# Frugal Innovations using IoT & ML to Enhance Quality of
# Maternal Health in Rural Areas

## Research Proposal

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# 1. Introduction

Good Maternal Health is a vital indicator of a country's developmental progress. While India has made progress in considerably reducing maternal mortality rate [MMR] over the last three decades[1], as per WHO statistics, of 5,36,000 maternal deaths occurring globally each year, 1,36,000 take place in India [2,3]. Despite the safe motherhood policies and programmatic initiatives at the national level, one woman dies during the process of childbirth every 18 minutes in India. Further, within India, there is a contrast of maternal mortality rate (MMR) across different states and the rural communities are very much underserved. States such as Assam, Rajasthan, Uttar Pradesh and Uttarakhand have disproportionately large proportions of deaths, while states such as Kerala, Tamilnadu and Maharashtra have low MMR rates that are comparable with middle income countries. It is evident from the government data that high MMR correlates with many factors such as poverty, per capita income, social & cultural norms, access to health care facilities, nutrition, education etc[1]. From a medical perspective, the causes include abortion, haemorrhage, hypertensive disorder, obstructed delivery & sepsis. Providing safe, timely and effective maternal and child care in remote and rural settings continues to be a challenge.

It is necessary to understand the maternal mortality situation in the country and to monitor the outcomes of various initiatives taken by the Government. All the states are categorized into three groups.
1. Empowered Action Group (EAG) States
2. Southern States
3. Other States

Assam, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, Odisha, Rajasthan, Uttar Pradesh and Uttarakhand are in "Empowered Action Group" (EAG) States, "Southern" States which include Andhra Pradesh, Telangana, Karnataka, Kerala and Tamil Nadu; and "Other" States covering the remaining States/UTs. It is a significant achievement that the Maternal Mortality Ratio of India has declined to 113 in 2016-18 from 122 in 2015-17 and 130 in 2014-2016, as indicated in the graph below, published in Sample Registration System (SRS) report in July 2020 [16].
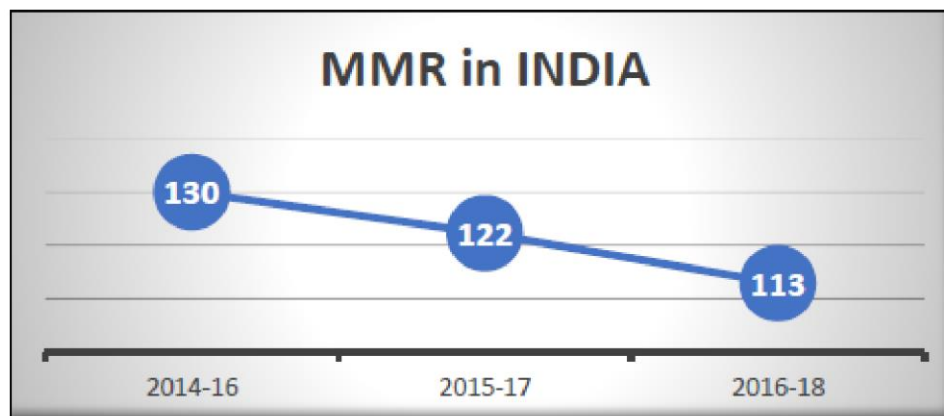
Fig 1- MMR in India in 2014-16, 2015-17 and 2016-18

