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RESEARCH ARTICLE

Does Sociological background influence the choice of Availing of Maternity Care facilities? A study on North-Eastern region of India using hybrid models of Multi-Criteria Decision Analysis

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Abstract

Background: The north-eastern part of India, dominated by a population belonging to various tribal communities, possesses diverse socioeconomic characteristics. The variation across communities in terms of availing maternity care is linked to socioeconomic traits.

Objective: To conduct a comparative performance appraisal of all 16 regions in North-East India regarding the availing of maternity care and explore the linkage between each state's socioeconomic characteristics and its relative success in delivering maternity care.

Methods: The study is based on the data from India's National Family Health Survey (NFHS – 4). We considered a total of 16 geographical areas, 11 criteria of maternity care, and 17 socioeconomic characteristics. We utilized hybrid models of AHP-TOPSIS and Entropy-TOPSIS for the ordinal evaluation of the regions concerning the delivery of maternity care and socioeconomic attainments. Finally, we analysed the associations between the two.

Results: The ordinal evaluations rank all 16 regions regarding socioeconomic attainments and the delivery of maternity care. The study finds that Manipur, as a state, excels in delivering maternity care, while Meghalaya is the poorest performer. Female literacy, female educational attainment, male literacy, and female fertility are critical factors significantly impacting women's availing of maternity care.

Keywords

Antenatal Care; Postnatal care; Female literacy; Male literacy; Pairwise matrix; Ideal best.

JEL codes: C61, E70, I12, I14

I. Introduction

Antenatal care, also known as preventive health care or maternity care, is how pregnant women learn to maintain healthy behaviour during this phase of life. Thus, antenatal care brings pregnant women into contact with the formal healthcare system. Any deficiency on the part of either breaches the continuous contact of expectant mothers with health workers, which can result in adverse effects on both the mother and the baby (Lincetto et al. 2006).

There is no doubt that proper antenatal care from an early stage of pregnancy is the key to proper maternal care and, ultimately, safe motherhood. Many sudden health complications during pregnancy require counselling and preventive measures by trained health personnel, in addition to the usual clinical examination treatments. A combination of counselling and treatment minimizes the risk of maternal morbidity and mortality. During antenatal care, expectant mothers are counselled about the potential complications that may arise during this phase of life. Regular health checks, including blood pressure measurements, tetanus vaccinations, and receiving folic acid and iron supplements, etc., help women move towards safe motherhood (Atuhaire et al., 2020).

Maternity care as a whole is a continuous process. Regular visits to trained health personnel enable pregnant women to receive the vital health services needed at each specific stage of pregnancy. The World Health Organization (WHO) recently revised the previous norm of visiting a healthcare centre at least four times during pregnancy to the minimum required antenatal contact of once each trimester. The new recommended norm is to have at least eight visits. Since this modification is a recent phenomenon, the data used in the study conform to the old norm. Studies reveal varied estimates ranging from a low of 13 percent in Sub-Saharan Africa to over 90 percent in European countries of the proportion of women receiving a minimum of four antenatal care services (UNICEF 2021). In South Asia, a country as large as India, the same variation trend is observed across its regions. Data obtained from the National Family Health Survey (NFHS) – 4 bears its testimony (UNICEF 2021).

Women, especially from lower economic strata in many developing countries, often give birth in unhygienic conditions. Unclean deliveries, improper umbilical cord care practices, and unhygienic surroundings result in deadly Maternal and Neonatal Tetanus (MNT), which causes a steep rise in mortality rates, especially in the absence of adequate healthcare facilities. However, such casualties can be prevented by maintaining hygienic surroundings for delivery and through inexpensive and effective immunization of children and women with Tetanus Toxoid Containing Vaccines (WHO 2020). Although India has successfully mitigated the deadly infection of Maternal and Neonatal Tetanus, it must be remembered that complete eradication of tetanus is impossible as the bacteria causing it are found abundantly in the environment. A country can be declared free from neonatal tetanus if the incidence of such infection drops below one per one thousand live births per year in all parts of the country (WHO). Thus, protection against neonatal tetanus still remains an essential component of successful child and maternity healthcare.

Anaemia remains a significant concern for maternal health in India during pregnancy and can lead to maternal death. To combat this preventable disease, the Government of India has been recommending iron-folic acid supplementation among pregnant women. However, there is evidence of non-compliance with the government's directives. Inadequate health education and lack of awareness among women and their family members are the root causes of such carelessness (Singh et al. 2020).

The Mother and Child Protection (MCP) Card is popular among women in India, especially pregnant women and mothers of children up to five years old. The card keeps records of routine health care services and immunizations provided to the mother and child. Registering pregnant women for the MCP card is considered an indicator of delivering better maternity health care services. Antenatal contacts with trained health personnel raise awareness among women about the importance of institutional deliveries, immunization, and other preventive measures for safe motherhood (Ministry of Health… 2018).

To ensure special care for maternal and neonatal health, the Government of India launched another intervention program called Janani Suraksha Yojana (JSY) or maternal care scheme in 2005. Funded by the government, JSY provides cash assistance for childbirth delivery and post-delivery care. The scheme operates through accredited social health activists (ASHAs) in economically depressed regions, including the eight states of North-East India. JSY is specifically targeted towards poor pregnant women and tracks each pregnancy. Beneficiaries register with the scheme to receive government assistance, and the proportion of pregnant women registered with JSY estimates women approaching safe motherhood (National Health Portal… 2015).

However, despite the government's efforts to ensure safe motherhood, there is still a widespread disparity in the delivery of antenatal care. Studies conducted at different times and in different parts of the world show that socioeconomic characteristics of communities influence the choice of maternal health care. For example, a study on the choice of childbirth delivery facilities in Malawi found that the place of residence influenced the preference for public health facilities among households in urban areas, while the women's level of education influenced their preference for public healthcare facilities (Machira & Palamuleni 2017). Similar factors such as social, demographic, economic, and cultural influences affect the provision of antenatal healthcare in countries like Nepal and other developing nations (Pandey & Karki 2014; Ali et al. 2018).

