

DESIGN AND DEVELOPMENT OF SMART MATERNITY WEAR WITH DETACHABLE HEALTH MONITORING MODULES

Thesis Submitted for the Award of the
Degree of

DOCTOR OF PHILOSOPHY
In
DESIGN (FASHION)

By

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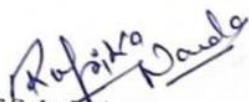
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March 2026

DECLARATION

I, hereby declared that the presented work in the thesis entitled "Design and Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer" in fulfillment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Neha Sah working as Associate Professor, in the School of Design (Fashion Design & Technology), of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgments have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled “Design and Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the School of Design (Fashion Design & Technology), is a research work carried out by Rupika Nanda, Registration No.- 12106195, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.


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***Dedicated To My Parents,
Whose endless love, guidance and
support Have made this journey
Possible***

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ABSTRACT

Clothing comfort is a fundamental consideration for consumers becoming an essential requirement during pregnancy. Pregnancy brings about significant physical and emotional changes, necessitating specialized clothing that adapts to the evolving needs of the expectant mother. As a woman enters the second trimester visible physical changes increase the demand for garments that offer enhanced support, flexibility and comfort. While some women may continue using regular clothing this can negatively influence self-image and emotional well-being. Therefore maternity wear should not only accommodate physical changes but also provide psychological support to promote a positive self-concept ultimately benefiting both mother and child.

Maternal care however extends beyond appropriate clothing. It encompasses a comprehensive support system that includes emotional, physical and technological elements to ensure the holistic well-being of the mother and fetus. In recent years, technological advancements have revolutionized maternity care through the integration of wearable and remote health monitoring systems. These technologies have facilitated improved communication, real-time health tracking and personalized healthcare which are especially crucial for women in rural or underserved areas.

Specifically Internet of Things (IoT)-enabled remote monitoring offers continuous observation of maternal and fetal health enabling early medical intervention, reducing hospital visits and promoting individualized care strategies. These innovations underscore the critical importance of maternal health in influencing favorable outcomes for both mother and baby.

Despite advancements in wearable technology there remains a significant gap in the development of solutions tailored to the unique physiological and comfort related needs of pregnant women. Addressing this gap the present study focuses on the design and development of smart maternity wear that integrates health monitoring capabilities with ergonomic garment design, ensuring both comfort and functional usability throughout the pregnancy journey.

Wearable sensors like ECG, GSR and pulse rate sensors are essential in healthcare for real-time data, early issue detection and personalized health insights. ECG sensors

monitor heart activity helping track changes in heart rate and rhythm due to pregnancy. GSR sensors detect skin conductance, indicating stress levels important since high stress may cause hypertension or preterm labor. Pulse sensors often used in wearables track heartbeats via optical methods helping monitor the increased heart rate during pregnancy. Together, these sensors in smart maternity wear provide a comprehensive health-monitoring solution. They empower pregnant women to manage their health and enable medical professionals to monitor maternal well-being more effectively.

This study focuses on developing smart maternity wear with integrated ECG, GSR and pulse rate sensors to monitor key health parameters in real-time. The goal is to create seamless, comfortable and functional apparel that responds to pregnancy-related physiological changes. By delivering continuous insights into cardiovascular and stress levels this innovation supports early detection, empowers expectant mothers, improves communication with healthcare teams, and is particularly beneficial for women in remote or underserved areas. The study further introduces a modular and detachable smart vest and glove system allowing technology components to be removed during laundering or when monitoring is not required thereby enhancing usability, comfort and user acceptance.

From the extensive literature review following objectives were framed. First; to understand the needs and problem areas of pregnant women in second and third trimesters. Second; to design the maternity outfits addressing the needs with embedded technology to monitor & communicate the health condition. Third; to develop the prototype ensuring the longevity of the design system. Fourth; to assess the performance of the maternity outfits on comfort, function and durability grounds. Keeping in mind the four objectives of the research questionnaire were framed for the purpose of data collection and to know the perspective of the pregnant women regarding their needs.

The present study adopted a mixed – method approach smart maternity clothing designed to monitor the health condition of pregnant women. Data were collected from 150 pregnant women in their second and third trimesters from hospitals in Ludhiana, Punjab. The sample was selected using a non-probability sampling method, specifically the purposive sampling technique. The findings revealed that most pregnant women

expressed the need for maternity wear integrated with health-monitoring technology. They emphasized the importance of comfort, functionality and durability in such garments to support their well-being during pregnancy.

Research is based on the primary data as the data were collected from the reputed hospitals of the Ludhiana, Punjab and data from secondary sources like journals, magazines, book & book chapters and from online sources were also collected.

Major findings of this research are:

- (1) Expectant mothers require clothing that prioritizes comfort and incorporates essential maternity-specific features such as loose and breathable fabrics, flowy silhouettes, a proper fit tailored to comfort, adjustable elements, smooth fabric texture and elasticity or stretch ability to accommodate the changing body during pregnancy.
- (2) Pregnant women preferred maternity dresses and skirts, maternity tops and bottom wear, maternity nursing/sleep wear, maternity Kurtis.
- (3) Pregnant women also want to try that type of clothing in which smart features are incorporated for monitoring the health vitals.
- (4) Maternity and nursing apparels developed by incorporating all the desired features were highly appreciated, acceptable and within the preferred price range.

This research contributes to the growing area of wearable technology for expecting moms by providing a novel approach that meets the practical and medical requirements of these particular user demographics.

KEYWORDS: Clothing Comfort, Maternity Period, Smart Health Monitoring, Wearable Sensors, IoT in Maternal Health and Public-Private Health Collaboration.

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CHAPTER -1

INTRODUCTION

**“Motherhood is a choice you make every day, to put someone else’s happiness
Even when you’re not sure what the right thing is.”**

– Donna Ball, “At Home on Ladybug Farm”

Motherhood is one of the most beautiful and transformative journeys in a woman’s life. It is far more than a physical change; it is a profound shift of the heart, mind and soul. As her body grows to nurture new life a mother undergoes emotional and mental growth while experiencing hope, excitement, uncertainty and love. Although this phase is often filled with joy and anticipation it also brings physical discomfort, hormonal fluctuations and emotional challenges as the body adapts to pregnancy.

From ancient times, societies around the world have honored the concept of motherhood. Civilizations such as those in Egypt, India, Rome and Greece recognized the sacred role of the mother. Yet when it came to maternity clothing historical solutions were often simple. Traditional Indian women wore loose drapes with adjustable ties which naturally accommodated bodily changes during pregnancy. Similarly, other cultures relied on oversized robes, gathered skirts or loosely fitted garments. While these designs served practical purposes, they often lacked conventionality and comfort. The concept of dressing with dignity, ease and style during pregnancy was largely neglected. Although traditional maternity garments successfully accommodated bodily expansion, they were largely limited to basic functional needs. These historical solutions lacked ergonomic support, adaptability to physiological changes and any form of health related functionality. As a result, maternity clothing remained disconnected from the broader healthcare needs of pregnant women.

It wasn’t until the late 19th and early 20th centuries that maternity wear started evolving beyond necessity. As women became more socially active and awareness around maternal health grew the fashion industry slowly responded. Maternity clothing began to reflect not just practicality but also purpose acknowledging that pregnancy was a unique time deserving of thoughtful design.

Nowadays, maternity clothes aren’t just about wearing whatever fits they’re made to

help pregnant women feel comfortable, stylish and supported during their pregnancy. As her body undergoes changes such as growing abdomen, postural shifts and swelling of the feet - a woman's need for comfort, mobility and self-confidence becomes increasingly important. The right maternity clothing doesn't just accommodate these physical changes; it also uplifts her emotionally. Clothing that fits well, feels soft, supports movement and respects her changing lifestyle while including how she eats, sleeps and moves which can help her feel beautiful, dignified and cared for. Despite these advancements modern maternity wear has largely focused on aesthetics, comfort and fit with limited consideration for integrating health monitoring functionality. The potential of maternity clothing as a medium for continuous physiological monitoring remains significantly under explored within both fashion design and maternal healthcare research.

Modern maternity wear blends function with fashion. It includes breathable fabrics, smart cuts and even technology-supportive designs that support health monitoring and ease of movement. In India, the shift from traditional wraps and loosely tied garments to thoughtfully constructed kurtas, tunics, cord sets and even smart vests marks a significant leap toward prioritizing a mother's well-being.

Maternity wear therefore is not just a garment but it's a gesture of empathy and empowerment. It acknowledges her strength, her struggles and her beauty during one of life's most precious journeys.

While maternity wear has advanced in aesthetic and structural design the integration of technology into these garments remains an under- explored frontier. The rise of smart textiles and wearable health technology has opened up new possibilities to bridge this gap. Expectant mothers especially those in rural or medically underserved areas often face challenges in accessing consistent healthcare. With the emergence of remote health monitoring systems a new opportunity arises: the wearable sensing systems integrated through a modular approach to track vital parameters such as heart rate, stress levels and body temperature.

The present study explores the design and development of smart maternity wear that not only supports the pregnant woman's physiological changes but also monitors and

communicates her health condition in real time. By integrating wearable sensors like ECG, GSR and pulse rate monitors into comfortable and functional maternity garments this research aims to create a self-reliant user-friendly solution. Smart maternity wear in the context of this study is defined as maternity clothing integrated with wearable sensing systems through modular and detachable components. This approach prioritizes safety, comfort, hygiene, wash ability and adaptability across different stages of pregnancy making it particularly suitable for maternity applications. Unlike permanently embedded electronic systems modular wearable components allow flexibility in use, ease of maintenance and enhanced safety for pregnant women. Detachable sensing units enable garments to be washed and reused while ensuring that the monitoring system remains adaptable to changing body morphology across trimesters. This design led approach enhances usability without compromising comfort or functionality.

This research uniquely bridges maternity fashion design and maternal healthcare technology through a user- centric modular smart garment system offering a novel contribution to both domains.

1.1 Background

Before pregnancy, women generally prefer to wear clothing that reflects their personal style, aligns with social trends and offers a sense of individuality. These garments are usually designed without the flexibility or functionality to adapt to significant body changes. However, pregnancy is one of the most special and crucial times for pregnant women in their entire lives and it is also a period characterized by complex emotional and psychological changes. Due to physical and psychological changes in the entire body it may have a negative impact on their mind set. Significant physical changes typically become evident during the second trimester and they can be prominently seen in the bust and abdomen areas. Average gestational weight gain is approximately 10-15 kg during a 40-week pregnancy. The changes in the body shape during the second trimester during which these kinds of changes make maternity wear more necessary. Maternity garments are required to accommodate the changes in the body because the last two trimesters are focused. Increasing the size and shape of the breasts and lower body along with the position, changes the body posture and limits the use of garments

with ordinary designs. Therefore, designing maternity clothes is required to meet physiological needs and provide the conditions for maintaining an active and quality lifestyle (Shamsaei et al., 2022). These physiological transformations necessitate maternity garments that go beyond size accommodation and address comfort, posture support, mobility and adaptability across different stages of pregnancy.

Due to rapid changes in the body, pregnant women require clothing that provides comfort, functionality, accommodates changing body morphology and also meets the criteria according to social and cultural values. In the regional context of Punjab, many pregnant women belong to economically stable households yet exhibit limited awareness of preventive maternal health practices due to gaps in formal health education and reliance on traditional care pathways. While financial capacity exists, independent health decision-making and proactive monitoring are often constrained by limited exposure to user-friendly health technologies. Understanding how women confirm pregnancy, follow medical instructions and manage routine health decisions independently therefore becomes essential. These insights help assess readiness for self-managed wearable health solutions and inform the design of systems that are intuitive, instruction-based and adaptable to varying levels of health literacy (Kagiri, T. (2024).

Although this study focuses on pregnant women in Punjab, the challenges related to regular health monitoring, limited health awareness and dependence on hospital visits are not confined to one region alone. Similar concerns have been reported in many developing countries where maternal healthcare services remain unevenly distributed. Therefore, improving access to safe, continuous and user-friendly maternal health monitoring contributes not only to local healthcare needs but also supports the broader objective of Sustainable Development Goal 3 (Good Health and Well-Being) which aims to reduce maternal mortality and improve maternal healthcare worldwide. For women (Weigle, 2021), an increase in body size produces an inflated perception of obesity. Since many societies are placing more and more value on having a thin and flexible body (Donovan, 2020). Because of the consequences of an enlarged abdomen and the pain from greater movement of the pelvic joints during pregnancy, the maternity clothing should also adjust the movement challenges resulting from the physical changes during pregnancy (Mackenzie, 2018; Wuytack, 2020). Clothing that not only

reduces the sense of an inappropriate body type but also has enough ventilation and adapts to the changing body shape is more acceptable during pregnancy due to pregnancy-related difficulties and increased perspiration. Furthermore, because maternity clothing can be adjusted to fit a variety of body forms ensuring usability beyond pregnancy. While maternity clothing addresses ergonomic and psychological comfort it remains largely limited to passive support and does not actively contribute to monitoring maternal health or physiological well-being.

Limited health awareness and restricted access to healthcare facilities, small injuries and routine check-ups, due to the unavailability of the healthcare organizations in rural areas, they had to travel long distances from one place to another. Every trimester of a pregnancy is measured at 14 weeks, and the total length of the pregnancy is 42 weeks. Due to this lack, pregnant women suffer so much because they are unable to go for routine check-ups, which can cause abnormal childbirth, increased risk of foetal mortality and various other complications, including gestational diabetes, high blood pressure, bleeding, weight gain, etc., which can have a harmful impact on the mother's child and other organs (Ansari, 2020). Monitoring remote systems increasing daily reach of health for at-risk populations, in which targeted groups are pregnant women and senior citizens in the health care sector. Basically, maternity health and well-being are related to psychological, physical and emotional transformation symptoms faced during pregnancy, delivery time and postpartum period as well as any kind of illness or maternal morbidity and mortality or any other kind of management practice. Maternal health and well-being has gradually gained prominence as a global health policy concern despite arriving relatively late on the world agenda for policy. This is largely due to Deborah Maine's ground-breaking article on maternal mortality. As a result, women's inalienable right to safe and respectful health services has been established by significant international policy events such as Alma Ata, the International Conference on Population and Development, the Millennium Development Goals, and the Sustainable Development Goals (SDGs) in recent decades.

However, it is crucial to understand that the wide idea of women's health cannot be restricted to the relatively narrow window of pregnancy, childbirth and the postpartum period if the world is to meet its 2030 SDGs women's health and gender equality

agendas (Samuel, 2023). Accordingly, the present research aligns with Sustainable Development Goal 5 (Gender Equality) by promoting women's empowerment through improved access to wearable health technologies that support informed health decision-making and facilitate continuous maternal health monitoring during pregnancy. Traditional maternal healthcare models rely on periodic clinical visits resulting in intermittent monitoring of maternal health parameters. This approach limits early detection of physiological stress, cardiovascular irregularities and any other pregnancy related risks particularly for women residing in rural or underserved regions. Although wearable health technologies have shown considerable progress in monitoring chronic diseases and general fitness very, limited attention has been given to integrating detachable wearable sensing systems within maternity garments. Most available smart wearables are designed as standalone devices or permanently embedded garments that do not adequately address the comfort, hygiene, washability and changing body dimensions experienced during pregnancy. This gap highlights the need for a user-centric smart maternity wear system that combines clothing functionality with flexible health monitoring.

In the present technological era, there is a growing demand for innovative healthcare solutions that extend beyond conventional hospital based systems. Advances in Internet of Things (IoT) technologies and wearable health monitoring systems offer new possibilities for continuous, remote and user centric maternal healthcare. In this context, the present research proposes a smart maternity wear system that integrates wearable sensing technology through a modular design approach to monitor and communicate maternal health conditions thereby supporting preventive and personalised maternity care.

Accordingly, the present research primarily focuses on pregnant women in Punjab while proposing a smart maternity wear system that has wider acceptability for maternal healthcare settings with similar healthcare and socio-cultural conditions.

1.2 Overview of Wearable Technology in Healthcare

The phrase -Internet of Things (IoT) refers to a network of interconnected physical

objects that communicate and exchange data through the internet using technologies such as wireless communication, intelligent sensing and automated identification systems. In the healthcare domain, IoT enables real-time data collection, transmission and analysis facilitating continuous health monitoring and timely medical intervention.

IoT- based healthcare systems are increasingly being adopted at community and household levels through the integration of wearable devices, cloud computing and data analytics platforms. These systems support personalised and preventive healthcare by enabling telemedicine and remote patient monitoring thereby shifting the healthcare model from disease treatment to disease prevention. Such advancements are particularly relevant for women's and maternal healthcare where continuous monitoring and early detection of risks are critical (Lu, 2020).

Wearable technology has evolved from simple self- monitoring tools such as thermometers and weighing scales to sophisticated healthcare devices capable of tracking multiple physiological parameters. Advances in information and communication technologies have transformed wearables into essential components of modern healthcare systems enabling continuous data capture and enhanced human computer interaction (Gao, 2019;Serhat, 2018). The digitization of health related data is driven by the expansion of mobile infrastructure, affordability of smartphones, increased public health awareness and the widespread adoption of wearable devices (Caulfield, 2018).

According to the International Electro technical Commission (IEC) wearable technologies are classified into four main categories: accessories – based wearables, textile or fabric- based wearables, patchable wearables and implantable wearables (Mouyal, 2021).Among these textile based and garment integrated wearables offer significant potential for continuous and non-invasive health monitoring particularly in user – centric healthcare applications.

Wearable devices encompasses a wide range of body-worn technologies including smart watches, fitness trackers, smart garments and extended reality devices. These technologies enable real time data collection, analysis and communication supporting

improved health management and user engagement. The seamless integration of wearable technology into daily life has expanded its application across various sectors with healthcare emerging as one of the most impactful domains.

Advances in material science, miniaturization of electronic components and wireless connectivity have significantly enhanced the functionality and acceptance of wearable devices. Wearables have transitioned from consumer oriented products to clinically relevant medical devices prescribed by healthcare professionals. Their integration into healthcare ecosystems has shown potential in improving preventive care, chronic disease management and overall healthcare delivery efficiency(Puri, 2024 ; Sharma, 2019).

Wearable devices enable continuous patient monitoring, which is particularly beneficial in managing chronic conditions such as diabetes, cardiovascular disease and respiratory disorders. Real time monitoring of vital parameters allows healthcare professionals to detect abnormalities early and initiate timely interventions (Lee, 2021). For instance, wearable ECG monitors facilitates early detection of cardiac irregularities while continuous glucose monitoring systems support dynamic management of diabetes thereby improving patient outcomes and quality of life (Kim, 2022; Patel, 2023; Sun, 2022).

Modular and Detachable Wearable Systems in Healthcare-

Recent research in wearable healthcare technologies has increasingly highlighted modular and detachable system architectures as flexible and user centered alternatives to fully integrated or permanently embedded wearable devices. Modular wearable systems allow sensing units, power modules and communication components to be attached or removed based on user needs, activity contexts and maintenance requirements. This design approach enhances usability, flexibility and long term adoption particularly in daily wear healthcare components may lead to discomfort or user fatigue.

In healthcare contexts, detachable wearable systems have gained attention as a practical solution for improving garment maintenance, hygiene management, component longevity and ease of repair, particularly in textile-based wearables that are used

repeatedly in daily life. By allowing sensing and electronic units to be separated from the textile structure, such systems reduce wear-related damage and support safer laundering practices. Detachability also enhances user autonomy, as individuals can decide when health monitoring is necessary rather than being subjected to continuous or compulsory data collection. This flexibility has been associated with higher user acceptance, especially among users who value comfort, discretion and ease of use in non-clinical and home-based health monitoring settings.

Additionally, modular wearable configurations enable adjustable sensor placement, making it possible to accommodate variations in body shape, posture and movement. This adaptability is particularly important for user groups undergoing ongoing physiological changes, where static sensor positioning may compromise comfort or signal reliability over time. Consequently, modular and detachable wearable architectures are increasingly viewed as a user-centric and sustainable design approach in contemporary healthcare technology development.

In addition to physical health, wearable technologies have demonstrated potential in monitoring mental health parameters by assessing physiological indicators related to stress, anxiety and sleep patterns. Metrics such as heart rate variability and skin conductance provide insights into emotional well-being and stress responses enabling early self-care interventions and professional support when required (Huang, 2021;James, 2024).

The integration of artificial intelligence (AI) and machine learning with wearable technologies has enhanced their analytical capabilities beyond real-time monitoring. AI driven algorithms analyse large volumes of wearable-generated data to identify patterns, detect anomalies and support predictive healthcare models. These advancements facilitate proactive health management by enabling early risk assessment and personalized healthcare recommendations (Garg, 2022;Xu Y. L., 2023;Puri , 2024).

Wearable technologies play a crucial role in telemedicine and remote patient monitoring by bridging the gap between healthcare providers and patients, particularly in rural and underserved regions. During the COVID-19 pandemic wearable devices enabled continuous remote monitoring when in person consultations was restricted

(Smith, 2020). By facilitating real- time data transmission, wearable devices reduce dependency on frequent hospital visits and enhance access to timely healthcare interventions (Brown, 2022).

The literature reviewed in the preceding sections indicates that although maternity apparel and wearable healthcare technologies have evolved independently their integration into a practical and user- friendly garment remains limited. This observation provides the basis for identifying the research problem addressed in the present study.

1.3 Problem Statement

Pregnancy represents a critical transformation phase in a women's life marked by profound physiological, morphological and psychological changes. Rapid and uneven alterations in body dimensions, posture, weight distribution, skin sensitivity and thermal perception significantly affect comfort, mobility and overall well being. During this phase, maternal comfort becomes an essential consideration as clothing directly interacts with the changing body and influences both physical ease and emotional confidence.

