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ANALYTICAL HIERARCHIAL PROCESS OF FACTORS AFFECTING MATERNAL MORTALITY

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Article Info

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Abstract

Maternal mortality remains a critical global health challenge, with complex, multifactorial determinants that require effective prioritization for targeted interventions. This study utilized the Analytical Hierarchical Process (AHP) to systematically assess and prioritize factors influencing maternal mortality. The AHP, a decision-making tool that employs pairwise comparisons and hierarchical structuring, allows for the quantitative evaluation of qualitative data, ensuring an accurate assessment of relative weights assigned to each factor. Expert opinions from health care professionals, opinions from women on antenatal visits from the survey inform the pairwise comparisons, providing a comprehensive understanding of each factor's significance. Results highlight that sepsis had the highest risk factor of 17.95%, followed by hypertensive disorder and postpartum hemorrhage, with a percentage risk factor of 16.53% and 16.15%, respectively. The health status of a woman, the quality of healthcare facilities, abortion, and antenatal care contribute almost the same to the risk factors, with percentage contributions to high risk of maternal mortality as 14.58%, 14,56%, 14.94%, and 14.29%, respectively. This study demonstrates AHP's potential as a valuable framework for policymakers to prioritize actions and allocate resources effectively, ultimately guiding evidence-based strategies for maternal health improvement. We recommend that priority should be given to Sepsis screening and management for hypertensive disorders in pregnant women and more attention should be paid to women with postpartum hemorrhage, among others.

INTRODUCTION

Maternal mortality is a significant public health concern worldwide, with an estimated 303,000 maternal deaths occurring globally in 2015 (World Health Organization (WHO, 2019). More than 99% of the women who die from pregnancy-related complications live in low- and middle-income countries where systematic data collection is of variable quality (Say, et al., 2014).

Maternal mortality remains an important public health challenge in many developing countries, including Nigeria. Nigeria accounts for approximately 20% of global maternal deaths, making it the second-largest contributor after

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India (WHO 2019). Several factors contribute to maternal mortality, including inadequate access to quality maternal health services, poor infrastructure, poverty, and sociocultural norms that affect women's health-seeking behaviors.

The high-risk factors for maternal mortality are multifactorial and complex and include inadequate access to quality healthcare, poverty, low educational status, cultural beliefs and practices, and poor infrastructure. These factors contribute to delays in seeking appropriate health care services, delays in reaching health care facilities, and delays in receiving adequate medical care.

Sub-Saharan Africa (SSA) has a high maternal mortality ratio in 2017. Nigeria, with a maternal mortality ratio of 917, is the most populous country in SSA and, as such, contributes largely to the burden of Maternal Mortality (WHO 2019). While several analyses of Maternal Mortality trends show that Nigeria is making progress in reducing the maternal mortality rate, the pace remains slow as a woman's chance of dying from pregnancy and childbirth is 1 in 13 and more startling is that most of these deaths are preventable (WHO 2019)

In this paper, we present the following points:

1. Research design

The research design to be adopted is an explorative research design that will be used to generate insights into risk factors, such as age, abortion, healthcare services, Antenatal care, educational background, health status, and post-partum hemorrhage. The quantitative research design will also be adopted to compare and prioritize High-risk factors to be identified in terms of their relative performance using Saaty Ranking Scale and Random Consistency Index (RCI).

Table 3.1: Saaty Ranking Scale Saaty (1980).

Rank	Remark	Explanation
1	Equal Importance	The two activities contribute equally to the objective of the
3	Moderate Importance of one over another	Experience and judgment slightly favor one another.
5	Strong Importance of one over another	Experience and judgment strongly favor one activity over another.
7	Strong Importance of one over another	The activity is strongly favored, and its dominance is demonstrated in practice.
9	Extreme Importance of one over another	Evidence favoring one activity over another is of the highest possible affirmative order.
2,4,6,8	Weak, moderate, strong plus, very strong The importance of one over another	When compromise is needed
Reciprocals of nonzero	If activity I has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value compared with I.	

2. Population of the Study

The study will focus on women under child-bearing age between the ages of 15 and 49 years and health workers in the study area.

3. Method of Data Collection and Analysis

Primary data will be collected by administering a questionnaire and conducting interviews. The questionnaire is AHP-type and compares each Criteria and their alternatives. Microsoft Office Excel will be used to analyze the data.