The World Health Organization (WHO) and UNICEF report in 2012 emphasized that adequate care by trained health personnel during pregnancy and childbirth is essential for safe motherhood. Inadequate care in these areas contributes to a significant number of maternal and neonatal deaths worldwide (WHO and UNICEF 2012). The United Nations' Millennium Development Report in 2015 highlighted that approximately two-thirds of global childbirths occur in healthcare facilities. However, low-income and lower-middle-income countries in sub-Saharan Africa and South Asia accounted for only 50% of institutional childbirth deliveries, while also experiencing over 85% of maternal deaths (UN 2015).

In India, the north-eastern region is generally considered economically backward. With a population dominated by various tribes, this region holds strategic importance as it shares borders with China, Bangladesh, Myanmar, Nepal, and Bhutan. The hilly terrain and remote locations pose challenges in accessing healthcare services for the population. Despite the government's efforts to address these geographical hurdles, achieving universal safe motherhood remains a challenge. Given the socio-strategic importance of the region, policymakers need to conduct a comparative assessment of states in terms of delivering maternity care. It is also crucial to understand any existing linkage between the socioeconomic characteristics of communities and their preferences for antenatal care.

With this background, the present study focuses on the sixteen regions of eight states in North-East India and aims to:

1. conduct a comparative performance appraisal of all eight states in terms of availing maternity care, using an ordinal evaluation approach.
2. explore the linkage between each state's socioeconomic characteristics and its relative success in delivering maternity care.

II. Materials and Methods

The study is based on data available in the National Family Health Survey, India (NFHS) – 4 (2015-16) (International Institute… 2017). The data is publicly available in the public domain. The NFHS survey is conducted under the stewardship of the Ministry of Health and Family Welfare, Government of India. The data is prepared based on four questionnaires for households, women, men, and biomarkers. The women's questionnaire seeks information on various parameters of maternity care from mothers who had their last two children born during the three years preceding the survey. The relevant sample in this case consists of eligible women in the 15-49 age group. The NFHS-4 data is representative.

The survey utilized a stratified two-stage sampling method. The 2011 census of India (the latest one available now) was used as the sampling frame. In the first stage, the primary sampling units were selected. In rural areas, a unit was a village, while in urban areas, it was Census Enumeration Blocks. In the second stage, systematic sampling was used to select 22 households from each selected rural and urban cluster. Information was collected from every member and visitor present in the household during the interview. The actual data was collected in two phases in 2015 and 2016. A total of 628,900 households were selected, out of which 616,346 households were found occupied. Finally, members of 601,509 households were interviewed. Thus, the household response rate was 97.6%. Among the women in the 15-49 age group, 723,875 were selected, out of which 699,686 women were interviewed, resulting in a response rate of 96.7%. Similarly, out of the 122,051 eligible men selected, 112,122 were interviewed, making the response rate 91.9%.

The present study has considered only the information collected on maternity care from households belonging to the eight states of the north-eastern region of India. Each north-eastern state has been further subdivided into urban and rural areas. Thus, a total of sixteen geographical areas have been selected. Since the state-wise NFHS-4 data is further segregated into rural and urban areas, the present study has used this segregated data set. The study has considered eleven criteria of maternity care, as mentioned in the NFHS-4 report. The criteria of maternity care are as follows:

1. Mothers who had antenatal check-ups in the first trimester (%) = C1
2. Mothers who had at least 4 antenatal care visits (%) = C2
3. Mothers whose last birth was protected against neonatal tetanus (%) = C3
4. Mothers who consumed iron folic acid for 100 days or more when they were pregnant (%) = C4
5. Mothers who had total antenatal care (%) = C5
6. Registered pregnancies for which the mother received Mother and Child Protection (MCP) card (%) = C6
7. Mothers who received postnatal care from some doctor/nurse/LHV/ANM/midwife/other health personnel within 2 days of delivery (%) = C7

8. Mothers who received financial assistance under Janani Suraksha Yojana (JSY) [a safe motherhood intervention program under the National Rural Health Mission (NRHM)] for births delivered in an institution (%) = C8
9. Average out-of-pocket expenditure per delivery in a public health facility (Rs.) = C9
10. Children born at home who were taken to a health facility for a check-up within 24 hours of birth (%) = C10
11. Children who received a health check after birth from some doctor/nurse/LHV/ANM/midwife/other health personnel within 2 days of birth (%) = C11

The entire analysis is carried out for 16 different geographical regions. These geographical regions are used as alternatives in the present model. These regions are:

1. Assam Urban=A1
2. Assam Rural =A2
3. Arunachal Urban = A3
4. Arunachal Rural =A4
5. Meghalaya Urban =A5
6. Meghalaya Rural =A6
7. Manipur Urban =A7
8. Manipur Rural =A8
9. Mizoram Urban =A9
10. Mizoram Rural =A10
11. Nagaland Urban =A11
12. Nagaland Rural =A12
13. Sikkim Urban =A13
14. Sikkim Rural =A14
15. Tripura Urban =A15
16. Tripura Rural =A16

For data analysis, the study has used a hybrid model of Multicriteria Decision Analysis (MCDA). The primary objective of MCDA techniques is to assess alternatives based on multiple criteria and objectives (Voogd 1983). There are specific reasons for using MCDA techniques in this analysis. While traditional methods rely on intuitive approaches, some arguments suggest that MCDA often provides better outcomes when it comes to ranking a set of alternatives (Bernroider & Schmöllerl 2013). For instance, Ishizaka and Siraj (2018) compared traditional methods with MCDA methods in a decision-making problem involving ranking and comparing, and found that MCDA methods yielded better results than intuitive approaches.

The analysis is divided into three sections. The first section involves calculating the weights of the maternity criteria, as required by MCDA. Various methods exist in the literature for calculating these weights, such as entropy, weighted sum method, CRITIC, etc. One popular method is the Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty (Saaty 2013) in the 1970s. AHP is an MCDA tool used to organize and analyse complex decision-making problems in social sciences and engineering. AHP decomposes multiple criteria into a hierarchical structure based on their relationships. The main objective is placed at the top of the hierarchy, with criteria in the middle level and alternatives at the bottom level. Pairwise comparisons of the criteria are made using a scale of 1, 3, 5, 7, 9, indicating the intensity of importance (Saaty 2013).

