estimates based on national definitions of unemployment. This indicator is measured in numbers of unemployed people as a percentage of the labour force, and it is seasonally adjusted. The labour force is defined as the total number of unemployed people plus those in employment.

When the unemployment rate is high, minimum wage is low. It comes when there’s an increase demand for job because of high number of labour forces unemployed. With more people available for work, employers have the choice of selecting the best skill employees at a low wage level.

Demographic Estimate: A country with More peoples means more demand for cars. Therefore, a car manufacturer will want to consider where more customers are. Even though the cars can always be exported but if a company has more of its customers at the production location, exportation cost will be reduced. This makes demographic estimate criterion beneficial.

Time required to Register Property

This is the length of time needed to register a property or a business from when the necessary documents are presented to when the necessary certificate or approval is issued.

It is measured in days. It varies from country to country. While some countries take few days, some take several days to months. The shorter the time required; the better as longer time can bread corruption. In a country where inflation rate is high, it can lead to investment capital depreciating.

Human development Index: HDI is a statistical tool used to measure a country’s overall achievements in its social and economic dimensions. The social and economic dimensions of a country are based on the health of people, their level of education attainment and their standard of living. It ranges from 0 to 1 with 1 being the most developed and zero (0) being the least developed. The higher the HDI, the better. A high HDI essentially means that the country in question offers a generally higher standard of living with decent health care and education and opportunity to earn money. When peoples have good health, good education and have what they will eat, the next thing is to think of luxury, that is why HDI is one of the positive indicators any investor might want to consider for choosing a country to invest.

Access to Electricity: Electrical power is an important input into production. When the electricity is turned off, operations and production are typically interrupted. Businesses must find other solutions to the unreliable electrical supply to maintain performance. To minimize losses, actions are done such as self-supplying electricity via generators. Yet, these responses by themselves can be expensive.

Therefore, it is important factor to consider when siting automobile industry as car production require the use of sophisticated machinery. In this study, it is difficult to quantify the total capacity of electrical energy in each of the alternative's countries, therefore the criterion used for electricity is Access to Electricity. This indicates the percentage of the population which is connected to the national grid and has access to electricity in each of the alternative countries.

4.4 Decision Variant (Alternative)

Once the criteria have been determined, decision variant appropriate for Siting industry such as automobile were identified. In determining decision alternatives, two main objectives were considered.

i) The countries with most demand for cars and
ii) the countries with best condition for business.

Consultations with the auto expert and the international business consultant shows that, Cote Ivoire, Ghana, Nigeria, and Senegal are the countries in West Africa with most demand for cars and with the best conditions for car business. Therefore, comparison with the best condition by Gross Domestic product, Exchange Rate, Inflation Rate, Profit Tax, Foreign Direct Investment, Corruption Perception Index, Time required to Register Property, Human development/Capital Index, Unemployment Rate, Demographic Estimate, Access to Electricity, Minimum wage, Most Business-Friendly Regulations will benefit both auto industry and stake holders in the automotive industry.

4.4.1 COTE D'IVOIRE

One of the most promising and rapidly expanding auto markets in the sub-region is Cote d'Ivoire. Many variables, including labour availability, R&D activities, geographic advantage, and government assistance, contribute to the Cote d'Ivoire automobile sector. Automobile sales in the nation are expected to experience a significant increase in sales by 2030 because to a favourable economic outlook and rising household spending power. The current automotive industry in Cote d'Ivoire is known to be influenced by rising electric car adoption rates and soaring consumer demand for cutting-edge safety, connectivity, convenience, and driver assistance technologies. Potential obstacles for automakers include controlling chip shortages, expanding the infrastructure for EV charging, and improving battery efficiency. OEM producers intend to enlarge their Cote d Ivoire production facilities. The Cote d Ivoire government regards the automotive sector as a significant source of revenue and is promoting the flow of FDIs into the sector (marketresearch.com, 2022).

4.4.2 GHANA

Ghana's automotive market was estimated at USD 4.60 billion in 2021, and by 2027, it is anticipated to have grown to USD 10.64 billion, showing a CAGR of 15%. (2022-2027). Due to supply chain interruptions in major automotive production canters across the world brought on by the COVID-19 outbreak, the automobile sector in Ghana experienced significant delays in the shipping of essential automotive components needed to complete vehicle assembly operations in 2020. Ghana imports over 70% of its automobiles from other countries. Ghana's automotive industry typically consists of wholesalers who deal in the retailing of new vehicles and sellers of imported used cars.

Due to the increase in "Made in Ghana" automobiles Kantaka Group started producing in 2016 and the growing number of trained workers in Ghana's automotive industry, Ghana, the third-largest economy in West Africa, is expected to see growth in the automotive sector throughout the projection period. Long-term projections indicate an increase in the nation's imports of automobile parts and components. According to its platform, the administration intended to eliminate specific import taxes and cut corporate tax to between 20 and 25 percent. Every year, Ghana imports roughly 100,000 automobiles. With an estimated yearly value of USD1.14 billion, almost 90% are second-hand cars. Leading suppliers include Germany, Japan, and the US (researchandmarkets.com, 2022).

4.4.3 NIGERIA

The National Directorate for Statistics' most recent data indicates that there were 11.8 million automobiles in Nigeria overall as of 2018. 39% (4.6 million) of these vehicles belonged to private owners, 56% (6.7 million) to businesses, 1.1% (135,000) to the government, and 0.4% (5,834) to diplomats.