Model

AHP involves mathematical calculations to determine the priority weights of the criteria and alternatives using a comparison matrix, and the priority vector is calculated using eigenvalue calculations.

4. AHP mathematical model

Pairwise comparison matrix of decision elements

Performing the pairwise comparison Matrix of the decision elements, a pairwise comparison matrix is created such that the criteria in row i (i= 1, 2...n) are ranked relative to each of the criteria represented by the n columns. Let a_{ij} define the element (*I, j*) of A, AHP uses a discrete scale (Saaty ranking scale) from 1 to 9, where a_{ij},=1 signifies that *i* and *j* are equally important, etc. (see table 3.1)

For consistency, aij=k automatically implies $a_{ji}=\frac{1}{k}$. also, diagonal element a_{ij} of A must be equal to 1 because a criterion is compared against itself. (*i=j) (Taha*, 2005).

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{1n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad 3.5.1$$

But $a_{ij}= \frac{1}{a_{ji}}$, where i≠j and a_{ij}=1, where i=j

Therefore, the pairwise comparison matrix (see table 3.2.2) becomes:

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{21}} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \quad 3.5.2$$

Estimating the weight of the decision elements

The relative weights of columns A and B can be determined by dividing each element of the column by the sum of the elements of the same column. The desired relative weight Wi of each row is computed as the row average of the resulting normalized matrix (Taha,2005). The eigenvector is defined as follows:

AW= Wλ 3.5.3

Where λ is the maximum eigenvalue of A. and it should be noted that this eigenvector solution is nominalized additively, i.e.

$\sum_{i=1}^{n} W_i = 1$ 3.5.4

Normalization of the pairwise matrix

$$\boldsymbol{C_{ij}} = \begin{pmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{pmatrix}$$

$$\boldsymbol{C_{ij}} = \sum_{i=1}^{n} \boldsymbol{c_{ij}}$$

Summation of columns i–j

$$\boldsymbol{X_{ij}} = \frac{\boldsymbol{c_{ij}}}{\sum_{i=1}^{n} \boldsymbol{c_{ij}}} = \begin{matrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{matrix}$$

Dividing each column element by the total number of columns to generate the normalized matrix

$$\boldsymbol{W_{ij}} = \frac{\sum_{i=1}^{n} x_{ij}}{n} = \begin{matrix} W_{11} \\ W_{12} \\ W_{13} \end{matrix}$$

The Consistency Index (CI) is given by the following:

CI = $(\lambda\_max - n) / (n - 1)$

Where: **λ_max** is the largest eigenvalue of the pairwise comparison matrix, and **n** is the number of elements.

The Consistency Ratio (CR) is given by

CR = CI / RI, and

Where: **RI** is the random index

Table 3.2.1: Random consistency Index Saaty (1980).

N	1	2	3	4	5	6	7	8	9	10	11
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The consistency index (RI) and the consistency Ratio (CR) are calculated as follows:

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

Where: λ_max is the largest eigenvalue of the pairwise comparison matrix, and n is the number of elements.

$$CR = \frac{CI}{RI}$$

This indicates that the value of CI is divided by the random index (RI) (see Table for random index) to obtain the CR. Note that the number RI to be picked is determined by the number of columns in the pairwise comparison matrix.

The CR value in the pairwise comparison matrix indicates consistency when the value is less than 0.10.

The CR value in the pairwise comparison matrix indicates consistency when the value is less than 0.1.