In this case, the hierarchical structure includes the main objective at the top: to evaluate and rank all sixteen geographical regions of N.E. India based on their progress in delivering maternity care. The middle level consists of 11 criteria for maternity care, while the bottom level comprises the sixteen geographical regions.

Once the criteria weights are determined, the second section utilizes the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) method, one of the famous and widely used methods of MCDA, to identify the best-performing alternative. This analysis leads to the ordinal evaluation and ranking of all sixteen geographical regions based on their performance in delivering maternity care (Janssen & Rietveld 1990).

The third section of the study investigates the association between socioeconomic traits of the population and their utilization of maternity care. Seventeen socioeconomic characteristics have been considered:

1. Sex ratio of the total population (females per 1,000 males) = S1
2. Sex ratio at birth for children born in the last five years (females per 1,000 males) = S2
3. Households with electricity = S3
4. Households with an improved drinking water source = S4
5. Households using improved sanitation facility = S5
6. Households using clean fuel for cooking = S6
7. Households using iodized salt = S7
8. Households with any usual member covered by a health scheme or health insurance = S8
9. Women who are literate = S9
10. Men who are literate = S10
11. Women with 10 or more years of schooling = S11
12. Women of age 20-24 years married before age 18 years = S12
13. Men of age 25-29 years married before age 21 years = S13
14. Total fertility rate (children per woman) = S14
15. Women of age 15-19 years who were already mothers or pregnant at the time of the survey = S15
16. Health workers ever talked to female non-users about family planning =S16
17. Current users ever told about side effects of the current method =S17

The sex ratio of the total population provides an indication of existing gender inequality, if any. The sex ratio at birth reveals how the community discriminates between male and female children. In India, sex detection of the fetus is banned due to the prevalence of bias against carrying a girl child, particularly in rural areas. Indicators such as households with electricity, households with an improved drinking-water source, households using improved sanitation facilities, and households using clean fuel for cooking reflect the standard of living. The use of iodized salt and the presence of health scheme or health insurance coverage in households indicate the level of awareness regarding health and hygiene. Women's literacy, men's literacy, and women's educational attainment illustrate progress in education for women. Early marriage and early pregnancy among men and women highlight a lack of awareness about health issues. Health workers engaging with female non-users about family planning and providing information on the side effects of current family planning methods demonstrate efforts by health service providers to raise awareness among local women regarding safe pregnancy prevention methods. All these parameters are associated with the socioeconomic development of a community in any region.

In this section, these socioeconomic characteristics serve as criteria. Based on their importance as indicated by the assigned weights, the states are evaluated in an ordinal manner. The TOPSIS technique is used for the ordinal evaluation of the regions, preceded by the entropy method for determining the criteria weights. The AHP method is avoided due to the complexity that would arise from evaluating a relatively large number of criteria (17 in this case). It is expected that different weight determination techniques would not result in significantly divergent outcomes when applied to the same dataset.

To investigate the existence of an association between socioeconomic characteristics and the utilization of maternity care, Spearman's Rank Correlation Coefficient is computed for the ordinal rankings of the regions. Pearson's correlation coefficient is calculated for each pair of criteria (Cs) and socioeconomic characteristics (Ss). For this analysis, Python's open-source program is utilized.

III. Results and Discussion

We have considered 11 criteria related to maternity care. The first section of the analysis focuses on the application of the Analytic Hierarchy Process (AHP) for determining the weights of these criteria. AHP, as a technique of Multicriteria Decision Analysis (MCDA), utilizes a pairwise comparison matrix at its core. This matrix reflects the relative importance assigned to each pair of criteria, with the main objective positioned at the top of the hierarchy. The first step in this process involves constructing a pairwise comparison matrix for the criteria, where the elements of the matrix represent the comparison values between each pair of criteria.

To complete the entire operation, AHP transforms the decision-making problem into a hierarchical structure, with various components located at different levels of the hierarchy. At each level, pairwise comparisons are made among the alternative criteria within that specific component to calculate the priority weights. Preference scales, based on the perception of decision-makers or expert opinions, are used to determine the pairwise comparison values.

It is important to consider both the preference of element i over j (aij) and the preference of j over i (aji) during pairwise comparisons since the intensity of preference may not be the same in both directions. When constructing the pairwise comparison matrix, both comparison values should be incorporated. A reciprocal relationship exists between aij and aji, such that aji = 1/aj (Basak 1998). In the present case, the elements are the criteria themselves. To construct the pairwise comparison matrix, we utilize Saaty's scale of relative importance, which is as follows:

Level of relative importance	Saaty's Scale
Equal Importance	1
Moderate Importance	3
Strong Importance	5
Very Strong Importance	7
Extreme Importance	9
Intermediate values	2, 4, 6, 8
Values for Inverse Comparison	1/3; 1/5; 1/7; 1/9

Now let's construct the pairwise comparison matrix (table 1). The elements of the matrix are based on the judgments of the decision-maker. In this case, to determine the scale of importance, we have sought the opinions of five medical professionals – two doctors and three trained nurses. Following the rule of averaging, the matrix is constructed using their collective opinions.

Table 1. Pairwise Comparison Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	1	0.20	0.5	0.14	0.11	0.333333	0.125	0.166667	0.25	0.142857	0.166667
C2	5	1	0.5	0.50	0.50	0.5	0.5	0.5	0.5	0.5	0.5
C3	2	2	1	0.25	0.20	0.5	0.25	0.333333	0.5	0.285714	0.333333
C4	7	2	4	1	0.50	3	0.5	2	3	1	2
C5	9	2	5	2	1.00	3	2	3	3	2	2
C6	3	2	2	0.33	0.33	1	0.25	0.5	0.33	0.2	0.5
C7	8	2	4	2	0.50	4	1	3	2	2	3
C8	6	2	3	0.5	0.33	2	0.33	1	3	0.5	1
C9	4	2	2	0.33	0.33	3	0.5	0.33	1	0.33	0.5
C10	7	2	3.5	1	0.50	5	0.5	2	3	1	2
C11	6	2	3	0.5	0.50	2	0.33	1	2	0.5	1

Source: author's estimations based on the NFHS-4 data

The diagonal elements are 1. It indicates that the relative importance of criterion Ci with criterion Ci is 1.