| Maternal Mortality Ratio: India, (per 100000 live births) | 2004-06 | 2007-09 | 2010-12 | 2011-13 | 2014-16 |
|---|---|---|---|---|---|
| **India Total** | **254** | **212** | **178** | **167** | **130** |
| Assam | 480 | 390 | 328 | 300 | 237 |
| Bihar/Jharkhand | 312 | 261 | 219 | 208 | 165 |
| Madhya Pradesh/ Chhattisgarh | 335 | 269 | 230 | 221 | 173 |
| Odisha | 303 | 258 | 235 | 222 | 180 |
| Rajasthan | 388 | 318 | 255 | 244 | 199 |
| Uttar Pradesh/Uttarakhand | 440 | 359 | 292 | 285 | 201 |
| **EAG & Assam Subtotal** | **375** | **308** | **257** | **246** | **188** |
| Andhra Pradesh | 154 | 134 | 110 | 92 | 74 |
| Telangana | | | | | 81 |
| Karnataka | 213 | 178 | 144 | 133 | 108 |
| Kerala | 95 | 81 | 66 | 61 | 46 |
| Tamil Nadu | 111 | 97 | 90 | 79 | 66 |
| **South Subtotal** | **149** | **127** | **105** | **93** | **77** |
| Gujarat | 160 | 148 | 122 | 112 | 91 |
| Haryana | 186 | 153 | 146 | 127 | 101 |
| Maharashtra | 130 | 104 | 87 | 68 | 61 |
| Punjab | 192 | 172 | 155 | 141 | 122 |
| West Bengal | 141 | 145 | 117 | 113 | 101 |
| Other States | 206 | 160 | 136 | 126 | 97 |
| **Other Subtotal** | **174** | **149** | **127** | **115** | **93** |

*Source - http://niti.gov.in/content/maternal-mortality-ratio-mmr-100000-live-births

Table 1- Maternal Mortality Ratio (MMR) (Per 100000 Live Births)

Considering the severity of the issue, it is being taken seriously at both national and international levels. MCH has been listed as one of the targets in the United Nations' Millennium Development Goals (MDG) framework[2] and is also a key concern of the Global Strategy for Women's and Children's Health[3]. MCH was included in the UN's Sustainable Development Goals (SDGs) in 2015 as part of the objective of guaranteeing the health and well-being of all people. The World Health Organization's (WHO) has also given priority to this issue & has published a Labour Care Guide[4].

Over the years, the Government of India has formulated several policies including the National Population Policy (NPP) 2000, the National Health Policy 2002, National Rural Health Mission (NRHM 2005 – 2017), and the New National Health Policy, 2017 which have laid down the goals for maternal & child health[5]. In 2013, the Government of India adopted the Reproductive, Maternal, New-born, Child and Adolescent Health (RMNCH+A) framework. Purpose of this framework is to address the various causes of mortality and morbidity among the women and children in various regions of the country. It was also helpful to understand the reasons for delays in accessing and utilizing health care services. Most recently, the Government of India launched its flagship health programme, the Ayushman Bharat Scheme, for strengthening the health indicators at the grass root level. Improvement of mother and child health is also an important part of this programme [6].

Over the last decade, there is increasing interest worldover to explore the potential of ICT in providing innovative healthcare solutions to deliver better care for mother and child in remote and rural settings [7]. With the help of ICT, patients can be diagnosed, treated and monitored remotely as it provides all the tools for virtual connectivity. Presently, in rural India the penetration of these digital health technologies is extremely limited, primarily due to infrastructural issues. Communication between patient and doctor communication is primarily through physical visits and patient information is largely maintained through handwritten records. Current healthcare system in villages uses minimal technologies for patient care. Studies indicate that while rural communities can benefit from digital health interventions, the precise benefits vary depending on the scale and characteristics of the intervention[8].

Maternal Mortality Ratio (MMR) and Maternal Mortality Rate (MMRate) are the two key indicators, which are helpful to define Maternal Mortality. As per World Health Organization (WHO), *Maternal Mortality Ratio (MMR)* is defined as the number of maternal deaths during a given time period per 100,000 live births during the same time period and the *Maternal Mortality Rate* (MMRate) is defined and calculated as the number of maternal deaths during a given time period divided by person years lived by women of reproductive age (age 15–49 years) in a population during the same time period. United Nations has set the target to reduce the global maternal mortality ratio to less than 70 per 100,000 live births in Sustainable Development Goals (SDG).

A vast majority of maternal mortalities (around 94%) occurred in low-resource settings, and most might have been prevented if timely interventions were made according to the 2017 WHO Global Report[10] Most of the maternal and child deaths are because of complications arising during labour and childbirth. Knowing when to wait and when to take life-saving action is critical. The WHO Labour Care Guide [2] serves as an excellent tool to implement WHO recommendations on maternal and child care. This is a great resource for skilled health care personnel to provide woman-centred, safe and effective care for every woman and new born baby.

