Original Research Article

Analytical Hierarchy Process (AHP)Model for Prioritizing Alternative Strategies for Malaria Control

ABSTRACT

Aim:"This study Analytical Hierarchy Process (AHP) Model for Malaria Control" was aimed at using analytical hierarchy process model to prioritize alternative strategies for malaria control.

Place and the Duration of the Study: The study was carried out in Bauchi State, Nigeria from May, 2017 to June, 2019.

Methodology: The study used primary and secondary data. The secondary data were the identified alternatives strategies for malaria control and the criteria for evaluating these strategies obtained from malaria control journals and World Health Organization report. The criteria and malaria control strategies were used as input for developing a 9-point scale used in a questionnaire to obtained responses from the Experts in scoring the pairwise comparison of the criteria and the alternatives. Analytical hierarchy process (AHP) model was used to develop the pairwise comparison matrices from the Experts opinions. Computations were carried out with the help of computer software, business performance management Singapore (BPMSG-AHP ONLINE).

Results: The result of the analysis shows that the use of insecticide treated nets was ranked the best strategy for malaria control (AHP score 0.348). Based on the findings of this paper, it is recommended that the use of treated mosquito net should be given much attention in controlling malaria in Nigeria.

Conclusion: We therefore conclude that in a multi -criteria decision making situation, AHP is a powerful tool to assists decision makers

Keywords: Analytical Hierarchy Process; Multi-criteria Decision Analysis; Alternative; Strategy; Malaria Control

1.0 Introduction

Decision making is one activity that we can't do without. In all aspects of our lives we are confronted with challenges that we need to make a decision. Decision may be simple or complex depending on the scenario and factors responsible.

According to Alexander [1], modern day decision has been inherently complex when many factors have to be weight against competing priorities. Decision making involves the use of intelligence, wisdom and creativity in order for humans to satisfy basic need or to survive. Evaluating a decision requires several considerations such as the benefits derived from making the right decision, the cost, the risk and losses resulting from the action taking if the wrong decision is made.

Some useful techniques in multi criteria decision analysis (MCDA) are goal programming, multi-attribute utility theory (MAUT) and analytical hierarchy process (AHP). AHP has been increasingly applied as a technique for MCDA in the field of healthcare[2].

AHP is a decision-making method that was developed by Saaty, the technique used to organize complex relationships between elements into structure or system based on subjective judgment such as experience [3].

AHP is a theory of measurement through pairwise comparisons and relies on the judgment of experts to derive priority scales [4]. It is one of the more popular methods of MCDM and has many advantages as well as disadvantages. One of its advantages is its ease of use. Its use of pairwise comparison can allowed decision makers to weight coefficient and compare alternatives with relative ease. It is scalable, and can easily adjust in size to accommodate decision making problems due to its hierarchical structure. And although it requires input data to properly perform pairwise comparisons, the data are rather easy to obtain. The method has experience problems of interdependence between criteria and alternatives. Due to the approach of pairwise comparisons, it can also be subjective to inconsistencies in judgment and therefore the question of reliability of the result arises and so, to evaluate the reliability of the obtained result, it is reasonable to find dependency between result of the AHP and inaccuracies of the initial data-Experts judgement [5].

AHP is an Eigen value approach to the pairwise comparisons. It also provides a methodology to calibrate the numerical scale for the measurement of quantitative as well as qualitative performances. The scale ranges from 1/9 for least valued than to 1 for equal and to 9 for absolutely more important than covering the entire spectrum of the comparisons. Some key and basic steps involves in this methodology are: 1. State the problem. 2. Broaden the objectives of the problem or consider all actors, objectives and is outcome. 3. Identify the criteria that influence the behaviour. 4. Structure the problem in a hierarchy of different levels constituting goals, criteria, sub-criteria and alternatives. 5. Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $\frac{n(n-1)}{2}$ comparisons, where n is the number of element with the considerations that diagonal elements are equal or 1 and the other elements will simply be reciprocals of the earlier comparison. 6. Perform calculations to find the maximum Eigen value, consistency index (CI), consistency ratio (CR) and normalized values for each criteria /alternative. 7. If the maximum Eigen value, (CI), and (CR) are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in the desired range [6].