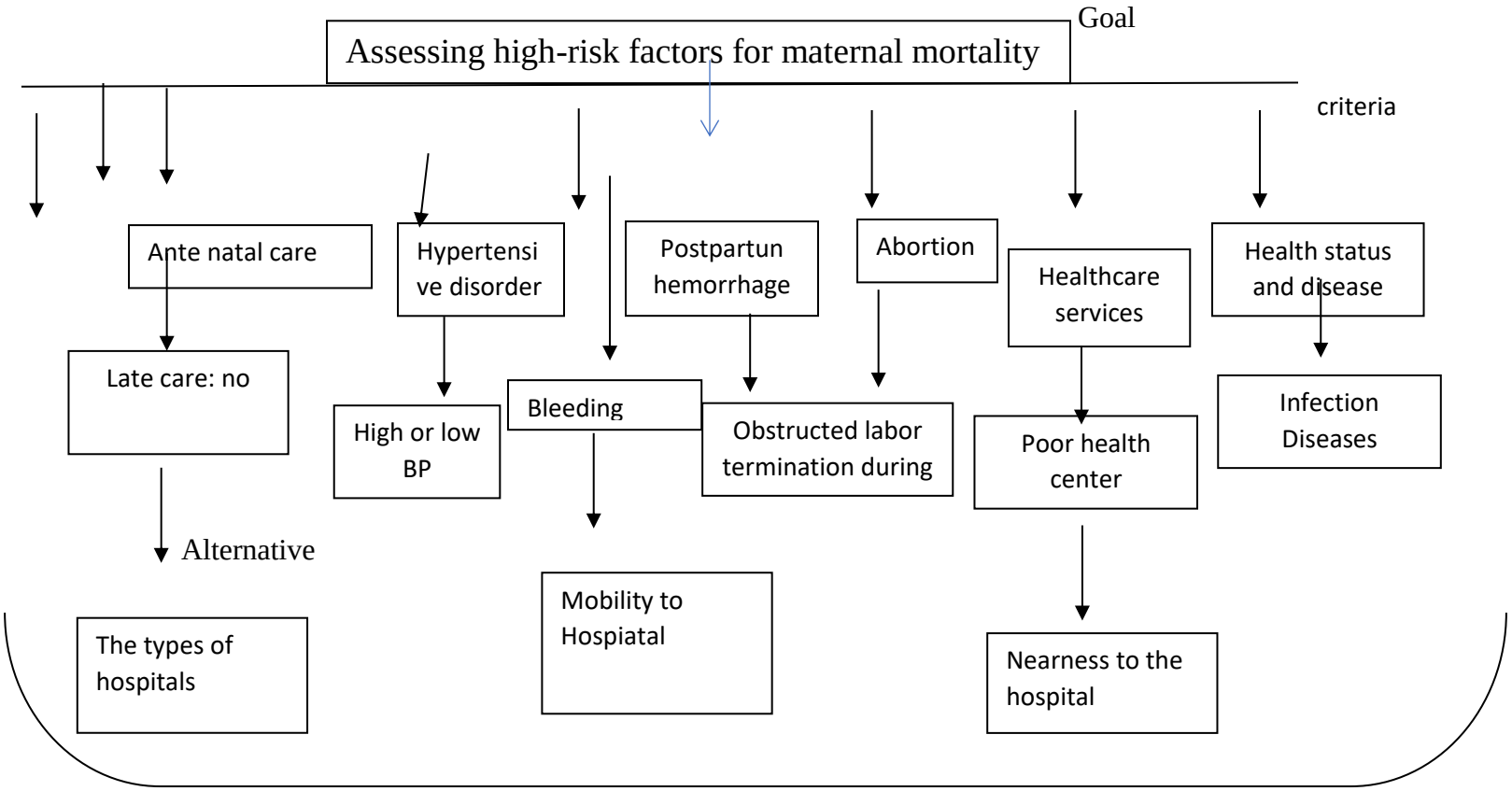

Table: 3.2.2 Pairwise Comparison Matrix

Criteria	HD	SP	PH	HS	QHS	AB AN
HD	1	HD/SP	HD/PH	HD/HS	HD/QHS	HD/AB HD/AN
SP	HD/SP	1	SP/PH	SP/HS	SP/QHS	SP/AB SP/AN
PH	PH/AD	SP/PH	1	PH/HS	PH/QHS	PH/AB PH/AN
HS	HD/HS	SP/HS	PH/HS	1	HS/QHS	HS/AB HS/AN
QHS	HD/QHS	SP/QHS	PH/QHS	HS/QHS	1	AB/QHS QHS/AN
AB	AB/HD	AB/SP	AB/PH	AB/HS	AB/QHS	1 AB/AN
AN	AN/HD	AN/SP	AN/PH	AN/HS	AN/QHS	AN/AB 1

KEY: Ante natal care (AN), Sepsis (SP), Postpartum Heamorrage(PH), Abortion (AB), Quality of Health Service (QHS), Health status (HS) &Hypertensive Disorder((HD).

5. Sample Technique

Sample is the fraction of any given population. Sampling is a technique or method of sample selection. The investigator or researcher conducting this research adopts the most appropriate sampling technique for the study, which is the multi-stage sampling technique.