Women die as a result of complications during and following pregnancy and childbirth. Most of these complications develop during pregnancy and most are preventable or treatable. Other complications may pre-exist but are worsened during pregnancy, especially if not managed as part of the care provided to the mother. The major complications that account for nearly 75% of all maternal deaths are severe bleeding (mostly bleeding after childbirth), infections (usually after childbirth), high blood pressure during pregnancy (pre-eclampsia and eclampsia), complications from delivery and unsafe abortion[11].

A WHO led multi country study indicated that an estimated 15 million babies are born too early every year, and approximately 1 million children die each year due to complications of preterm birth[12]. Globally, prematurity is the leading cause of death in children under the age of 5 years. Many surviving children face a lifetime of disability, including learning disabilities and visual and hearing problems. Worryingly, in almost all countries with reliable data, preterm birth rates are increasing.

The risk of maternal mortality is highest for adolescent girls under 15 years old and complications in pregnancy and childbirth are higher among adolescent girls aged 10-19 compared to women aged 20-24. Women in less developed countries have, on an average, many more pregnancies than women in developed countries, and their lifetime risk of death due to pregnancy is higher. A woman's lifetime risk of maternal death is the probability that a 15-year-old woman will eventually die from a maternal cause. This ratio is 1 in 5400 in high income countries, and rises to a shockingly high figure of 1 in 45 in low income countries[13, 14].
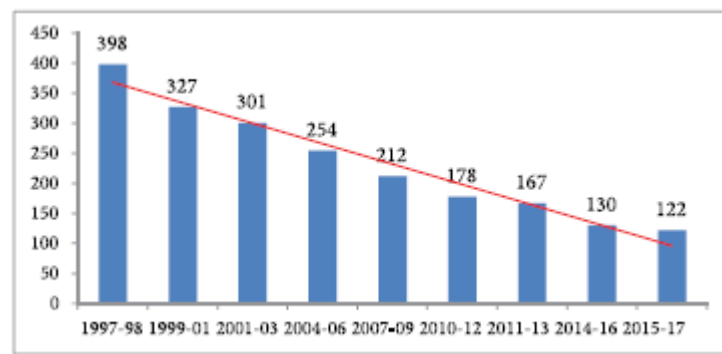


Fig 2 – Accelerated pace of decline in MMR for India

In India, the Ministry of Health & Family Welfare, has launched various initiatives namely Surakshit Matritva Aashwasan (SUMAN), Janani-Shishu Suraksha Karyakram (JSSK), Pradhan Mantri Surakshit Matritva Abhiyan (PMSMA), Labour room & Quality Improvement Initiative (LaQshya) and many more to care for the health of the mother and the newborn child. The expected outcomes of these initiatives are "Zero Preventable Maternal and Newborn Deaths and high quality of maternity care delivered with dignity and respect" [5].

The number of women choosing to give birth in health facilities in India has increased in past decades, driven by urgent global efforts to reduce maternal deaths. The proportion of deliveries by traditional birth attendants (TBAs) remained steady at a little more than one-third over the past decade and a half, with a slight decline in the percentage conducted by an Auxiliary Nurse Midwife/Lady Health Visitor (ANM/LHV). Altogether, nearly 50% of women now seek professional care at delivery[11].

Progress has been made towards maternal and newborn targets set out in the 2030 Agenda for Sustainable Development – but it is slow, with vast inequalities worldwide. Deaths of mother and newborn babies in rural areas are still high compared to urban areas. Lack of knowledge, malnutrition, family income, education, social status, skilled health workers, available facilities, cost of equipment could be some of the causes for poor quality of care and death of mother and child in rural areas. A key requirement, for further reduction of maternal and child deaths, is to understand the causes of deaths so that effective policy interventions and health programme decisions can be set into motion. More importantly, there are various aspects that need to be improved at the ground level in rural areas.