Consequently maternity wear plays a vital role in supporting adaptive fit, comfort and functional ease while accommodating continuous bodily changes across different trimesters.

Alongside clothing needs pregnancy also necessitates regular health monitoring of both the mother and the baby to enable early identification of potential complications such as cardiovascular irregularities, stress related conditions or other pregnancy associated health risks.

Conventional healthcare monitoring practices largely rely on periodic clinical check ups which may be time consuming and less accessible for urban, working, young and educated pregnant women who manage professional responsibilities alongside pregnancy. This demographic increasingly seeks independent, continuous and non - intrusive monitoring solutions that can track basic physiological parameters, reduce frequent hospital visits and complement routine medical consultations.

Electrocardiography (ECG) is particularly relevant for maternal health monitoring during pregnancy due to the increased cardiovascular demand placed on the

maternal body. Physiological adaptations such as elevated blood volume, increased cardiac output and hormonal fluctuations may influence heart rate patterns and cardiac rhythm sometimes without overt symptoms. ECG-based monitoring enables non-invasive assessment of maternal cardiac activity and provides valuable indicators related to heart rate variability and physiological stress. Incorporating ECG monitoring through a detachable vest-based system offers a practical and user-friendly approach as the vest allows appropriate sensor positioning near the torso while maintaining comfort and freedom of movement. The detachable nature of the monitoring module enables pregnant users to selectively engage in health monitoring when required without continuous attachment of electronic components. This design approach supports comfort, washability and garment longevity while aligning with the daily lifestyle needs of urban, working and independently managing pregnant women.

Recent advancements in wearable health technologies and smart textiles have enabled continuous monitoring in general healthcare contexts particularly for chronic disease management and early detection of health conditions. However most commercially available wearable systems are not specifically designed for pregnancy. They inadequately address pregnancy specific requirements related to comfort, ergonomics, usability, safety and adaptability to progressive body changes experienced throughout different trimesters. This limitation reduces their suitability and long term acceptance among pregnant users.

Existing research in smart garments has largely emphasized non - modular or minimally detachable wearable architectures within garments. While technologically functional, such designs often introduce challenges including thermal discomfort, increased rigidity, restricted flexibility, laundering difficulties, reduced garment life span and compromised wearability all of which are critical factors in everyday maternity clothing. These issues become particularly significant during pregnancy when comfort, softness, breathability and ease of maintenance are non - negotiable requirements.

Moreover limited research has examined modular or detachable system approaches that offer greater flexibility and user control. Detachable or auxiliary systems have the potential to allow pregnant women to selectively integrate or remove monitoring

components based on need, activity or context thereby improving usability, washability and long term acceptance. There is a notable lack of design led investigations that balance maternity garment aesthetics, comfort driven silhouettes and health monitoring functionality without overburdening the primary garment.

A significant research gap exists in exploring dual - layer maternity systems where:

This duality-based approach emphasizes the co-existence of fashion-driven maternity silhouettes and optional smart functionality rather than forcing continuous technological attachment. The primary maternity garments are designed to prioritize comfort, ease of wear, silhouette adaptability, and additional room for bodily expansion, offering a diverse range of styles such as smart casuals suitable for everyday use. These garments remain fully functional, aesthetically complete and socially appropriate even in the absence of any electronic components.

The secondary garment conceptualized as a detachable smart vest; functions as an independent wearable that supports health monitoring when required. The vest may be worn over or under the primary garment, or independently paired with bottom wear, thereby serving a dual purpose—as a fashion-forward layering element and as a carrier for detachable sensing modules. In cultural contexts where dupattas or layering pieces are traditionally worn, the vest offers a contemporary alternative that enhances visual appeal while discreetly supporting health monitoring.

The detachable nature of the sensing modules ensures that usability, washability and garment longevity are not compromised. Even in the absence of sensors, the vest remains fully wearable and relevant, allowing pregnant users to exercise choice over when and how health monitoring is undertaken. This approach avoids the burden of continuous attachment of electronic components, respects user comfort preferences and enhances long-term acceptance of smart maternity wear.

Therefore the present research proposes a dual- layer smart maternity wear system consisting of functional maternity garments and a detachable smart vest integrated with removable health monitoring modules. The proposed system aims to improve comfort, usability, hygiene and adaptability while enabling non-invasive maternal health monitoring in daily life.

1.4 Objectives of the Study

1. To understand the needs and problem areas of pregnant women in the second and third trimesters.
2. To design a maternity range with adaptive silhouettes and a vest based detachable health monitoring module.
3. To develop the maternity garments ensuring the longevity of the design & monitoring system.
4. To assess the performance of the maternity garments on comfort, function and durability parameters.

1.5 Limitations of the Study

1. The wear trial and performance evaluation were conducted with a sample size of 15 pregnant women, limiting the generalizability of the findings.
2. The study evaluated a detachable health monitoring module integrated into maternity wear therefore the findings are not applicable to fully embedded textile based smart garment systems.
3. The study assessed the prototype under short term use. Long term durability, repeated laundering and extended real world performance were beyond its scope.
4. Individual differences in physiological characteristics, technological familiarity and perceptions of wearable health monitoring devices may have influenced user acceptance and subjective evaluations.

CHAPTER-2

REVIEW OF LITERATURE

Maternity wear is clothing that is specifically made for a women's stage of pregnancy. A time where the anthropometric requirements of the human form are drastically different. This is due to a substantial weight growth that is not evenly distributed throughout the body, meaning that some body parts expand significantly more than others. The waist, bust and hips have the most noticeable increase. The thighs, biceps and other areas are also growing (Anand, 2012).

A Comprehensive review of related research work and literature is ultimate necessary in any research work. It provides gainful insights into the research arena which may help in development of instrument, selection of sample and interpretation of findings. The review of literature pertaining to the study **“Design and Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer”** has been collected from well reputed journals, books and online source. This review also aims to identify existing research gaps related to the integration of health monitoring technologies into maternity clothing.

The literature related to the Maternity Clothing, Pregnancy, Wearable Technology, Healthcare Sectors, Internet of Things (IoT) and Industry 4.0 were recorded under the following sub heads:

2.1. Maternity Clothing

- a. Maternity Fashion : A New concept
- b. Psychological and Physiological Changes During Pregnancy
- c. Clothing Requirements Across Different Stages of Pregnancy

2.2. Smart Maternity Wear

- a. History of Smart Maternity Wear
- b. Concept of Smart Maternity Wear
- c. Classification of Smart Maternity Wear
- d. Functions of Smart Maternity Wear

2.3. Smart Textile Technology (Smart Wearable)

2.4. Smart Textile Applications

- a. Sports
- b. Healthcare
- c. Fashion and Entertainment
- d. Military, Public Sector & Safety Applications : Implications for Maternal Healthcare

2.5. Features Integrated into Maternity Clothing

- a. Designing Features for Clothing
- b. Methods of Garment Construction

2.6. Production of Smart Maternity Wear with Technology

- a. Sensors (wearable technology)
- b. Communication Technology
- c. Portable Power Sources
- d. Formation of the Module

2.1. Maternity Clothing

The key message we emphasize every day is to prioritize holding onto your personal style, no matter what. Embrace your pregnancy without letting go of the essence of your unique fashion identity. The style you cherished before pregnancy should continue to represent who you are during this transformative time. Remember, you're still the same individual and it's likely taken you years, if not decades to refine and perfect your signature look *by Cherie Serota and Jody Kozlow Gardener*(Musial, 2003). These perspectives establish the foundation for understanding maternity wear not only as clothing but as a functional and psychological support system during pregnancy.

2.1.1. Maternity Fashion: A New Concept

The maternity clothing industry is promoting the idea of maintaining personal style as well as fashion identity during pregnancy time (Musial, 2003). The author critiques the market strategies that encourage the pregnant women to embrace the chic and stylish maternity wear also aligning with the societal expectations of beauty and self-confidence maintaining during this transformation period. Musial also highlights how strategies that extend maternity fashion have reinforced the consumerism while catering to the physical and emotional needs of expectant mothers.

Maternity dress consumption influences the construction of self and identity during the transitional phase of pregnancy (Ogle, 2013). The period named liminal represents a significant shift as women navigate the changes in their appearance, social roles and self-perception. The author argues that maternity clothing serves as a tool for women to reconcile their pre-pregnancy period identity with their emerging roles. By selecting and wearing maternity garments women can control their appearance maintaining a sense of normality and expressing individuality while adapting to their changing bodies. The study also highlights how maternity dress consumption allows women to manage the societal expectations while preserving personal style and negotiating their evolving identity during pregnancy.

Maternity clothing addresses the physical, psychological and social needs of pregnant women (Sohn, 2015). The author also highlights the maternity wear's multiple functions which include comfort and flexibility required during a growing body clothing in which women feels confident and attractive while countering negative feelings about body image and helping them balance their pre-pregnancy style with the new role of motherhood while maintaining a sense of self and social identity.

Maternity wear should be designed to accommodate bodily changes using adjustable waistbands, breathable fabrics and ergonomic structures while also fostering a positive self-image (Shamsaei, 2022). However, while these studies emphasize comfort, identity, sustainability and cultural relevance the incorporation of real time health monitoring technologies into maternity fashion remains largely unexplored. Recent findings also emphasize the importance of sustainability recommending the use of eco-friendly materials and smart textiles to enhance both functionality and environmental responsibility. However, most existing studies primarily focus on Western markets with limited consideration of cultural preferences and affordability issues in developing regions. The integration of wearable health-monitoring technology into maternity clothing remains an emerging area that requires further exploration. Future advancements in maternity fashion should prioritize technological innovation sustainable development and cultural inclusivity to better support maternal well-being and style preferences.

The maternity wear market has seen substantial growth driven by increasing fashion awareness among pregnant women and a growing number of working expectant mothers. Intelligence (2022) Forecasts suggest that the market will expand from USD 10.009 billion in 2020 to USD 15.235 billion by 2027 reflecting changing consumer preferences. A shift is evident from traditional loose maternity clothing to modern well-fitted designs that allow women to maintain their style during pregnancy. This transformation is especially noticeable in developing countries where women seek maternity wear that is both fashionable and functional while managing professional and personal commitments. The demand for versatile, comfortable and stylish maternity attire has fuelled advancements in fabric technology and adaptable designs. As the industry continues to evolve future trends are expected to emphasize sustainability, smart textiles and personalized fit to enhance both style and comfort for mothers-to-be.

Consumer attitudes toward maternity fashion in the United States emphasizing the evolving preferences of pregnant women (Lapolla, 2022). Their study highlights that expectant mothers seek stylish, comfortable and adaptable clothing that accommodates body changes while maintaining a sense of personal identity. Many women express dissatisfaction with the limited variety and high cost of maternity wear leading some to modify existing garments or purchase oversized non-maternity clothing. The research also underscores the emotional and psychological impact of maternity fashion as well-designed clothing can boost confidence and promote body positivity during pregnancy. The authors suggest that the maternity fashion industry should focus on affordability, inclusivity and sustainability to better meet consumer needs. As maternity fashion continues to evolve integrating innovative textiles and versatile designs will be key to addressing the diverse expectations of modern mothers.

Generation Z's expectations regarding maternity wear highlighting their preference for stylish, sustainable and multifunctional clothing during pregnancy (Weigle, 2022). The study reveals that Gen Z consumers prioritize comfort and adaptability favouring designs that accommodate body changes while remaining fashionable. Sustainability is a key concern with many expecting mothers seeking eco-friendly fabrics and ethically produced maternity wear. The research also notes a shift toward versatile clothing that can be worn both during and after pregnancy reducing waste and increasing practicality.

Additionally digital engagement plays a significant role as Gen Z consumers rely on social media and online platforms to explore and purchase maternity fashion. The study suggests that the maternity wear industry must embrace sustainability, digital innovation and multifunctional design to meet the evolving needs of this generation.

The documentation and design development of a multipurpose maternity collection inspired by South-eastern Ethiopian traditional attire (Akale, 2024). Their study emphasizes the significance of cultural heritage in maternity fashion, integrating traditional motifs, textiles and craftsmanship into modern designs. The research highlights the need for functional and adaptable maternity clothing that accommodates body changes while preserving cultural identity. Sustainability is also a key focus with the study advocating for locally sourced materials and eco-friendly production methods. Additionally, the findings suggest that maternity fashion should balance aesthetic appeal with practicality; ensuring garments can be worn before, during and after pregnancy. The study underscores the potential for regionally inspired maternity wear to promote both cultural appreciation and sustainable fashion solutions.

A holistic 3D visual analysis approach to improve the design of breastfeeding and postpartum fashion. Their study emphasizes the importance of functional, comfortable and aesthetically appealing clothing that supports new mothers during the postpartum period (Stanley, 2024). By utilizing 3D visualization techniques the research enhances garment fit, adaptability and ease of breastfeeding access. The findings highlight the need for ergonomic and user-friendly designs ensuring that postpartum clothing meets both practical and emotional needs. Sustainability is also considered with recommendations for durable multifunctional materials that extend wearability beyond the postpartum phase. These studies reinforce the need for maternity garments that balance cultural identity, functional adaptability and emerging technological possibilities.

Emerging maternity fashion trends for 2025 (Segev, 2025) emphasize feminine and stylish designs with a resurgence of bows, frills and flattering silhouettes that highlight the baby bump. The growing demand for comfortable yet sophisticated attire has led to the popularity of wide-leg trousers and peplum tops offering both ease and elegance. Versatility remains a key focus with expectant mothers seeking adaptive wardrobe pieces such as belly bands and nursing-friendly clothing that accommodate body

changes throughout pregnancy and postpartum. Functional fashion is gaining traction incorporating technical fabrics and adjustable designs to enhance both practicality and style. The trend also reflects an increasing preference for multi-use maternity garments allowing women to seamlessly transition between different stages of motherhood. These developments indicate a shift toward fashion-forward adaptable maternity wear that prioritizes both aesthetic appeal and everyday functionality. Despite rapid market growth and fashion innovation most maternity wear developments remain aesthetic driven rather than health – centric.

2.1.2. Psychological and Physiological Changes During Pregnancy

Pregnancy involves natural physiological changes that support fetal development and prepare the body for labor. Understanding the normal parameters of these changes is essential for identifying and managing common pregnancy-related medical conditions such as hypertension, gestational diabetes, anaemia and hyperthyroidism. Recognizing these variations helps healthcare providers differentiate between normal adaptations and potential complications ensuring timely diagnosis and intervention. Proper management of these conditions is crucial for maternal and fetal well-being reducing the risk of complications during pregnancy and childbirth (Bohn, 2022).

A narrative review highlighted that pregnancy involves unique bodily changes such as increased size and shape of breasts and the lower body along with lordosis which alter body posture and limit the use of standard garment designs(Shamsaei, 2022). These changes necessitate maternity clothing that accommodates rapid body transformations and aligns with cultural and social beauty standards. Appropriate maternity attire can enhance body image during pregnancy strengthen the maternal-fetal bond and effectively convey maternal identity. Therefore designing maternity wear requires attention to physiological needs and the promotion of an active quality lifestyle for expectant mothers.

Recent research continues to examine the physical transformations women experience during pregnancy including weight gain and body shape changes and how these affect body image (Hodgkinson, 2014). A 2023 update from the American College of Obstetricians and Gynaecologists (ACOG) highlights the importance of monitoring gestational weight gain to offer proper medical guidance to expectant mothers.

According to the guidelines typical weight gain during pregnancy ranges from 11.5 to 16 kilograms though this varies based on individual health factors. As their bodies change many women reassess their body image and self-perception. Healthcare professionals are advised to be attentive to body image issues during pregnancy particularly for those at higher risk to ensure better maternal health outcomes.

Nearly 20% of pregnant women experience mental health challenges during both the prenatal and postpartum stages which if not properly managed can negatively impact the well-being of both the mother and the infant (Alipou, 2018). Disorders such as prenatal anxiety and depression have been associated with negative health outcomes including premature birth, low birth weight and challenges in forming a strong mother-infant bond. Additionally external factors such as familial support, financial stability and accessibility to healthcare services significantly influence the severity of these mental health concerns. Providing timely psychological support comprehensive prenatal care and maternity-friendly policies can play a crucial role in improving emotional health ultimately leading to a safer and more positive pregnancy and postpartum experience for both mother and child.

High-risk pregnancies can greatly increase psychological distress, often resulting in heightened levels of anxiety, fear and emotional instability. Expectant mothers dealing with conditions such as gestational diabetes, pre-eclampsia or the risk of preterm labor frequently experience significant stress due to concerns about their own well-being and that of their baby. Isaacs (2020) suggests that women with high-risk pregnancies are more prone to emotional and psychological struggles including depression and a sense of helplessness. The unpredictability of medical complications, frequent doctor visits, and necessary lifestyle adjustments can further contribute to mental exhaustion. Additionally the anxiety surrounding potential pregnancy complications may lead to sleep disturbances, social isolation and difficulty managing daily activities. To address this concern it is crucial to implement strong support systems, including access to mental health counselling social support networks and consistent medical care, to alleviate stress and promote better outcomes for both the mother and the baby. In this context, continuous and non-intrusive health monitoring systems embedded into everyday maternity garments could play a vital role in supporting maternal well-being.

Such systems have the potential to facilitate early identification of physiological stress responses and psychological discomfort without disrupting daily activities. By enabling on going monitoring in a comfortable and familiar form, smart maternity wear may reduce the burden of frequent clinical visits while offering timely insights into maternal health particularly for women experiencing high risk or anxiety related pregnancies.

The transition to motherhood involves significant psycho social changes as women adjust to the emotional, psychological and social shifts that come with pregnancy. During this transformative phase expectant mothers often reflect on their evolving identity moving from an individual sense of self to embracing the role of a caregiver. The anticipation of becoming a mother can bring about shifts in priorities, responsibilities and expectations influencing both emotional well-being and interpersonal relationships. As they prepare for parenthood women may experience a combination of excitement and apprehension while adapting to new challenges. This period of psychological adjustment is crucial for developing a strong maternal identity which is fundamental in nurturing a secure bond with the baby. Furthermore the presence of a supportive environment including encouragement from family, guidance from healthcare providers and strong social connections plays a vital role in easing this transition and enhancing maternal mental health both during pregnancy and in the postpartum period (Amato, 2005).

Maternity wear that is designed to accommodate bodily changes during pregnancy can significantly enhance emotional well-being by providing comfort and security. Soft, breathable and flexible fabrics that adjust to a growing body not only improve physical comfort but also help reduce stress and create a sense of normalcy. Furthermore well-fitted and stylish maternity clothing can boost self-confidence by minimizing concerns related to body image changes such as weight gain and shifting proportions. The availability of fashionable yet functional maternity apparel allows expectant mothers to maintain their personal style while ensuring comfort and practicality. As a result maternity clothing goes beyond more functionality it plays a vital role in promoting confidence, emotional well-being and a positive pregnancy experience (Shamsaei, 2022).

Cultural and societal factors play a crucial role in shaping the psychological experiences

of pregnancy. The ways pregnant celebrities are portrayed in the media along with the growing focus on trendy maternity fashion influences how expectant mothers perceive their bodies and make clothing choices. Lapolla (2022) on consumer attitudes in the U.S. indicates that many pregnant women look to celebrity maternity styles for inspiration prompting them to seek clothing that is both stylish and practical. This trend highlights the impact of popular culture in redefining maternity wear encouraging women to embrace fashion while ensuring comfort and functionality during pregnancy.

A two-way relationship between psychiatric disorders and pregnancy outcomes where untreated mental illness can contribute to complications like low birth weight, preterm labor and difficulties in maternal-infant bonding. At the same time, pregnancy-related stress and medical concerns can exacerbate existing mental health conditions, creating a cycle of psychological distress. Early detection and intervention through mental health screenings, therapy and appropriate medical treatment are crucial in promoting both maternal health and fetal development. Ensuring comprehensive mental health care including counselling, necessary medication and social support can significantly enhance well-being for both mother and child throughout pregnancy and the postpartum period (Hafez, 2023).

Pregnancy-induced brain modifications, particularly in areas responsible for empathy, social understanding and emotional regulation enhance a mother's capacity to care for and respond to her infant. These changes play a crucial role in fostering nurturing behaviours deepening emotional attachment and promoting the well-being of both mother and child. Additionally neurological adaptations heighten sensitivity to infant signals supporting protective instincts and encouraging a responsive care giving environment. These findings emphasize the biological basis of maternal adaptation highlighting how the brain prepares women for parenthood. A deeper understanding of these transformations can assist healthcare professionals in offering better guidance and emotional support to new mothers facilitating a smoother transition into their care giving role (Kim, 2016).

2.1.3 Clothing Requirements across Different Stages of Pregnancy

Understanding clothing requirements across different life stages provides insight into how apparel must adapt to physiological, functional and psychological changes. This

perspective helps inform the design of maternity wear which similarly requires adaptability, comfort and functional support during a transitional life stage. A person's clothing should be chosen based on what their body requires. They need to improve the appearance as well. The person should keep in mind that their personality and physical attributes are always changing. Each person has a particular preference for color, fabric, patterns and other elements and their needs for clothing vary depending on their stage of life. Individual differences in age, personality and role are the cause of the variance in choices. Every life transition, including birth, starting school, going to college, finding a job, getting married, becoming a parent and even passing away calls for a new wardrobe. Even in the course of daily life, scenario after circumstance necessitates a change of clothes to assist and signify the situational shift.