The next step is the normalization of the pairwise comparison matrix. Every element of the normalized matrix is calculated as follows:

$$nij = mij / \sum_{j=1}^{11} mij$$

nij = element of row ***i*** and column ***j*** of the normalized matrix; mij = element of row ***i*** and column ***j*** of the pairwise comparison matrix. i = 1, 2,….,11; j = 1, 2,….,11.

The criterion weight of Ci is calculated by taking the simple average of the elements of the ith row of the normalized matrix (table 2).

Thus, the calculated criteria weights are:

The next requirement in the process is to check the consistency of the pairwise comparisons. This is necessary to ensure that the comparisons follow a logical sequence and are not random (Abbas & Kocaoglu 2016). To assess consistency, we calculate the Consistency Ratio. The pairwise comparisons will be considered consistent if the value of the Consistency Ratio is less than or equal to 0.1.

The first step in determining the Consistency Ratio is to multiply the elements of each column in the Pairwise Comparison Matrix shown in Table 1 by the corresponding criteria weights assigned to those columns.

In the next step, we sum the elements across each row to obtain the weighted sum value for each geographical region.

For each geographical region, we compute the ratio of the weighted sum value to the criteria weight. This is done to determine the consistency of the pairwise comparisons.

By calculating the arithmetic mean of the ratios obtained for each geographical region, we can determine the principal eigenvalue λmax.

In the present case, λmax = 11.70911.

Consistency Index: CI = (λmax – n)/(n – 1); n = number of criteria = 11 in the present case.

Consistency Ratio = CI/ RI; RI = Random Matrix Consistency Index number.

Table 2. Criteria Weights

Criteria	Details of the Criteria	Weights
C1	Mothers who had antenatal check-up in the first trimester (%)	0.016
C2	Mothers who had at least 4 antenatal care visits (%)	0.053
C3	Mothers whose last birth was protected against neonatal tetanus (%)	0.038
C4	Mothers who consumed iron folic acid for 100 days or more when they were pregnant (%)	0.124
C5	Mothers who had full antenatal care (%) =C5	0.190
C6	Registered pregnancies for which the mother received Mother and Child Protection (MCP) card (%)	0.048
C7	Mothers who received postnatal care from a doctor/nurse/LHV/ANM/midwife/other health personnel within 2 days of delivery (%)	0.167
C8	Mothers who received financial assistance under Janani Suraksha Yojana (JSY) [a safe motherhood intervention program under the National Rural Health Mission (NRHM)] for births delivered in an institution (%)	0.086
C9	Average out of pocket expenditure per delivery in public health facility (Rs.)	0.064
C10	Children born at home who were taken to a health facility for check-up within 24 hours of birth (%)	0.130
C11	Children who received a health check after birth from a doctor/nurse/LHV/ANM/midwife/other health personnel within 2 days of birth (%)	0.084

Source: author's estimations based on the NFHS-4 data

Regarding the computation of the Random Matrix Consistency Index (RI), different scholars have conducted experiments with varying numbers of runs and sample sizes, resulting in different RI values. Saaty (1980) initially calculated RIs up to n=10 and found RI=1.49 when n=10. Alonso and Lamata (2004) extended this calculation using the Saaty scale up to n=15 and found RI=1.5141 when n=11. Later, Alonso and Lamata (2006) developed a general method for calculating RI, which yielded RI=1.5141 for n=11. Since this paper also involves 11 criteria, the RI value of 1.5141 is used to compute the Consistency Ratio. The computed CR value is 0.047274, which is less than the threshold value of 0.10. Thus, the pairwise comparison matrix and the corresponding criteria weights are consistent.

The criteria weights, represented by the eigenvectors, indicate the relative importance of each criterion. The calculated criteria weights show that the most significant criterion is complete antenatal care for women, followed by receiving postnatal care from trained health personnel. The third most crucial criterion is children born at home but taken to a health facility within 24 hours of birth. Conversely, the criterion of antenatal check-up in the first trimester is of the least importance. The second least important criterion is mothers' protection against neonatal tetanus during their last childbirth, followed by the registration of pregnancies for an MCP card as the third least important criterion. Based on these criteria and their relative importance, the next section of the paper aims to investigate which of the sixteen geographical regions performs best in delivering maternity care. The study utilizes the TOPSIS technique, a part of the MCDA approach, for this purpose.

The TOPSIS technique, introduced by Hwang and Yoon (1981), finds applications in various fields such as economics, business, and engineering. Although TOPSIS has been widely used in academia, its application as part of MCDA techniques in healthcare is relatively new. Goetghebeur et al. (2008) proposed an MCDA-based model for healthcare decision-making, considering the complexity and various factors involved in the decision-making process. Sussex et al. (2013) conducted a pilot study using the MCDA approach to evaluate orphan medicinal products' eligibility for funding. Andrei et al. (2014) applied MCDA techniques to evaluate medical technologies in Hungary, aiming to identify the best technology based on healthcare priorities. Allaki et al. (2019) used the TOPSIS technique to assess different methods for selecting samples in Canadian Notifiable Avian Influenza surveillance programs.

The first step in the TOPSIS technique is to create a pairwise matrix, with criteria represented in the columns and alternatives presented in the rows. The matrix is provided in Table 3.

The next step is the vector normalization of the pairwise matrix. The elements of the normalized matrix are calculated in the following way:

First, we take a square of each element of the pairwise matrix. Then we take the square root of the sum of elements over each column. Next, we divide the squared value of each element of every column by the square root of the sum of elements over that column. The value, thus calculated corresponding to each element, becomes the value of the corresponding element in the normalized matrix.