Analytical hierarchy process has been applied in so many studies, including Prioritization of Evacuation of Solid Waste at Municipal Solid Waste Disposal Center [7]; Analysis of Poverty and Inequality Among Farmers in Yola North Local Government Area of Adamawa State Nigeria [8]; Analytical Hierarchy Process Modelling for Malaria Risk Zone in Vadora District, Gujurat[9]; A systematic literature review and evaluation shows that more than two hundred studies were carried out in which the AHP was applied.

Management and planning for implementation of alternative strategies to control malaria can be considered to take place in a multi-criteria environment. The application of MCDA in healthcare shows that the techniques are also suitable to malaria control. In healthcare, certain problems carry quantitative features which can be evaluated numerically, however others carry qualitative features that are complex to evaluate numerically, AHP can assist in assigning priorities and weight [10].

Malaria control and prevention seem to have followed a slow lane in spite of many years of intervention programmes. Strategies to control malaria includes vector control which reduces transmission by the mosquito vector from humans to mosquitoes and then back to humans (this is achieved using insecticide treated mosquito nets or indoor residual spraying); chemoprevention which prevents the bloodstage infections in humans; case management which includes diagnosis and treatment of infections [11]; spraying breeding sites with dichlorodiphenyltrichloroethane(DDT); intermittent preventive treatment [12]; and other personal protection measures such as use of repellents on exposed skin and clothes , wear long pants, long-sleeves shirt and a hat, and staying indoors behind the screen entries. The followings are also identified by World Health Organization as strategies to roll back malaria: evidence based decision using surveillance, appropriate responses and building community awareness; focus research to develop new medicines, vaccines and insecticides as well as to enhance epidemiological operational research activities; coordinated action for strengthening existing health services, policies and providing technical support and harmonized actions to build a dynamic global movement through partnership.

In spite of many years of intervention programmes, malaria control and preventions seem to follow slow lane. Many studies were carried out to prevent infection and the spread of the disease. Alternative strategies for malaria control were provided without prioritizing them. The society need to know the strategy that experts consider more efficient in malaria control in order to give more attention to it. There is therefore the need to prioritize these alternative strategies and identify the one with the highest priority so that more effort will be geared towards that and more resources will be channelled in that direction.

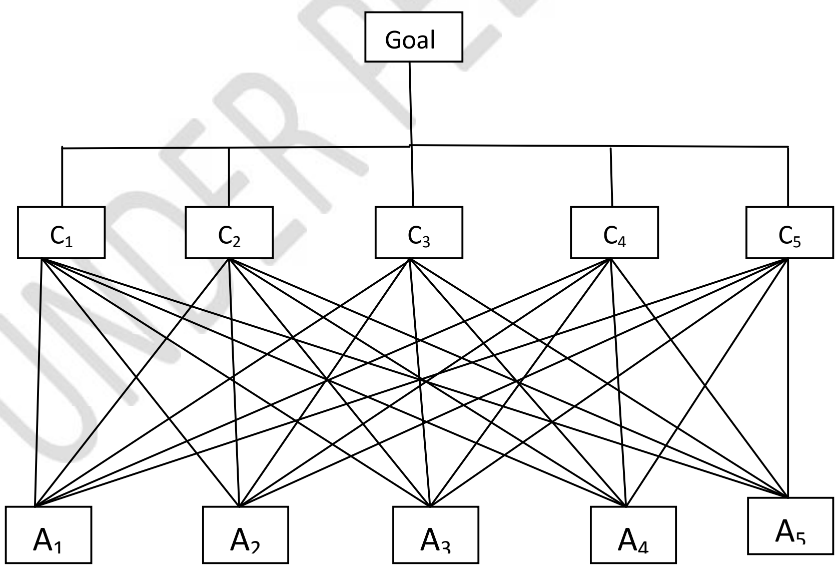
The aim of this study is to use Analytical Hierarchy Process (AHP) model to prioritize alternative strategies for malaria control in Bauchi State, Nigeria.

2.0 Material and Methods

Primary and secondary data were both used in this study. Questionnaire was designed and administered to experts (medical personals in various healthcare units of Bauchi State) to obtain the relative importance of each alternative and criteria over the other.

