# CHAPTER 1
# INTRODUCTION

Infant incubators are important equipment in which we can saved life of many numbers of those born prematurely. Infant incubator assists doctors to monitor all the different aspects around the child environment, it used to make them similar conditions to those that were in the ideal conditions inside the mother womb. Infant incubators helped to preserve the life of premature babies and reducing the death among the infant baby being physically present with the patients has become a huge problem for doctors. In such cases, implementing IoT with hospital equipment such as a baby incubator, has become one of the main goals for us. Providing an app that can track the baby's condition remotely will prove to be very fruitful. Our main goal is to make a smart baby incubator that can detect baby's condition and in case anything goes wrong, the system can trip itself so that the conditions can return to a normal state.

## 1.1 Concept of Incubator:

A transport incubator is an incubator in a transportable form, and is used when a sick or premature baby is removed, e.g., from one hospital to another, as from a community hospital to a large medical facility with a proper neonatal intensive-care unit. In biology, an incubator is a device used to grow and maintain microbiological cultures or cell cultures. The incubator maintains optimal temperature, humidity and other conditions such as the carbon dioxide ($CO_2$) and oxygen content of the atmosphere inside. Premature babies, also known as preemies, are those that are born before the mother has reached 37 weeks of gestation. They are born too soon before certain key organs are able to develop. Depending on how premature the baby is, he or she may have an underdeveloped digestive tract, lungs, immune system, & even skin. To help these babies survive outside of the womb, they will be placed in an apparatus known as an incubator, which provides the newborn the environmental conditions needed to thrive while in the neonatal intensive care unit (NICU). An incubator is a self-contained unit roughly the size of a standard crib equipped with a clear plastic dome. Because preemies lack body fat, they are less able to regulate body temperature. To this end, the incubator ensures the ideal environmental conditions by either allowing the temperature to be adjusted manually or providing auto adjustments based on changes in the baby's temperature. But this is not its only function an incubator serves. An incubator also protects the preemie from infection, allergens, or excessive noise or light levels that can cause harm. It can regulate air humidity to maintain the integrity of the skin and even be equipped with special lights to treat neonatal jaundice common in newborns.

**1.2 Problem statement:**

Premature and low birth weight infants often lack access to advanced neonatal care due to the high cost and limited availability of conventional incubators. These devices frequently miss features like real-time monitoring, remote accessibility, and power backup, compromising infant health. This project aims to design a cost-effective, IoT enabled smart infant incubator to provide a stable, controlled environment with enhanced monitoring and infection control, ensuring better neonatal care and accessibility for resource-constrained healthcare centres.

**1.3 Objectives:**

**1. Provide optimal environment:** Maintain a stable and controlled environment with appropriate temperature, humidity, and oxygen levels.

**2. Enhance infant health:** Support the health and development of premature and low birth weight infants.

**3. Reduce infection risk:** Incorporate features to minimize the risk of infections.

**4. Increase accessibility:** Develop cost-effective solutions to make advanced neonatal care available to a wider range of healthcare centres, including those with limited budgets.

**5. Ensure safety and reliability:** Build a reliable system with continuous operation capabilities, including power backup options.

# CHAPTER 2
# LITERATURE SURVEY

A literature review is a survey of scholarly sources on a specific topic. It provides an overview of current knowledge, allowing we to identify relevant theories, methods, and gaps in the existing research that you can later apply to our paper, thesis, or dissertation topic.

**[1] Intelligent Baby Incubator.**

In this research, we have proposed intelligent infant incubator to attain monitoring and controlling of environment in the infant incubator. This project is useful for rural areas. This equipment can also be used in small health care systems. This project is simple and efficient in maintaining the temperature of the room and the chamber. It will be the guidance for the people who are seeking to make the infant incubators.