Table 3. TOPSIS: Pairwise Matrix of Criteria and Alternatives

Criteria → Alternatives ↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
A1	68.3	60.3	92	43.9	30.4	95.6	71.4	42.4	5244	1.8	24.8
A2	53.5	44.8	89.6	30.5	16.6	96.4	51.9	69.9	3646	1.9	22.6
A3	39.2	37.3	74.9	11.1	3.9	85.8	37.8	12.9	9630	0.8	6
A4	36.2	23.5	60.6	7.5	3.4	90.5	26.1	24.5	5028	0.6	8.7
A5	68.3	71.3	89.2	53.8	38.4	88.4	76.4	26.2	2915	3.2	14.5
A6	50.7	46.3	77.5	33.2	20.9	94.6	42.6	28.6	3408	1.3	8.1
A7	84.9	81.7	92	50.9	45.1	30.4	77.7	21.2	11007	0	14.9
A8	72.6	62	87.1	32.7	27.8	34.2	57.4	30	9886	0.4	8.5
A9	77	77.5	88.5	59.3	47.9	97.8	77	44.9	5019	2.9	13.2
A10	52.4	42.9	75.7	47.1	27.2	95.1	50.2	52.2	3274	2.3	8.6
A11	36.7	28.6	77.3	7.7	4.9	71.4	36.2	27.5	6448	0.3	2.1
A12	19.7	9.3	58.1	3	1.3	74.8	16.5	31	5492	0	1.4
A13	77.2	75.6	98.5	48.7	36.7	98.4	79.3	11.9	4032	0	9.5
A14	75.7	74.2	96.6	54.9	40.2	99.4	71.6	38.3	3975	0	14.4
A15	77.1	77	99	16.3	9.8	83.7	72.6	21.3	5449	0	6.9
A16	62.7	59.9	90.9	12.4	6.8	82.7	58.4	37.3	4571	0	9

Source: author's estimations based on the NFHS-4 data

$$mij = vij^2 / \sqrt{\sum_{i=1}^{16} vij^2}$$

where mij = element of row ***i*** and column ***j*** in the normalized matrix.

vij = element of row ***i*** and column ***j*** in the pairwise matrix

In the next step, each element of the normalized matrix (mij) is multiplied by the weight of the criterion (wj) presented in the corresponding column to obtain pij = mij * wj. The maximum and minimum values for each column are determined. The maximum value represents the ideal best, and the minimum value represents the ideal worst for each criterion among the alternatives.

Ideal best for jth criterion:

$$I_j^+ = Max\left(m1j, m2j, \ldots, m15j, m16j\right)$$

Ideal worst for jth criterion:

$$I_j^- = Min\left(m1j, m2j, \ldots, m15j, m16j\right)$$

The next task in the process is to find the Euclidian distance of *mij* from I_j^+ and the Euclidian distance of mij from I_j^-. For every Alternative I, it is calculated as:

Euclidian Distance from ideal best:

$$D_i^+ = \sqrt{\sum_{j=1}^{11} \left[mij - I_j^+\right]^2}$$

Euclidian Distance from ideal worst:

$$D_i^- = \sqrt{\sum_{j=1}^{11} \left[mij - I_j^-\right]^2}$$

Finally, the performance score of each Alternative I is calculated as follows:

$$P_i = \frac{D_i^-}{(D_i^+ + D_i^-)}$$

The ordinal ranking of the alternatives based on the performance scores reflects the relative success of the regions. It is presented in Table 4.

The estimated performance scores and corresponding rankings indicate that the top five regions in terms of availing maternity care are: Manipur Urban, Manipur Rural, Arunachal Pradesh Urban, Nagaland Urban, and Nagaland Rural, respectively. On the other hand, the five least-performing regions are Meghalaya Urban, Mizoram Rural, Meghalaya Rural, Assam Rural, and Sikkim Rural. Manipur has emerged as the most successful state, followed by Nagaland, in effectively providing maternity healthcare to its population.

In the next section, we proceed with the ordinal evaluation of the regions regarding their socioeconomic achievements (table 5). The entropy method is employed to determine the weights of the 17 socioeconomic criteria. The entropy method, introduced by Claude Shan-

Table 4. Performance Scores and Ranking of the Alternatives

Alternatives	Geographical Regions	Performance Scores	Ranks
A1	Assam Urban	0.22735	7
A2	Assam Rural	0.11036	13
A3	Arunachal Pradesh Urban	0.76473	3
A4	Arunachal Pradesh Rural	0.20864	9
A5	Meghalaya Urban	0.07219	16
A6	Meghalaya Rural	0.09610	14
A7	Manipur Urban	0.99021	1
A8	Manipur Rural	0.80621	2
A9	Mizoram Urban	0.20879	8
A10	Mizoram Rural	0.08912	15
A11	Nagaland Urban	0.34308	4
A12	Nagaland Rural	0.24889	5
A13	Sikkim Urban	0.13521	11
A14	Sikkim Rural	0.13145	12
A15	Tripura Urban	0.24529	6
A16	Tripura Rural	0.17263	10

Source: author's estimations based on the NFHS-4 data

non in 1984, mathematically measures the information content of a source. It quantifies the uncertainty associated with the source. By observing a specific outcome, the entropy method helps estimate the information gained. When applied to a decision matrix, the entropy method is useful in computing the weights based on the data elements (Shannon 2001).

The first step of the entropy method is the normalization of the data given in Table 5. This is done by:

$$N_{ij} = \frac{X_{ij}}{\sum_{i=1}^{16} Xij}$$

i = number of regions (rows), and j = socioeconomic criteria (Columns).

Next, we calculate Entropy (Ej) in the following way:

$$Ej = -k \sum_{i=1}^{16} Nij * \ln(Nij),\ j = 1,2,\ldots,17.$$

Here k is a constant number and is expressed as the reciprocal of the logarithm of several alternatives. Thus, in the present case, k = 1/ln(16) = 0.360674

The next task is to calculate the weight vector. It is calculated as:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{17}\left(1 - E_j\right)}$$

The weights of the socioeconomic traits, thus calculated, are found to be as follows (table 6).