Nigeria is reliant on imports to satisfy domestic demand because there isn't enough domestic car manufacture. According to the U.S. Census Bureau, passenger cars represented the greatest export from the United States to Nigeria in 2020 ($701 million). Due to high import tariffs on automobiles (70%) associated with the new automotive policy and a large decline in the number of vehicles imported between 2015 and 2017, auto imports experienced tremendous growth between 2004 and 2014.

That period saw an economic recession. For instance, less than 7,000 brand-new automobiles were imported into Nigeria in 2017. Leading multinational automakers showed interest in the Automotive Industry Development Plan (NAIDP) when it was introduced in 2014, which prompted the government to resume small-scale vehicle manufacture. In Nigeria, there are currently 31 licensed car, truck, and bus manufacturers with a combined installed capacity of 205,000 vehicles annually, according to the National Automotive Design and Development Council (NADDC). Unfortunately, because of the enormous financing, infrastructural, and capacity constraints, only roughly seven businesses are assembling. Owing to these difficulties, automakers are now relocating to Ghana, a neighbouring country, and establishing assembly factories there with the intention of exporting the finished vehicles to Nigeria. (trade.gov, 2022).

4.4.4 SENEGAL

Senegal may turn out to be one of the most alluring export destinations for the Polish automotive industry, particularly producers of vehicle parts and accessories, according to research by PAIH's foreign trade office in Dakar. In Senegal, all automobiles and parts are imported. Every year, some 100,000 automobiles, mostly SUVs and pickups, are brought into the nation. Due to the country's challenging climatic and infrastructure circumstances, these vehicles frequently need to have parts replaced. Senegal's automotive market is worth $100 million USD. The import of second-hand vehicles is increasing by 8% yearly. The Foreign Trade Office in Dakar conducted a study of automobile owners and owners of stores selling auto parts, and the results revealed that the availability and quality of parts are the major issues. 70% of users do their own part delivery and purchases.

The Agency provides business support at every stage of activity in the new market to businesses that realize the potential of the Senegalese market niche. The PAIH advises creating a cooperation for Polish automakers. The Polish Development Fund (PFR) group of financial and consulting institutions member PAIH provides support tools for entry into the African market, such as insurance and finance, which is crucial for businesses in the SME sector.

(www.paih.gov.pl, 2019) .

4.5 Data Collection

The data for this study were secondary data and were drawn from three main sources, World bank database, OECD.org and countryeconomy .com, with majority coming from world bank database. Data for Exchange Rate, Inflation Rate, Profit Tax, Foreign Direct Investment, Corruption Perception Index, Time required to Register Property, Human development/Capital Index, Unemployment Rate, Access to Electricity, Minimum wage and Most Business-Friendly Regulations were all drawn from the world bank database whereas Demographic estimates and Gross Domestic Product were from OECD.org and countryeconomy.com respectively.

ALTER/CRI	CRITERIA									
	GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE
COTE D'IVOIRE	69,765.00	108.200	4.10	8.80	3.50	3.500	28160542	39.00	0.550	69.70
GHANA	79,157.00	56.100	10.00	10.00	3.50	4.700	33,475,870	33.00	0.632	85.90
NIGERIA	440,777.00	83.600	17.00	21.00	3.00	9.800	218,541,212	92.00	0.535	55.40
SENEGAL	27,640.00	99.200	2.50	16.20	3.50	3.700	17316449	41.00	0.511	70.40

Tables 4.2 Criteria and corresponding data for the study

Criteria	**Sub-Criteria**	**Sources**
Economic & Political	GDP	**https://countryeconomy.com/gdp**
	MW	
	IR	**https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=CI-GH-NG-SN&name_desc=false.**
	PT	https://data.worldbank.org/indicator/IC.TAX.PRFT.CP.ZS?end=2022&locations=CI-GH-NG-SN&start=2022&view=bar.
	CPI	**https://www.transparency.org/en/cpi/2020**
Social and Amenities	UR	https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=CI-GH-NG-SN
	DE	https://stats.oecd.org/Index.aspx?QueryId=94462
	TRRP	https://data.worldbank.org/indicator/IC.PRP.DURS?end=2022&locations=CI-GH-NG-SN&start=2022&view=bar
	HDI	https://data.worldbank.org/indicator/HD.HCI.OVRL?end=2020&locations=CI-GH-NG-SN&start=2020&view=bar.
	ATE	https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CI-GH-NG-SN.

Tables 4.3 Sources of data used.

4.6 Choosing Method for finding Compromise Variant

After structuring the decision problem at hand, a multicriteria method was needed to evaluate the overall scope of the alternative with respect to criteria set. Analytical Hierarchy process (AHP) and Simple Additive Weighting techniques were employed. AHP was used in determining the criteria weight of the selected criteria while SAW was used to rank the variant. AHP is significant because it assists decision-makers in turning subjective assessments into objective measurements. To further quantify the relative importance of the performance criteria and assign important weightings to them, the AHP provides a pairwise comparison technique.

4.6.1 AHP Model Development and Problem Formulation.

As in indicated in section 4.3 above, all quantitative variables affecting the decision process was determined through literature review and support from automobile production experts who has experience in the auto industry and a consultant who is well verse in international auto business. In doing so two factors were considered:

i) country of highest possible demand for cars and
ii) country with the best condition for automobile business

The acquired information was used to form a hierarchical structure based on the goal, criteria, sub-criteria, and alternatives.