6. Validity and reliability of the instrument

A pilot study will be conducted to improve the validity and reliability of the instrument by correcting any ambiguity in the instrument. The pilot study was conducted by a random distribution of 30 questionnaires, whereby face validity and content validity were used to examine the appropriateness of the instrument to ascertain the degree to which questions or indicators in the data gathering instrument adequately represent the variable measured. Ambiguous questions observed from the responses provided were corrected by the researcher before going to the field to gather data for the study.

Second, the reliability of the instrument will be used to check the Cronbachs Alpha reliability coefficient reliability test yielded 0.624. This figure shows a high positive correlation, suggesting that the instrument has an acceptable level of validity and reliability. According to (Pallant), reliability scores greater than 0.60 are acceptable.

7. Determination of Sample Size

According to (Miaoulis & Michener,1976) the level of precision, confidence level, and degree of variability are the three criteria needed for determining the appropriateness of a sample size. A total of 30 questionnaires were distributed within the study area for the pre-test. The findings from the pretest enabled the study to determine its sample size, as given by Abe J.B (2010). To obtain an optimal sample size value sufficient for the study, the mathematical formula below was used.

$$n = \frac{Z^2 \alpha/_{2PQ}}{d^2}$$

where n is the sample size, Z α/2 is the standard normal value (1.96), and d is the margin.
of error

Thus, at α = 0.05, we obtain

$$\frac{(1.96)^2, (0.43)\ (0.5)}{(0.05)^2} = 376.63$$

Therefore, the sample size is approximately 377+5% (non-response = 400 questionnaires.

8. Data Presentation

Table 4.1: Pairwise Comparison Matrix Generated from Questionnaire (Participants)

Criteria	HD	SP	PH	HS	QHS	AB	AN
HD	1	6	0.25	1/6	5	1/5	1/4
SP	1/6	1	1/2	3	3	2	2
PH	2	3	1	1/5	1	1/7	1/4
HS	1	¼	1/5	1	1/4	1/3	3
QHS	1/7	1/3	2	4	1	1/5	2
AB	1	1/3	1	1/3	5	1	3
AN	1/3	1/6	4	1/5	1/4	1/3	1
Total	**5.642857**	**11.08333**	**8.95**	**8.9**	**15.5**	**4.209524**	**11.5**

The questionnaires were ranked according to Saaty nine scales and are summarized in Table 1. The sum of each column was obtained, and each element in the column was divided by the total number of columns. The result is the normalized table, as shown in Table 4.2.

9. Data Analysis and Results

Table 4.2: Normalized Pairwise Comparison Matrix

Criteria	HD	SP	PH	HS	QHS	AB	AN
HD	0.1772	0.5414	0.0279	0.0187	0.3226	0.0475	0.0217
SP	0.0295	0.0902	0.0559	0.3371	0.1935	0.4751	0.1739
PH	0.3544	0.2707	0.1117	0.0225	0.0645	0.0339	0.0217
HS	0.1772	0.0226	0.0223	0.1124	0.0161	0.0792	0.2609
QHS	0.0253	0.0301	0.2235	0.4494	0.0645	0.0475	0.1739
AB	0.1772	0.0301	0.1117	0.0375	0.3226	0.2376	0.2609
AN	0.0591	0.0150	0.4469	0.0225	0.0161	0.0792	0.0870

The normalized matrix was obtained by dividing each column element by the total number of columns. This was done to minimize bias in the expert judgment.

Table 4.3: Priority, Weight, and Lambda for the Synthesized Matrix for Health Workers

Criteria	Priority Vector	Weight	Λ
HD	0.1653	0.9327	5.6429
SP	0.1795	1.8458	11.1668
PH	0.1615	1.6344	9.8878
HS	0.1458	1.1838	7.1617
QHS	0.1456	1.0367	6.2717
AB	0.1494	0.6288	3.8044
AN	0.1429	1.1741	7.1034

λ_{max} = 7.2912, CI = 0.0485, RI = 1.32, CR = 0.0368 < 0.1 accepted

The priority vector results revealed that sepsis had the highest risk factor of 17.95%, followed by hypertensive disorder and postpartum hemorrhage with percentage risk factors of 16.53% and 16.15%, respectively. The health status of women, quality of healthcare facilities, abortions, and antenatal care contribute almost equally to the risk factors.