There is a huge wealth of traditional knowledge related to MCH available with vaidyas, hakims, grandmothers, dais etc. Tapping into this knowledge and utilising it along with modern digital technologies can lead to enhancement of health metrics for women and new-born children.

In summary, it emerges that an integrated approach to address MCH needs in rural areas is critical. There is a need for establishing a stronger and quality assured  support infrastructure to assist professionals providing rural MCH services. The human resource capacity of health care professionals in rural communities needs to be enhanced and the preparedness of young mothers to actively engage in improving their health and health care needs to be expanded. Investing in Information and Communications Technology (ICT) infrastructure appears to be an efficient way to achieve goals of the Government of India for which there is an urgent need to design, develop and deploy existing and new resources strategically.

This study proposes that frugal and innovative, digital technological solutions can be designed, developed and deployed to enable the rural healthcare system to effectively reduce MMRate and improve the health of mothers and newborns in rural India.

**2. Literature Review & Research Gap**

Various studies and research are available to find out the causes of limited success of maternal health services. Recently, phase-I of the fifth National Family Health Survey (NFHS-V) was completed. The first such survey was conducted in 1992-93. It provides the fact sheets for various states and union territories of India. Ali et al used the data of NFHS III and IV respectively held in 2005 & 2015. The disparity, in usage of MCH & antenatal care (ANC) services, lies in different socio-economic classes in the country. Authors conclude that exposure to mass media is a critical factor affecting access to MCH services[17]. Apart from MMR, infant mortality rate (AMR) is another critical factor that needs to be taken seriously[18].

Similar study as above has been carried out by Awasthi et al in [19]. They analyzed the Annual Health Survey data (2010-13) and census data of 2011 to find the disparity in maternal, newborn and child healthcare service access in 9 high focus states at district level [19]. Frank Peck et al mentioned in their study that rural communities faced lack of facilities due to remoteness and less population density of villages[8]. Ali Balhasan, and Shekhar Chauhan also reviewed the different sources of data related to mother and child mortality rates in SAARC region[17]. There are different factors contributing to it such as:

i. In India more than 25% of women do not have any antenatal visit to a doctor.

ii. Malnutrition is very high that puts the health of mother and child on risk

iii. Around 8% of deaths are attributed to the poor hygienic conditions during and after birth, inadequate access to potable drinking water etc.

iv. Ineffective family planning programs and awareness also contributes to the increased complications during pregnancy and eventually leading to the increased mortality.

v. Women literacy rate, average age at first marriage, fertility rate (average number of children born by a woman), women financial independence etc., are other contributing factors for MCH issues.

According to the Rural Urban census data 2011, the distribution of rural and urban population is 68.84% & 31.16% [22]. Compared to 2001 census data, the level of urbanization increased from 27.81% to 31.16 % in 2011 and the rural population declined from 72.19 % to 68.84% [22]. Rural

people visit urban areas for better health facilities. In remote areas, sometimes people travel 30 kms to avail healthcare services (Gramvaani, 2013). Wang and Hofe also considered travel time as the most precise measure in their study (Wang and Hofe, 2008). It could be one reason for high maternal deaths in villages. Sanitation, maternal education, infant care, vaccination, and better systems of health care have brought particular benefits to women and infants, evident in the falling mortality of mothers and infants [21].

ICT can play a vital role to improve the health services in remote areas. Frank Peck et al also found in their study that digital technologies are very helpful for rural patients in managing chronic health conditions and patent recovery also [8]. Most of the ICT enabled equipment are available in urban areas. Cost and trained users may be the reason for it. ICT can provide a cost effective solution for rural areas. Brebner et al and Wesson also mentioned in their study that ICT technologies can also be used for improving maternity and emergency services. Doctors can check the patients remotely with the use of video conferencing. Sometimes during the visit with doctor patients forget to carry the previous prescriptions in this case technology helps to maintain the records digitally. And there is no need to carry all the prescriptions and patients reports during each visit.