The secondary data was obtained from world health organization reports on malaria and other journals on malaria control preventions. Interviews were also conducted to identify the malaria strategies practice in the study area. The major malaria control strategies (alternatives) and criteria were identified. The following were identified as the goal, alternatives and criteria to malaria control in the study area.

Figure 1: The hierarchical structure of the problem.



***G* = GOAL**; Control malaria in Bauchi

ALTERNATIVES: - The following were identified as major alternatives to malaria control

A_1 = Insecticide treated net (ITN)/ long lasting insecticidal net (LLIN).

A_2 = Indoor residual spraying (IRS)

A_3 = Larval source management (LSM)
A_4 = Intermittent preventive treatment of pregnant women and children under five.
A_5= Providing quality assured treatment to all patients.
CRITERIA: The following were the criteria identified:-
C_1 = Accessibility
C_2 = Affordability
C_3 = Availability
C_4 = Acceptability
C_5 = Convenient

2.1 Method of Analysis

The Saaty analytic hierarchy process model was adopted for this study. The problem was decomposed into objective, alternatives and criteria.

Based on the pairwise comparison of the alternatives and criteria that was obtained from the Experts, matrices were formed. The entries in the matrices were based on the verbal judgment of the Experts. In order to designate the importance of each parameter; we weighted them using a pairwise comparison method which is one of the component of AHP. To assist in the weighing method of the pairwise matrix, the Saaty's pairwise comparison table was used. This was carried out by asking the Experts to select which alternative is more important than the other with respect to a given criterion and to state how much important. A table of intensity of importance was provided to guide the Experts.

Table 1: The Fundamental Scale of Absolute Numbers.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	Experience and judgment slightly favour one activity over another
3	Moderate importance	Experience and judgment slightly favour one activity over another
4	Moderate plus	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
6	Strong plus	Experience and judgment strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another, its dominance demonstrated in practice.
8	Very, very strong	The evidence of favouring one activity over another is of the highest possible order of affirmation
9	Extreme importance	The evidence of favouring one activity over another is of the highest possible order of affirmation

Source: Saaty (2008)

The table of pairwise comparison was constructed for each criterion. This was done to compare each alternative against the other with respect to the given criterion. Another matrix was again constructed to obtain the relative weights for each criterion with respect to the goal.

2.2 Ranking of criteria and alternative

Eigenvector solution approach was used for ranking of priorities from a pairwise matrix. The ranking P_i of alternative A_i is calculated using the following formula (weighted sum model);

$$P_i = \sum_{j=1}^{n} a_{ij} w_j \quad (1)$$

With w_j the weight of criterion C_i, and a_{ij} the performance measure of alternative A_i with respect to criterion C_i, performance values are normalized.

2.3 Consistency of the comparison matrix.

Consistency implies coherent judgment on the part of the decision maker regarding the pairwise comparisons. Mathematically, we say that a comparison matrix A is consistent if

$$a_{ij} a_{ik} = a_{jk} \text{ for all } i, j \text{ and } k \quad (2)$$

This property requires all the columns (and rows) of A to be linearly dependent.

It is usual for all comparison matrices to be consistent. Indeed, given that human judgment is the basis for the construction of these matrices, some “reasonable” degree of inconsistency is expected and tolerated.

To determine whether or not a level of consistency is “reasonable” we need to develop a quantifiable measure for the comparison matrix A. If A is perfectly consistent it will produce a normalized matrix N in which all the columns are identical – that is, given that w is a column vector of the relative weight $w_i, i = 1,2, \ldots, n, A$ is consistent if,

$$Aw = nw \quad (3)$$

For the case where A is not consistent, the relative weight, w_i is approximated by the average of the n element of row i in the normalized matrix N. Letting $\bar{w}$ be the computed average vector it can be shown that

$$A\bar{w} = n_{max}\bar{w}, \; n_{max} \geq n \quad (4)$$

In this case, the closer n_{max} is to n, the more consistent is the comparison matrix A. Base on this observation, AHP computes the consistency ratio as

$$CR = \frac{CI}{RI} \quad (5)$$

$$CI = \text{Consistency index of A} = \frac{n_{max} - n}{n-1} \quad (6)$$

$$RI = \text{Random consistency of } A = \frac{1.98(n-2)}{n} \quad (7)$$

The random consistency index, (RI), was determine empirically as the average CI of a large sample of randomly generated comparison matrices, A.