A study conducted on the design and evaluation of clothing for neonates¹ and found that thousands of preterm new-born's or neonates are born weeks or even months early every day. The neonate's birth weight is frequently dangerously low, possibly one-first to one-sixth the size of typical neonates, due to their early gestational development. Their petite stature, often combined with health issues, results in certain special wardrobe requirements (Sandberg, 2002). Clothes made especially for the tiny baby in the critical care unit might create a micro environment that lowers heat loss, satisfies the unit's medical requirements and gives the baby a sense of security and well-being. Additionally, when their babies appear more normal² in clothes, parents feel better about them (Blatz, 2001).

As said warmth, comfort and cleanliness are the three musts³ when it comes to infant clothes. The time of year, the overall weather, the temperature of the child's room and the infant's health will all have an impact on the kind and quantity of clothing the baby requires. Cotton is the best fiber for baby clothes since it is soft and can be cleaned hygienically by washing in boiling or extremely hot water (Imran, 2020).

Pre-schoolers require clothing that protects them from scratches, rough sidewalks and other skin injuries because they are often moving about. Lightweight clothing that offers the most warmth and protection is ideal. Children who wear heavy clothing are more likely to become exhausted and limit their activities. Fire-resistant fabrics should be used. Because they make it easier to notice children on the playground, in the yard

or on the street bright colors are preferred for outerwear. The textile's color, pattern and texture should all fit the child's age and size. During the preschool years, growth is particularly fast. Longer-lasting clothing that keeps its good fit and look over time is one of the biggest demands for this age group (Maxwell, 2007).

She said that loose-fitting shoulders provide for more range of motion for lifting and stretching in preschool attire. Reaching, bending and standing or sitting without bending are all made possible by having enough space through the hips and crotch. Wrist bands that are too tight should be rounded off. Lower garment elastic should be robust enough to support clothing.

Clothes had a significant impact on children. A young child's clothing choices can help him meet some of his basic requirements, attract more attention from his peers and identify his sex. It should be chosen to support improved peer interaction, self-reliance and social skill practice and child development. The clothing should be comfortable, flexible, adaptable to the body's fast growth, easy to use for frequent toileting and stylish in both fabric and design (Paju, 2018).

Two essential demands for adolescents are belonging and self-worth which are symbolized by buying and displaying stylish clothing (McNeill, 2018).

Pregnancy causes a woman to go through physical and physiological changes; therefore her clothing needs will differ from those under normal circumstances. During this time, a woman matures to a new level and becomes a mother. At various points during her pregnancy she has her own wants and demands (Bjelica, 2018).

A pregnant woman will begin to feel uneasy as her body changes form if her garments are not made to accommodate her growing expand. Tops may be loose across the shoulders but tight over the stomach and skirts may ride up and appear far shorter than usual. In order for a pregnant lady to feel comfortable and look amazing it is crucial to have some appropriate maternity clothing (Akinyotu, 2023).

Due to increased blood flow, pregnant women may experience discomfort from the heat and should wear cooling materials like linens and cottons. Additionally, during the summer their skin may become sensitive to synthetic textiles which might lead to hot

scratch rashes. In these situations it is advised to wear clothing composed of natural fibers (Ho, 2008).

Some expecting moms perspire more than usual; in these situations wearing layered dresses can help them stay cool and warm. There should be much space for development in maternity clothing. A pregnant woman will appear more put together in well-fitting clothing than in loose oversized items.

Research has shown that maternity clothing has become more significant in recent years. Pregnant women are kept in the spotlight by the expectation that they engage in regular social activities. The necessity of maintaining a professional look at work emphasizes the significance of wearing appropriate maternity attire (Weigle, 2022).

A pregnant woman's real wardrobe demands will depend on how long she continues to work and participate in social and communal activities. If her job is terminated in the early stages of pregnancy, she does not need to have career clothes in her wardrobe; but, if she intends to continue working she must purchase appropriate apparel. It's crucial that her wardrobe has enough clothes that are suitable for the social events she attends outside the house.

He also highlighted the necessity of postpartum clothing once the baby is born. Available money, the adaptability of maternity clothing, the state of pre maturity clothing, the postpartum figure and the particular woman's mood and whether or not the baby is breastfed will all play a role in the selection. Clothing must include nursing-specific characteristics if the infant is breastfed.

Moms used to spend all of their time at home in the past. Their standing in society has evolved in the modern era due to educational advancements. As a result, nursing moms find it challenging to breastfeed while wearing regular clothes since they have to rise up, unstuck or unbutton their garments. Nursing in public can be difficult and bothersome for them since it frequently exposes more flesh than they would want. Having nursing attire is also crucial since it makes breastfeeding in public easier and more discrete (Nomaguchi, 2020).

According to research, elderly individuals have distinct fashion demands than younger

people since they are more conservative and less receptive to changes in style.

Many retirees' lower incomes cause them to be more concerned about durability and cost. Clothing for young children with physical limitations must have several features such as safety features, wide openings, easily closed closures and soft-feeling materials. Many older persons have trouble stretching their arms above their heads and closing their backs. Standard-sized clothing usually has to be altered due to physical changes in body proportion. Lightweight, warm textiles are preferred over bulky ones since the former are uncomfortable (Wilfling, 2023). These findings collectively highlight that maternity clothing like apparel for other sensitive life stages must address comfort, adaptability, dignity and functional support laying the groundwork for integrating smart and health responsive features into maternity garments.

2.2. Smart Maternity Wear

Designers select materials with qualities including look, comfort, durability and shape retention and weather protection while developing new apparel items. These elements don't entirely meet the new elements including fever, heart attack symptoms and the body's natural regulation of body temperature among others. Such sophisticated qualities are present in smart textiles. The wearer can be informed, protected and relaxed with the help of smart textiles (Slater, 1977). Smart maternity wear refers to maternity garments that integrate textile based sensing technologies, wearable electronics and communication systems to monitor support and communicate physiological and psychological health conditions of pregnant women in a non-invasive and user centric manner.

2.2.1 History of Smart Maternity Wear

The existence of humans has undergone great change as a result of civilization and numerous scientific and technological sectors are undergoing daily transformation that directly affects people (Younes, 2023). Conductive threads and conductive materials the fundamental components required to create smart textiles have existed for more than a millennium. For instance to improve the decorative textile applications craftspeople have been wrapping delicate metal foils primarily made of gold and silver around fabric threads for generations. Additionally, for a shimmering touch gold-wrapped threads are used to embroider several of Queen Elizabeth's garments. People began to grow

acclimated to electric appliances around the end of the 19th century as a result of major developments in human growth. Designers and engineers started fusing jewellery and clothes with electrical connections. For instance they created a line of motorized and illuminated necklaces, headgear and brooches as well as outfits like evening gowns with light studding (Garver, 2025).

The ground-breaking body covering exhibition at the Museum of Contemporary Craft in New York City primarily examined the connection between clothing and technology. The centrepiece of the show were the astronaut's space suits and clothes which had the ability to heat and cool themselves, light up and inflate and deflate. Textiles from the designer Diana Dew's collection which included belts that could activate alarm sirens and an electroluminescent party dress line were on display (Buszek, 2011).

The evolution of smart maternity wear is closely linked to the broader advancement of smart textiles in healthcare a field that has increasingly attracted interest from researchers and engineers for its potential to enhance health monitoring and treatment. Traditionally maternity clothing focused primarily on providing comfort and flexibility during pregnancy. However with the integration of smart textile technology these garments have been transformed into advanced medical tools. By embedding sensors and interactive fabrics smart maternity wear enables continuous monitoring of maternal and fetal health contributing to the commercialization of innovative healthcare solutions. Researchers have examined various ways to classify smart textiles based on their functionality and application, further reinforcing the role of smart maternity wear as a crucial development in this sector. The transition from conventional maternity apparel to technologically enhanced garments marks a significant shift in healthcare, prioritizing non-invasive, comfortable and real-time monitoring solutions. This progression not only highlights the historical advancements in smart textiles but also points to the on-going challenges and future possibilities in enhancing the intelligence, accessibility and effectiveness of maternity wear for improved maternal health management (Esfahani, 2021). Despite these advancements, most smart textile developments in healthcare have remained device centric or prototype based with limited translation into everyday maternity garments that prioritize comfort, adaptability across trimesters and user acceptance.

Valuable insights into the historical development of smart maternity wear situating it within the larger framework of medical clothing and digital health advancements. Traditionally, maternity garments were designed primarily for comfort and functionality but with technological they have evolved into sophisticated apparel that integrates health monitoring capabilities. The progress emergence of smart textiles represents a pivotal shift in this transformation incorporating wearable sensors to enhance maternal and fetal health surveillance. The study emphasizes the role of smart textile medical devices such as the belly-band for labor monitoring and the baby band for neonatal care as key innovations in this field. These developments also highlight the emergence of modular and detachable monitoring components in maternity wear designed to enhance usability, facilitate garment maintenance and allow technology reuse across multiple garments. Such modularity responds to the rapidly changing body dimensions during pregnancy while maintaining comfort and functional flexibility. By seamlessly embedding technology into clothing smart maternity wear has redefined medical surveillance making it less visible and more comfortable thus bridging the gap between clinical monitoring and home-based care. This shift aligns with broader healthcare trends that aim to create hospital environments resembling home settings making medical technology feel more natural and less invasive. Additionally the study highlights how smart maternity wear extends medicalization beyond hospital settings shaping maternal healthcare practices throughout pregnancy and early childhood. However while these advancements hold great promise concerns persist regarding over-medicalization, increased parental anxiety and data privacy. The evolution of maternity wear into a digital health innovation illustrates the intersection of fashion, engineering and medical science signifying a crucial advancement in the field of smart maternity wear (Joyce, 2019).

The development of smart maternity wear is closely tied to advancements in healthcare and textile technology driven by the need to overcome the limitations of traditional disease management systems. As healthcare transitions from a reactive illness-focused approach to one that is personalized, predictive and preventive textiles have played a key role in this shift. Throughout history; textiles have served both practical and comfort-driven purposes but their integration with diagnostic, therapeutic and power-

generating functions has led to the emergence of electronic textiles transforming wearable healthcare. Smart maternity wear has evolved from this innovation providing expectant mothers with garments that enable real-time health monitoring and therapeutic support while ensuring ease of wear. This advancement represents a major transformation in maternal healthcare fostering proactive monitoring of both maternal and fetal well-being. By utilizing smart textiles as a point-of-care solution maternity wear has progressed from being purely functional to becoming an active healthcare tool reflecting the continuous evolution of textile technology and digital health solutions (Chen, 2024). However, the literature indicates a lack of user – centric design frameworks that integrate wearable monitoring technologies seamlessly into maternity apparel without compromising comfort, aesthetics or cultural acceptability.

2.2.2 Concept of Smart Maternity Wear

A textile structure that detects and reacts to various environmental stimuli is the fundamental idea behind smart textiles. In its most basic form the smart textile senses and responds on its own without the aid of a controlling unit in it's more sophisticated form however it uses a processing unit to sense, react and respond to a specific function. The graphic illustrates how intelligent technology can both detect and respond to environmental changes and initiate actions to improve functionality. When applied specifically to maternity wear, these smart textile principles must account for dynamic anthropometric changes, heightened sensory sensitivity and emotional well-being during pregnancy.

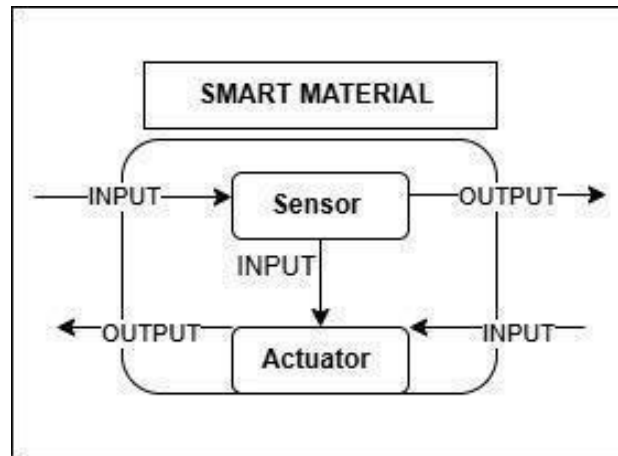
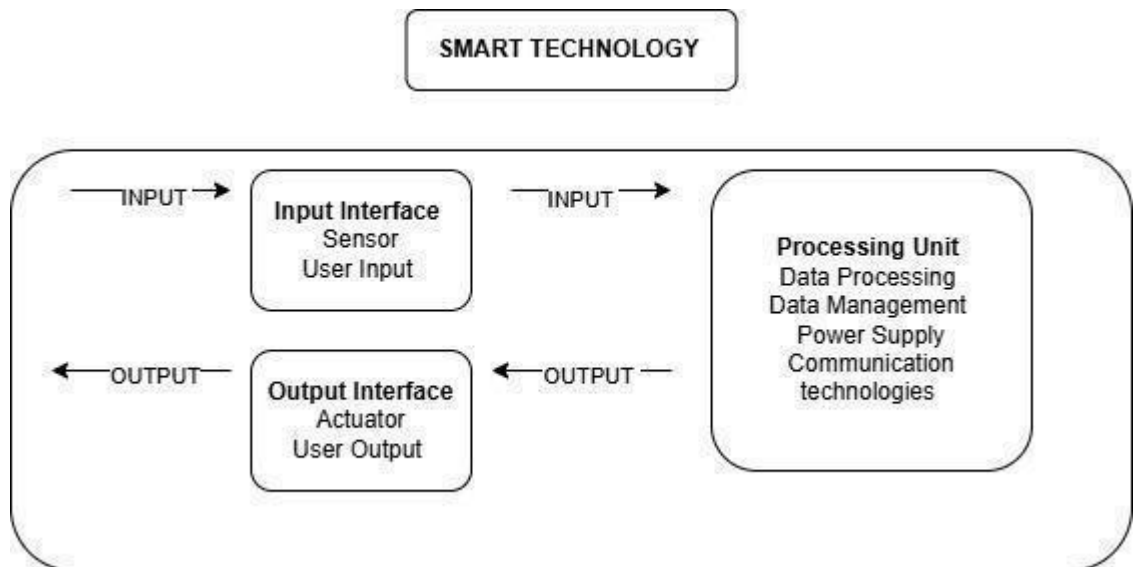


Figure 2.1: Structure of Smart Textiles
 (Source: Created by the author using draw.io)



The figure illustrates how smart fabrics react to different stimuli and alter their size, shape or color based on built-in qualities.

Figure 2.2: Mechanism of Smart Textiles
 (Source: Created by the author using draw.io)

An important development in maternal healthcare is smart maternity wear which is the result of integrating technology into maternity clothing. These cutting-edge clothes give expectant mothers comfort, support and real-time health monitoring by fusing wearable electronics, Internet of Things-enabled sensors and functional materials. Unlike existing wearable devices that function as external accessories the present research emphasizes garment – integrated and modular smart maternity wear that aligns with everyday clothing practices. The novelty of this approach lies in combining functional maternity garment design with detachable sensor based monitoring systems that ensure comfort, adaptability and continuous health communication.

The purpose of smart maternity gear is to continuously monitor the health of both the mother and the fetus by tracking critical physiological factors like blood pressure, body temperature, heart rate, fetal movement and physical activity. Wireless communication technologies and biosensor integration enable smooth data transfer to mobile apps or healthcare practitioners, facilitating prompt medical interventions as needed. For example gadgets such as Nuvo's Invu wearable track the heart rates and contraction activity of both mothers and fetus's sending this information to medical professionals in real time (Liu, 2024).

The adaptive design of smart maternity gear which adapts to changes in the body throughout pregnancy is one of its primary features. Comfort is guaranteed by the use of elastic, breathable and moisture-wicking materials and the expanding belly is supported by adjustable features. Additionally common pregnancy-related discomforts like back pain and poor circulation are lessened by posture-enhancing features like compression zones and built-in lumbar support. In order to address issues with dehydration some sophisticated smart maternity clothing also incorporates temperature-regulating textiles that adapt to changes in body temperature and hydration monitoring devices that alert users to their level of hydration. These developments are demonstrated by innovations like smart maternity bands with sensors to monitor vital signs (Dias, 2018).

Smart maternity equipment is an eco-friendly and long-term investment because it encourages sustainability and multi functionality in addition to health monitoring. With characteristics that may be converted into nursing wear or postpartum recovery apparel

many of these clothes are made to be used for longer periods of time after giving birth. Furthermore the fashion industry's utilization of recyclable, biodegradable or sustainably derived materials is in line with current environmental concerns.

Beyond just helping individual users smart maternity apparel also advances the larger objective of digital healthcare revolution. These advances have the potential to significantly impact preventive healthcare by decreasing the frequency of hospital visits through remote maternal health monitoring especially in underserved or rural areas with restricted access to medical services. For instance a study showed that it is feasible to use an Internet of Things (IoT) smart bracelet to continually monitor pregnant women's heart rates, sleep patterns and physical activity levels, giving them real-time information in between session (Saarikko, 2020).

AI-powered insights play a crucial role in enhancing personalized maternal healthcare by providing real-time data-driven recommendations to support expectant mother's well-being.

However despite its promising benefits the widespread adoption of smart maternity wear is hindered by factors such as high costs, limited awareness and the need for further validation of sensor accuracy and long-term effectiveness. Nonetheless continuous progress in smart textiles compact sensor technology and IoT-enabled healthcare solutions suggests significant potential for this field. As research delves deeper into the integration of fashion, technology and maternal health smart maternity wear is anticipated to become a vital component of modern pregnancy care ensuring both comfort and health monitoring for mothers-to-be (Kagiri, 2024).

2.2.3 Classification of Smart Maternity Wear

Smart maternity wear integrates advanced materials and technologies to enhance comfort, functionality and health monitoring for expectant mothers. The classification of smart maternity wear can be derived from the broader categorization of smart materials which are typically divided into passive, active and ultra-smart textiles based on their functionality and response to external stimuli (Çelikel, 2020).

1. Passive Smart Maternity Wear

Passive smart textiles are the first generation of smart materials that provide additional

features without actively responding to environmental changes. These textiles enhance maternity clothing by incorporating properties such as anti-microbial, anti-odour, anti-static and UV protection which contribute to hygiene and safety during pregnancy. Conductive fabrics, composite textiles and ceramic-coated materials are examples of passive smart textiles used in maternity wear. These materials can sense environmental changes such as temperature or moisture but do not actively react. Some maternity garments incorporate optical fiber sensors to monitor body movements or temperature fluctuations but their role is limited to sensing rather than actuating (Sarhaddi, 2022).

2. Active Smart Maternity Wear

Active smart textiles; the second generation of smart materials not only sense changes in the environment but also respond to them. These textiles are equipped with both sensors and actuators that adapt to specific conditions making them highly relevant for maternity wear. Active smart maternity wear may include garments with temperature-regulating materials, moisture-wicking fabrics or shape-memory fibers that adjust to body changes during pregnancy. Technologies such as phase-change materials (PCM), thermo-regulated textiles and electrically heated maternity garments can help maintain thermal comfort and alleviate pregnancy-related discomforts such as back pain and swelling (Persson, 2018). Additionally, hydration-monitoring fabrics and posture-support clothing with built-in compression zones exemplify active smart maternity wear designed to enhance maternal well-being.

3. Ultra Smart Maternity Wear

Ultra-smart textiles represent the most advanced category of smart materials capable of sensing, reacting and adapting to various stimuli autonomously. These textiles incorporate artificial intelligence, IoT-based sensors and advanced communication technologies to provide real-time health monitoring for expectant mothers. Ultra-smart maternity wear may include garments with embedded biosensors to track vital signs such as heart rate, blood pressure, fetal movements and stress levels. Some designs incorporate AI-driven analytics to provide personalized health recommendations ensuring optimal maternal care. Examples of ultra-smart maternity wear include smart maternity bands, AI-powered pregnancy monitoring suits and intelligent wearable systems that connect with mobile applications to provide real-time feedback on

maternal and fetal health (Hossain, 2023).

This classification framework supports the conceptual positioning of the present study within the active to ultra – smart category emphasizing modular sensing and communication rather than permanently embedded systems.

2.2.4 Functions of Smart Maternity Wear

Smart textiles integrate advanced technologies to provide enhanced functionality beyond traditional fabrics. Their capabilities can be broadly categorized into five main areas: sensing, actuation, data processing, communication and energy management. These functionalities make smart textiles valuable across various applications, including healthcare, fitness, defence and maternity wear (Zhang, 2023).

1. Sensing Features in Smart Textiles

Sensing is one of the most critical aspects of smart textiles enabling the real-time tracking of physiological and environmental conditions (Angelucci, 2021). These textiles are embedded with specialized sensors that detect and measure various parameters including:

Temperature Detection: Smart fabrics can monitor body temperature and external climatic conditions contributing to thermal regulation.

Acoustic Monitoring: Integrated sensors can capture internal body sounds such as heartbeats, lung activity, digestive processes and joint movements supporting medical diagnostics.

Biological and Chemical Analysis: Some smart textiles assess biomarkers like sweat composition, pH levels and exposure to chemicals.

Pressure Sensing: Pressure-sensitive fibers allow the monitoring of blood pressure variations aiding in cardiovascular health tracking.

Bio-Potential Measurements: These textiles can record electrocardiogram (ECG), electroencephalogram (EEG) and electromyogram (EMG) signals, assessing cardiac, neurological and muscular functions.

Ultrasound-Based Monitoring: Certain textiles utilize ultrasound sensors to analyze

blood flow patterns and detect vascular conditions.