An evaluation model consisting of 2 main criteria and 10 sub-criteria were developed as shown in Fig 4.1

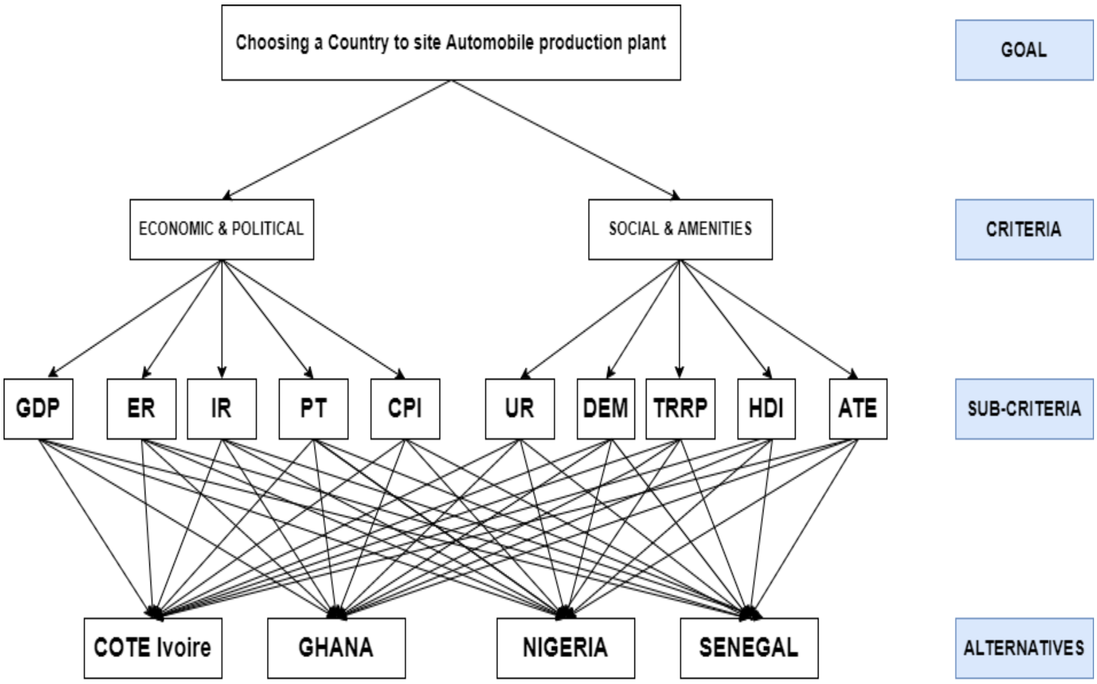

Figure 4.1 Decision hierarchy for choosing a country. Source: Own design

The advantages of this hierarchical decomposition are that, by structuring the problem in this way, it was possible to better understand the goal to be achieved, the criteria to be used and the alternatives to be evaluated.

4.6.2 Pairwise Comparison Matrix for AHP

A pairwise comparison of the decision-making criteria was carried out once the hierarchical structure had been built. The results are displayed in Table 4.3. For each of the compared pairs, each cell in the comparison matrix will have a value from the numeric scale depicted in Table 3.3, reflecting our relative preference. This was carried out with the aid of specialists and advisors, as was mentioned in section 4.3 above.

	GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE
GDP	1	3.00	3.00	5.00	5.00	5.00	5.00	7.00	7.00	7.00
MW	0.33	1	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
IR	0.33	0.50	1	3.00	3.00	5.00	5.00	7.00	7.00	7.00
PT	0.20	0.20	0.33	1	2.00	3.00	3.00	5.00	5.00	5.00
CPI	0.20	0.20	0.33	0.50	1	2.00	2.00	3.00	5.00	7.00
UR	0.20	0.14	0.33	0.33	0.50	1	3.00	5.00	7.00	9.00
DE	0.20	0.14	0.20	0.33	0.50	0.33	1	3.00	5.00	7.00
TRRP	0.14	0.11	0.14	0.20	0.33	0.20	0.33	1	3.00	7.00
HDI	0.11	0.11	0.14	0.20	0.20	0.14	0.20	0.33	1	5.00
ATE	0.11	0.11	0.14	0.20	0.14	0.11	0.14	0.14	0.20	1
TOTAl	**2.83**	**5.51**	**8.61**	**13.76**	**15.67**	**19.780**	**22.67**	**34.47**	**43.200**	**58.00**

Table 4.4 pairwise comparison matrix.

4.6.3 Normalized Decision Matrix and Criteria Weights

In MCDM, normalization procedures often convert criteria (attributes) with various measurement units to a standard scale with a range of 0 to 1. (Pavlicic,2011).

MCDM normalizing techniques often convert criteria (attributes) with various measurement units to a single scale with a range of 0 to 1. (Pavlicic, 2011)

The decision matrix had to be normalized because every criterion has a different set of units. This was done by multiplying each option score by the total of the columns, as indicated in Table 4.4. The normalized table that resulted is presented in Table 4.5.

All the components in the row were averaged to determine the criteria weight. In other words, the element in each row's cell is added up and divided by the decision matrix's specified number of criteria, 10 in this case. Table 4.5's findings show that GDP (0.2774) received more attention than minimum wage (0.2253). In our pick of countries, the criterion for access to electricity has the lowest weight (0.0131).

	GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE	Mean	CWEIGHT
GDP	0.353	0.544	0.348	0.363	0.319	0.253	0.221	0.203	0.162	0.121	**2.8872**	0.2887
MW	0.118	0.181	0.348	0.218	0.191	0.152	0.132	0.087	0.069	0.052	**1.5491**	0.1549
IR	0.118	0.091	0.116	0.218	0.191	0.253	0.221	0.203	0.162	0.121	**1.6931**	0.1693
PT	0.071	0.036	0.039	0.073	0.128	0.152	0.132	0.145	0.116	0.086	**0.9769**	0.0977
CPI	0.071	0.036	0.038	0.036	0.064	0.101	0.088	0.087	0.116	0.121	**0.7582**	0.0758
UR	0.071	0.026	0.038	0.024	0.032	0.051	0.132	0.145	0.162	0.155	**0.8359**	0.0836
DE	0.071	0.025	0.023	0.024	0.032	0.017	0.044	0.087	0.116	0.121	**0.5594**	0.0559
TRRP	0.050	0.020	0.016	0.015	0.021	0.010	0.015	0.029	0.069	0.121	**0.3661**	0.0366
HDI	0.039	0.020	0.016	0.015	0.013	0.007	0.009	0.010	0.023	0.086	**0.2376**	0.0238
ATE	0.039	0.020	0.016	0.015	0.009	0.006	0.006	0.004	0.005	0.017	**0.1366**	0.0137
TOTAL	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**		1.0000

Table 4.5 Normalized Decision Matrix and Criteria Weights

4.6.4 Consistency verification (Consistency Ratio)

The consistency ratio is a metric that indicates the consistency between pairwise comparisons.

It indicates how much one deviates from the consistency.

A pairwise comparison is consistent when it has a consistency ratio CI < 0.1.

The consistency index in this study was calculated using equations 3.1, 3.2 and 3.3.

The criteria or the priority weight vector was multiplied by the pairwise matrix and the resulting table is shown in Table 4.6 In doing so, another important vector Weighted sum (Wsum) was obtained.

	GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE	WSUM	Cweight
GDP	0.289	0.465	0.508	0.488	0.379	0.418	0.280	0.256	0.166	0.096	**3.3448**	0.2887
MW	0.096	0.155	0.508	0.293	0.227	0.251	0.168	0.110	0.071	0.041	**1.9203**	0.1549
IR	0.096	0.077	0.169	0.293	0.227	0.418	0.280	0.256	0.166	0.096	**2.0794**	0.1693
PT	0.058	0.031	0.056	0.098	0.152	0.251	0.168	0.183	0.119	0.068	**1.1832**	0.0977
CPI	0.058	0.031	0.056	0.049	0.076	0.167	0.112	0.110	0.119	0.096	**0.8726**	0.0758
UR	0.058	0.022	0.056	0.032	0.038	0.084	0.168	0.183	0.166	0.123	**0.9296**	0.0836
DE	0.058	0.022	0.034	0.032	0.038	0.028	0.056	0.110	0.119	0.096	**0.5912**	0.0559
TRRP	0.041	0.017	0.024	0.020	0.025	0.017	0.018	0.037	0.071	0.096	**0.3652**	0.0366
HDI	0.032	0.017	0.024	0.020	0.015	0.012	0.011	0.012	0.024	0.068	**0.2346**	0.0238
ATE	0.032	0.017	0.024	0.020	0.011	0.009	0.008	0.005	0.005	0.014	**0.1435**	0.0137
TOTAl	**0.82**	**0.85**	**1.46**	**1.34**	**1.19**	**1.653**	**1.2682**	**1.26**	**1.026**	**0.79**		

Table 4.6 Consistency evaluation table

From Eqn. 3.3 λ max = {(3.3448/0.2887) +(1.9203/0.1549) +(2.0794/0.1693) +(1.832/0.0977) +(0.8726/0.0758) +(0.9296/0.0836) +(0.5912/0.0559) +(0.3652/0.0366) +(0.2346/0.0238) +(0.1435/0.0137)}/10

After the computation, the largest eigenvalue in the matrix, $\lambda max = 11.19$

Number of criteria used n = 10, Consistency Index CI = 0.132

Random index RI = 1.49, obtained from Table 3.4

CR = (0.132/1.49) = 0.088, CR < 0.1

It means that the pairwise comparison is consistent and therefore the priority weight can be relied on for further calculations.

4.6.5 Rankings of the criteria

The table below shows the ranking of each priority or criteria where GDP is rank as the most important criteria.

CRITERIA	CRITERIA WEIGHT
GDP	**0.2887**
MW	0.1549
IR	0.1693
PT	0.0977
CPI	0.0758
UR	0.0836
DE	0.0559
TRRP	0.0366
HDI	0.0238
ATE	0.0131

Table **4.7** Criteria Weight from Normalized matrix

The findings in Table 4.7 indicate that more priority is given to GDP (**0.2887**), followed by minimum wage (0.2253). The access to electricity criterion has a minimum weight (0.0131) in our country selection decision.

4.7 Application of SAW Method

After determining the criteria weights that influence the selection of a country using AHP method as described in section 4.5.1, I proceeded to rank the decision variants using the SAW method introduced by Fishburn (Fishburn, 1967) and MacCrimmon (MacCrimmon, 1968). Again, the criteria considered included Minimum Wage, Inflation Rate, Profit Tax, Corruption Perception Index, Unemployment Rate, Demographic Estimates, Time Required to Register Property, Human development Index, and Access to Electricity.

Alternatives include Cote D'Ivoire, Ghana, Nigeria, and Senegal.

Since the objective of the SAW is to determine the optimum alternative, it is very important to determine the highest (beneficial) and the lowest (cost) expected criteria. In this study, GDP, CPI, UR, DE, HDI, and ATE were considered as benefit criteria whiles MW, IR, PT and TRRP were the cost criteria. Table 4.8 summarizes the characteristics of each criterion.