**[2] Central Real-time Monitoring System for Premature Baby Incubator.**

By using both software and hardware, this paper designs a set of real-time central monitoring system for premature babies that can collect infants real-time temperature, humidity and video information and realize following functions: Make the monitoring temperature data continuous, accurate and real-time, and increase device safety. The monitoring circuit of the central real-time monitoring system for premature babies, which is independent of the baby incubator, does not affect the incubator's normal operation. The accuracy of the monitoring data will not be affected by the state of the baby incubator, and can be compared with the temperature and humidity data displayed in the incubator to ensure the monitoring record data accuracy. In practice, there is a difference between the incubator temperature and the baby's skin temperature, and doctors generally concern the most body temperature.

**[3] Development of a Monitoring and Control System of Infant Incubator**.

In this paper a design based on Arduino microcontroller to monitor an infant incubator was presented. The main parameters for infant incubator which aimed to be controlled in this system are temperature and humidity. To achieve this goal, a hardware design is developed with compatible Arduino software, thus the above-mentioned parameters can be monitored for the normal growth of the infant. This system can provide optimum automatic control of temperature of the infant using arduino, according to air temperature in the infant chamber. The control of relative humidity in chamber is required to reduce the thermal loss from them. In this system the infant temperature can be automatically controlled in great level of precision as well as to maintain high relative humidity, so, the thermal losses can be minimized. The developed system has been designed to be user friendly, cost effective and accurate.

**[4] Design, Control, and Simulation of a Neonatal Incubator.**

For the simulation; a steady-state error of 0.038% and 0.014% was achieved with a rise time of 28 cycles and 38 cycles for temperature and humidity respectively. With further tuning the temperature of the incubator was successfully brought to within 0 .4% of the setpoint value and the humidity to within 0 .3% of the setpoint value. From these results it can be concluded that this method of simulation can verify the operation and provide a starting point for the tuning of a Mamdani controller.

**[5] Smart Baby Incubator.**

Although Smart health care systems have been in the spotlight for researchers lately, including AI, IoT, Cloud computing, and Machine Learning, these technologies could revolutionize intelligent healthcare systems that could detect even minor changes, reducing human resources to almost zero. But the main focus of this project was to provide an easy to operate, cheap, and readily available baby incubator, with its features and benefits. Hence, a smart baby incubator that can detect baby's condition and in case anything goes wrong, the system can trip itself so that the conditions can return to a normal state is been fabricated. Furthermore, we integrate it with IoT and a mobile application so that doctors can check the baby's condition remotely. The proposed incubator also provides a complete and controlled environment as well as the required amount of oxygen levels, perfect light exposure and humidity that exactly matches with the mother's womb.

**[6] Advanced Portable Preterm Baby Incubator.**

The developed Advanced incubator promotes the existing infant incubators. In addition to the main function of the Advanced incubator such as warming, the incubator adds the mobility feature which makes the handling of the infant more easily, allows for breastfeeding and conserves the infant mother bond. The warming system consists of 3 main parts batteries, heaters, and insulation. Batteries are the sources of energy which give the system its mobility feature, it can store enough energy to power the system. The stored energy is converted by a heater which acts as simple resistor that converts electrical energy into thermal energy. The last part is the isolation, it provides the use of the temperature that expands the batterie’s life span. To conclude, advanced incubator provides the warming feature of incubator, also it provides other features such as continuous monitoring and temporary treatment to get the healthcare necessary to the infant survive.

**[7] Android based Internet Accessible Infant Incubator.**

An Android based infant incubator was designed and presented in this paper that would enable the medical specialist to monitor and control temperature and humidity of incubator. Under normal conditions, no data loss was observed. On average, the incubator took 3 seconds to acquire the desired parameters after being set by medical specialist. The range of temperature achieved is ±5 °C with the median value of 23 °C at normal room temperature.

**[8] Smart Infant Incubator Based on LoRa Networks.**

This paper has presented a low-cost system for infant incubators based on the use of temperature and humidity sensors, and a set of weight sensors, which allows us to monitor the progress of the baby. The baby incubators are connected to the network using LoRa. Finally, the NFC interface allows identifying doctors and the view of the patient evolution with tablets and the introduction of new data by the doctor. As a remarkable feature of this proposal is the material cost of the system, since each incubator could be equipped for less than $ 80. On the other hand, it is possible to acquire inexpensive versions of a Lora gateway for about $50. Therefore, we can define our proposal as a low cost system. This type of systems could be considered to use in developing countries where the ability to access medical services is limited. Finally, this system could be integrated in a more complex architecture for monitoring the activity of patients.