**Research Gap**

Information and Communication Technology (ICT) is playing a vital role in making the MCH services better. The literature provides a variety of examples of ICT intervention in the health care domain such as telemedicine, telehealth, telecare, assistive technologies, Ehealth, bots and many more. These solutions are successful in urban areas. But in rural areas, attempts to improve healthcare services through ICT have met with limited success mainly due to the lack of infrastructure upon which to build solutions, difficult to use, lack of awareness, skilled attendants at birth (SBA), efficiency and correctness of result.

However, these solutions cannot solve the problem until the ground reality is properly understood and researched. There are obvious predicaments for implementing ICT based solutions in the rural areas due to infrastructural issues, poverty, illiteracy, and social & cultural norms. ICT supported frugal innovations are better suited for rural settings. These solutions should have the following traits:

i. Easy to use
ii. Cost effective
iii. Less power consumption
iv. Local language support
v. Connectivity

ICT based solution should be so easy that Auxiliary Nurse Midwives (ANMs), Accredited Social Health Activist (ASHA), midwifes can use it after a necessary training. These are the stakeholders in the rural health care system that can monitor the health of a pregnant woman and new born baby in rural areas. And in case of any complications a proper care could be provided to both mother and child.

This proposed prototype will monitor the vital parameters such as body temperature, blood pressure, Fetal Heart Rate (FHR), Mother Heart Rate (MHR), uterine contraction and nutrition also. All the monitored parameters will be displayed graphically in the android app with the use of various advanced graph plotting techniques. If any vital will go beyond the threshold value then the system will generate an alarm. And women can check about that specific vital which is abnormal. A right step at the right time will definitely enhance the health of both mother and child.

## 3. Research Questions and Methodology

*RQ 1 : What are the various causes of high maternal deaths and poor maternal & child health (MCH) services in villages?*

**Methodology for Research Question-1**

WHO defines maternal death [9] as "The death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes".

To identify the reasons for high maternal deaths and poor MCH services, a field work in the remote villages of Uttarakhand and UP would enable interaction with diverse stakeholders in the rural health ecosystem. This field study proposes to interact with rural women, sarpanch of the gram panchayats, health-care professionals in the rural public health centres, vaids and hakims, ASHA workers, auxiliary nurse midwife (ANMs) and traditional birth attendants (Dais). This would enable study of the rural health ecosystem pertaining to MCH and help determine the causes for higher deaths of mothers and newborn babies in rural areas. Four villages in the district of Bijnor in Uttar Pradesh and four villages in the district of Udham Singh Nagar in Uttarakhand have been chosen for the field study. The villages in Bijnor (UP) are Chanda Nangli, Nangal, Baldia, Shahpur and the villages in Udham Singh Nagar (Uttarakhand) are Khatola, Sekeniya, Chandan Nagar, Gularbhoj. The selection of these villages has been done keeping in mind the lack of availability of affordable MCH services in these villages.

Primary data would be collected on the basis of personal interview with individual women in the villages. A detailed questionnaire is prepared after multiple discussions with various doctors to collect data in structured format. Basic health details of rural women will be collected with the help of a questionnaire digitally. Observations from field surveys will help to identify the real causes of high maternal deaths and poor MCH services in selected villages.

*RQ 2 : How can the quality of maternal and child health services be improved using ICT technologies such as IoT and Machine Learning?*

**Methodology for Research Question-2**

In the last one decade, the intervention of information and communication technologies, especially artificial intelligence has revolutionized almost every aspect of human life. Healthcare is no exception. Information and communication technologies (ICT) are gradually making the lives of Indian people. Government is pushing digital connect through its Digital India campaign. Almost every ministry of Indian government has some offerening on their digital platter. To monitor and improve the Maternal and Child Health (MCH) services in rural areas ICT intervention is necessary. Internet of Things (IoT) and Machine Learning (ML) is used together to develop the model. This model is divided into two parts.