If $CR = .1$, the level of inconsistency is acceptable, otherwise, the inconsistency is high and the decision maker may need to re-estimate the element a_{ij} of A to realize better consistency.

We compute the value of n_{max} from $A\overline{w} = n_{max}\overline{w}$ by noting that the ith equation is

$$\sum_{j=1}^{n} a_{ij}\overline{w}_j = n_{max}\overline{w}_i,\ i = 1,2,3 \dots, n \quad (8)$$

Given $\sum_{i=1}^{n} \overline{w}_i = 1,$ (9)

we get

$$\sum_{i=1}^{n} \left(\sum_{j=1}^{n} a_{ij}\overline{w}_j \right) = n_{max} \sum_{i=1}^{n} \overline{w}_i = n_{max} \quad (10)$$

This means that the value of n_{max} can be determined by first computing the column vector $A\overline{w}$ and the summing up its elements.

3.0 Data Analysis

This chapter presents the results of the analysis done on Experts' opinion on the best alternative strategy to malaria control using the identified alternatives and criteria.

3.1 Presentation of Tables and Results

The following pairwise comparison matrices were obtained based on Experts' verbal judgments of the criteria and the alternatives. The normalization matrices and results of Table 2 to Table 5 are the results of analyzing each of these matrices.

Table2: Pairwise Comparison and Normalization Matrix for the Criteria

Pairwise Comparison Matrix						Normalization Matrix						
	C_1	C_2	C_3	C_4	C_5		C_1	C_2	C_3	C_4	C_5	Avg.
C_1	1	1/3	1/2	½	½	C_1	0.10	0.05	0.06	0.18	0.07	0.092
C_2	3	1	4	½	2	C_2	0.30	0.15	0.44	0.18	0.27	0.268
C_3	2	½	1	1/3	2	C_3	0.20	0.07	0.11	0.12	0.27	0.154
C_4	2	2	3	1	2	C_4	0.20	0.29	0.33	0.35	0.27	0.288
C_5	2	3	1/2	½	1	C_5	0.20	0.44	0.06	0.18	0.13	0.202
SUM	10.00	6.83	9.00	2.83	7.50	C.R						0.91

Table 3: Pairwise Comparison and Normalization Matrices for the Alternative Given Each Criterion

Pairwise Comparison Matrices						Normalization Matrices						
C_1	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**C_1**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Avg**
A_1	1	3	3	3	4	**A_1**	0.45	0.60	0.32	0.32	0.38	0.414
A_2	1/3	1	3	3	3	**A_2**	0.15	0.20	0.32	0.32	0.29	0.256
A_3	1/3	1/3	1	½	2	**A_3**	0.15	0.07	0.11	0.05	0.19	0.114
A_4	1/3	1/3	2	1	½	**A_4**	0.15	0.07	0.21	0.11	0.05	0.118
A_5	1/4	1/3	½	2	1	**A_5**	0.11	0.07	0.05	0.21	0.10	0.108
SUM	2.24	4.99	9.50	9.50	10.50	**C.R**						0.097
C_2	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**C_2**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Avg**
A_1	1	4	5	3	4	**A_1**	0.49	0.68	0.31	0.38	0.39	0.450