**[9] Designing a Low-Cost Multifunctional Infant Incubator.**

Based on the survey results from India and Ethiopia, cost reduction and infection control were concerns that took priority over cooling. For this reason, design and experiments revolved around constructing a suitable infant incubator using low-cost disposable materials with high insulating properties while consuming minimal power. The current prototype design features double-paned cardboard walls with a thickness of 12.7 mm to increase the flat-pack ability. This effectively increases manufacturing and shipping efficiency. The lid was made from triple-paned clear PVC film sheets for increased visibility and insulation. To make the baby chamber entirely biodegradable, alternative materials to PVC such as cellulose acetate plastic sheets are being researched. At laboratory temperatures of about 22 °C, the incubator was able to achieve a steady 37.5 °C using 30 W of power on average. In India, where the average temperature is much higher, the power consumption will be significantly reduced, making a small battery more than sufficient to power the device. The worst-case scenario was also considered, in which ambient temperatures can reach as low as 15 °C. Studies at different temperatures and humidity are ongoing. Operating the incubator at lower ambient temperatures can be easily achieved with larger batteries that will be able to provide enough power for this application.

# CHAPTER 3
# COMPONENTS & REQUIREMENTS

## 3.1 HARDWARE REQUIREMENTS:

- Nodemcu
- Regulated Power Supply
- Arduino Controller
- Dht11 Sensor
- Pulse Sensor
- Liquid Crystal Display

### 3.1.1 Node MCU:

It is an essential component in this system as it serves as a microcontroller with built-in Wi-Fi capability. It allows for remote monitoring and control of the incubator, making it possible for healthcare professionals to monitor the infant's vitals and environment in real time from a remote location. This could be particularly important in a neonatal intensive care unit (NICU), where timely intervention is critical.

**Fig 3.1.1: NODE MCU**

### 3.1.2 Regulated power supply:

A regulated power supply is crucial for ensuring stable and consistent power delivery to all components. Premature infants are highly sensitive to environmental factors, and any fluctuation in power could disrupt the incubator's functioning, leading to unsafe conditions. The regulated power supply guarantees that all components receive the correct voltage, ensuring the system operates reliably without risking electrical malfunctions.

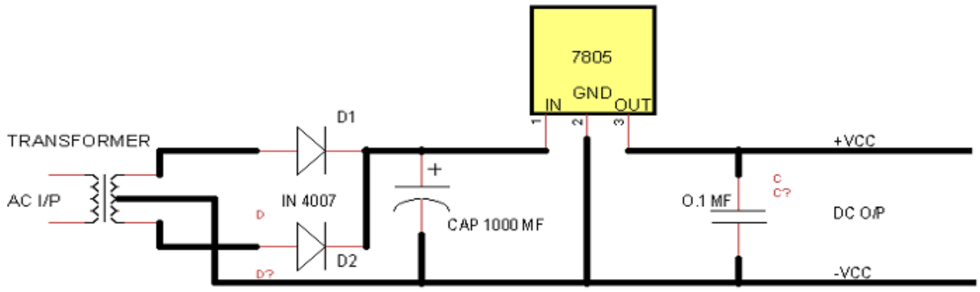


**Fig 3.1.2: Regulated power supply**

### 3.1.3 Arduino controller:

The Arduino platform provides the flexibility and customization needed for such a system. It allows the integration of various sensors and components to create an efficient and functional incubator environment. Arduino serves as the core of the system, processing input from sensors, controlling actuators like fans or heaters, and making real-time decisions based on pre-set conditions to maintain the ideal environment for premature infants.

| | |
|---|---|
| Microcontroller | ATmega328P |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limit) | 6-20V |
| Digital I/O Pins | 14 (of which 6 provide PWM output) |
| PWM Digital I/O Pins | 6 |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 20 m A |
| DC Current for 3.3V Pin | 50 m A |
| Flash Memory | 32 KB (ATmega328P)of which 0.5 KB used by boot loader |
| SRAM | 2 KB (ATmega328P) |
| EEPROM | 1 KB (ATmega328P) |
| Clock Speed | 16 MHz |