Table 5. Socioeconomic Characteristics of 16 Geographical Regions

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
A1	996	794	95.5	89.1	62.2	76.5	99.8	12.6	87	93.2	47.4	24.7	15	1.4	8.1	14.8	56.5
A2	993	945	75	82.9	45.1	15.6	99.5	10	69.2	80.7	22.5	31.7	15	2.3	14.4	17.6	55.2
A3	973	851	99.2	94.7	73.3	87.4	99.4	54.4	80.9	91.4	51.1	18.5	15	1.7	9.8	11.1	51.1
A4	953	948	85	85	57.1	30	99.3	59.7	60.1	81.9	23.7	25.5	25.5	2.3	10.8	12.8	51.2
A5	1067	891	99	85.2	67.9	65.5	98.7	23.2	93.4	95.7	59.4	8.5	3	1.7	3.4	16.5	64.7
A6	991	1029	89.2	62.9	58.1	9.3	99.3	37.9	79.6	80.8	25.8	19.7	16.3	3.5	10.1	26.5	60.5
A7	1081	962	95.9	47.1	47.8	63.3	99.7	3.5	89.9	97.4	57	12.1	11.4	2.1	6.1	8.7	52.8
A8	1030	962	90.1	38	51.3	28	99.4	3.7	81.7	95.1	38.4	14.7	17.3	2.9	8.2	8.8	43.1
A9	1043	926	99.7	94.1	90.9	92.8	99.3	42.3	98.6	99.3	52	7.1	10.1	2	6.2	12.4	55
A10	973	975	90.9	87.7	73.3	30.8	98.6	50.5	85.6	98.6	21.5	17	21.3	2.7	8.7	16.7	49.7
A11	1011	1011	99.6	79.9	68.2	67.1	99.6	4.3	89.9	93.2	51.1	9.3	2	1.8	2.8	6.9	32
A12	946	932	95.6	80.9	78.8	14.7	99.4	7	75.2	80.7	21.9	15.9	12	3.4	7.8	6.1	32.1
A13	936	632	99	99.3	76	93	99.8	32.6	89.5	93.3	50.2	16.4	11.5	1.1	2.4	16.6	47.1
A14	944	911	99.6	96.8	94.2	42.4	99.5	29.2	85.2	90	36.1	14.1	9.9	1.2	3	21.4	62.1
A15	1051	1100	99	97.7	65.1	68.6	99.7	31.7	88.4	95.2	39.8	26.5	9.6	1.4	13.3	9.7	43.8
A16	978	928	90	82.8	59.6	16	99.8	69.5	77	87	16.3	35.7	18	1.8	20.7	7.6	37.9

Source: author's estimations based on the NFHS-4 data

Table 6. Weights of the Socioeconomic Criteria

Criteria	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
Weights	0.05951	0.05945	0.05949	0.05925	0.05930	0.05756	0.05952	0.05653	0.05945	0.05949	0.05876	0.05854	0.05834	0.05892	0.05791	0.05865	0.05931

Source: author's estimations based on the NFHS-4 data

The assigned weights indicate that the use of iodized salt by households is the most critical socioeconomic criterion, followed by the sex ratio (i.e., the ratio of females to males per 100 population). Male literacy emerges as the third most important factor, while the proportion of households with access to electricity at home is the fourth most important. The fifth most crucial criterion is the sex ratio at birth during the last five years. Similarly, we can identify the five least important criteria. Interestingly, health insurance coverage of households is the least important criterion, followed by access to clean fuel for cooking, the proportion of women in the age group of 15-19 who were already mothers or pregnant at the time of the survey, the proportion of males in the age group of 25-29 who were married before reaching 21 years, and the proportion of women in the age group of 20-24 years who were married before reaching 18 years.

Once the weights of the socioeconomic criteria are determined, we can proceed with the ordinal evaluation of the regions based on these 17 socioeconomic characteristics (table 7). Similar to the previous case, we use the TOPSIS method. Following the process described earlier, the TOPSIS technique generates the following ordinal ranking of the 16 geographical regions.

The fundamental reason for selecting the north-eastern region of India for this study is that the region is one of the most economically vulnerable regions in the country. Providing better healthcare facilities has a significant impact on the socioeconomic development of any region. Ensuring proper maternity care for every pregnant woman is the responsibility of every community. This study aims to explore the existing variations among the eight provinces and urban areas within the region. The study is particularly important in light of the efforts made by the central government to uplift the socioeconomic conditions of the entire region. The findings of this study will help policymakers identify areas that require attention.

Table 7. Performance Scores and Ordinal Rankings of the Regions

Alternatives	Regions	Performance Scores	Ordinal Rank
A1	Assam U	0.324297	15
A2	Assam R	0.543704	8
A3	Arunachal U	0.417717	14
A4	Arunachal R	0.539397	9
A5	Meghalaya U	0.529234	10
A6	Meghalaya R	0.685989	3
A7	Manipur U	0.63898	4
A8	Manipur R	0.59666	6
A9	Mizoram U	0.596078	7
A10	Mizoram R	0.605393	5
A11	Nagaland U	0.694813	2
A12	Nagaland R	0.502404	12
A13	Sikkim U	0.192662	16
A14	Sikkim R	0.488785	13
A15	Tripura U	0.838578	1
A16	Tripura R	0.521132	11

Source: author's estimations based on the NFHS-4 data

In terms of socioeconomic achievement, Tripura Urban is the best performer, followed by Nagaland Urban, Meghalaya Rural, Manipur Urban, and Mizoram Rural. Sikkim Urban is the worst performer, followed by Assam Urban, Arunachal Urban, Sikkim Rural, and Nagaland Rural. One interesting observation is that urban areas dominate the five best-performing regions, while rural areas dominate the five worst-performing regions. Thus, in terms of socioeconomic attainment, urban areas outperform rural areas.