Motion and Respiration Tracking: Embedded accelerometers and strain sensors help track movements, posture and respiratory activity.

Odour Detection: Advanced fabrics can analyze body odour such as sweat composition to identify hydration levels or metabolic disorders.

Radiation and Spectroscopic Analysis: Some smart textiles detect infrared (IR) radiation and perform spectroscopy-based assessments for environmental and medical applications.

Skin Condition Monitoring: Electrical and mechanical properties of the skin such as elasticity and hydration levels can be evaluated to assess dermatological health.

In maternity applications, these sensing functions are particularly valuable for continuous, non – invasive monitoring of maternal stress, cardiovascular activity and physical comfort.

2. Actuation in Smart Textiles

Actuation allows smart textiles to respond to stimuli by initiating appropriate reactions. Unlike passive textiles that only record data, actuating textiles actively engage with their environment or the wearer (Ramlow, 2021). The primary actuation mechanisms include:

Mechanical Response: Textiles integrated with shape-memory alloys (SMA) or electro active polymers (EAP) can contract or expand providing postural support or compression therapy.

Chemical Release: Certain smart fabrics are designed to dispense therapeutic agents such as medicated dressings for wound healing or cooling gels activated by sweat.

Optical Adjustments: Some textiles incorporate light-emitting fibers or electroluminescent materials that enable color changes or illumination in response to external stimuli.

Thermal Regulation: Smart textiles utilizing phase-change materials (PCMs) or electric heating elements can provide warmth in cold environments.

Electrical Stimulation: Conductive fabrics can generate small electric pulses aiding in neuro-muscular stimulation, pain relief or biofeedback therapy.

3. Data Processing in Smart Textiles

Data processing plays a crucial role in smart textiles as embedded sensors generate extensive and complex real-time data. To effectively manage and interpret this information textiles are integrated with advanced computational techniques such as artificial intelligence (AI) and machine learning (ML) (Sarker, 2023).

- **Self-Learning Systems:** AI-driven textile technologies can identify wearer behavior patterns, optimize thermal comfort and predict potential health risks based on historical data.
- **Cloud-Based Data Storage:** Many smart garments connect to cloud platforms, enabling real-time storage, analysis and sharing of health data with medical professionals or fitness applications.
- **Predictive Analytics:** Smart textiles utilize advanced algorithms to identify potential health issues such as dehydration, postural imbalances or cardiovascular irregularities.

4. Communication in Smart Textiles

Smart textiles incorporate wireless communication technologies that facilitate seamless connectivity between wearers, medical professionals and external devices. This function is essential for real-time data exchange ensuring timely interventions and enhanced usability (Wang, 2024).

Bluetooth and Wi-Fi Connectivity: Many smart garments sync with mobile apps and wearable health monitoring systems to provide instant updates on user health metrics.

Near-Field Communication (NFC): Certain textiles integrate NFC technology for contact less authentication, medical data access and emergency identification.

5. Energy Management in Smart Textiles

Power supply is a crucial aspect of smart textiles as embedded sensors and actuators require efficient and sustainable energy sources (Ramasubramanian, 2022). The latest advancements in energy management include:

Flexible and Stretchable Batteries: Textile-based lightweight and rechargeable lithium-ion batteries provide portable power solutions.

Energy Harvesting from Movement: Some fabrics generate electricity through piezoelectric and tribo electric nano generators converting motion into usable power.

Solar-Powered Smart Fabrics: Textiles embedded with photovoltaic cells enable energy harvesting from sunlight making them ideal for outdoor applications and long-term wearable use.

Wireless Power Transfer: Advanced energy-efficient textiles integrate inductive charging and wireless communication technologies reducing dependency on physical battery replacements.

5G and IoT Integration: The emergence of 5G-enabled textiles and IoT-based smart wearables ensures high-speed low-latency communication which is particularly beneficial for remote healthcare applications.

2.3 Smart Textile Technology (Smart Wearable)

The term smart textiles has gained significant attention in both industry and media in recent years. These textiles differ from traditional fabrics as they possess interactive functionalities and are designed for innovative non-commodity applications. Smart textiles represent rapidly evolving high-tech advancement within the textile sector (Köhler, 2014). The terms smart and intelligent textiles are often used interchangeably to describe materials that can detect changes in their environment respond to these stimuli and adapt accordingly by incorporating functional elements into the textile structure (Dulal, 2022).

Smart textiles refer to textile products that incorporate conductive fibers, filaments and yarns into fabric structures through various techniques such as weaving, knitting and embroidery or non-woven methods. These advanced textiles are designed to interact with their surroundings and respond accordingly. Also known as e-textiles they play a crucial role in enhancing public welfare by integrating technology into everyday clothing and accessories (Rodrigues, 2024).

The term smart in smart textiles can be interpreted in multiple ways it can imply

intelligence and functionality or simply refer to being stylish and trendy. As a result smart clothing represents a fusion of both technological innovation and fashion appeal. In the textile communication industry, smart and intelligent textiles are often used synonymously. These textiles are increasingly embedded in everyday items such as belts, watches and caps seamlessly integrating technology into daily life (Mattila, 2006).

The intelligent nature of smart textiles can be incorporated at various levels. It can be introduced at the fiber stage enhanced by weaving in specialized threads or achieved through coatings and finishing treatments applied to the fabric. Additionally smart textiles can be designed to integrate independent electronic components directly within the textile structure enabling advanced functionalities (Heo, 2018).

Smart textiles represent a new generation of fabrics designed for diverse applications, including home furnishings, fashion, technical textiles, protective gear and medical textiles. Their development is rooted in three key domains- textile design and technology, smart materials and computing science and engineering. Each of these fields plays a vital role in the overall system-textile design and technology focus on material selection and fabrication processes; smart materials enable responsiveness to external stimuli and computing science and engineering contribute to the creation of dynamic functionalities and operational mechanisms (Van Langenhove, 2007).

The primary goal of smart textiles is to integrate interactive capabilities by combining advanced materials with embedded computing technologies. Incorporating these elements within textile structures paves the way for the development of fabrics with novel behaviours and enhanced functionalities pushing the boundaries of traditional textile applications (Marculescu, 2003).

Smart materials in our environment are becoming increasingly advanced often referred to as being intellectualized due to their ability to modify their fundamental properties in response to external stimuli or environmental conditions (Syduzzaman, 2015). Modern technology has enabled the execution of specific functions with fewer components and a single material reducing the need for multiple elements.

Smart or functional materials play a crucial role in smart textile systems, as they possess

the capability to detect, react and adapt to their surroundings through an active control mechanism. These materials exist within a Technology Space¹ which is categorized based on their core characteristics particularly in the fields of sensing and actuation (Bi, 2022).

Characterized by one or more distinctive properties, smart materials undergo significant alterations when exposed to external stimuli in a controlled manner. They are designed with intrinsic sensors, actuators and control systems allowing them to perceive stimuli respond in a predetermined way within an appropriate time-frame and revert to their original state once the stimulus is no longer present (Wang, 2019).

Within this technological landscape, smart maternity wear emerges as a specialized application of smart textiles requiring a balanced integration of medical functionality, garment design and user comfort.

2.4. Smart Textile Applications

Smart textiles sometimes referred to as electro-textiles, intelligent textiles or e-textiles are advanced textile systems capable of sensing, reacting and in some cases adapting to external stimuli such as mechanical, thermal, chemical or biological (Hertleer, 2004). Functional textiles as opposed to smart textiles are materials that have had a specific purpose added to them by composition, construction, finishing or substance (e.g., coatings or additives).

Sometimes the design paradigm used to include electronic capabilities into the textile architecture is also used to categorize smart textiles. On the extreme side of the range are smart textiles, which just serve as a substrate for the attachment of printed circuit boards, sensors and output devices (garment and fabric level integration). Similar to wearable computers which are electrical systems with sensors and computational components constructed from easily available off-the-shelf components (D. Marculescu, 2003) that can be strapped to the body these textiles have very minimal device integration. There has been a push to incorporate planned functionalities disappearing² inside the textile structure in subsequent developments in this subject (Wagner, 2002). This distinction between garment level integration and modular attachment systems is particularly relevant in healthcare and maternity applications

where user comfort, wash ability, maintenance and adaptability are critical. Modular and detachable smart textile architectures allow electronic components to be removed during garment care and reused across multiple garments addressing both usability and longevity concerns.

Due to the on-going reducing of electronics, numerous desk electrical gadgets have become portable in recent decades. It is reasonable to believe that some of these portable gadgets would eventually get so compact and handy that they can be worn (Liang, 2019). Sports, healthcare/medical, fashion/entertainment and the military/public sector are the four divisions of the industry. There are examples where the fields overlap frequently due to the repackaging of comparable or even identical technology for a new end application. Among these sectors, healthcare and maternity care represent one of the most sensitive application domains requiring non-invasive, reliable and user – centric smart textile applications.

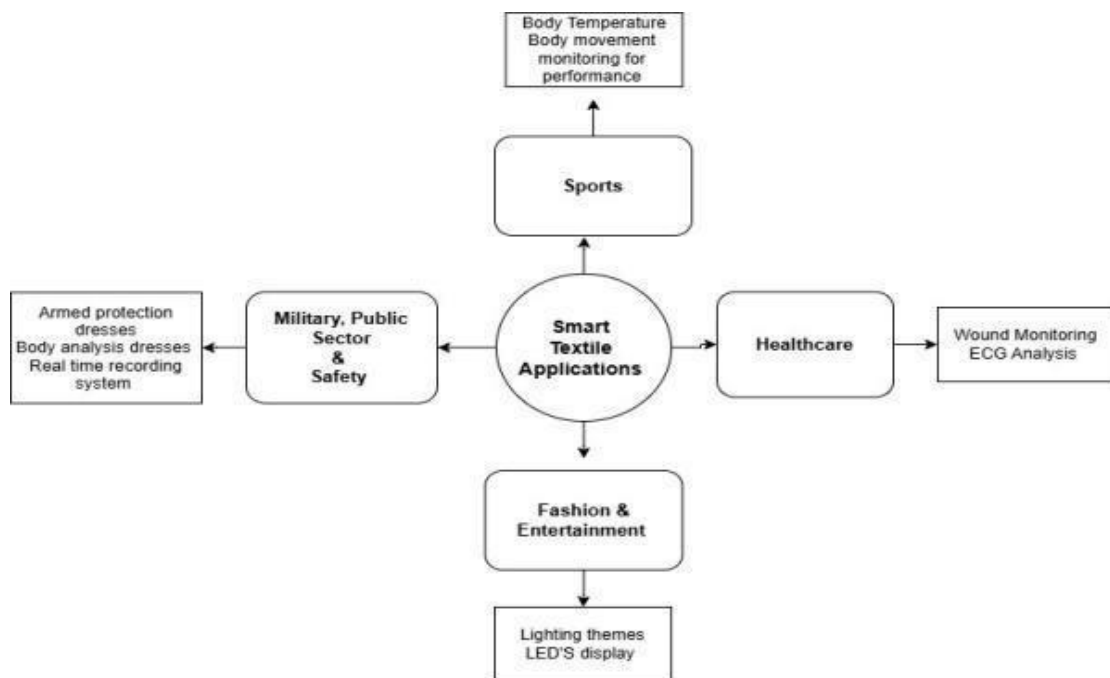


Figure 2.3: Smart Textile Applications
(Source: Created by the author using draw.io)

2.4.1. Sports

An increasing number of users have responded to the development of textile-based smart wearable sports systems, driven by design, technology and the possibility of improved performance. Technical textiles and high tech solutions have long been

adopted early by the sports industry and this hasn't altered for commercial smart clothing or wearable technology. Training/professional sports and informal sports are the two main categories into which the sportswear category can be separated, and each category makes use of various forms of technology. Bio-physical monitoring technologies are used in professional sportswear and training and they overlap with healthcare. Entertainment and communication technologies have been incorporated into casual sportswear (Hayes, 2016).

The use of smart textiles in sports has significantly transformed athletic performance assessment, injury prevention and training strategies. Also known as electronic textiles (e-textiles) these fabrics integrate sensors, actuators and communication systems to deliver real-time data on an athlete's physiological and bio-mechanical parameters (Stoppa, 2014). By enabling continuous and seamless monitoring these advanced textiles help athletes optimize their training regimens and reduce the risk of injuries.

One of the key applications of smart textiles in sports is physiological tracking. Sportswear embedded with sensors can monitor vital parameters such as heart rate, body temperature, hydration status and respiratory rate offering valuable insights into an athlete's endurance and overall health. This real-time feedback allows coaches and medical teams to assess fatigue levels and customize training plans. Additionally pressure-sensitive smart fabrics analyze muscle activity and movement patterns providing bio mechanical feedback to improve posture and technique (Wood, 2016).

Another critical function of smart textiles is injury prevention and rehabilitation. Compression garments equipped with electromyography (EMG) sensors can detect muscle strain and irregular movement patterns alerting athletes to potential injuries before they develop (Jain, 2005). Furthermore smart garments featuring temperature regulation mechanisms aid in muscle recovery by controlling body temperature and enhancing blood circulation thereby reducing muscle stiffness and soreness (Langenhore, 2007).

Enhancing athletic performance is another vital aspect of smart sportswear. GPS-enabled textiles enable real-time tracking of movement and speed offering athletes data-driven insights to refine their performance (Leitch, 2003). Moreover wearable textiles with haptic feedback technology provide real-time corrections on posture and motion,

further optimizing athletic technique.

The future of smart textiles in sports is evolving with the incorporation of artificial intelligence (AI) and the Internet of Things (IoT). These advancements enable sophisticated analytics, predictive modelling and cloud-based data sharing providing a comprehensive evaluation of an athlete's physical condition (Kamila, 2013). Additionally sustainable energy solutions such as piezoelectric and triboelectric fabrics that generate power from body movements are being developed to enhance the efficiency and longevity of smart sportswear (Jamadar, 2016). Although sports applications have led innovation in physiological monitoring through smart textiles these technologies provide a foundational reference for healthcare focused garments including maternity wear where continuous monitoring must be achieved without compromising comfort or mobility.

2.4.2. Healthcare

The market for smart textiles is expanding daily. The significance of e-textile systems in the traditional textile business has grown due to shifts in human behavior and the need for user-defined facilities. The initial application for smart textiles was in medical e-textiles (Fleury et al., 2015; Teferra et al., 2019). Since then, the market for e-textiles has expanded dramatically for a variety of uses in wireless communications, fitness tracking and military (Bahru et al., 2020; Park, 2003).

As e-textiles and their related industries have seen an increase in investment consumer awareness of this newly developing field has grown due to the progressive development of the integration of electronic systems into textiles for e-textile systems and their applications. Consequently, this development eventually decreased the cost of production and made it easier for clients to obtain these new e-textile systems (Gopalsamy et al., 2005; Shah et al., 2021). It is early to declare that e-textile systems are fully included into the Internet of Things (IoT) infrastructure, nevertheless. Improvements in security, safety and dependability are still needed to ensure wearable e-textile devices IoT nodes. There will be more products available on the market as infrastructures and standardizations advance leading to a nice growth rate in the end (Tao et al., 2018; Kim et al., 2020). Despite these advancements, most healthcare e-textile solutions remain device centric and are often designed for controlled clinical

environments. There is limited literature focusing on the integration of such technologies into everyday wearable garments tailored for specific populations such as pregnant women.

The integration of e-textiles was initially pioneered in the medical field. Many items in the medical industry today make use of electronic structures. Diagnostic and monitoring devices and therapeutic devices are the two main categories into which wearable medical equipment can usually be separated. These categories are described in more depth within our discussion (Figure 2.4). These developments demonstrate the feasibility of textile based monitoring systems however their translation into maternity specific garments that accommodate changing body morphology and prolonged daily wear remains under explored.

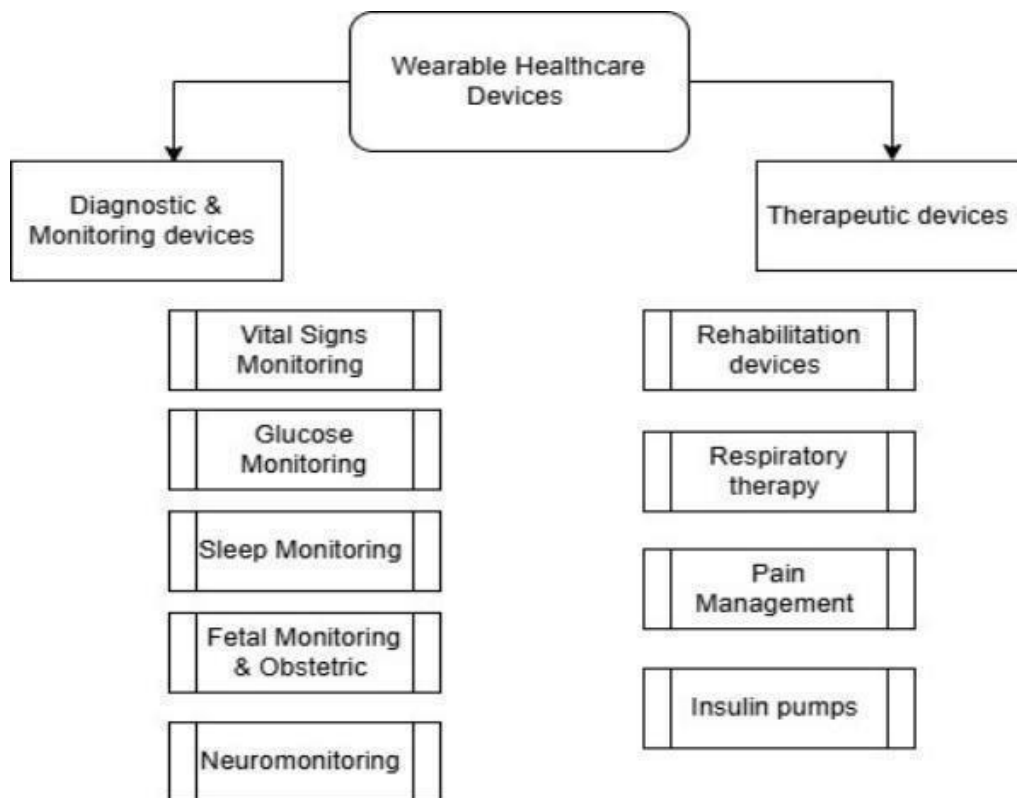


Figure 2.4: Healthcare E- textiles Devices
(Source: Created by the author using draw.io)

Vital sign monitoring devices are typically included in wearable healthcare. E-textile systems were first installed in this area; however they are no longer restricted to it. The usage of ECG sensors in underwear is a common example (Koncar et al., 2020). Hospitals can utilize undergarments with integrated textile-based flexible sensors to

take real-time measurements of vulnerable patients. If immediate action is needed, this data can be sent to the central database. The medical field also uses fiber optic sensors (FOSs), which are suitable for tracking biological factors (such as heartbeat and breathing monitoring) during magnetic resonance imaging treatments (Ankhili et al., 2019). These healthcare applications collectively illustrate the potential of smart textile as continuous monitoring platforms reinforcing their suitability for maternal health applications that require long term, non – intrusive physiological surveillance.

Wearable e-textile systems have also been used in therapy to replace traditional methods such as neuromodulation devices for trans cutaneous electrical nerve stimulation (TENS) and spinal cord stimulation (SCS) as well as devices for radio frequency ablation and cryoablation; wearable textiles are also used to prepare intrathecal infusion pumps and external infusion pumps; e-textile systems are also developed for the treatment of migraine and facial pain; cancer treatments have also experimented with e-textile systems and neuropathic pain is another example of a shift toward e-textile system preparations.

Additionally lung ventilation treatment and associated cardiac functions are being treated with wearable e-textile devices (Rymarczyk et al., 2019). Photo dynamic therapy uses wearable e-textile systems that emit light and are made using optical fibers (Gaubert et al., 2020). Similarly studies of metabolic disorders are being conducted using chemical sensors incorporated into wearable fabrics. Photo therapy is another application for smart textiles. NeoMedLight created the ground-breaking The BiliCocoon[®] bag and nest system. The nest system which is used for kangaroo care and incubation has a pad that permits wrapping (Grancarić et al., 2018).

2.4.3. Fashion and Entertainment

The fashion industry plays a crucial role in the design, manufacturing and selling of clothes and garments. Moreover the industry encompasses diverse sectors including fabrication of raw materials, manufacture of fashion clothes and garments by designers, commercialization and marketing communication (Elmogahzy, 2019). Goal 9 requires the fashion industry to use digital technologies like IoT, AI, block chain, AR and VR to develop intelligent infrastructure and promote innovation. With their distinct and clever qualities these new technologies have the potential to create sustainable

industrialization (Staudenmayer, 2025).

Innovative clothing, textiles and accessories must be stylish, adaptable, dependable and intelligent in order to achieve this. This is possible because of the availability of energy-efficient communication protocols as well as tiny electronic chips and sensors. At its core fashion is a form of self-expression through attire, shoes, lifestyle, clothing, hairstyles, makeup and body posture in a particular setting, time and location (McLeod, 2002). Thus it was determined that the creation of fashionable clothing and footwear is a component of fashion in addition to clothing. AI can be used to predict fashion trends, select dresses based on environmental factors, predict health outcomes and more. Additionally the integration of block chain and IoT enables efficient real-time tracking and tracing of fashion-related operations which aids in estimating the amount of material generated and consumed as well as the development of a circular economy in the industry (Wang, 2020; Agrawal, 2021). This convergence of fashion and technology is especially relevant for maternity wear where garments must fulfil both aesthetic expectations and functional healthcare requirements.