**Fig 3.1.3: Technical specification of Arduino Controller**

### 3.1.4 DHT11 sensor:

The DHT11 sensor is essential for maintaining the optimal environment required for the care of premature infants. These infants have underdeveloped thermoregulation systems, making them vulnerable to temperature and humidity imbalances. The DHT11 sensor continuously monitors both temperature and humidity inside the incubator. It ensures that the temperature stays within the critical range of 32°C to 34°C, preventing hypothermia, and maintains humidity levels between 50-60%, reducing the risk of dehydration and skin issues. By integrating the DHT11 sensor into incubators, healthcare providers can create a stable, controlled environment that supports the infant's growth and health, improving survival rates and overall outcomes.

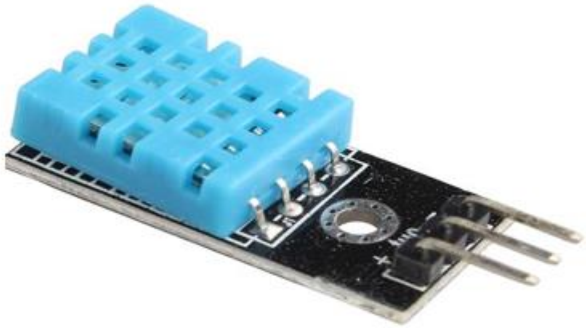

**Fig 3.1.4: DHT11 sensor**

### 3.1.5 Pulse sensor:

The Pulse sensor plays a vital role in monitoring the heart rate of premature infants, who are at a higher risk of cardiovascular issues such as irregular heartbeats or bradycardia. The pulse sensor uses light-based technology, often through photoplethysmography (PPG), to detect blood flow changes with each heartbeat, providing real-time data on the infant's heart rate. This continuous monitoring allows healthcare providers to detect any abnormalities early, such as drops in heart rate or signs of distress, enabling prompt intervention. By integrating the pulse sensor into incubators, healthcare facilities can ensure that premature infants are closely monitored for cardiovascular stability, improving the chances of early detection and treatment of potential complications, and ultimately enhancing the survival and health outcomes of these vulnerable infants.

**Fig 3.1.5: Pulse sensor**

### 3.1.6 Liquid Crystal Display:

The Liquid Crystal Display (LCD) is an essential component for providing clear, real-time visual information about the infant's condition and the environment within the incubator. The LCD screen displays key data such as the infant's heart rate, temperature, humidity levels, and oxygen saturation, allowing healthcare providers to easily monitor these critical parameters at a glance. The use of an LCD in incubators enhances the efficiency and accuracy of care, as medical staff can quickly detect any deviations from optimal conditions and make timely adjustments. By offering clear, user-friendly displays, the LCD helps ensure that caregivers are always informed and able to respond immediately to any changes in the infant's health, ultimately improving the quality of care and outcomes for premature infants.