Further interesting insights can be gained by considering variations within the urban areas. Tripura's urban areas rank first with a score of 0.83858, which is significantly higher than Sikkim's urban areas, which score a mere 0.19266 and rank last among all sixteen regions. Other better-performing urban areas include those in Nagaland and Manipur. The performance scores of urban areas in the remaining states are relatively lower. A closer examination of these regions reveals specific reasons for such variations. Tripura's urban areas are dominated by its provincial capital, Agartala. Like other state capitals, Agartala has better healthcare service provisions. Furthermore, Agartala in Tripura and Guwahati in Assam are the only two state capitals in the entire North-Eastern region located in plain areas. The rest of the state capitals, which form part of the urban areas in their respective provinces, are situated in hilly terrain. Plain areas offer distinct advantages over hilly areas in terms of healthcare provision. While provisioning healthcare facilities is relatively easier in plain areas, the availability of trained medical personnel, caregivers, medicines, vaccines, etc., is often more adequate in plain areas.

On the other hand, many hilly areas in the region have rugged terrain and face challenges such as inadequate electricity supply and safe drinking water, which make life difficult for local residents. These challenges sometimes hinder the performance of urban areas in hilly terrain. However, along with the topographical advantage, the state administration of Tripura has a track record of consistently performing well in recent years.

It can be easily understood why rural areas score lower than urban areas, given that most of the region's rural areas are located in hilly terrain. Challenges posed by such rugged topography often hinder the performance of rural areas compared to their urban counterparts. However, variations exist within rural areas among different states. Meghalaya, Mizoram, Manipur, and Assam outperform the rural parts of other provinces. One contributing factor to these variations can be attributed to divergent literacy rates. While the entire region boasts a moderate to high literacy rate, these four provinces have achieved higher literacy rates compared to the national average. Additionally, first-hand exposure to the region reveals that awareness regarding the necessity and availability of healthcare facilities is directly proportional to the educational attainment of the local population, particularly among females.

Now, we have two sets of rankings for the regions: one based on the availability of maternity care and the other based on socioeconomic characteristics. The ordinal evaluation, in the form of rankings, reflects the relative assessment of the regions using specific criteria. These two sets of rankings assess each region using different criteria. To understand the association between these two assessments, we employ two techniques. The first one is Spearman's Rank Correlation analysis, which calculates the Rank Correlation Coefficient to indicate the overall degree of association between the two sets of criteria. To understand the one-to-one degree of association between Cs and Ss, we utilize a Python program to evaluate Pearson's Correlation Coefficient for each pair of C and S.

The Spearman's Rank Correlation Coefficient is calculated as follows:

$$R = 1 - \frac{6 * \sum d_i^2}{n * \left(n^2 - 1\right)}$$

Here, R represents the Rank Correlation Coefficient, di denotes the difference between each pair of ranks, and n represents the number of observations (alternatives in the current case).

The Rank Correlation Coefficient is calculated as: R = +0.120588.

This value indicates a very weak and statistically insignificant overall degree of association between the two sets of criteria. However, the positive sign suggests a proportional relationship between the two sets of criteria.

To assess the degree of association between each pair of Cs and Ss, we construct the following matrix (table 8). The Pearson's Correlation Coefficients are computed using the available data in Table 3 and Table 5.

The discrepancies in the degree of association reveal that the level of association varies for each pair of criteria. A Correlation Coefficient value above |0.7| indicates a high degree of association, while a value between |0.5| and |0.7| signifies a moderate level of association. Values between |0.3| and |0.5| indicate a low level of correlation, while the remaining values indicate a weak degree of association.

Table 8 presents the one-to-one association between each pair of C and S. It is evident that the strongest correlation exists between S4 and C6, which represents the association between households with an improved drinking-water source and registered pregnancies where mothers receive Mother and Child Protection (MCP) cards. The correlation coefficient value is +0.84. Further investigation reveals that awareness among households plays a significant role in this association. Given the topography of the North-Eastern region, with hilly terrain and dependence on streams for drinking water, communities with well-educated members tend to prioritize health and hygiene. These communities ensure access to safe drinking water for all households and raise awareness among pregnant women, leading to the utilization of welfare schemes such as MCP card registration. Hence, the strong association between these parameters is evident.

The next notable correlation is observed between S7 and C10, representing the association between households using iodized salt and children born at home who were taken to a health facility for check-ups within 24 hours of birth. The correlation coefficient value is –0.78. Users of iodized salt are typically above the subsistence level and are more likely to opt for institutional childbirth delivery. Conversely, women from lower economic strata may not have the means to afford iodized salt or access institutional childbirth delivery. Thus, the inverse relationship between S7 and C10 serves as a proxy for the relationship between income, poverty, and institutional birth.

Among moderately correlated pairs of criteria, the highest correlation is observed between S17 and C11, representing the association between current users of family planning informed about the side effects and the proportion of children who received a health check after birth from trained health personnel. The correlation coefficient is +0.7. S17 indicates conscious household members who are aware of health and hygiene requirements and have interactions with health personnel. These members also understand the importance of newborn health checks. Therefore, a positive degree of association between these parameters is expected. Similarly, the associations between S17 and C4 and between S9 and C7, with correlation coefficients of +0.69, also demonstrate positive correlations. S17 represents households with interactions with health workers, C4 represents the proportion of mothers who consumed iron folic acid during pregnancy, and C7 represents the proportion of mothers who received postnatal care within two days of childbirth. Interaction with health workers or trained health personnel is crucial in both scenarios, leading to the positive associations observed. The associations between the remaining criteria can be explored in a similar manner.