This characteristic is important for the normalization process as the equation used depends on whether the criteria have cost attribute or benefit attributes. All criterial which has its higher values desired are benefit criteria and equation 3.7 was used and those with lower values desired are cost criteria and equation 3.8 was used.

CRITERIA NAME	CODE	ATTRIBUTE
Gros Domestic Product	GDP	Benefit
Minimum Wage	MW	Cost
Inflation Rate	IR	Cost
Profit Tax	PT	Cost
Corruption Perception Index	CPI	Benefit
Unemployment rate	UR	Benefit
Demographic estimate	DE	Benefit
Time Required to Register Property	TRRP	Cost
Human Development Index	HDI	Benefit
Access to Electricity	ATE	Benefit

Table 4.8 Criterion characteristics. Source: Own elaboration

4.7.1 Deriving the Appropriate Rating of each Alternative.

The appropriateness rating of each alternative was derived once the criteria that will be used as a guide in making judgments were established.

From the data obtained shown in Table 4.2, a decision matrix was created for the Variant as shown in Table 4.9

		CRITERIA									
		GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE
Criteria Characteristics		benfit	cost	cost	cost	benefit	benefit	benefit	cost	benefit	benefit
Criteria Weight											
	COTE D'IVOIRE	69,765	108.20	4.10	8.80	3.50	3.500	28160542	39.00	0.550	69.70
VARIANTS	**GHANA**	79,157	56.10	10.00	10.00	3.50	4.700	33,475,870	33.00	0.632	85.90
	NIGERIA	440,777	83.60	17.00	21.00	3.00	9.800	218,541,212	92.00	0.535	55.40
Countries	**SENEGAL**	27,640	99.20	2.50	16.20	3.50	3.700	17316449	41.00	0.511	70.40
Basal Varian	**D**	27,640	56.10	2.50	8.80	3.00	3.50	17,316,449	33.00	0.511	55.40
Ideal Variant	**H**	440,777	108.20	17.00	21.00	3.50	9.80	218,541,212.0	92.00	0.632	85.90
Difference	$\lvert H_i - D_i \rvert$	413,137	52.1	14.5	12.2	0.5	6.3	201,224,763.0	59	0.121	30.50

Table 4.9 Decision matrix for Variants

Following the creation of a decision matrix based on the criteria, the matrix is normalized using equation **3.7.** and equation **3.8.** The resulting normalized matrix is shown in Table 4.10

		CRITERIA									
		GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE
Criteria Characteristics		benfit	cost	cost	cost	benefit	benefit	benefit	cost	benefit	benefit
Criteria Weight											
	COTE D'IVOIRE	0.102	0.000	0.890	1.000	1.000	0.000	0.054	0.898	0.322	0.469
VARIANTS	GHANA	0.125	1.000	0.483	0.902	1.000	0.190	0.080	1.000	1.000	1.000
=	NIGERIA	1.000	0.472	0.000	0.000	0.000	1.000	1.000	0.000	0.198	0.000
Countries	SENEGAL	0.000	0.173	1.000	0.393	1.000	0.032	0.000	0.864	0.000	0.492

Table 4.10 Normalized matrix

The Weight vector in Table 4.7 representing the weight of each attribute is insert to the normalized matrix of Table 4.10 and the resulting table is shown in Table 4.11.

		CRITERIA									
		GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE
Criteria Characteristics		benfit	cost	cost	cost	benefit	benefit	benefit	cost	benefit	benefit
Criteria Weight		0.2887	0.1549	0.1693	0.0977	0.0758	0.0836	0.0559	0.0366	0.0238	0.0137
	COTE D'IVOIRE	0.102	0.000	0.890	1.000	1.000	0.000	0.054	0.898	0.322	0.469
VARIANTS	**GHANA**	0.125	1.000	0.483	0.902	1.000	0.190	0.080	1.000	1.000	1.000
=	**NIGERIA**	1.000	0.472	0.000	0.000	0.000	1.000	1.000	0.000	0.198	0.000
Countries	**SENEGAL**	0.000	0.173	1.000	0.393	1.000	0.032	0.000	0.864	0.000	0.492

Table 4.11 Normalized matrix with weight of each criterion

4.7.2 Overall Priority and Ranking

To derive the overall priority of the variants, Equation 3.9 was utilized. The weight vector representing the weight of each attribute obtained from AHP analysis is multiplied by the normalized attributes resulting from the Simple Additive Weighting method. The result of the multiplication was added for each variant to get the total score for each variant. The values been generated are summarised and the rank of Countries is determined as shown in Table 4.12.

		CRITERIA											
		GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE	Overall Priority	Rank
Criteria Characteristics		benfit	cost	cost	cost	benefit	benefit	benefit	cost	benefit	benefit		
	COTE D'IVOIRE	0.029	0.000	0.151	0.098	0.076	0.000	0.003	0.033	0.008	0.006	0.404	3.000
VARIANTS	**GHANA**	0.036	0.155	0.082	0.088	0.076	0.016	0.004	0.037	0.024	0.014	0.531	1.000
	NIGERIA	0.289	0.073	0.000	0.000	0.000	0.084	0.056	0.000	0.005	0.000	0.506	2.000
Countries	**SENEGAL**	0.000	0.027	0.169	0.038	0.076	0.003	0.000	0.032	0.000	0.007	0.351	4.000

Table 4.12 score of Variants

Country	Overall Priority	Rank
Ghana	0.531	1
Nigeria	0.506	2
Cote D’Ivoire	0.404	3
Senegal	0.351	4