The seamless and common integration of sensors into textiles and the creation of conductive yarn are currently made possible by the quick union of electronics and textiles. A new era in retail might be brought in by smart fabrics which can communicate with smartphones to process biological data like temperature, respiration, heart rate, stress, movement or even hormone levels (Dejene, 2025). The foundation of modern medicine, from preventive to advanced treatments is earlier more accurate and genuine diagnosis backed by thorough treatment monitoring. Accurate and dependable real-time sensor data can be obtained via smart clothing (Joshi, 2016). A major possibility for the future interface between the physical and digital worlds is smart clothing which is created by incorporating smart wearables into clothes. It can expand or replace smartphones and other portable linked devices (Wang, 2019; Liu, 2017). Embedding such intelligent functionalities into maternity garments offers an opportunity to normalize health monitoring by integrating it seamlessly into everyday clothing rather than external medical devices.

In the entertainment sector smart textiles are transforming performances and enhancing audience interaction. Costumes embedded with interactive technologies enable

performers to engage with their surroundings and spectators in real-time, creating immersive and dynamic experiences. For instance, garments that react to sound tempo or audience responses can visually adapt bringing a new layer of engagement to live shows. Additionally smart textiles contribute to the innovation of wearable musical instruments allowing artists to generate sound through body movements and gestures detected by fabric-integrated sensors (Pantouvaki, 2014).

Despite these innovations the widespread adoption of smart textiles in fashion and entertainment faces several obstacles. Key challenges include durability, ease of maintenance, power supply and user comfort all of which must be improved to enhance practicality and consumer acceptance. Moreover studies indicate that consumer scepticism regarding functionality, safety and accessibility remains a significant hurdle limiting the integration of smart clothing into the mainstream market (Lee, 2020). These challenges highlight the importance of modular system design particularly in maternity applications where comfort, durability and maintenance are critical factors.

2.4.4. Military, Public Sector & Safety Applications: Implications for Maternal Healthcare

The military has been a leading adopter of wearable computing and smart textile technologies utilizing these innovations to enhance communication, battlefield command systems and soldier performance. These systems integrate personal wearables with vehicle-based, static and satellite technologies working in unison to optimize military operations. For instance the U.S. military has been actively developing smart clothing and wearable solutions to improve combat efficiency (Lamberg, 2019). One such initiative is the Future Force Warrior program introduced by the Naval Air Technical Training Center (NATICK); which aimed to deploy advanced bionic warrior suits by 2020. These futuristic suits incorporate intelligent armour, biometric monitoring, integrated weaponry, advanced communication systems and exoskeletal support to enhance soldier capabilities (Shi, 2019).

Similarly, in the United Kingdom, law enforcement agencies have adopted wearable technologies, such as suits equipped with head-mounted cameras and Personal Data Assistants (PDAs). These devices assist in recording and transmitting crucial data

during patrols and suspect interrogations, functioning similarly to in-car video surveillance systems. Additionally wearable safety solutions are increasingly utilized to monitor personnel operating in hazardous or remote environments. These innovations include sensors that detect exposure to harmful chemicals and assess biophysical conditions ensuring enhanced situational awareness and safety for security forces. Although these wearable systems were originally developed for defence and public safety applications their underlying technologies such as physiological sensing, wireless communication and real-time monitoring are equally relevant in healthcare. Similar principles can be adapted for maternity care where continuous monitoring of maternal health parameters through comfortable wearable garments can improve preventive healthcare and support timely medical intervention.

Military wearable technology can be classified based on sensor applications with several key functions improving operational efficiency:

a. Enhancing Targeting Precision

Modern firearms integrated with sensors can track targets, analyze environmental factors like wind speed and weather conditions and compute the optimal bullet trajectory. This enables soldiers to aim accurately without direct line-of-sight allowing them to shoot from behind cover or over obstacles significantly improving combat effectiveness (Belous, 2020).

b. Monitoring Soldiers Physical Monitoring

Miniaturized biosensors embedded in military gear or directly on the soldier's body can continuously track vital parameters such as heart rate, respiration and hydration levels. These real-time health assessments help identify soldiers at risk of fatigue, dehydration or injury. Additionally commanders can receive alerts if a soldier sustains critical injuries allowing for swift medical intervention (Dias, 2018).

The same sensing technologies can be adapted for maternity applications to monitor physiological parameters such as heart rate, stress response and other maternal health indicators. Unlike military environments, maternity wear requires greater emphasis on comfort, flexibility, washability and user acceptance. Therefore, wearable systems intended for pregnant women must prioritize ergonomic garment design along with

reliable physiological monitoring.

c. Enhancing Communication Between Troops & Military Animals

The scope of military wearables has expanded to include monitoring the health and well-being of animals such as horses, mules and dogs which play vital roles in military operations. Sensor technologies can track these animals' physical conditions ensuring their readiness for missions. For example bomb-detection dogs can be trained to trigger specific sensors when detecting explosives instantly alerting both their handlers and command centers (Kuiack, 2022).

d. Providing Comprehensive Battlefield Awareness

Smart textiles integrated with environmental sensors enhance a soldier's situational awareness by relaying crucial battlefield data. These sensors can provide real-time updates on location, terrain conditions, satellite imagery, radar-based intelligence and enemy troop movements. Such information improves strategic decision-making offering soldiers a tactical advantage on the battlefield (Panda, 2016).

As advancements in sensor technology and material science continue, wearable systems developed for defence and public safety demonstrate the reliability of real-time physiological monitoring under demanding conditions. However, direct adoption of these technologies for maternity care is not appropriate because pregnant women have different comfort, safety and usability requirements. Therefore, the principles of physiological sensing, wireless communication and real-time monitoring can be adapted into soft, lightweight and user-centered smart maternity garments that support continuous maternal health monitoring while ensuring comfort, hygiene and ease of use.

These observations from defence and public safety applications provide an important conceptual foundation for the present study which adapts similar wearable sensing principles within a user-centered smart maternity wear system designed specifically for the physiological, ergonomic and healthcare needs of pregnant women.

2.5 Incorporated Features of Maternity Clothing

Maternity clothes are important for the feelings of the mother and the comfort of the unborn baby. Pregnancy is a wonderful time in life and it's important to dress for the

event. Clothes that are cut to accommodate the growing belly that don't cut off circulation and bind are so important. Too tight clothes that constrict are not good for expectant mother and baby. Maternity clothes are good for physical and mental well-being and a show to the world of your proud accomplishment (Day, 2023).

The average women gains 25-35 pounds throughout a pregnancy. A woman typically only gains 2 – 4 pounds during the first trimester and then gains about one pound per week throughout the second and third trimesters. A pregnant woman accumulates most of this weight is from the weight of the baby, the placenta and the uterus. However, a pregnant woman's breasts typically become larger and the rest of her body may get a little bigger due to increased blood supply and stores of fat for delivery and breastfeeding (Alex, 2020).

These significant physiological changes during pregnancy highlight the need for maternity garments that not only accommodate body growth but also support continuous health monitoring without causing discomfort or restriction.

There are some maternity clothing requirements which include garments should be expandable for the expectant mother, excess fabric is the most common approach, adjustable features at the waistline accommodate the enlarging abdomen, stretch panels may be inserted in the abdominal area of maternity- wear bottoms so that stretch panels expand as the abdomen enlarges and they should be long enough and wide enough to avoid uncomfortable binding. This clothing may have zip openings near breasts area for the feeding purpose as the mother needs (Rashid, 2024).

Some suitable raw materials in producing maternity clothing include cotton, viscose with the little percentage of elastane will be very suitable, bio cotton is very preferable, green and eco-friendly for health, polyester should be mixed with high amount of cotton/viscose, light weight knit ; like single jersey, rib (within 200 GSM) will be better and high-tech fabrics such as elastane are the material of choice for maternity wear to be form- fitting while allowing the abdominal area to expand necessary (Othman, 2024) .Such material characteristics are also essential for smart maternity wear as sensor integrated textiles must remain breathable, stretchable and skin – friendly to ensure prolonged daily use.

2.5.1 Designing Features for Clothing

During the Baroque period, women adapted their clothing styles to accommodate pregnancy by opting for loose, flowing dresses. One such example was the *Adrienne*, a gown-like garment characterized by voluminous folds and a lack of a defined waistline designed to drape gracefully over the growing body. Additionally, garments similar to men's waistcoats were worn, featuring adjustable laced vents at the back, allowing for width regulation as pregnancy progressed. These were typically worn under bed gowns, providing both coverage and comfort. Aprons were also commonly associated with maternity wear likely serving as a practical way to conceal the gaps left by front-closing jackets that no longer fit properly (Lowell, 2024).

By the Georgian and Regency periods, adaptable dresses became increasingly popular designed in such a way that they could accommodate a changing body shape. Many of these styles, although not explicitly labelled as maternity dresses were practical throughout pregnancy and suitable for nursing. Inspired by philosophers and reformers like Rousseau, such styles gained favour among upper-class women (Holmes, 2015).

Modern maternity fashion emphasizes both comfort and proportion during the later stages of pregnancy, particularly in the final three months when the baby bump is most prominent. Instead of wearing overly baggy clothing expectant mothers are advised to opt for well-fitted trousers that contour the thighs complemented by jackets or sweaters with snug sleeves to maintain a balanced silhouette (Koch, 2011).

Avoiding unnecessary bulk is key therefore; styles like bell sleeves, oversized tops and heavy knitwear are best left out. Instead, opt for garments with hidden jersey panels, adjustable button-side panels, extendable waistbands or deep stretch waistbands that provide flexibility while ensuring a flattering silhouette. Below-the-bump and low-rise jeans or trousers are preferable to minimize discomfort caused by waistbands pressing against the abdomen. Additionally, boot-cut or wide-leg pants help create visual balance, whereas narrow-leg jeans can make the body appear disproportionate (Kerr, 2011).

Deep V-neck or wrap-style tops and dresses create a more flattering silhouette for women with a larger bust. Likewise knee-length cardigans in darker shades made from

fine knit fabrics help elongate the body while avoiding extra bulk. These modern styling strategies ensure that maternity wear is not only functional but also fashion-forward enabling expectant mothers to maintain their personal style while prioritizing comfort (Fisher, 2021).

Heavy embroidery should be avoided by expecting mothers as it will make them appear larger and wider. Stick to elegant details that are both comfortable and stylish such as lace, floral designs, sequins and pin tucks. She will appear thinner if she dresses in dark neutral hues. Modern maternity clothing color schemes feature all shades of pink, blue, and green which can be coordinated with stripes and prints or worn alone (Gomes, 2019).

According to the author (Hoppus, 2007) maternity clothing should be made of stretch materials and allow for proper growth in all areas. Wraps are fantastic for expectant mothers since they give excellent bump coverage and accentuate the cleavage. In the first trimester, ties assist hold in excess fabric on dresses and shirts while in the final trimester, they loosen.

He also mentioned that bodily changes are crucial while creating pregnancy clothing. Clothing with extensible elements and no restrictions is necessary for changing silhouettes. Support for the abdomen is advised and breast support must be increased. Affordable stylish maternity clothing can be created by highlighting the upper body and blending in with the natural hues of pregnancy which camouflage the center curves. Regardless of the technique room must be made for hemline and waist adjustments and expansion.

Pregnancy curves are better complemented by some lines and silhouettes than by others. Made of materials with enough substance to maintain their shape, the bell, bubble, cone (also known as a pyramid or tent) and trapeze are all great dress and coat styles for pregnancy wear. Instead of hiding natural lines some styles alter them (Hollander, 1993).

Considering that maternity gowns are worn for a very little period of time, they should be both elegant and adaptable. Pregnant ladies can dress up or down to fit their individual style and various occasions. Anything that serves to break up or obscure the

precise form of the figure is good, including fairly straight dresses that can be worn over loose, straight coats or jackets. Waists any excessive fullness that would spread out across the stomach and bring attention to it should be avoided and if possible one should always be high (Weigle, 2022).

One or two-piece clothing can be used to conceal the center contour because they offer this function. The most common maternity dress is a jacket over a slim skirt most likely because it creates the appearance of slimness below a wide top. Nevertheless, appealing one-piece clothing can be successfully camouflaged by deftly adjusting pleats, folds, and gathers to produce the required fullness. One example is the Blouson style. Straight, adjustable skirts can be worn with over blouses that are gathered and turned at low hip level or at three-quarter tunic level. The empress Josephine created the empire style during one of her pregnancies, which can also have enough fullness in the front to conceal the growing belly. Permanent accordion pleats can even be used to modify the tubular silhouette, as shown in the chemise (Lu, 2017).

Vertical lines in garments that direct the eye upward can be utilized to draw attention to the upper body portion. A lovely neck and shoulder are emphasized by unique necklines and eye-catching necklaces. In addition to bright hats and eye-catching earrings, jabots, colourful scarves and contrasting collars draw attention to the face. Though it should be noted that this upward emphasis can be overdone and that using too many of these items at once can create a cluttered impression, imitation flowers, ribbons and intriguing costume pins at the shoulder throat level also draw attention upward (Talbot, 2013).

They added that if the expectant mother is tall she can wear a two-piece costume with contrasting colors and textures but if she is short or average in height she should wear a top and skirt that match. Remember that color has an impact on figure size. Dark colors tend to make one appear smaller, whereas light hues tend to make one appear larger. Conversely, dark hues tend to highlight the silhouettes while light hues tend to hide them. The wearer's size is similarly impacted by a colors brightness or dullness (Sullivan, 2017).

The author states that when selecting appropriate textiles for pregnancy clothing,

texture, weight and design should be taken into account. Shiny materials are challenging to wear because they reflect light which enlarges the form and reveals its irregular shape (Hussien, 2024).

Conversely, light is absorbed by drab materials which reduces size and hides the figure. Some very lovely concealing clothing has been made from this material despite the fact that bulky or stiff fabrics are typically seen as unattractive for maternity wear because they also make the wearer appear larger. Transparent fabrics can be utilized well despite their contour-revealing qualities if many thicknesses are treated as one or if they are carefully created over an opaque foundation (Bari, 2019).

Maternity clothing frequently uses textiles with patterns. Checks, stripes, plaids and prints give the costume interest and help hide the silhouette. The size of the pattern should match the wearer's size for optimal effect. Fabrics for pregnancy clothing should ideally have enough body to maintain their shape without being overly heavy or flimsy or too stiff or soft. They should ideally have a texture that is uninteresting but still has enough design or intrigue to break up the monotony. In this category, textiles such as seersucker, bengaline, faille, chambray, corduroy, flannel, gingham, broad cloth, poplin and lace are suitable. Similarly effective fabrics can be used to achieve the same results. It is recommended to incorporate features like Velcro and a front zipper opening into the design to allow lactating mothers to breastfeed with ease and comfort (Semler, 2023).

The materials used for nursing should be easily cleaned require little to no ironing and save a lot of time and effort. Spots and smudges are often concealed by plaids, tweeds and patterns (Stewart, 2015).

According to the author (Murray, 2013) nursing moms clothes should be distinctive and tailored to their specific needs including openings that make nursing easier. Designed a particular kameez for nursing women and it was discovered that the kameez with the horizontal opening was the most pleasant followed by the kameez with the vertical opening. The runner's upward opening in case the vertical placket was more comfortable than the downward one. The vast majority of responders stated that all of the designed kameez were necessary for commercial production since they were stylish, practical and suitable for casual wear (Srivastava, 2011). These historical and

contemporary design strategies provide a valuable framework for the development of smart maternity garments where traditional adaptability features can be combined with modern sensor integration through modular or detachable systems.

2.5.2 Methods of Garment Construction

In the 18th century, a tailor's success relied on his expertise in measuring, cutting, sewing and pressing garments to complement a gentleman's physique by enhancing his appearance and concealing any imperfections. To record measurements the tailor used an unmarked strip of paper, marking notches to represent each required dimension for a suit. The accuracy and style of the final garment depended on the tailor's ability to skillfully translate these notches onto the fabric. The strip also contained the customer's initials and served as a reference for future garments, though only the tailor could interpret the recorded marks. After noting the measurements, the tailor selected a pre-existing paper pattern that closely matched the customer's size. He then traced the pattern onto the fabric, adjusting the chalk outlines based on the notched measurements while considering the customer's unique posture and build. The notches themselves were not linked to any numerical values (Apawudza, 2021).

The Industrial Revolution, which began in England and later spread to the United States lasted for a century and introduced new manufacturing techniques for clothing. Handcrafting was gradually replaced by machine production, and the adoption of dark, uniform-like attire among men contributed to the rise of mass-produced, ready-made garments. Despite these advancements, tailors in the 19th century continued using traditional tools such as scissors, needles, and goose irons. By 1820, the inch tape measure had been introduced, marking a significant shift in measurement practices. Previously, tailors relied on their personal methods of taking measurements but this evolved into standardized guidelines that ensured consistency. The introduction of the tape measure reduced dependence on the tailor's individual skill and judgment, minimizing errors and variations in garment sizing (Mohajan, 2019).

18th-century tailor tropes and stated that the expert tailor/miter used chalk to design each outfit on lining cloth. The outside fashion cloth was then patterned after the lining parts were attached to the body. This indicates that in order to create a sense of the body the tailor used both linear and body form techniques (Becker, 2017).

A variety of devices ranging from a square with an inch-measurement attachment to upright devices that measured critical body points on a customer who was positioned next to the device were developed in the 19th century to aid in the measuring process and acquire the numerous measurements of the human body. These systems are known as proportional and direct measure. Because the standardized method assumed that human bodies had predetermined proportions, it eliminated the necessity for many manual measurements. The likelihood of human measuring inaccuracy was reduced by the proportional system. Most significantly, it helped create proportionate sizing for ready-made garment production.

In the middle of the 19th century, pattern drawing methods were also created. These procedures aided in the creation of uniform designs for clothing items like breeches which were the first to be offered for sale as ready-made. Two pattern-making trends emerged that had an impact on fit: wrinkle-free, fitted clothing generated from measurements and requiring precise procedures and an awareness of anatomy or less fitting clothing cut from standardized patterns (Smith, 2022). there are three fundamental ways to make a garment. They are pattern-making, drawing and draping. An engineering technique based on a set of body dimensions is called drafting. The rough or incorrect side of brown paper is used for drafting. Drafting are often created using the specific body dimensions of the customer rather than the conventional specifications. Bodice, sleeve, skirt and trouser blocks are examples of basic drafting. To create a garment, these drafting are modified to fit a certain pattern. Seam allowances are not included in drafting. Every drawing must have grain line. This approach is two-dimensional. Only after a garment has been stitched can the design's appearance be seen (Xanthaki, 2014).

Making patterns is both a science and an art. It is a two-dimensional approach just like drafting. Every paper pattern features intricate annotations and seam allowances.

For mass manufacturing, they are often manufactured using standard measurements. They must thus be extremely precise. Similar to fundamental drafting, flat patterns (basic slopers) can be modified for a specific design.

She added that a commercial basic pattern that has already been modified to suit the person is the starting point for flat pattern production. The process of creating a pattern

for a selected design involves modifying this modified basic pattern. The task is completed on a level surface using paper. Because the flat pattern already has a defined shape and the right degree of ease, the novice doesn't have to worry about these aspects making it an excellent approach for beginners. But, in order for the pupil to understand the effect of the design being formed, it is frequently beneficial if the pattern is made out of muslin or another cheap cloth (Dong, 2009).

Draping is an artistic technique where a person fits fabric to a dress form's contours to create her own design. With this approach, it's enjoyable to watch how the pattern evolves and how the garment will appear. Draping is done using muslin. After blocking, ironing and arranging the lengthwise and width wise yarns perpendicular to each other, the muslin is placed over the dress form or dummy. Standard dimensions or a specific person's size might be used for the dress form. The pattern can be seen when draping, and any required adjustments may be performed because it is a three-dimensional approach. It is a costly method of clothing fabrication that is not widely used in India. For further usage in the flat pattern, rudimentary slopers are occasionally constructed from draped muslins (McConnell, 2021).

Author highlighted that the results of the construction of custom-designed special occasion dresses for four women with spin bifida or ontogenesis imperfect, aged 16 to 20 indicate that the most effective way to achieve a good fit and create the appearance of body symmetry and proportion is to drape the muslin sample garments directly on the body. The fitting techniques used in this project may also be applied to other populations to achieve a good fit (Hayat, 2024). The majority of contemporary sectors, computer-aided design (CAD) and production have grown in importance. The use of the CAD system in the textile and clothing sector has resulted in a significant degree of automation. A three-dimensional non-contact body measuring system has been created and is now a common CAD input device. This was accomplished by simulating the typical clothing design process in which patterns are created based on a predetermined ideal garment model while taking the customer's anthropometric measurement results into account (Ikubanni, 2022).

Using suitable mathematical techniques like data segmentation and Fourier series expansion a compact torso body model was extracted from massive three-dimensional

point cloud data in this study. The surface geometry of a desired garment was then captured by stereo vision technique and converted into a triangular mesh structure after which an equalized geometry between those two models was obtained using the surface warping algorithm. The garment model was then refined using a multi-resolution mesh generation algorithm creating optimized garment patterns for each individual's body shape (Kim, 2003).

The mechanical characteristics of the fabric and the actual surface geometry of the body model are not taken into account at any point throughout the conventional procedure.

The present two-dimensional system will benefit from the addition of a three-dimensional CAD module which will shorten the development time and improve quality control. It may be used to satisfy the increasing demands of demand-activated production and mass customization in the clothing business, which is popular in the majority of contemporary manufacturing sectors (Reffat, 2007).