10. **Conclusions**

Maternal mortality is the death of a woman during pregnancy, childbirth, or delivery. The age of the patient may range between 15 and 45 years. These age brackets are considered the standard age of childbirth for women. The

data obtained for this study were analyzed using a multi-criteria decision-making approach (MCDM). First, the data were summarized in a pairwise comparison matrix (see Table 4.1), and the column totals were calculated. The individual elements of each column were then divided by the column totals to form the normalized table (Table 4.2). The weight, priority vector, lambda, and lambda maximum were all calculated from the normalized matrix.

The results revealed that sepsis was the highest risk factor (17.95% follow by hypertensive disorder and postpartum hemorrhage, with percentage risk factors of 16.53% and 16.15%, respectively. The health status of a woman, the quality of healthcare facilities, abortion, and antenatal care contribute almost the same to the risk factors, with percentage contributions to high risk of maternal mortality as 14.58%, 14,56%, 14.94%, and 14.29%, respectively.

This is a call for concern because there is a high correlation between these variables and maternal mortality. Although women aged 15 years are considered the age of birth, it is perilous for women at that age to deliver with ease. Sometimes, they experience complications during child birth and may results mortality either the mother or the child. For instance, postpartum hemorrhage, hypertension, and sepsis were significant factors of maternal mortality in this study. This indicates that healthcare policy makers and decision makers should prioritize these three variables and the others considered in this study. This study is in line with the report of the World Health Organization (WHO, 2019), which reported an estimated 303,000 maternal fatalities worldwide in 2015 and noted that maternal mortality is a serious public health concern. Over 99% of pregnant women who die due to difficulties during their pregnancy live in low- and middle-income nations where systematic data collection is of varying quality (Say, *et al.*, 2014). The report further stated that maternal mortality is a significant public health concern in many developing nations, including Nigeria. Research has shown that Nigeria is the second largest contributor after India, accounting for almost 20% of maternal fatalities worldwide (WHO, 2019). Maternal mortality is caused by several variables, such as poor infrastructure, poverty, and sociocultural norms, which influence women's health-seeking habits. Inadequate access to high-quality maternal health services is another. Other high-risk factors are hypertensive disorder, postpartum hemorrhage, health status of women aged below childbearing age, quality of health care facilities, sepsis abortion, and other related causes of risk factors of maternal mortality.

11. SUMMARY

Maternal Mortality Is the death of a woman during pregnancy, childbirth, or within 42 days after delivery or termination of pregnancy with risk factors of sepsis, abortion, healthcare services, Antenatal care, hypertensive disorder, health status, and postpartum hemorrhage for Federal Medical Center Keffi.

To efficiently Assess the high-risk factors for maternal mortality in FMC Keffi, the AHP model was used to rank and assess these factors with Microsoft Excel used for the quantitative analysis of primary data obtained by questionnaire administration.

The results obtained from the Analysis records to be Sepsis17.95%, Hypertensive Disorder 16.53% Postpartum hearmorrage, 16.15%, Ante natal care, 14.29%, Health Status, 14.58%, Abortion, 14.94%, and Quality of health care, 14.56%.

12. CONCLUSION

Maternal mortality is a significant health concern worldwide, with more than 99% of women who die from pregnancy-related complications living in low- and middle-income countries where systematic data collection is of variable quality.

The study carried out revealed these high-risk factors for maternal FMC Keffi to be sepsis (17.95%, Hypertensive disorder 16.53%, Post partum Hemmorrage with 16.15%,

13. RECOMMENDATION

We recommend that priority should be given to Sepsis screening and management for hypertensive disorders in pregnant women and more attention should be paid to women with postpartum hemorrhage, among others.

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APPENDIX I

Questionnaire

Health Practitioners

1. Sex (a) male (b) female
2. Marital status (a) Single (b) Married (c) Divorced (d) Widowed (e) Separated.
3. Age (a) 15–25 years (b) 26–35 years (c) 36–45 years (d) 46 years and above.

Options	Equal importance	Equally less important	Moderate importance	Moderately important	Strong importance	High level of importance	Very important	VeryVery important	Extreme importance
	1(A)	**2(B)**	**3(C)**	**4(D)**	**5(E)**	**6(F)**	**7(G)**	**8(H)**	**9(I)**

6 Health Status (HBV, HIV, and other health related complication)

I	How important is the Health Status of a Mother to Postpartum Hemorrhage regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

7 Quality of Health Care Service (Poor health service or No Health service)

I	How important is the Quality of health care service to the health status of a mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is the Quality of health care service to Postpartum Hemorrhage as regards to Maternal Mortality.	1	2	3	4	5	6	7	8	9

8 Abortion

I	How important is abortion regarding the quality of health care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is Abortion to the Health status regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
III	How important is Abortion to Postpartum Hemorrhage regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

9 Age (Below child bearing age or above child bearing age)

I	How important is Age to Abortion regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is Age to the Quality of Health Care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
III	How important is Age to Health status regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
IV	How important is Age to Postpartum Hemorrhage as regards to Maternal Mortality.	1	2	3	4	5	6	7	8	9

Ten Educational Background.