Table 4.13 Ranks of Variant

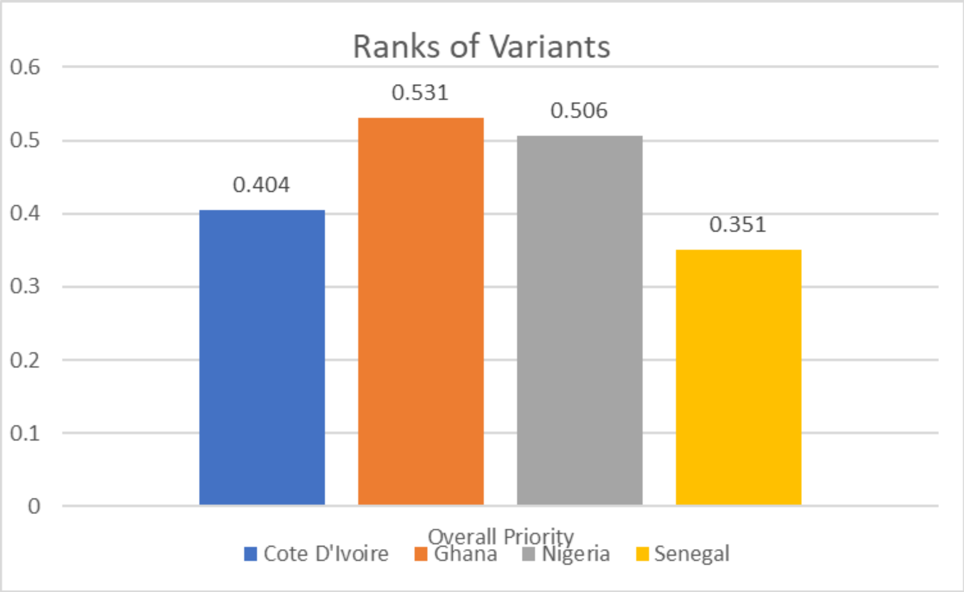

Fig 4.2 Preference Ranking chart of preferred country. Source: own elaboration

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Results

The decision matrix is produced by pair-wise factor comparisons using the AHP, and all the data were computed using the SAW method. Table 4.13 displays the final results of those actions. Figure 4.2's bar chart provides a graphic depiction of the findings.

The study's findings indicate that among the four nations considered, Ghana is the best place to locate an automobile manufacturing facility, followed by Nigeria. The two countries don't really differ that much from one another. Cote D'Ivoire and Senegal, respectively, are in third and fourth place.

5.2 Sensitivity Analysis

Sensitivity analysis is a crucial step in the process that is necessary to assess the output reliability of the AHP and identify the factors that influence the outcome. Alternative scenarios must be created to do the analysis; this entails testing various criterion weights and observing how overall priorities change prior to making a final conclusion. A few other potential outcomes are given in the pages that follow.

Case 1: all criteria assumed to have the same weight.

Each weight in this case is given a value of 1/7. Table 5.1 demonstrates that the ranking is only slightly impacted. The best option remains Ghana; however, Cote D'Ivoire now holds the second spot, while Senegal and Nigeria have moved up to take the third and fourth spots, respectively. Ghana and all the other nations receive some points in this scenario.

The primary cause of this is the higher weights assigned to each criterion, with the exception of the GDP criterion. Table 4.13A Criteria assumed to have equal weight.

		CRITERIA											
		GDP	MW	IR	PT	CPI	UR	DE	TRRP	HDI	ATE	Overall	Rank
Criteria Characteristics		benfit	cost	cost	cost	benefit	benefit	benefit	cost	benefit	benefit	Priority	
	COTE D'IVOIRE	0.015	0.000	0.127	0.143	0.143	0.000	0.008	0.128	0.046	0.067	0.677	2.000
VARIANTS	GHANA	0.018	0.143	0.069	0.129	0.143	0.027	0.011	0.143	0.143	0.143	0.969	1.000
	NIGERIA	0.143	0.067	0.000	0.000	0.000	0.143	0.143	0.000	0.028	0.000	0.525	4.000
Countries	SENEGAL	0.000	0.025	0.143	0.056	0.143	0.005	0.000	0.124	0.000	0.070	0.565	3.000

Table 4.13B Overall Priority with assumed equal weight.