Human body scanner for mass customization of clothing as part of their research on body scanning and modelling for custom fit garments¹ has been created. The scanner, which is based on multi-line triangulation and computational geometry techniques, can rapidly obtain 3D images of a person's front and back sides automatically extract crucial dimensions for clothing design and create a customized body scanning system and application software that would allow clothing manufacturers to offer custom design services to customers looking for custom-fit clothing (Bindahman, 2012).

The most essential components of contemporary industry is three-dimensional computer-aided design. Certain clothing like form-fitting underwear or protective clothing requires more usefulness than style. A computer-aided design (CAD) system may be an effective tool for creating and producing these highly practical, mass-customized clothes (Yuan, 2018).

By modeling and flattening the 3D clothing models; a simple pattern generating method has been created that produces flat garment patterns. A garment is separated into two zones for this purpose: the fit zone and the fashion zone. By digitizing the body scan

data the fit zone was modelled, allowing for parametric changes to its size and form. In order to allow users to build different garments naturally, the fashion zone was developed by parameterizing the aesthetic look of garment silhouettes. Additionally, a database management system for garment form templates has been created to enable users to quickly construct a variety of clothing items, from simple to elegant. At last, a method for projecting flat patterns has been created to create flat designs while taking into account the garment's physical characteristics and production feasibility. To keep up with the next trends in manufacturing, such mass customization and quick-response systems automatic pattern generating systems will be an essential tool (Mourtzis, 2014).

Author also believed that, thanks to computers creating patterns has become a simple task in modern times. Various software programs are now on the market to satisfy the demands of manufacturers. Among the several software programs utilized are OptiTex, Tukatech, Lectra and Gerber. The Pattern Master's work is now easier thanks to these programs. They have reduced the time and expense of the pattern-making process (Ranjan, 2020).

Measurement input and pattern drafting are made possible by pattern creation software. By explicitly drafting patterns to suit measurements, these software programs reduce the amount of fitting trial and error that occurs in the sewing room. With these programs, creating a pattern from a 3D shape just takes a few steps. A 3D body scanner is used to gather a person's measurements. A virtual three-dimensional model of the person's body is produced using the measurements. The user can specify a clothing surface in relation to the 3D body model using the 3D to 2D program. The application automatically unwraps the garment after the surface has been specified and generates a 2D flat pattern in dxf format (Lu et al., 2017). Such advanced pattern – making and body – scanning techniques are particularly beneficial in smart maternity wear design where precision fitting is essential for effective sensor placement and reliable physiological data collection.

2.6 Production of Smart Maternity Wear with Technology

The process of creating smart clothing by wearable technology has to consider so many factors that it has to be collaborative between end-users, textile specialists, electronics, fashion and clothing designers and manufacturers. The collaboration between these

sectors is sometimes difficult, with differences in language, working practices, development time frames and marketing strategies. The complexity and broadness of knowledge required makes smart textile research interesting but also challenging. From a slow start, this new industry sector now seems to be growing at a good pace, with many new products being released and new companies getting involved in the development of smart clothes and wearable technology (McCann, 2022). In the context of maternity wear, this collaboration becomes even more critical as technological integration must respect garment comfort, safety and user acceptance while allowing flexibility through detachable or modular electronic components.

The initial generation of these systems, emerging in the 1980s, involved the simple attachment of electronic devices to garments or their placement in pockets. By the 2000s, the second generation introduced electrical connectivity by incorporating conductive yarns directly into the fabric structure. For nearly two decades, conductive fabrics have been utilized for various purposes including dissipating static energy, shielding against electromagnetic fields and offering benefits like thermal regulation, anti-allergic and antibacterial properties. However, it was soon recognized that fabrics made with conductive fibers such as carbon, gold, stainless steel, silver or copper had significant potential for embedding ‘soft’ networks into textiles, transforming them into ‘smart’ fabrics. Unlike conventional technical textiles, smart textiles are not passive; they can detect and react to external stimuli, including touch, temperature and heartbeat (Hughes, 2018). The present research aligns with this evolutionary trajectory by adopting a modular integration approach rather than fully embedded systems, ensuring ease of maintenance, adaptability and prolonged usability.

Without sacrificing the fabric’s natural qualities, intelligent textiles may include flexible display panels, mobile phones, global positioning systems (GPS) and antennas. The conductive yarns have the appearance, texture, and functionality of conventional cloth. In an electrical circuit, the fabric itself frequently serves as a switch to carry out a task for an external electronic device. The conductive components in electronic textiles can serve as a transducer, supply input and output signals or supply power. Mechanical, thermal, chemical, magnetic and other environmental stimuli are sensed and responded to by them.

The integration of electronic functionality in clothing can vary depending on the application with some designs incorporating technology directly into the fabric, while others take a modular approach, allowing garments to serve as a platform for multiple interchangeable components. Wearable computing has evolved alongside these developments, focusing primarily on creating highly portable computing devices, yet it has played a significant role in shaping smart clothing and wearable technology. Before the 2000s, the widespread adoption of smart apparel was hindered by technological limitations often resulting in products that failed to meet user needs and expectations. However as the technology continues to advance newer products are beginning to align with consumer demands. Although the industry remains in its early stages and has significant room for growth, its future promises exciting innovations and advancements (Diamandis, 2020).

With a wide range of electro-conductive materials, including mono filament metal wires and conductive yarns, conductive circuits can be directly incorporated into textiles through techniques like weaving and knitting, resulting in electrically conductive fabrics. However, integrating conductive yarns into fabric structures is a complex process and rarely uniform, as it requires balancing functionality with comfort. The resulting fabric must remain soft and wearable rather than stiff or rigid. Woven fabrics in particular can form intricate networks that function as sophisticated electrical circuits combining both conductive and non-conductive elements. Additionally, they can be designed with multiple layers and spaces to accommodate electronic components (Raji, 2017).

Typical system architecture of a wearable electronic or photonic product consists of several fundamental components including interface, communication, data management, energy management and integrated circuits (Tao, 2005).

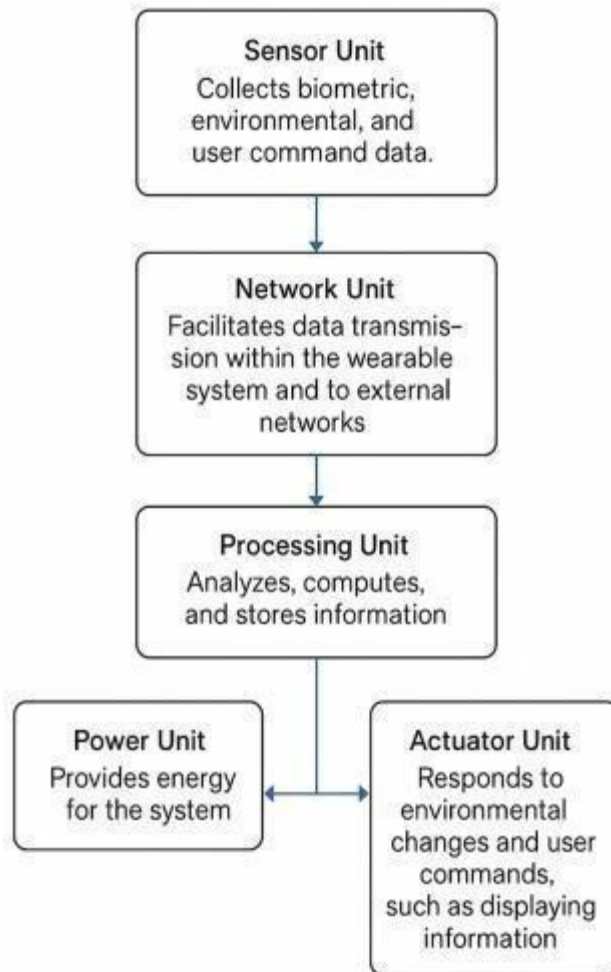


Figure 2.5: Components of Wearable System
(Source: Created by the author using draw.io)

Main Components of a Wearable System:

- **Sensor Unit:** Collects biometric, environmental and user command data.
- **Network Unit:** Facilitates data transmission within the wearable system and to external networks.
- **Processing Unit:** Analyses, computes and stores information.
- **Power Unit:** Provides energy for the system.
- **Actuator Unit:** Responds to environmental changes and user commands, such as displaying information.

2.6.1 Sensors (Wearable Technology)

A sensor is a device that converts information from a specific domain into an electronic signal. In wearable technology, sensors collect physical, mental, chemical and

biological data from the human body. The evolution of sensors is driven by micro-electro-mechanical systems (MEMS) and nanotechnology which have enabled the development of compact and cost-effective sensing solutions for electrical, mechanical, chemical and optical parameters (Aderibigbe, 2023).

Sensors are electronic components that detect changes in their environment and relay this data to other electronic devices. They are integrated into various applications including medical, industrial and everyday consumer products. Sensors function as the eyes, ears and sense of touch of an electronic circuit converting physical stimuli into electrical signals. This transformation process is referred to as transduction. To ensure comfort and functionality, researchers emphasize that garment-integrated sensors should not interfere with the wearer's daily activities (Salter, 2022).

Types of Sensors

A sensor system typically consists of sensors, measuring and processing circuits and an output mechanism. Sensors can be classified into two categories:

1. **Contact Sensors:** These require direct physical contact with the subject or environment. They are commonly used in healthcare applications including electrocardiography (ECG), electromyography (EMG) and electroencephalography (EEG). Contact sensors must be designed for biocompatibility and comfort, as extended contact may cause skin irritation or sensor degradation (Zarei, 2023).
2. **Non-Contact Sensors:** These function without direct contact with the subject, commonly used in ambient and behavioral monitoring. Examples include passive infrared (PIR) sensors for motion tracking and ambient environmental sensing (Lowe, 2014).

Integration of Electronic Components

To interconnect electronic devices within a fabric, conductive threads can be woven or knitted into textiles. Various techniques are used to integrate electronics into smart textiles:

1. **Soldering:** Utilizes metal alloys (e.g., lead, tin, silver) to create electrical contacts within the fabric. However, soldering may not be suitable for wearable applications

due to its toxicity and impact on fabric flexibility.

2. **Bonding:** Employs conductive adhesives to attach components to textile substrates, offering non-toxic, flexible, and durable integration.
3. **Stapling:** Uses mechanical pressure to attach components to conductive circuits within textiles, allowing movement within the circuit but increasing wear over time.
4. **Joining:** Directly connects electronic components to conductive textile threads using stitching or weaving techniques (Agcayazi, 2018).

2.6.2. Communication Technologies

Communication technologies and communication applications have been rapidly changing and developing, especially in recent years. The medium of communication by which the information is transmitted through the air without cables and by using electromagnetic waves like infrared, radio frequencies and satellite is called wireless communication technology. In the area of wireless technologies and applications, these have found their way into many areas that previously have been considered as science fiction. The use of communications in textile and fashion is a relatively new discipline and is an existing development in its rapid evolution and the pervasive nature of its incorporation into everyday life. A development of technologies in communications is to combine textile technologies and fashion with wireless communication, to provide piconets-micro communications networks around the human body (Islam, 2019). There are three areas to analysis in deciding the communication technology for health care monitoring:

1. **Personal Communications Network (PCN)** - to receive the information provided by the various sensors in the smart clothing, and to store and prepare this to be transferred for analysis.
2. **Wide Area Network (WAN)** - how to take the information stored by the PCN and transfer it to another physical location; this could be in another part of the country or anywhere in the world.
3. **Information Systems (IS)** - how to analyze the data received, to monitor the subjects under observation and provide reporting information to end users

The most commonly used communication technologies in Wearable electronics are Bluetooth Low Energy (BLE), Wireless LAN (Wi-Fi) and Zigbee.

2.6.2.1. Bluetooth

Bluetooth wireless technology is a short range communication medium to connect fixed devices portably and maintains high levels of security. The key features of Bluetooth technology are robustness, low power consumption and low cost and most commonly in wireless communications market. During pairing with devices, it identifies and connects to any two devices easily. It also prevents interference from other non-paired external devices in the area. It preserves battery life by using only required power supply (Nikoukar, 2018).

Bluetooth technology has achieved global acceptance because Bluetooth enabled devices in proximity use radio waves to communicate between devices that have a range of 15-50 feet. Bluetooth enabled electronic devices can communicate wirelessly by connecting through short-range micro networks known as piconets. Each device can simultaneously communicate with up to a maximum of seven other devices within a single piconet. Bluetooth enabled devices can enter and leave radio proximity by dynamically and automatically established piconets. This enables users to enjoy a variety of solutions such as a hands-free headset for voice calls and synchronization with Personal Digital Assistant (PDA), Apple iPhone, laptop and mobile phone applications (Hussain, 2025).

2.6.2.2. Wi-Fi

Wi-Fi is a form of low-power wireless communication used by many electronic devices such as laptops, systems, smart phones. A wireless router serves as the communication hub in its setup and these networks are extremely limited in range due to low power of transmissions. Wi-Fi is a common home networking application that provides portability without need of any cables. Wi-Fi networks need to be secured with passwords for security purposes in order not to be accessed by others (Miteku, 2015).

Advantages

- Ease of integration and convenience is achieved by allowing users to access network resources from nearly any convenient location.
- Can access internet even outside of the normal working environment in case of

emergence of public wireless networks is needed.

- Expandability of network is possible with the existing equipment when there is sudden increase in number of clients.

Disadvantages

- Radio Frequency transmission and wireless networking signals are affected by a wide variety of interference that are beyond the control of the network administrator.
- Wireless networks may be utilized by some of the various other encryption technologies leads to security problems.
- When need of increase in range for a larger structure, additional access points need to be purchased.
- It is a complex process to set up during installation of an infrastructure -based wireless network.

2.6.2.3. Zigbee

Zigbee is a wireless communication designed to satisfy the unique needs of low cost wireless sensor, low power consumption and control networks. It can be used almost anywhere as it is easy to implement and requires little power to operate. Zigbee has been developed for receiving data from simple structure like the data from the sensors. For example in previous inventions, a wearable e-nose prototype which looks like compact armband was developed for monitoring the auxiliary odor released from the human body with the use of Zigbee wireless technology. Zigbee is used in commercial applications like sensing and monitoring applications. Zigbee gives flexibility to do more with the reliable wireless performance and extremely long device battery life (Craig, 2004).

2.6.3. Portable Power Sources

Electronic devices have become a necessary part of everybody in their modern life to carry something like watches, mobile phones, music players, cameras and laptop computers. Special electronic devices essential and important for health care applications such as cardiac pacemakers, hearing-aids and temperature or pulse rate monitors are in trend. All of these devices require a power supply to function its performance effectively and for that batteries have been employed in almost all of

them. The battery was invented by Alessandro Volta in 1800 is a well-established electrical power source (Volta, 2016).

Power consumption required by wearable electronics covers a wide range of power levels from a few micro-watts to tens of Watts. Currently, conventional batteries cannot be fully integrated into textile structures because of their rigidity. However, they may be embedded into clothing without causing significant inconvenience to the wearers if the power level required is low. For example, button batteries have been considered apart from providing power as buttons or decorations for smart jackets. The most commonly used batteries on today's markets are lead acid, alkaline, nickel-cadmium (NiCd), nickel-metal-hydride (NiMH), lithium ion (Li-ion) and lithium polymer (Li-polymer). Fuel cells have a substantially large theoretical energy density and are seen as a possible technology to meet the power requirement of wearable computing at the high performance end. A fuel cell is an electrochemical device that converts hydrogen and oxygen into water and in the process, produces electricity and heat. However, in terms of high energy density, small dimension and flexibility, significant effort toward research is still needed to realize its full potential as a solution to the power problems of wearable computing. High performance computing requires are natively large power supply usually in the range of 50 W (Sazali, 2020).

To develop a sustained power supply which covers the life time of smart textiles is an extremely difficult challenge. A medium-term solution is to combine power harvesting with energy storage. Power harvesting devices continuously convert various forms of ambient energy into electricity while the storage devices accumulate (Perera, 2022). The challenge is to efficiently convert the limited energy available around the human body into electrical power. The development of miniature thermoelectric devices in recent years opens up a possibility for wearable applications. A more adventurous attempt is to develop flexible thermoelectric thin films or polymers that can be woven into fabrics (Ramasubramanian, 2022).

The Lithium Ion battery provides the highest energy density with a large charge cycle making it the fastest growing and most promising battery for numerous portable applications. Lithium Ion Polymer is a potentially lower cost version of the Li-ion and it can be potentially flexible (Xu, 2023).

2.6.4. Formation of the Module

Miniaturization of electronic components has made it possible to build small portable and handheld computer devices that can be carried almost anywhere and at anytime. The smart textile requires a central processing unit that will carry out data from the different sensors and decide action on the basis of the results. The processing unit consists of hardware and software where the software causes unique dynamic behavior in real time. The traditional package of computing material is a computer that allows data processing as well as communication. The processing unit is a complex structure of electronic circuitry that executes stored program instructions and the structure includes integrated circuits, power supply, secondary storages and communications technologies (Wolf, 2012).

Micro-controller contains all essential elements of a microcomputer on a single chip for building simple products of wearable electronics with any design. It is applied in the fields of real time applications, industrial control and instrumentation and intelligent computer peripherals like smart textiles. The advantages of micro-controller are

- It has many bit handling instructions hence controlling is more effective.
- Time taken to complete a control function using micro controller is less.
- Micro-controller IC chip itself contains Memory (RAM, ROM, as EPROM) Parallel and duplex serial ports to interrupt controller and D/A converters.
- It can function as a computer with the addition of no external digital parts.
- The pins of micro-controller are programmable that is capable of having several different functions depends on the wishes of the programmer high speed of operation and even it can handle Boolean functions.
- Process control equipment using micro controllers are cheaper, occupy less space and contain more number of internal registers.
- It can be used in motor, robotics, in missile guidance and control, in medical instrumentation, oscilloscopes, telecommunications, smart textiles, wearable electronics, automobiles, driving an LCD (liquid crystal display), frequency and temperature measurement, period measurement and pulse width measurement.

Recent developments in wearable healthcare technology indicate a growing shift

toward modular and detachable system architectures particularly for garment-based monitoring solutions. Review studies on wearable health systems emphasize that modular configurations allow sensing, power and communication components to be assembled as independent units, improving flexibility, maintenance and long-term usability (Phuyal, Sudip, et al., 2024). Such systems are especially relevant in textile-based wearables where repeated use and laundering necessitate separation between electronic components and fabric structures.

Literature further highlights that detachable wearable modules support user-centric healthcare monitoring by allowing selective attachment of sensors based on need, activity or comfort preferences. This approach has been associated with improved hygiene management, extended device lifespan and greater user acceptance in home-based and non-clinical health monitoring environments (Zahab, M. (2024). As a result, modular system formation is increasingly recognized as a practical and sustainable strategy in the development of wearable healthcare technologies.

2.6.5 Selection of Operating Systems for Wearable Devices

In recent years, the advancement of mobile and wearable technologies has significantly accelerated particularly in the collection of human vital signs and activity data. As a result the wearable technology market now hosts a wide variety of operating systems (OS) each offering different capabilities and limitations.

One of the major challenges faced by developers is the difficulty in selecting the most appropriate operating system for their wearable device. This is primarily due to the incompatibility between systems & applications developed for one OS are generally not compatible with another. Since the operating system plays a crucial role in determining the functionality, performance and usability of wearable devices, a strategic approach is necessary for OS selection (Zikria, 2018).

Key Objectives for Selecting Wearable Operating Systems:

- The design of the operating system should be more convenient for users to use wearable devices.
- The operating system should be managed more effectively and take advantage of

resources like hardware, software and data of wearable devices.

- The operating system should permit new system functions to be developed, tested and included scalability
- The operating system should support integrated and collaborative network work of different manufacturers and devices so that it can achieve the portability and interoperability of applications.

Android is expected to build a uniform and standard operating system platform, accelerating to the development of wearable devices.

From the comprehensive review of literature, it is evident that while significant advancements have made in smart textiles and wearable healthcare technologies there exists a clear research gap in the design and development of smart maternity wear that seamlessly integrates health monitoring capabilities into everyday maternity garments. Limited studies address user – centric design, adaptability across pregnancy stages and modular integration of wearable sensors. This study seeks to bridge this gap by designing and developing smart maternity wear that monitors and communicates the health condition of the wearer through a functional, comfortable and modular garment based solution (Krisjanous, 2022).

CHAPTER-3

RESEARCH METHODOLOGY

The present study entitled Design & Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer¹ was conducted to understand the needs & problem areas of pregnant women in second & third trimester; to design the maternity outfits addressing needs with embedded technology and assess the performance of maternity outfits on comfort, function & durability grounds. The methodology adopted to carry out the present study has been categorized under the following sub heads. The demographic information, clothing problems, preferences for functional and designing features etc. were obtained by a survey, while the last one includes the creation, design, testing, evaluation and acceptability assessment of pregnancy and nursing clothing patterns. The present study follows a mixed- method research approach integrating qualitative user need assessment with quantitative evaluation and experimental prototype development. This approach enabled a comprehensive understanding of pregnant women's clothing needs and the functional performance of smart maternity wear. The detailed methodology adopted to carry out the present study has been categorized and explained under the following sub heads.