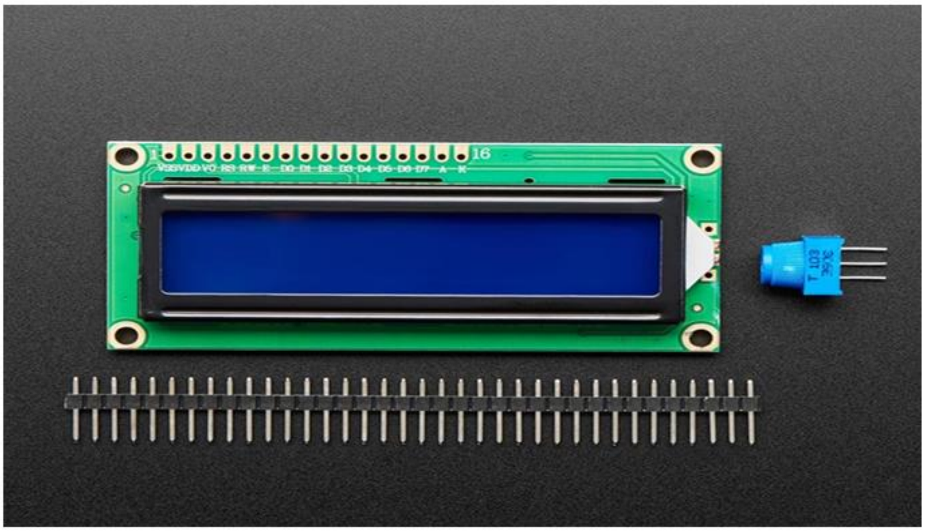

**Fig 3.1.6: Liquid Crystal Display**

### 3.2 SOFTWARE REQUIREMENTS:

To implement the proposed system the following software’s are required:

- Arduino IDE
- Blynk framework

### 3.2.1 Arduino IDE:

Arduino is an opensource computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical and digital world. The project's products are distributed as open- source hardware and software which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself (DIY) kits.

### 3.2.2 Blynk framework:

Blynk is an IoT platform for iOS or Android smartphones that is used to control Arduino, Raspberry Pi and NodeMCU via the Internet. This application is used to create a graphical interface or human machine interface (HMI) by compiling and providing the appropriate address on the available widgets. Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, visualize it and do many other cool things.

**There are three major components in the platform:**

1. **Blynk App:** It allows you to create amazing interfaces for your projects using various widgets which are provided.
2. **Blynk Server:** It is responsible for all the communications between the smartphone and hardware. You can use the Blynk Cloud or run your private Blynk server locally. It's open-source, could easily handle thousands of devices and can even be launched on a Raspberry Pi.
3. **Blynk Libraries:** It enables communication, for all the popular hardware platforms, with the server and process all the incoming and outcoming commands. The process that occurs when someone presses the Button in the Blynk application is that the data will move to Blynk Cloud, where data magically finds its way to the hardware that has been installed. It works in the opposite direction and everything happens in a blink of an eye.

# CHAPTER 4
# METHODOLOGY

The IoT-enabled infant incubator integrates sensors to monitor critical parameters such as heart rate, ambient temperature, humidity, and body temperature. A NodeMCU microcontroller processes this data and controls devices like heaters, fans, and UV LEDs through a relay unit to maintain optimal conditions. A stable power supply with voltage regulation ensures uninterrupted operation, while Wi-Fi connectivity enables real-time remote monitoring and alerts via a cloud platform. Safety is prioritized with fail-safe mechanisms, and the system is designed for reliability and user-friendliness, offering an efficient, adaptive solution for improved neonatal care.