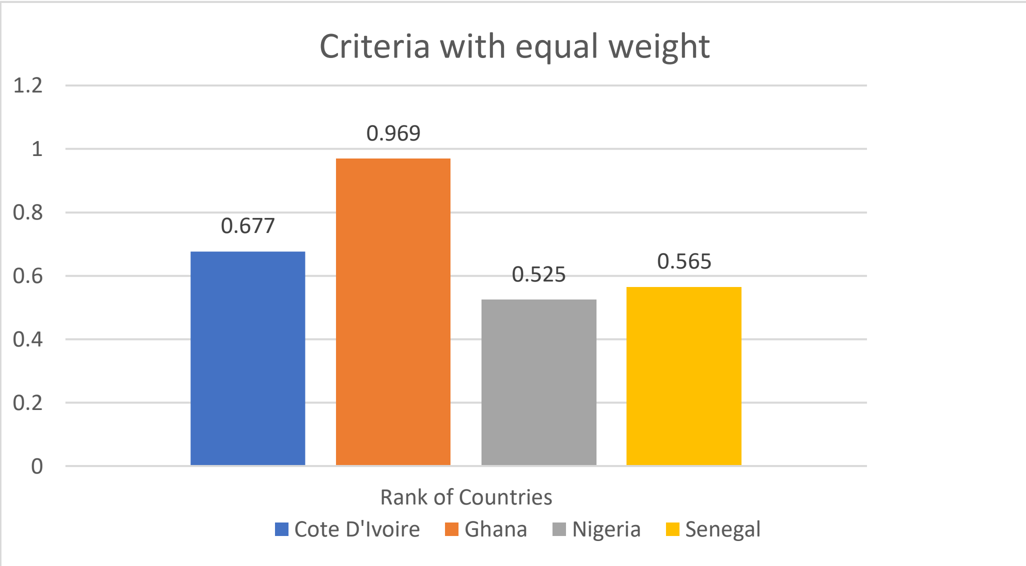

Fig 5.1 Preference Ranking chart of preferred country with equal weight. Source: own elaboration

Case 2: GDP criterion is removed.

In this case, the most significant weight or the ranking criterion is eliminated. This situation is being tested to see if the most significant weight also serves as the only driver of the output. This led to a revised AHP analysis that only took the final nine criteria into account. Overall priorities are established when results consistency has been confirmed, as illustrated in Tables 4.14A and 4.14B.

		CRITERIA								
		MW	**IR**	**PT**	**CPI**	**UR**	**DE**	**TRRP**	**HDI**	**ATE**
Criteria Characteristics		**cost**	**cost**	**cost**	**benefit**	**benefit**	**benefit**	**cost**	**benefit**	**benefit**
Equall Criteria Weight		0.2422	0.2453	0.1368	0.1025	0.1099	0.0710	0.0457	0.0299	0.0167
	COTE D'IVOIRE	0.000	0.890	1.000	1.000	0.000	0.054	0.898	0.322	0.469
VARIANTS	**GHANA**	1.000	0.483	0.902	1.000	0.190	0.080	1.000	1.000	1.000
=	**NIGERIA**	0.472	0.000	0.000	0.000	1.000	1.000	0.000	0.198	0.000
Countries	**SENEGAL**	0.173	1.000	0.393	1.000	0.032	0.000	0.864	0.000	0.492

Table 4.14A Criteria without GDP

		CRITERIA										
		MW	**IR**	**PT**	**CPI**	**UR**	**DE**	**TRRP**	**HDI**	**ATE**	**Overall**	**RANK**
Criteria Characteristics		**cost**	**cost**	**cost**	**benefit**	**benefit**	**benefit**	**cost**	**benefit**	**benefit**	**Priority**	
	COTE D'IVOIRE	0.000	0.218	0.137	0.103	0.000	0.004	0.041	0.010	0.008	0.520	2.000
VARIANTS	**GHANA**	**0.242**	**0.118**	**0.123**	**0.103**	**0.021**	**0.006**	**0.046**	**0.030**	**0.017**	**0.705**	**1.000**
=	**NIGERIA**	0.114	0.000	0.000	0.000	0.110	0.071	0.000	0.006	0.000	0.301	4.000
Countries	**SENEGAL**	0.042	0.245	0.054	0.103	0.003	0.000	0.040	0.000	0.008	0.495	3.000

Table 4.14B Overall Priority without GDP

As in example 1, Ghana continues to be preferred, Cote D'Ivoire is still in second place, Senegal is in third place, and Nigeria is in fourth place. As a result, it is reasonable to state that the selection of the best options is not considerably impacted by the absence of the GDP criterion.

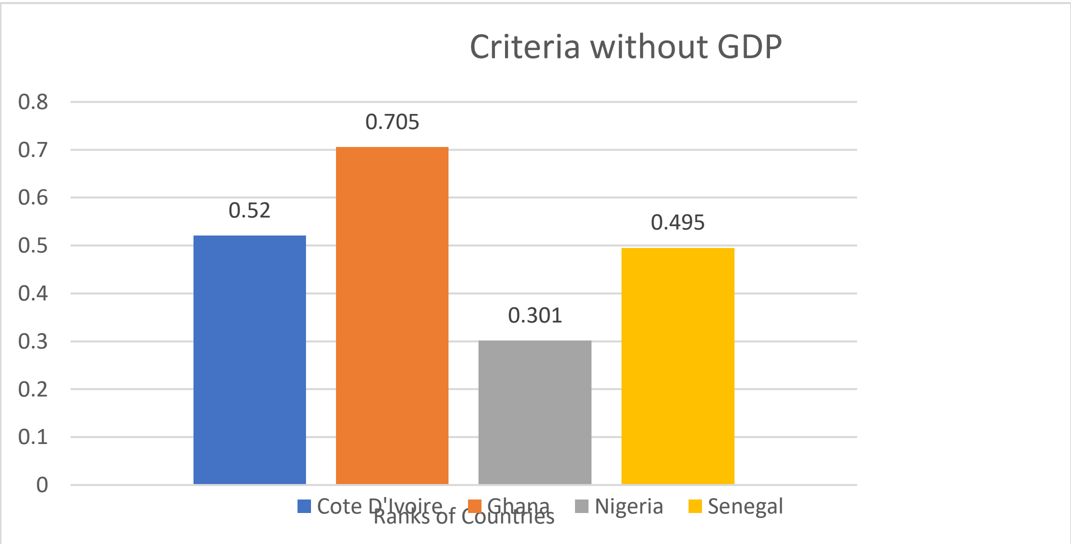

Fig 5.2 Preference Ranking chart of preferred country without GDP Source: own elaboration.