3.1 Research Method

3.2 Conceptual Framework of the Study

Phase I: Need Assessment and Tool Development

3.3 Understanding the Needs and Problem Areas

3.4 Development of Research Tool

3.4.1 Selection of Tool and Technique

3.4.2 Construction of the Tool

3.4.3 Validation and Finalization of the Tool

3.5 Sampling Procedure

3.5.1 Locale of the Study

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3.7 Data Analysis Techniques (Need Assessment)

Phase II: Design & Development of Maternity Garments

3.8 Design Development Based on Need Assessment

3.9 Preparation and Evaluation of Design Sketches

3.10 Prototype Development and Evaluation

3.10.1 Standard Measurement Chart

3.10.2 Trial Construction Using Muslin Fabric

3.10.3 Integration of IoT in Smart Vests and Gloves

3.10.4 Raw Material Specifications and Selection Criteria

3.11 Final Construction of Selected Maternity Designs

3.12 Costing of Developed Maternity Garments

3.13 Evaluation of Constructed Garments

3.13.1 Wear Trial-Based Assessment

3.13.2 Acceptability and Functional Performance

3.14 Catalogue Development for Visual Documentation

3.15 Final Data Processing and Statistical Analysis

3.1 Research Method

To accomplish the objectives of the study; a descriptive– experimental mixed research design was adopted. The descriptive phase of the research was conducted to gain in depth insights into the requirements, difficulties and preferences of the expectant mothers especially those in their second and third trimesters. A structured questionnaire was used to collect information on demographic characteristics, current clothing habits, issues experienced with regular maternity garments and preferences related to both functional features and possible technological enhancements in maternity wear. This step helped in identifying the practical limitations of existing clothing options and recognizing the specific expectations related to comfort, appearance and cultural compatibility and garment functionality.

The experimental phase focused on designing, developing and accessing the smart maternity garments. This stage involved various steps such as idea generation, pattern drafting, fabric selection, construction and the integration of health-monitoring components (e.g., ECG, GSR, temperature and pulse rate sensors). Garments were

produced in two stages initially for refining fit and functionality and subsequently for evaluating durability and system integration. The combination of descriptive and experimental methods ensured that the developed garments were grounded in real user needs while being technically validated through systematic prototype development and testing.

3.2 Conceptual Framework of the Study

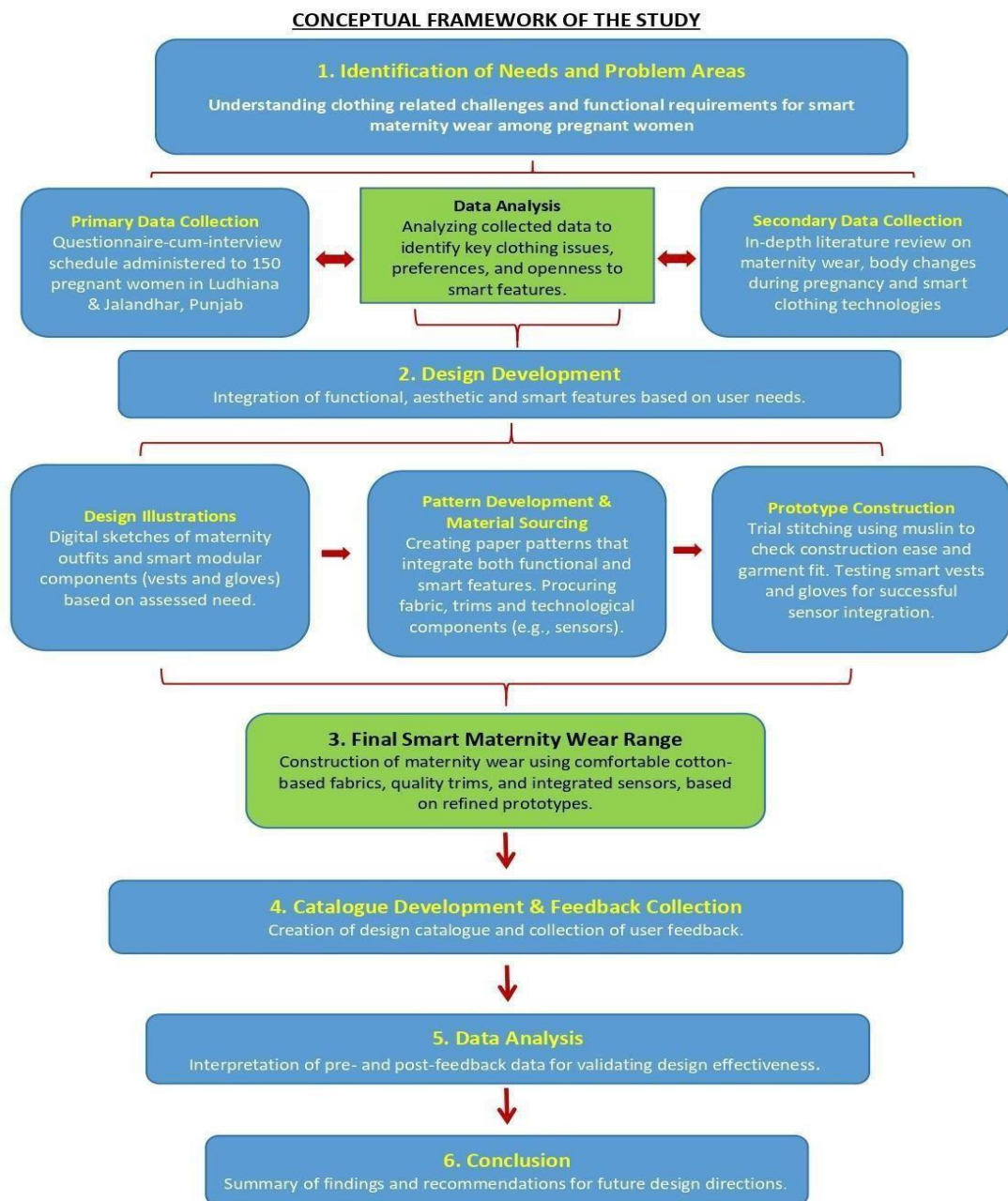


Figure 3.1: Conceptual Framework of the Study

The conceptual framework illustrates the sequential flow of the study beginning with

user need assessment followed by design development, prototype construction, integration of smart technologies and multi stage evaluation. This framework establishes a clear linkage between user requirements, design decisions, technological integration and performance evaluation of smart maternity wear.

Phase- I Need Assessment & Tool Development

3.3 Understanding the Needs & Problem Areas

During the later stages of pregnancy, particularly the second and third trimesters women face considerable physical and emotional shifts that affect their clothing choices making comfort, adaptability and practicality essential. As their bodies change there is a growing need for maternity wear that accommodates these transformations while ensuring ease and support in everyday activities.

3.4 Development of Research Tool

3.4.1 Selection of Tool & Technique

To collect relevant and in-depth information about the clothing practices of pregnant women, their problems with existing clothing and preferences for features in smart maternity wear, a structured questionnaire-cum-interview schedule was developed and used as the principal data collection tool. Keeping in mind the varied educational backgrounds and literacy levels of the respondents, this combined approach facilitated both the accurate recording of responses and clarification of doubts where necessary, ensuring reliable and contextually suitable data.

3.4.2 Construction of Tool

The questionnaire was carefully framed to gather detailed inputs from the participants and comprised of 23 questions, divided into two major parts.

- Part 1 focused on demographic and socio-economic information, including name, age, educational qualification, occupation, family type, annual household income and contact details.
- Part 2 addressed the physiological and emotional changes experience by expectant women during pregnancy, preferences for maternity & postnatal clothing, awareness regarding smart garments, purchasing behaviour and desired

functional features in maternity apparel.

The questionnaire-cum-interview schedule was organized into the following three thematic sections:

Section I: Demographic and Personal Information

This section collected background data to understand the socio-economic context of the participants. It covered questions related to:

1. Age group
2. Educational qualification
3. Occupation (working/non-working)
4. Family type and size
5. Number of earning members
6. Annual household income
7. Stage of pregnancy (for expectant mothers)
8. Frequency of nursing (for lactating mothers)

Section II: Existing Clothing Practices and Challenges

This section explored the current clothing practices of participants, focusing on:

1. Maternity clothing styles currently in use
2. Shopping practices (online/offline)
3. Common challenges related to clothing comfort, fit, flexibility, and mobility
4. Physical and emotional discomfort associated with existing clothing options

Section III: Preferences in Garment Attributes and Functional Features

Divided into two sub-sections, this part delved into:

- **Subsection A:** General Garment Preferences such as fabric type, breathability, stretchability, silhouette preferences, ease of wear, and suitability across trimesters.
- **Subsection B:** Functional and Design Features focusing on:
 - Preferred methods for accommodating body changes (pleats, gathers, panels)
 - Supportive features such as waist ties, drawstrings, elastication
 - Garment opening mechanisms and placement (plackets, fasteners like zippers, hooks, buttons, and Velcro)

- Preferences in sleeve and neck designs
- Interest in integrated wearable technology (such as sensors)

3.4.3 Validation & Finalization of Tool

To ensure the tool's relevance, clarity and validity, the draft questionnaire was first reviewed and evaluated by a panel of subject matter experts, including faculty from the Department of Fashion Design and Technology and professionals from healthcare sectors. Constructive feedback from the reviewers was incorporated to improve the effectiveness of the tool. Subsequently, a pilot test was done with a small sample of expectant mothers (not included in the final sample) to pre-test the tool. This process aimed to assess the tool's reliability, clarity and practical applicability. Based on the data obtained during the pilot testing, the structure and wording of the questionnaire were refined. Dummy tables were also tested at this stage to check for consistency and compatibility with data analysis software.

The final version of the questionnaire included a mix of closed-ended and scaled questions, with several questions based on a 5-point Likert scale to measure agreement or satisfaction across key variables such as:

- **Comfort** (ease of wear, fabric feel, breathability)
- **Fit** (expandability, body adaptability, ease of movement)
- **Design Features** (aesthetic preferences, silhouette, maternity-specific adaptations)
- **Functionality** (usability, garment support, openness to sensor integration)
- **Durability and Maintenance** (wear resistance, care needs)

Each item in the tool was carefully aligned with the research objectives to support systematic quantitative analysis through software such as SPSS. The final questionnaire-cum-interview schedule proved effective in eliciting comprehensive, structured and analyzable data related to the clothing needs and functional requirements of pregnant women.

3.4.4 Ethical Considerations

Ethical considerations were strictly followed throughout the study. Prior to data collection informed consent was obtained from all participants. Respondents were assured that their participation was voluntary and that the information shared would remain confidential and be used solely for academic research purposes. No personal identifiers were disclosed at any stage of data analysis or reporting.

3.5. Sampling Procedure

3.5.1. Locale of the Study

Ludhiana and Jalandhar, two cities in Punjab were specifically chosen to carry out the current study. These are among Punjab's most well-known and densely populated cities, renowned for their strong textile sector, advanced medical facilities and multicultural population. Furthermore, the researcher has direct access to these sites, making it easier to reach the intended respondents and assuring efficient communication, rapid data collecting and an uninterrupted study procedure. The healthcare institutes or hospital organizations were selected according to the non-probability- purposive sampling method. The permission was obtained from the respective gynaecology departments for interviewing the patients.

For the purpose of this research, two hospitals from Ludhiana namely CMC Hospital and Lifeline Hospital and one hospital from Jalandhar Cantt, Civil Hospital, were purposively selected. These hospitals were chosen due to their accessibility to expectant women from middle and higher income groups and their active maternity care services.



Figure 3.2: Visit to Lifeline Hospital, Ludhiana for Primary Data Collection



Figure 3.3: Visit to CMC Hospital, Ludhiana for Primary Data Collection

3.5.2 Selection Criteria of Respondents

A total of 150 respondents were considered adequate and manageable to obtain the required data. These participants were personally contacted and requested to share their independent opinions regarding current clothing practices, challenges experienced with regular maternity wear and their preferences for general clothing attributes as well as the design and functional features of maternity apparel. Inclusion criteria comprised pregnant women in their second and third trimesters that were willing to participate and capable of providing informed responses. Women with severe medical complications requiring intensive care were excluded from the study to avoid discomfort and ethical concerns.

The respondents were selected using a purposive non- probability sampling technique from selected hospital settings in Jalandhar and Ludhiana, as this approach was considered appropriate for identifying pregnant women who met the predefined inclusion criteria and could provide relevant information for achieving the objectives of the study. However, since the respondents were drawn from selected hospitals within a limited geographical area, the findings may not be generalizable to all pregnant women across different regions or healthcare settings. Nevertheless, purposive sampling is widely adopted in design-oriented and exploratory research where participants possessing specific characteristics are required for product development and user evaluation. Future studies may include larger sample sizes from multiple geographical locations using probability sampling techniques to enhance the generalizability of the findings.

3.6 Method of Data Collection

The data were collected directly through personal interviews by administering the schedule to the healthcare staff after explaining the objectives of the study. The respondents were assured that the information provided would be kept confidential and used for the purpose of this research only with a view to draw general conclusions & the specific information pertaining to their particular will not be disclosed to anybody. After finalizing the composition of the sample, the main study was carried out to collect the required data. The pre-data collection phase was conducted over a period of two-months. During this phase, 150 expectant women were personally approached and invited to

participate in the study. Data were gathered using a structured interview schedule, specifically designed to gain in-depth insights into their existing clothing practices, the challenges they encountered with conventional maternity wear, and their preferences regarding garment attributes such as design, comfort, fabric choice, and functional features. To ensure the authenticity and richness of the responses, the interviews were conducted in person. Whenever needed, additional explanations were provided to clarify the questions for the respondents enabling them to express their opinions more effectively. In some instances, a cross-questioning technique was used to probe deeper into specific responses and to collect more qualitative information.

The data collected during this stage were carefully analyzed to draw meaningful patterns. The findings were compiled to develop a clear understanding of the specific clothing needs and expectations of expectant women. These insights obtained during this phase directly informed the design parameters and technological integration strategies adopted in the development of smart maternity wear.

3.7 Data Analysis Techniques (Need Assessment)

The data collected during the study were coded, tabulated and analyzed using appropriate statistical tools and techniques to draw meaningful inferences. The data were initially entered and organized in Microsoft Excel, which was used to generate various tables and charts for better visualization and interpretation.

The following statistical methods were employed in the analysis:

(a) Percentage

Simple percentages were calculated to assess the personal and family profile of expectant mothers.

(b) Weighted Mean Scores, Mean Scores and Ranks

Weighted mean scores, mean scores and ranks were calculated to assess the following.

- (i) Preference of expectant mothers for their existing clothing practices and problems faced with regular clothes.
- (ii) Preference regarding general attributes of garments.
- (iii) Preference for functional and designing features to be incorporated in maternity garments and smart vest.

Scoring and ranking methods were also employed to determine the level of preference for various factors. Each factor was assigned a score based on its priority or importance as perceived by the respondents. The most preferred factor received the highest score, while the least preferred one received the lowest. These scores were then compiled and assigned ranks to identify key areas of concern and interest.

Arithmetic Mean- $\bar{x} = \sum x_i / n$ where; $\bar{x}$ = arithmetic mean of the variable (x), x_i = value of the i^{th} observation on x and n= total no. of observations.

(c) Rank Co-relation

Spearman's rank correlations were computed to find out the differences in the choice preferences-of expectant mothers and Clothing and Textiles experts regarding casual wears, formal wear, ways of creating fullness and type of fasteners using the following formula-

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Where

$d = R_1 - R_2$ i.e. the difference of rank in 2 characteristics

n= number of observations. Correlation factor C is added to $\sum d^2$ for repeated ranks.

$(m(m^2 - 1))/12$ where m_j = no. of times the y^{th} rank is repeated and $r = 1 - 6(\sum d_i^2 + c)/n(n^2 - 1)$

(d) Chi-square Test

The chi-square test was applied to examine the association between categorical variables such as socio-demographic factors and clothing preferences or problems faced.

This test helped to test the independence of attributes using the following formula for χ^2 -

$\chi^2 = \sum \frac{(O-E)^2}{E}$ Where O = observed frequency, E = expected frequency and $\sum$ = Summation across all categories.

(e) Student's t- Test

The Student's t-test was utilized to statistically evaluate the feedback received from the participants. This analysis offered valuable insights into how well the garments were accepted and how effectively they met user's needs, confirming the practicality and functionality of the design features for both pregnancy and postpartum use. In addition to garment related parameters, descriptive analysis was used to interpret user feedback regarding sensor comfort, perceived usefulness and acceptance of technology integrated maternity wear.

Phase II: Design & Development of Maternity Garments

3.8 Design Development Based on Need Assessment

Based on the findings from the preliminary survey, review of related literature and the researcher's creative input, a range of maternity wear designs were conceptualized and developed. The proposed garments included maxi/midi dresses, cord sets, tunics and a specially designed waistcoat integrated with wearable technology for health monitoring. These designs were thoughtfully created to accommodate the evolving physical and emotional needs of expectant women throughout different stages of pregnancy. Eleven designs of functional maternity outfits were sketched on the basis of survey results and observation of the researcher. Appropriate sketches of designs were developed keeping in mind the physical changes and functional aspects during pregnancy and nursing period.

The design emphasis was placed on comfort, flexibility and functionality. Key features integrated into the garments included:

- **Loose and breathable silhouettes** to enhance ventilation and minimize discomfort.
- **Maternity leggings and jeggings** offering support while ensuring flexibility and ease of movement.
- **Smooth and soft fabric textures** those are gentle on sensitive skin.
- **Flowy silhouettes** that adapt to bodily changes without appearing oversized or shapeless.
- **Pants and skirts with drawstrings, elastic bands or stretchable panels** to allow easy adjustment as the body expand.

- **Adjustable features** such as button tabs, ties, and extendable panels to promote a customizable fit.
- **Focus on proper fit** to ensure the garment aligns with the wearer's comfort without compromising style.

All garments were developed with special consideration of the physical transformations experienced during pregnancy. The primary goal was to eliminate common issues such as poor fitting, discomfort and the lack of aesthetic appeal often associated with traditional maternity clothing. While nursing wear was not a primary focus in the current study, the principles of modesty, discretion, and accessibility were referenced as part of the initial design philosophy drawn from literature. Special emphasis was placed on incorporating modular and detachable smart components to ensure ease of maintenance, wash ability and adaptability across pregnancy stages.

3.9 Preparation and Evaluation of Design Sketches

As part of the design development process a range of maternity garment illustrations were first created manually followed by digital renderings using CorelDRAW, widely used design software. These illustrations were thoughtfully designed to address the specific needs of expectant women in their second and third trimesters, focusing on comfort, adaptability, flexibility and functional support.

A total of 16 illustrated smart casual maternity wear designs were developed offering versatile clothing options suitable for both indoor and outdoor use. These designs aimed to cater to the evolving lifestyle and comfort needs of pregnant women by blending functionality with aesthetic appeal. The smart casual approach ensured a balance between relaxed wearability and a presentable style making the garments ideal for daily activities, social interactions and light professional settings.

To assess the practicality and effectiveness of the proposed designs, illustrations were presented to a panel of five expert members from the fields of textiles, clothing and fashion. Each design was evaluated based on key criteria including comfort, fit, silhouette, design features, overall appearance and the functional integration of smart elements. Based on the qualitative assessment, the experts provided valuable suggestions and recommendations.

Their feedback emphasized important aspects such as breastfeeding accessibility, ease of wear, use of soft-textured fabrics and the inclusion of discreet nursing access points. Additional refinements were suggested including the incorporation of adjustable features to accommodate changes in body size, improved nursing access points for user convenience and modifications to the overall garment length. Specifically, it was recommended that the dress length should fall above the ankle or around the calf to avoid floor-length garments that may hinder walking comfort.

Ultimately 11 designs were selected and finalized for garment construction. These selections reflected a balance of functional relevance, aesthetic appeal and expert-informed modifications ensuring that the final smart maternity wear collection met the practical and emotional needs of expectant mothers during the later stages of pregnancy.

3.10 Prototype Development & Evaluation

To evaluate the practicality and effectiveness of the maternity wear designs trial wear garments were first made using muslin fabric; a commonly used material in the fashion industry for initial fittings due to its affordability and ease of handling. These muslin samples allowed for testing the accuracy of patterns, fit, ease of movement and overall garment construction.

The trial versions included trims, accessories and integrated sensors to assess both the functional and technical aspects of the designs. Garments were stitched according to the design specifications and fitted on mannequins or models to simulate real - life use during pregnancy. This step was essential in identifying and correcting any design flaws.

As a result important adjustments were made to features such as elasticity, breathability and adaptability. Elements like flowy silhouettes, elasticated waistbands, breathable fabrics and adjustable components were refined to enhance comfort and functionality. This trial phase played a key role in ensuring that the smart maternity garments would meet the needs of expectant mothers effectively.

3.10.1 Standard Measurement Chart

The size chart of the maternity outfits was developed based on the standard measurements of pregnant women to accommodate the changes experience during the

pregnancy. The size chart was created following the guidelines outlined by Aldrich (2015) and Armstrong (2019).

Table 3.1: Standard Measurement Chart for the Maternity Garments

Size	Bust (in)	Length (in)	Sleeve length (in)	To fit waist (in)	Waist (in)	Hips (in)	Across shoulder (in)	Out seam length (in)	Inseam length (in)
S	36	46	17	31	32	39	14	38	26
M	38	46	17	33	34	41	14.5	38	26
L	40	46	17	35	36	43	15	38	26
XL	42	46	17	41	38	45	15.5	38	26
2XL	44	46	17	43	40	47	16	38	26
3XL	46	46	17	45	42	49	16.5	38	26

These measurements were used in the maternity garments – dresses, top & bottom, vest and tunic

3.10.2 Trial Construction Using Muslin Fabric

During the trial construction phase, prototypes of smart maternity garments were developed using muslin fabric to test design accuracy, functionality and ease of wear. The focus was on incorporating adjustable features, nursing access and IoT integration, ensuring the garments addressed the specific needs of expectant mothers in their second and third trimesters.