A_2	1/4	1	5	3	3	**A_2**	0.12	0.17	0.31	0.38	0.29	0.254
A_3	1/5	1/5	1	½	1/3	**A_3**	0.10	0.03	0.06	0.06	0.03	0.128
A_4	1/3	1/3	2	1	2	**A_4**	0.16	0.06	0.13	0.13	0.19	0.138
A_5	1/4	1/3	3	½	1	**A_5**	0.12	0.06	0.19	0.06	0.10	0.106
SUM	2.03	5.86	16.00	8.00	10.33	**C.R**						0.074
C_3	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**C_3**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Avg**
A_1	1	1/3	4	3	3	**A_1**	0.20	0.15	0.25	0.39	0.32	0.262
A_2	3	1	4	3	3	**A_2**	0.61	0.45	0.25	0.39	0.32	0.404
A_3	1/4	¼	1	1/5	½	**A_3**	0.05	0.11	0.06	0.03	0.05	0.060
A_4	1/3	1/3	5	1	2	**A_4**	0.07	0.15	0.31	0.13	0.21	0.174
A_5	1/3	1/3	2	½	1	**A_5**	0.07	0.15	0.13	0.06	0.11	0.104
SUM	4.91	2.24	16.00	7.70	9.50	**C.R**						0.078
C_4	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**C_4**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Avg**
A_1	1	2	5	3	3	**A_1**	0.42	0.52	0.31	0.36	0.35	0.392
A_2	1/2	1	5	3	3	**A_2**	0.21	0.26	0.31	0.36	0.35	0.298
A_3	1/5	1/5	1	1/3	½	**A_3**	0.08	0.05	0.06	0.04	0.06	0.058
A_4	1/3	1/3	3	1	1	**A_4**	0.14	0.09	0.19	0.12	0.12	0.132
A_5	1/3	1/3	2	1	1	**A_5**	0.14	0.09	0.13	0.12	0.12	0.120
SUM	2.36	3.86	16.00	8.33	8.50	**C.R**						0.021
C_5	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**C_5**	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**Avg**
A_1	1	1/3	1/3	3	3	**A_1**	0.13	0.13	0.08	0.27	0.27	0.176
A_2	3	1	2	3	3	**A_2**	0.39	0.40	0.50	0.27	0.27	0.366
A_3	3	½	1	3	3	**A_3**	0.39	0.20	0.25	0.27	0.27	0.276
A_4	1/3	1/3	1/3	1	1	**A_4**	0.04	0.13	0.08	0.09	0.09	0.086
A_5	1/3	1/3	1/3	1	1	**A_5**	0.04	0.13	0.08	0.09	0.09	0.086
SUM	7.66	2.49	3.99	11.00	11.00	**C.R**						0.057

Table4: Final Priority Vector for the Criteria

CRITERIA	Accessibility (C_1)	Affordability (C_2)	Availability(C_3)	Acceptability(C_4)	Convenient(C_5)
PRIORITIES	0.092	0.268	0.154	0.288	0.202

Table5: Priority Vectors and Ranking of the Alternatives Given Each Criterion

	Accessibility (C_1)		Affordability (C_2)		Availability (C_3)		Acceptability (C_4)		Convenient (C_5)		Final Priority Vector	
	Prio.	Rnk	Prio.	Rnk	Prio.	Rnk	Prio.	Rnk	Prio.	Rnk	Prio	Rnk
A_1	0.414	1	0.450	1	0.262	2	0.392	1	0.176	3	0.348	1
A_2	0.256	2	0.254	2	0.404	1	0.298	2	0.366	1	0.314	2
A_3	0.114	4	0.128	4	0.060	5	0.058	5	0.276	2	0.127	4
A_4	0.118	3	0.138	3	0.174	3	0.132	3	0.086	4	0.130	3
A_5	0.108	5	0.106	5	0.104	4	0.120	4	0.086	4	0.106	5

It can be observed in Table 2 and Table 3 that the value of the consistency ratio (CR) is less than 0.10, which means all the matrices are within acceptable range.

3.2 Overall Priority Vector

The final Priority vector was obtained by multiplying the priority vectors of the criteria by the priorities for each alternative for each objective.

In Table 5 the priorities (Prio.) and the rank (Rnk) for each alternative with respect to each criterion has been calculated.

Based on the results of Table 4 and Table 5, the best alternative strategy for malaria control was A_1 (Insecticide treated nets).

4.0 Conclusion

Analytical Hierarchy Process (AHP) Model for Prioritizing Alternative Strategies for Malaria Control was carried out in Bauchi State, Nigeria. If the priority orders can be followed as identified in the study the use of insecticide treated net should be given high priority in the effort to prevent and control the spread of malaria in Nigeria. If the results of the study would be implemented the problem of malaria spread and control will be minimized greatly. We therefore conclude that in a multi -criteria decision making situation, AHP is a powerful tool to assists decision makers.

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