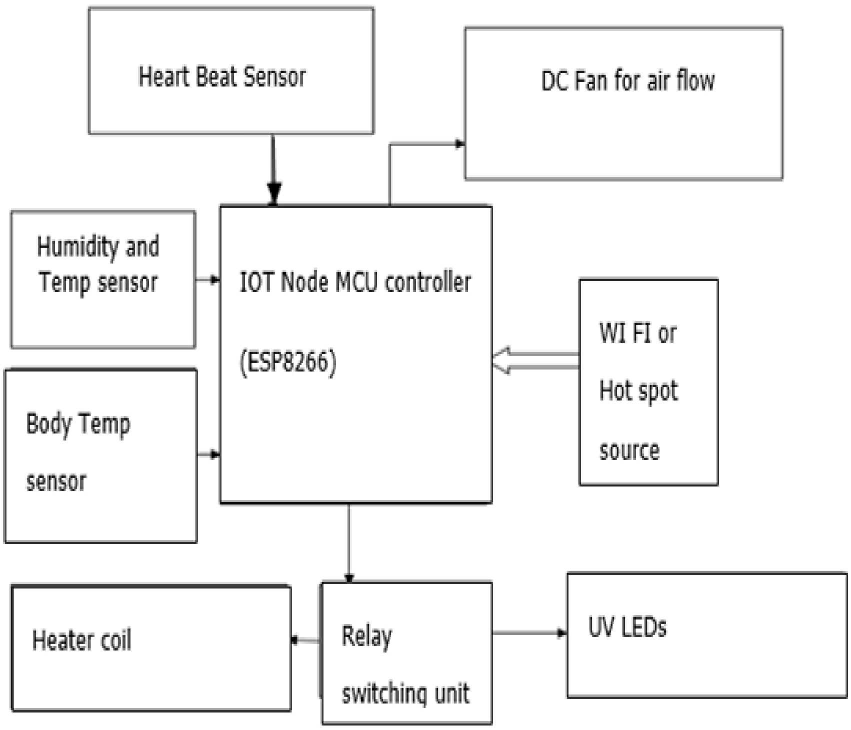


**Fig: 4.1 Block Diagram**

# CHAPTER 5
# APPLICATIONS

1. **Temperature and Humidity Control**: Advanced incubators incorporate sensors like the DHT11 to continuously monitor and adjust the temperature and humidity inside the incubator. This ensures that premature infants, who are unable to regulate their body temperature effectively, are kept at the ideal temperature range (typically 32°C to 34°C). Maintaining optimal humidity (50-60%) prevents dehydration and respiratory issues, crucial for the infant's development.
2. **Heart Rate and Oxygen Saturation Monitoring**: Using pulse sensors and oximeters, incubators can track the infant’s heart rate and blood oxygen levels in real-time. This continuous monitoring helps detect early signs of distress, such as bradycardia (low heart rate) or hypoxemia (low oxygen levels), allowing healthcare providers to intervene promptly. This is critical for premature infants, who are more susceptible to cardiovascular and respiratory complications.
3. **Real-Time Data Display**: Liquid Crystal Displays (LCDs) are integrated into incubators to provide caregivers with immediate access to vital information, such as temperature, heart rate, and oxygen saturation levels. This easy-to-read display allows healthcare professionals to monitor the infant’s condition at a glance, ensuring quick and accurate decision-making.
4. **Automated Alerts and Alarms**: Modern incubators are equipped with automated systems that send real-time alerts to healthcare staff if any parameters (such as temperature, heart rate, or oxygen levels) fall outside the safe range. This ensures that immediate action can be taken, reducing the risk of complications and improving the infant’s chances of survival.
5. **Data Logging and Remote Monitoring**: Advanced incubators allow for continuous data logging, storing vital information over time for later analysis. Additionally, many systems allow for remote monitoring, enabling healthcare professionals to track the infant’s progress and condition from other locations, providing more flexibility and enhancing the level of care.
6. **Integration with Healthcare Systems**: Many incubators are now integrated with hospital information systems, allowing seamless communication between the incubator’s monitoring system and the medical team. This ensures that all relevant data is accessible to healthcare providers, fostering a collaborative approach to care.

# CHAPTER 6

# ADVANTAGES & DISADVANTAGES

**Advantages:**

1. **Enhanced Monitoring and Care:**
   - **Real-time Monitoring:** Advanced incubators integrate sensors such as pulse monitors, temperature, humidity sensors, and oxygen saturation trackers to continuously monitor the infant's condition. This helps healthcare providers quickly detect any abnormalities and intervene promptly.
   - **Early Detection of Health Issues:** Continuous monitoring of heart rate, temperature, and oxygen levels can detect issues like bradycardia (low heart rate), hypoxemia (low oxygen levels), or unstable body temperature early, reducing the risk of severe complications.
2. **Improved Environmental Control:**
   - **Optimal Temperature and Humidity:** Sensors like the DHT11 ensure that the incubator maintains the ideal temperature (32°C to 34°C) and humidity (50-60%) for premature infants. This prevents hypothermia, dehydration, and respiratory complications, which are common concerns for preterm infants.
   - **Comfort and Stability:** Advanced incubators offer a controlled, comfortable environment that helps premature infants grow and develop more effectively, improving their chances of survival.
3. **Ease of Use and Data Display:**
   - **Clear Visual Information:** LCD screens provide caregivers with immediate access to key data such as the infant's heart rate, temperature, and oxygen levels, allowing for quick and efficient monitoring.
   - **Automated Alerts:** Integrated alarm systems notify healthcare professionals when the infant's condition falls outside safe parameters, enabling quick interventions that prevent complications.
4. **Data Logging and Remote Monitoring:**
   - Continuous Data Tracking: Data from incubators can be logged and stored for future analysis, allowing for better long-term monitoring of the infant's health and progress.