Table 8. Degree of Association between every pair of Cs and Ss

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
C1	0.50	-0.14	0.25	-0.10	0.01	0.39	0.20	-0.08	0.59	0.62	0.44	-0.15	-0.23	-0.50	-0.14	0.17	0.42
C2	0.51	-0.16	0.34	-0.01	0.09	0.46	0.18	-0.03	0.65	0.62	0.50	-0.18	-0.31	-0.56	-0.16	0.19	0.45
C3	0.38	-0.17	0.22	0.08	0.02	0.38	0.35	-0.11	0.56	0.49	0.39	0.02	-0.39	-0.65	-0.05	0.18	0.30
C4	0.31	-0.29	0.21	-0.03	0.27	0.31	-0.31	-0.11	0.61	0.55	0.41	-0.49	-0.22	-0.23	-0.49	0.51	0.69
C5	0.38	-0.29	0.28	-0.13	0.24	0.37	-0.19	-0.20	0.65	0.59	0.51	-0.56	-0.27	-0.24	-0.53	0.38	0.61
C6	-0.51	-0.24	-0.05	0.84	0.51	0.05	-0.24	0.56	-0.09	-0.26	-0.26	0.21	0.06	-0.24	0.06	0.58	0.34
C7	0.49	-0.24	0.34	0.07	0.13	0.51	0.12	-0.06	0.69	0.66	0.53	-0.22	-0.38	-0.60	-0.23	0.19	0.45
C8	-0.04	0.28	-0.62	0.04	-0.07	-0.49	-0.28	-0.05	-0.20	-0.18	-0.51	0.26	0.19	0.26	0.31	0.23	0.15
C9	0.35	0.08	0.19	-0.57	-0.31	0.25	0.35	-0.32	0.07	0.29	0.40	-0.21	0.01	0.04	-0.06	-0.58	-0.28
C10	0.33	0.04	-0.13	0.15	0.11	0.10	-0.78	0.13	0.26	0.23	0.15	-0.28	-0.08	0.14	-0.11	0.38	0.56
C11	0.27	-0.12	-0.42	-0.03	-0.23	-0.03	-0.07	-0.10	0.01	0.04	0.08	0.13	0.01	-0.23	0.06	0.44	0.70

Source: author's estimations based on the NFHS-4 data

However, upon closer examination, it becomes apparent that some of the socioeconomic criteria are significantly associated with the maternity care indicators. Criterion S9 is related to women's literacy. As expected, women's literacy shows a moderately high positive correlation with the following indicators: (i) C1 – mothers who received antenatal check-ups in the first trimester; (ii) C2 – mothers who had at least four antenatal care visits; (iii) C3 – mothers whose last birth was protected against neonatal tetanus; (iv) C4 – mothers who consumed iron and folic acid for 100 days or more during pregnancy; (v) C5 – mothers who received complete antenatal care; and (vi) C7 – mothers who received postnatal care from trained health personnel within two days of delivery. Thus, six out of the eleven indicators show a positive and significant association with women's literacy. All of these six indicators highlight the essential requirements for ensuring safe motherhood. A household with literate women is expected to be more conscious of these requirements. Consequently, the household members are also expected to possess adequate knowledge about the necessary measures for ensuring safe motherhood. As a result, it is unsurprising to observe a positive and moderately high correlation.

Similarly, both men's literacy (S10) and the percentage of women with ten or more years of schooling (S11) show a moderately high positive association with four of the maternity care indicators. Indicators C1, C2, C4, and C5 are associated with S10, whereas indicators C2, C5, and C7 are associated with S11. Women's years of schooling also demonstrate a moderately negative association with the utilization of financial assistance from a government-sponsored scheme (C8). In India, particularly in rural areas, a girl child's years of schooling are negatively correlated with her family's poverty level (Malik 2013). From this perspective, the negative association between S11 and C8 is evident. Thus, the socioeconomic criterion of both male and female literacy rates significantly influences the selection of seven out of the maternity care indicators. In addition to literacy, women's fertility rate (S14) also exhibits a moderately negative association with C1, C2, C3, and C7. It is widely recognized that women's fertility rate is inversely related to their level of education. Therefore, a higher fertility rate indicates lower or no educational attainment for women. Inadequate educational attainment, in turn, leads to a lack of awareness among women regarding the importance of maternity care for ensuring safe motherhood.

In India, the nature of maternity care availed by different communities is generally determined by the socioeconomic and socio-demographic characteristics of those communities. Rural women with low levels of education and belonging to lower socioeconomic strata often do not choose institutional maternity care. In contrast, in urban areas of India, families from higher economic strata tend to prefer private healthcare facilities over public sector facilities. This preference is also influenced by the presence of more highly educated women in these households. Household income levels play a crucial role in determining the preference for private-run facilities for maternity care compared to public facilities (Das et al. 2016). A study conducted in Mumbai city, India, also revealed that the likelihood of utilizing institutional maternity care, including prenatal and delivery care, increased with a longer stay in Mumbai, higher educational attainment, and greater wealth (Das et al. 2016). However, even in the informal settlements of Mumbai, institutional maternity care is common across all economic statuses. The study also found that the perception of Mumbai residents regarding the capabilities of primary healthcare facilities resulted in inefficient utilization of these facilities (Alcock et al. 2015).

IV. Conclusion

The present study aims to assess the delivery of maternity care in India's strategically significant north-eastern region. The study's importance lies in providing policymakers with insights into the region's relative success in delivering maternal healthcare. Additionally, the study evaluates the socioeconomic achievements of different regions on an ordinal scale. The findings highlight the better socioeconomic attainment in urban areas compared to rural areas. Given that socioeconomic attainment influences the choice of maternity care, addressing this issue in rural areas is crucial. Several pairs of Cs and Ss demonstrate a high or moderately high degree of association. These significantly associated pairs of indicators become important variables of interest for policymakers. The study establishes that female literacy, female educational attainment, male literacy, and female fertility are essential socioeconomic factors that significantly impact the selection of maternity care services. These services include antenatal check-ups in the first trimester, at least four antenatal care visits, protection against neonatal tetanus, consuming iron folic acid for 100 days or more during pregnancy, availing complete antenatal care, and postnatal care from trained health personnel. The study also reveals an inverse relationship between maternity care utilization and fertility rates. The North-Eastern part of India holds strategic importance and has been a priority for socioeconomic development. The Government of India recognizes the significance of achieving safe motherhood as a critical parameter of socioeconomic development. Continuous efforts have been made to raise awareness among the region's population regarding the necessary steps for ensuring safe motherhood. However, disparities in maternity care availability across the region remain common. Addressing the deficiency in women's educational attainment in the region is a prerequisite for tackling this issue.

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