1. Android/ios based application (Part-I)
2. Web based (Part-II)

In Android/ios based application (Part-I) of this model, various sensors are used to captured the data of a pregnant woman. Specialized sensors like Temperature sensor, pulse sensor, piezoelectric sensor, Accelerometer sensor and chest or skin electrodes are used to capture the specific data such as body temperature, heart rate, blood pressure, ECG signals and movement. In part – I, all the sensors are connected to each other with a lithium ion battery. All the captured data will be transmitted to the android/ios application. In the backend of android/ios application advanced algorithms of machine learning would be implemented to analyse the captured data. In application various advanced data visualization techniques are used for data visualization. One buzzer is also connected with sensors. If the value of any monitored parameters will be beyond the threshold value then the buzzer will be activated. So that user can check the application for that specific value and take the necessary action to control that value. Part – I will work in offline mode when the user will not be connected to the internet. Once user will be connected to internet and all permission are given by the user then data will be transferred to the cloud for web interface.
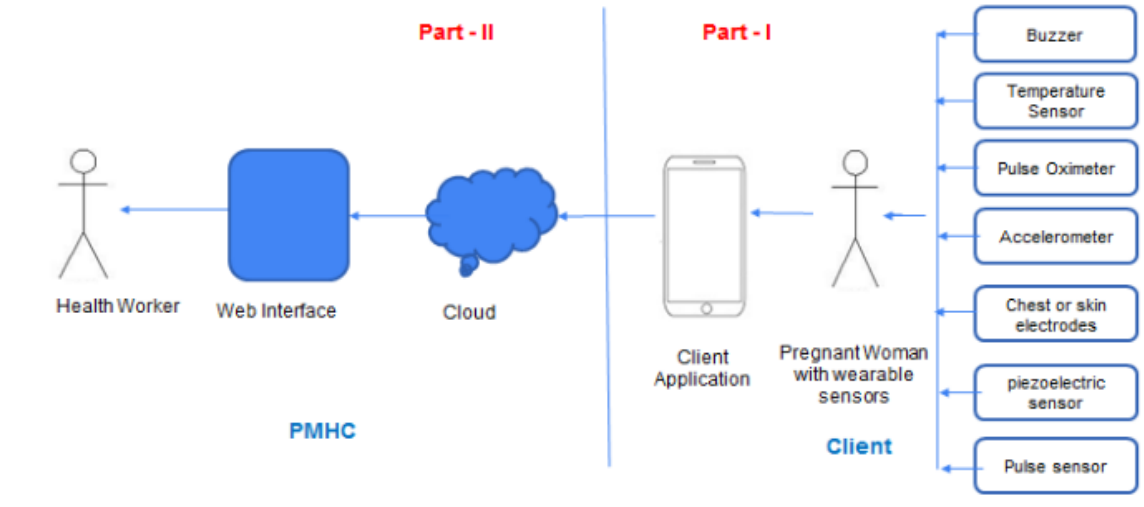
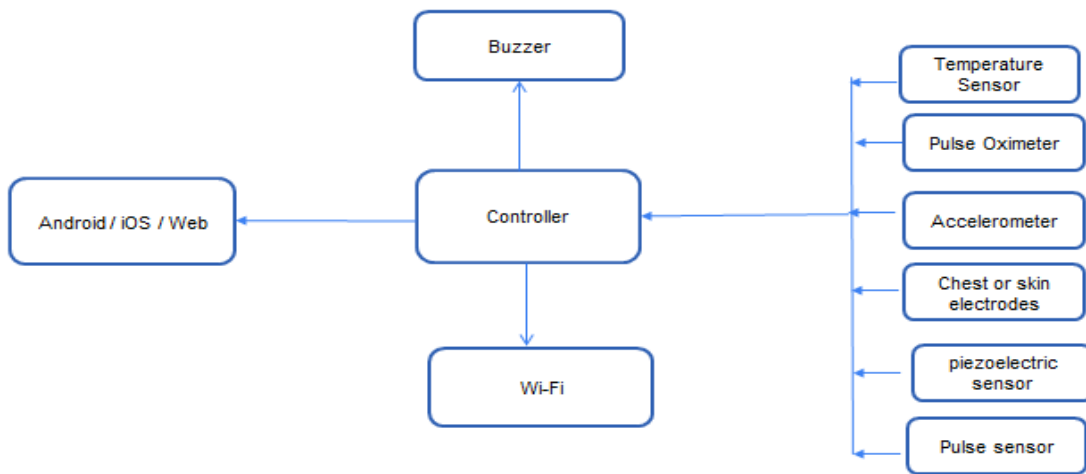Fig 1 - Proposed Model for Monitoring MCH in Rural areas using