5.3 Making the final decision.

Now that several calculations and the Sensitivity Analysis have been completed, decisions can be made. A rather distinct Alternative is revealed at the conclusion of the AHP analysis: Ghana has demonstrated economic viability and favourable business conditions. Considering the chosen criteria, Ghana is the recommended location for citing automobile production plant.

6 CONCLUSSION

The decision to locate automobile plant cite in the best country in West Africa is a practical illustration of how mathematical methods can be used in decision-making. The Analytical Hierarchy Process and Simple Additive Weighting of Multicriteria Decision Making were employed in this study. The variant was rated using SAW, and the weight of the selected criteria was determined using AHP. The target country selection analysis utilizing AHP proved to be resilient despite certain unavoidable constraints, as is shown by sensitivity analysis.

Ghana ended up being the most economically viable location for an automobile production in West Africa. According to the initial analysis, Nigeria appeared to be the alternate country to Ghana. However, after doing a sensitivity analysis, Cote d'Ivoire was shown to be the best alternative to Ghana. The study demonstrated that using free statistics and the expertise of specialists, AHP enables the execution of an indicative location selection analysis.

The study also enabled the researcher to recognize and define the priorities used when considering potential new locations. A thorough literature review, the opinions of experts, and consultant recommendations were used to choose pertinent nation selection criteria.

Analytical Hierarchy Process has been demonstrated to be a useful tool for complicated strategic decisions like choosing an international site.

It must be highlighted that this study is restricted to choosing only the West African nation that is economically viable for the installation of an automobile plant; the region, community, and the site are not considered; as a result, all criteria employed are based on country level location selection. Further research could consider the precise region, neighbourhood, and location in Ghana where an auto manufacturing plant might be built.

REFERENCES

Mu, E. and Pereyra-Rojas, M. (2017)," Practical Decision Making: An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions V2",

Munier, N. (2011), "A Strategy for Using Multicriteria Analysis in Decision-Making A Guide for Simple and Complex Environmental Projects", Springer Dordrecht, ISBN 978-94-017-8442-9.

Olson, D. L. (1996), "Decision Aids for Selection Problems", Springer New York, NY, ISBN 978-0-387-94560-6

Marco *Dean* (*2022*). Multiple-criteria decision-making (MCDM) for Optimal Selection, Oct 27, 2022

Marco Dean Practical guide to Multi Criteria Analysis, 2022

Triantaphyllou, E., and Mann, S.H. (1994 b). Some Critical Issues in Making Decisions with Pairwise Comparisons, Proceedings of the Third International Symposium on the AHP, George Washington University, Washington, DC.

Triantaphyllou, E., and Mann, S.H. (1995). Using The Analytic Hierarchy Process for Decision Making in Engineering Applications: Some Challenges

Triantaphyllou, E., (2002). Multi-Criteria Decision-Making Methods: A comparative Study. New York: Springer.

Dyer, J. S. (1990). Remarks on the Analytic Hierarchy Process. Management Science, 36(3), 249-258.

Belton, V., & Stewart, T. J. (2002). Multiple Criteria Decision Analysis: An Integrated Approach. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Fishburn, P. 1967. Additive utilities with finite sets:
Applications in the management sciences. Naval Research Logistics

Chen, S.J. and C.L. Hwang, Fuzzy Multiple Attribute Decision Making: Methods and Applications, Lecture Notes in Economics and Mathematical Systems, Sringer-Verlag, Berlin, Germany, 1992.

Hwang C.L. and K. Yoon, Multiple Attribute Decision Making: Methods and Applications, Springer-Verlag, New York, NY, 1981.

Wang, L., and T. Raz, "Analytic Hierarchy Process Based on Data Flow Problem," Computers & Industrial Engineering, 20, 1991.

Miller, D.W., and M.K. Starr, Executive Decisions and Operations Research, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1969.

Saaty, T.L. (1980). The Analytic Hierarchy Process. McGraw-Hill International, New York, NY, U.S.A.

Saaty, T.L. (1983). Axiomatic Foundations of the Analytic Hierarchy Process, Management Science, 32: 841-855.

Saaty, T.L. (1990). An Exposition of the AHP in Reply to the Paper 'Remarks on the Analytic Hierarchy Process', Management Science.

Saaty, T.L. (1994). Fundamentals of Decision Making and Priority Theory with the AHP. RWS Publications, Pittsburgh, PA, U.S.A.

A. Guitouni *et al.* Tentative guidelines to help choosing an appropriate MCDA method Eur. J. Oper. Res. (1998)

Saaty, T. L. (1986). Axiomatic foundation of the Analytic Hierarchy Process. Management Science, 32(7), 841-855.

Saaty, T. L. (1989). Group Decision Making and the AHP. In Golden, B. L., Wasil, E. A., and Harker, P. T. (Eds.), The Analytic Hierarchy Process: Applications and Studies (pp. 59- 67). New York, USA: Springer Berlin Heidelberg.

Fishburn, P.C. (1967). Additive Utilities with Incomplete Product Set: Applications to Priorities and Assignments. American Society of Operations Research (ORSA), Baltimore, MD, U.S.A.

Miller, D.W., and Starr, M.K. (1969). Executive Decisions and Operations Research. Prentice-Hall, Inc., Englewood Cliffs, NJ, U.S.A. 9

Fishburn, P. 1967. Additive utilities with finite sets: Applications in the management sciences. Naval Research Logistics

Wang, L., and Raz, T. (1991). Analytic Hierarchy Process Based on Data Flow Problem. Computers & IE, 20.