I	How important is the educational background to the Age of a mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is educational background to Abortion regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
III	How important is educational background to the quality of health care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
IV	How important is the educational background to the health status of a mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
V	How important is educational background to Postpartum Hemorrhage regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

Eleven Neonatal care (late ante natal care or No Antenatal care)

I.	How important is Ante natal care to educational background regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
I.	How important is Ante natal care to the Age of a Mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
I.	How important is antenatal care to a Mother that does Abortion regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
I.	How important is antenatal care to Healthcare services regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
I.	How important is Ante natal care to the Health status of a Mother regarding Maternal mortality.	1	2	3	4	5	6	7	8	9
I.	How important is Ante natal care for postpartum hemorrhage in terms of maternal mortality?	1	2	3	4	5	6	7	8	9

Twelve Types

of Hospital (Public or Private)

I	How important is the type of Hospital to nearness to Hospital.	1	2	3	4	5	6	7	8	9
II	How important is the type of Hospital to Mobility to Hospital.	1	2	3	4	5	6	7	8	9
III	How important is the accessibility of healthcare facilities to Maternal Mortality.	1	2	3	4	5	6	7	8	9
I	How important is Nearness to Hospital to Mobility to Hospital.	1	2	3	4	5	6	7	8	9

13. Hypertensive Disorder

I	How important is hypertension to maternal mortality?	1	2	3	4	5	6	7	8	9

14. Sepsis

I	How important is Sepsis to maternal mortality?	1	2	3	4	5	6	7	8	9

15. Postpartum Hemorrhage to mortality

I	How important is Postpartum hemorrhage to maternal mortality?	1	2	3	4	5	6	7	8	9

APPENDIX II

Questionnaire

1. Sex (a) male (b) female
2. Marital status (a) Single (b) Married (c) Divorced (d) Widowed.
3. Age (a) 15–25 years (b) 26–35 years (c) 36–45 years (d) 46 years and above.

Options	Equal importance	Equally less important	Moderate importance	Moderately important	Strong importance	High level of importance	Very important	VeryVery important	Extreme importance	**Item**
	1(A)	**2(B)**	**3(C)**	**4(D)**	**5(E)**	**6(F)**	**7(G)**	**8(H)**	**9(I)**	

4 Neonatal care (late ante natal care or No Antenatal care)

I	How important is Ante natal care to Educational background regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is Ante natal care to the Age of a Mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

III	How important is Ante natal care to Abortion in a Mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
IV	How important is antenatal care to Healthcare services regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
IIV	How important is Ante natal care to the Health status of a Mother regarding Maternal mortality.	1	2	3	4	5	6	7	8	9

Educational Background.

I	How important is the educational background to the Age of a Mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is educational background to Abortion regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
III	How important is Educational background to the quality of health care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
IV	How important is the educational background to the Health status of a Mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

6 Age (Below child bearing age or above child bearing age)

I	How important is Age to Abortion regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is Age the Quality of Health Care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
III	How important is Age to Health status regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

7 Abortion

I	How important is abortion regarding the quality of health care service regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9
II	How important is Abortion to the Health status regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

8 Quality of Health Care Service (Poor health service or No Health service)

I	How important is the Quality of health care service to the health status of a mother regarding Maternal Mortality.	1	2	3	4	5	6	7	8	9

9 Types of Hospital (Public or Private)

I	How important is the type of Hospital to nearness to Hospital.	1	2	3	4	5	6	7	8	9
II	How important is the type of Hospital to Mobility to Hospital.	1	2	3	4	5	6	7	8	9

Ten Nearness to Hospital (Close or Far)

I	How important is Nearness to Hospital to Mobility to Hospital.	1	2	3	4	5	6	7	8	9

11. Hypertensive Disorder

I	How important is hypertension to maternal mortality?	1	2	3	4	5	6	7	8	9