- Remote Access: Some incubators allow remote monitoring, enabling healthcare providers to keep track of the infant's condition even from other locations, offering increased flexibility and oversight.

5. **Collaboration and Integration:**
   - Integrated Systems: Many incubators are linked with hospital information systems, allowing seamless data sharing among healthcare providers. This promotes coordinated care, ensuring that all relevant medical professionals are informed of the infant's condition.

**Disadvantages:**

1. **High Cost:**
   - **Expensive Equipment:** Innovative incubators with advanced features such as sensors, LCD screens, and automated systems can be costly to acquire and maintain. This may limit their availability in resource-limited healthcare settings, especially in developing countries.
   - **Ongoing Maintenance:** Regular maintenance and calibration of the sensors and technology are necessary to ensure accurate readings and reliable performance, which adds to the overall cost of the incubator system.
2. **Dependency on Technology:**
   - **Potential for Malfunction:** Like any electronic device, incubators with advanced technology may face issues such as sensor malfunction, software glitches, or hardware failures, which could disrupt care or lead to inaccurate readings if not properly maintained.
   - **Reliance on Power Supply:** Advanced incubators rely on consistent power supply, and power outages or interruptions could jeopardize the care provided to the infant.
3. **Complexity of Use:**
   - **Training Requirements:** Healthcare providers need proper training to use sophisticated incubators and interpret the data provided by integrated sensors and displays. Without adequate training, there is a risk of misinterpreting data or failing to react appropriately in emergencies.
   - **Overreliance on Automation:** While automated systems and alerts are beneficial, they might lead to healthcare providers becoming overly reliant on technology, potentially reducing their ability to manually assess and respond to the infant's needs.

4. **Risk of Over-Monitoring:**
    - **Stress on Infants:** Continuous monitoring and the presence of many sensors and alarms might inadvertently cause stress to the infant. Excessive noise or interference from alarms might disrupt the infant's rest and affect their development.
    - **Parental Stress:** In some cases, parents of premature infants might experience heightened anxiety from constant monitoring and alarms, which could add emotional stress to the already difficult situation.
5. **Privacy Concerns:**
    - **Data Security:** As incubators integrate more with hospital information systems and enable remote monitoring, there may be concerns about the security and privacy of sensitive patient data. Ensuring that this data is protected from unauthorized access is crucial in maintaining patient confidentiality.

# CONCLUSION

In the first phase of our project, "Innovative Care: Incubator Solutions for Premature Infants in Healthcare Facilities," we have successfully established a strong foundation for designing a technologically advanced infant incubator aimed at addressing critical challenges in neonatal care. Through an extensive literature review and needs assessment, we have identified the limitations of current incubator systems, including the lack of affordability, accessibility, and real-time monitoring capabilities, especially in resource-limited healthcare settings. Our project proposes an IoT-enabled solution that incorporates advanced features such as real-time remote monitoring of key parameters like temperature, humidity, oxygen levels, and heart rate, as well as automated regulation of these conditions to create an optimal microenvironment for premature infants. A unique addition is UV sterilization to reduce infection risks, combined with a reliable power supply featuring backup mechanisms to ensure uninterrupted operation. The system is designed to be cost-effective, user-friendly, and accessible to a broader range of healthcare facilities. During this phase, we have successfully conceptualized the block diagram and outlined the system’s architecture, emphasizing safety, reliability, and functionality. This comprehensive groundwork will guide the next phase, where the focus will shift to prototype development, component integration, and testing. The progress made in this phase reinforces the potential of this project to transform neonatal care by providing a reliable, innovative, and affordable solution that significantly enhances the survival rates and health outcomes of premature infants, bridging the gap between advanced medical technology and practical accessibility.

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