Fig 2 - Proposed wearable IoT Device with sensors

*RQ 3 : How can Traditional Medicinal Knowledge of the rural community and Modern Medical Knowledge be used together with ICT to provide cost effective solutions for rural communities?*

**Methodology for Research Question-3**

People in rural communities have some traditional knowledge with them which passes through generation to generation. Rural people use this traditional knowledge to treat their minor health issues and for major health problems they use the modern medicinal system. This is the time to revisit and revive some of the best practices from the traditional knowledge of India. Details about various treatments, which can be done by using traditional ways, can be identified and stored into the system digitally. Machine Learning (ML) techniques can apply to combine both the medicinal system and provide the best solution which is more effective and economical to rural people. Artificial Intelligence (AI) would be used to make the system intelligent so that various suggestions could be provided to rural people through this trained system. This system will be helpful for the wellbeing of individuals in remote areas.

Research will be based on primary and secondary data. District Combined Hospital, Bijnor, Uttar Pradesh and Jawaharlal Nehru District Hospital, Rudrapur, Uttarakhand have been identified to collect the secondary data. Historical data, current status of maternal and child health will be collected from the Ministry of Health and Family Welfare, Government of India. For primary data collection five villages have been identified from district Bijnor and Udham Singh Nagar. Targeted population will be visited with a questionnaire.

**4. Research Objectives**

Based on the literature study and preliminary interaction with various stakeholders in the MCH and rural health ecosystem, this research proposes to investigate the following objectives :

1. Study the delivery of rural maternal and child health (MCH) in selected villages of Uttar Pradesh and Uttarakhand and to identify the causes of limited success in rural areas
2. Evaluate the landscape of ICT technologies and identify Frugal Digital Health Innovations to enhance the quality of MCH services delivery in diverse remote and rural areas.

3. Design and develop a technology enabled and culturally acceptable Digitally Enabled MCH Framework which combines ICT technologies such as IoT and ML with Traditional Medicinal Knowledge.

**5. Sample Selection Technique**

There are many techniques for sample selection. Researchers use probability and nonprobability bases sampling according to their research. In Random sampling 'random sample' is selected from the list of everyone in the population. It is a more accurate and precise technique and also used in large scale sample size selection. If data is not available as a list to study and even not possible to create the list then nonprobability sampling is used. In our study we have to collect the data of pregnant women in the selected villages. We have to select a sampling technique which gives the guarantee that the observed sample will be the representative of the whole population from it is selected and all the members of the population have an equal opportunity of being selected in the sample.

In our scenario probability sampling is more suitable for selecting the sample from the whole population. It provides a precise, statistical description of a large population. Generally large scale surveys use the probability sampling methods. It will also be helpful to generalize the results.

Population = Rural women of reproductive age 18 to 53 Years.

Sampling Frame = Pregnant women in the selected villages for study.

**6. Conclusions**

The primary motivation to carry out this research is to identify the causes for poor quality of MCH in rural areas and to identify the potential solutions using ICT to provide portable, cost effective, easy to use solutions that can benefit rural women. One of the other dimensions of this research is to identify the possibilities of utilising the power of digital technologies in synergy with the skills and resources available with traditional health care systems (AYUSH). A third aspect of the research would be to explore the potential and the mechanisms of utilising traditional knowledge available with AYUSH practitioners as well as custodians of vernacular knowledge. The issue of authenticity of the vernacular knowledge and its acceptability among rural people would also be

ascertained through field studies. The insights gained from this research could contribute both to government policy interventions and to the deployment of context-specific technologies in diverse rural settings of India.

In conclusion, there are endless possibilities for frugal innovations based on information and communication technologies such as IoT to contribute towards massive improvements to the current model in health, and especially to MCH in the rural sector. There are obvious challenges such as connectivity and infrastructure that need to be identified and addressed.

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