Figure 3.4: Prototype of Adaptive Nursing Features

This garment included user-friendly design elements such as front openings with buttons and zippers, drawstrings and knotting options. These features provided comfort and adaptability while discreet nursing access supported postnatal functionality.



Figure 3.5: Prototype of Maternity Garment

The vest, styled as a waistcoat featured in-seam inner pockets designed to hold ECG sensors. From the outside it maintained a normal garment appearance ensuring aesthetics were not compromised while enabling wearable technology integration.



Figure 3.6: Prototype of Vest

This maternity dress was equipped with a front opening for breastfeeding a drawstring to adjust fit as per body changes and a functional pocket for utility. It blended practicality with comfort and ease of movement.

3.10.3 Integration of IoT in Smart Vests & Gloves

Body Mapping and Smart Sensor Placement

1. Identification of Vital Parameters

The selection of vital parameters for monitoring was based on the health requirements of pregnant women. The chosen parameters included:

- **Electrocardiogram (ECG)** for monitoring heart activity.
- **Galvanic Skin Response (GSR)** for detecting mood changes and emotional stress.
- **Pulse rate (Beats per Minute - BPM)** for evaluating cardiovascular condition.

2. Sensor Point Finalization on the Body

To ensure accurate and comfortable sensing, specific body locations were finalized for sensor placement after a detailed review of biomedical standards and ergonomic considerations:

- **ECG Sensors** were best suited for the upper body specifically the chest region to capture clear heart signals.

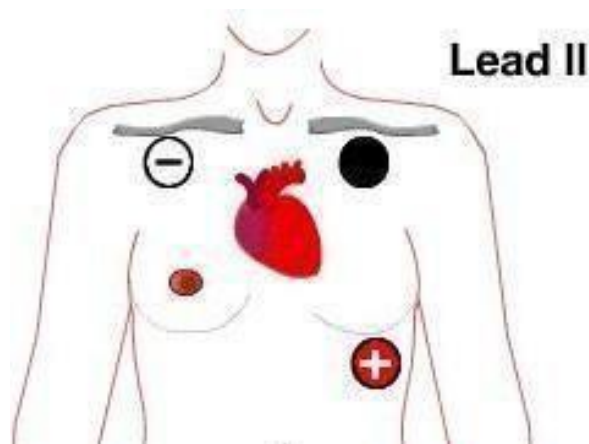


Figure 3.7: ECG Sensing Points from Chest Region (Source: <https://allnurses.com/ekg-lead-placement-t64073/>)

- **GSR Sensors** were found to function most effectively on the two middle fingers which offer consistent skin resistance readings.

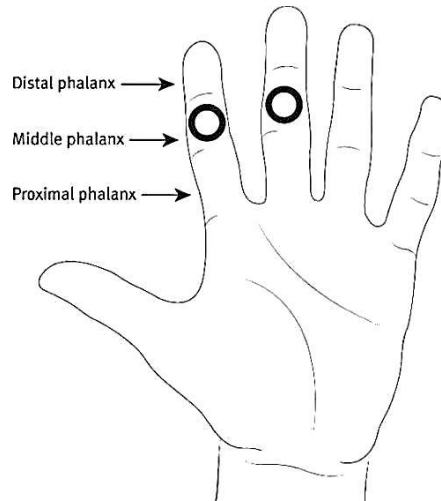


Figure 3.8: Mood Swings Sensing Points
(Source: Self Created by author using CorelDraw)

- **Pulse Sensors** were placed on the index finger, a common and reliable site for photoplethysmographic (PPG) monitoring.

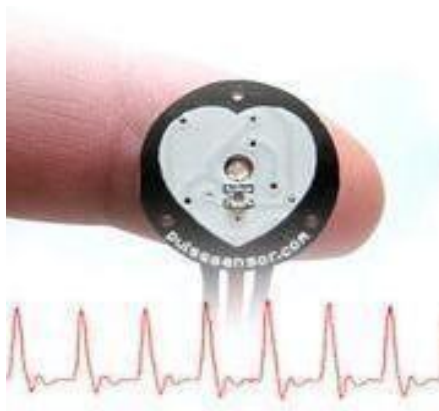


Figure 3.9: Pulse Point
(Source: <https://iyzer.in/product/pulse-rate-sensor-heart-rate-sensor-module/>)

These placements were finalized based on signal accuracy, user comfort and garment integration feasibility.

3. Selection of Suitable Sensors and Placement

The following sensors and modules were finalized for integration:

- **ECG Monitoring:** Textile-based electrodes or snap ECG modules to be placed on a vest-style garment.

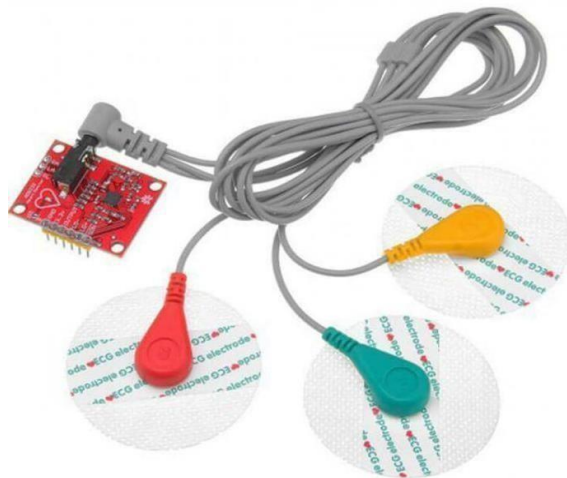


Figure 3.10: Electrocardiogram Sensor
 (Source: <https://www.amazon.in/REES52-module-AD8232-measurement-monitoring/dp/B01K0MION>)

- **GSR Monitoring:** Skin resistance sensors suitable for finger placement used to detect emotional fluctuations (mood swings).



Figure 3.11: Galvanic Skin Response (GSR) Sensor
 (Source: <https://www.theengineerstore.in/products/gsr-skin-current-sensor-v2-0>)

- **Pulse Monitoring:** PPG-based pulse sensor to measure BPM via the index finger.

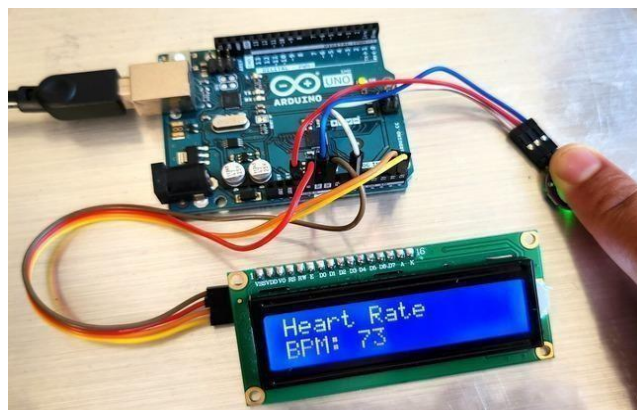


Figure 3.12: Pulse Sensor
 (Source: <https://how2electronics.com/pulse-rate-bpm-monitor-arduino-pulse-sensor/>)

- **Wireless Transmission:** NodeMCU ESP8266 module was used for transmitting sensor data to the cloud via Wi-Fi.



Figure 3.13: NodeMCU ESP8266 Module
(Source: <https://www.amazon.in/Generic-Nodemcu-Esp8266-Internet-Development/dp/B07262H53W?th=1>)

- **Power Supply:** A portable power bank with a Type-C connector was selected for its portability and recharge ability.



Figure 3.14: Portable Power Bank
(Source: <https://in.sharge.com/products/flow-mini>)

4. Quality Assessment and Material Procurement

After finalizing the types of sensors and their placement points, careful consideration was given to sourcing high-quality components to minimize technical errors or malfunctions. All electronic modules and conductive materials were procured from trusted vendors ensuring reliable operation throughout the monitoring period.

5. Garment Type and Finalization

Based on the specific sensor and its corresponding body location, the following garment styles were designed:

- **For ECG Monitoring:** A vest was chosen as the most suitable garment due to its stability and chest coverage. The ECG sensors were integrated directly into the chest region using conductive textiles and secure stitching techniques.
- **For GSR and Pulse Sensors:** Two separate gloves were developed. Each glove was designed with sensor placement pockets allowing safe and firm positioning of modules on the middle and index fingers. Additional compartments were included for securing the micro controller and wiring neatly inside the glove.

6. Sensor Integration and Assembly

After finalizing the garment designs, the sensors and modules were integrated into their respective locations using a combination of stitching, sewing threads and modular pouches. Special care was taken to ensure that the wiring did not interfere with wearer comfort or mobility.

7. Data Transmission and Visualization

Once the sensors were integrated firmware programming was carried out for each sensor module using Arduino IDE. The data collected from ECG, GSR and pulse sensors was transmitted wirelessly via the NodeMCU ESP8266 module. The Blynk IoT mobile application was utilized to receive and display the sensor data in real-time offering user-friendly visual monitoring for the wearer or healthcare provider.

8. Testing Phase

Prototypes of the smart maternity wear were developed with integrated sensors to monitor key health indicators, aiming to assess the longevity and reliability of the designed system. Vest prototype integrated sensors to monitor key parameters such as heart rate, temperature and fetal movements, which are crucial for maternal and fetal health. The prototypes also underwent evaluations for data accuracy, battery life and connectivity to mobile devices for real-time health communication. This testing phase

facilitated improvements in sensor placement, fabric compatibility and overall garment durability, ensuring that the smart maternity wear remains functional and comfortable over an extended period. Through these evaluations, the study established a foundation for refining smart wearables tailored to the unique needs of pregnant women.



Figure 3.15: Testing of ECG Sensor & Vest

To address the physiological variability, comfort concerns and maintenance challenges associated with wearable health monitoring during pregnancy the present study deliberately adopted a modular and detachable system design rather than a fully embedded electronic garment. Pregnancy represents a dynamic and transformational phase marked by continuous changes in body morphology, posture, skin sensitivity and thermal perception particularly during the second and third trimesters. Embedding electronic components permanently within the primary maternity garments may compromise comfort, restrict adaptability, reduce washability and shorten garment lifespan. Therefore, a two-layered design strategy was implemented, wherein the primary maternity garments were developed exclusively to ensure comfort, fit adaptability and aesthetic acceptability while health monitoring functions were supported through auxiliary detachable components.

Within this modular system, a detachable smart vest (waistcoat) was designed as the primary carrier for ECG sensing. The vest-based configuration was selected due to its anatomical proximity to the thoracic region, which allows stable electrode placement and reliable acquisition of cardiac signals. Continuous monitoring of maternal heart

activity through ECG is clinically significant during pregnancy as it assists in identifying cardiovascular stress, abnormal heart rhythms and physiological strain that may arise due to increased blood volume, elevated cardiac output and hormonal fluctuations. Positioning ECG sensors within a vest enables consistent skin contact while minimizing discomfort, pressure and movement restriction. Importantly, the detachable nature of the vest allows the sensing module to be removed during washing, enhancing hygiene, durability and user compliance.

In addition to the ECG vest, detachable smart gloves were incorporated as a supplementary wearable component to support peripheral physiological sensing. Sensor placement directly on primary maternity garments poses challenges due to frequent hand and body movements, garment looseness, and variable fabric drape across trimesters. Gloves offer a stable and ergonomically suitable platform for monitoring parameters such as pulse rate, skin temperature and galvanic skin response, as the hands provide consistent vascular access and relatively stable contact points. The inclusion of gloves also reduces the need for excessive sensor integration across the main garment surface, thereby minimizing bulk, rigidity and thermal discomfort. Furthermore, gloves are easy to don and doff, allowing selective monitoring based on user preference and daily routine, which is particularly relevant for working and independently active expectant mothers.

During prototype testing, several sensor placement challenges were identified, including motion artifacts caused by postural changes, discomfort due to prolonged skin contact and variability in sensor accuracy as body dimensions evolved. To mitigate these issues sensor distribution was intentionally decentralized across modular components rather than concentrated within a single garment. This distributed approach enhanced data reliability while preserving wearer comfort and freedom of movement. Iterative adjustments were made to sensor positioning, attachment methods and fabric interfaces to ensure optimal performance without compromising the softness, breathability or flexibility of the maternity wear.

Overall, the integration of a detachable ECG vest and sensor-enabled gloves reflects a design-led, user-centric methodology that balances health monitoring functionality with essential clothing requirements. By allowing the primary garments to retain their

core clothing functions while enabling optional and selective physiological monitoring through detachable modules the system improves usability, washability, longevity and user acceptance.

This approach addresses a significant gap in existing smart maternity wear research, which largely relies on fully embedded electronic garments that often fail to adapt to the progressive and sensitive nature of pregnancy.

These outcomes lay the foundation for broader clinical validation and potential future commercialization.

3.10.4 Raw Material Specifications and Selection Criteria

The selection of textile materials and electronic components for the developed smart maternity wear was based on their functional suitability, comfort, compatibility with wearable healthcare applications and integration with the proposed IoT system. The primary fabric was selected after comparative functional evaluation of different basic alternatives while the electronic components were chosen based on their reliability, compactness and suitability for continuous physiological monitoring. The detailed functional evaluation of the fabric materials has been reported separately in the author's published study (Nanda et al., 2026). The specifications and rationale for selecting the materials used in the present study are summarized in the Table 3.2.

Table 3.2: Raw Material Specifications and Selection Criteria

Sr. No.	Material/ Component	Specification	Reason For Selection
1	95% Cotton, 5% Jersey Knitted Fabric	Soft, breathable, lightweight knitted fabric with good stretch and recovery.	Selected due to its superior breathability, flexibility, waist expandability, ease of movement and adaptability to the changing body dimensions during pregnancy. Comparative functional evaluation demonstrated its overall suitability for smart maternity wear (Nanda et al., 2026).
2	100% Cotton Woven Fabric	Breathable woven cotton fabric with low stretch and firm structure.	Included for comparative evaluation because woven fabrics are commonly used in maternity garments. Although it provided good breathability and cost-effectiveness, its lower stretch, waist expandability and adaptability limited its suitability for accommodating progressive body changes during pregnancy (Nanda et al., 2026).
3	100% Viscose Woven Fabric	Lightweight woven viscose fabric with good drape and moderate breathability.	Included for comparative evaluation due to its comfort and aesthetic drape. It showed moderate performance in breathability and durability but lower extensibility than the knitted fabric, resulting in a lower overall ranking in the MOORA analysis (Nanda et al., 2026).
4	ECG Sensor	Bio potential Sensor	Selected for continuous monitoring for maternal heart activity with reliable signal acquisition.
5	Pulse Sensor	Optical heart rate sensor	Selected for real-time monitoring of maternal pulse rate using a compact and non-invasive sensing technique.
6	GSR Sensor	Skin conductance sensor	Selected to monitor physiological stress response through changes in skin conductivity.
7	ESP32 Microcontroller	Wi-Fi enable microcontroller	Selected for sensor integration, wireless communication and real-time transmission of physiological data.
8	Conductive Thread and Connecting Wires	Flexible Conductive Material	Selected to establish electrical connectivity between sensors and the control unit while maintaining garment flexibility.
9	Rechargeable Power Bank	Portable DC power source	Selected to provide uninterrupted power supply for the wearable monitoring system during use.

The material selection adopted in the present study was supported by functional performance evaluation including assessments of breathability, stretch and recovery, ease of movement, waist expandability and fastening durability. However, comprehensive laboratory based material characterization such as detailed mechanical, thermal and electrical characterization of individual textile materials was beyond the scope of the present investigation. Therefore, the present research primarily focuses on the design, development and functional evaluation of the smart maternity wear prototype using carefully selected materials supported by prior functional performance assessment.

3.11 Development of Patterns & Sourcing of Material

Once the garment illustrations were finalized and muslin test fits were successfully completed the next step involved creating accurate patterns for each maternity wear design. These patterns were developed to address the changing body shape during the second and third trimesters, focusing on flexibility, comfort and functional design elements.

Simultaneously the sourcing of appropriate materials was undertaken with a strong emphasis on selecting fabrics that offered comfort, breathability, stretch ability and compatibility with wearable technology. A diverse range of natural and blended fabrics was chosen to ensure softness, durability and skin-friendliness. This included pure cotton for dresses and vests, cotton-rayon blends for paneled garments to enhance drape and softness, stretchable knit fabrics for tunics and single jersey knit fabric for gloves to support ease of movement and seamless sensor integration.

All fabrics were carefully selected and purchased from local textile markets in Ludhiana, Punjab known for their wide variety and quality of knitwear and cotton fabrics. The ECG and temperature sensors were procured through online sources (Amazon) to ensure access to compact, reliable modules compatible with wearable applications. Additionally portable batteries and micro controller components were sourced from a local electronics and gadget shop in Ludhiana, Punjab ensuring timely availability and ease of integration during the prototyping phase.

Table 3.3: Materials Used and Their Basic Properties

Sr. No.	Garment Type	Material Used	Composition	Properties	Purpose
1.	Maternity Dresses & Vests	100% Cotton	Natural fiber	Soft, breathable, hypoallergenic, easy to wash	Ensures comfort and breathability
2.	Paneled Maternity Dresses	Cotton-Rayon Blend	60% Cotton, 40% Rayon	Smooth texture, better drape, moisture absorbent	Enhances comfort and visual appeal
3.	Tunics	Knitted Cotton Fabric	100% Cotton Knit	Stretchable, soft, breathable, allows ease of movement	Provides flexibility during pregnancy
4.	Smart Gloves	Single Jersey Knit Fabric	Cotton/Elastane Blend	Lightweight, stretchable, sensor-compatible, conforms to hand shape	Integrates wearable sensors effectively

3.12 Final Construction of Selected Maternity Designs

The construction of maternity garments was carried out using standardized garment drafting techniques based on Zarapkar (Zarapkar, 1998) and body measurements adapted from Armstrong (Armstrong, 2006). These standards were used to develop the basic block pattern which served as the foundation for all garments.

The final garment designs were based on the preferences expressed by 150 pregnant women during the pre-data survey phase. These respondents, all in their second and third trimesters provided detailed insights into their clothing needs and challenges. Commonly highlighted preferences included the desire for adjustable features, soft and breathable fabrics, comfortable silhouettes and garments that could accommodate body

changes during pregnancy. Based on this data, selected designs were finalized for construction. The fabric types, textures, patterns and colors were chosen by aligning the survey results with relevant literature findings to ensure both functional and aesthetic suitability. The garments incorporated features such as stretchability, elastic waistbands, drawstrings and loose-fitting silhouettes to provide enhanced comfort and adaptability. Each garment was constructed using the adapted patterns and sewn with appropriate techniques to ensure durability, ease of movement and proper fit. The construction process aimed to reflect both the practical and psychological comfort of expectant women while addressing their physical needs during the later stages of pregnancy.

The smart vest and gloves were thoughtfully designed to provide both comfort and functionality for expectant mothers. The vest features a smocking pattern allowing for an adjustable fit that adapts seamlessly to the body's changes during pregnancy. Made from cotton-blended fabric the vest offers breathability and softness while ensuring durability for regular use. Integrated wearable sensors such as ECG, pulse and GSR are carefully integrate within the vest to monitor vital signs. Strategically placed pockets are included to securely keep the electronic modules, ensuring ease of use and safety.

The smart gloves are made from stretchable knit fabric offering a snug and comfortable fit. These gloves are embedded with GSR sensors to track mood changes and pulse rate, supporting emotional and physiological monitoring. Together the smart vest and gloves serve as an effective user-friendly wearable system that combines comfort-focused design with real-time health tracking to enhance maternal care.

3.13 Cost of Developed Maternity Garments

To determine the production expenses cost sheets were prepared for all the maternity garments including the development of the smart vest to assess the overall cutting and manufacturing costs. The particulars included in the cost sheets according to maternity range – general garment features, selection of fabrics, functional features, smart vest features, type of sensors, trims & fasteners and additional things (labor cost, finishing, smart tech integration) etc. Each costing sheet included the season as the whole maternity range will be of spring- summer season, style number, type of garment, size

and item description. The costing of the constructed maternity garments was calculated by considering all components involved in the production process. The total cost included the following elements:

- Fabric Cost: Based on the actual cut length of fabric used for each garment.
- Trims and Accessories Cost: Included expenses for elastic bands, buttons, zippers, hooks and other functional additions.
- Stitching Charges: Based on the labor cost associated with garment construction.
- Finishing Charges: Minor expenses involved in the final finishing processes (e.g., ironing, tagging, packaging, etc.).

To determine the final sale price, Goods and Services Tax (GST) applicable to apparel was added to the base cost. The total cost price was then calculated, and a reasonable profit margin was factored in to estimate the market-ready price of each garment. This systematic approach ensured that the garments were not only functional and aesthetically appealing but also economically feasible for both small-scale production and potential commercialization. A detailed cost sheet has been provided in Appendix - IV; which outlines key information such as style number, season, item description, sample size, and cost components including fabric, trims, accessories and labor (CMT). This structured costing approach ensures transparency, helps maintain budget control and assists in pricing the product competitively while ensuring profitability. It is especially important for planning, forecasting and making informed decisions throughout the production and retail stages.

3.14 Evaluation of Constructed Garments

3.14.1 Wear Trial Based Assessment

To evaluate the practical usability, comfort and overall satisfaction of the constructed maternity garments post-trial feedback was collected from selected participants. A total of 15 expectant women were surveyed with the final constructed garments for real-life usage. Each respondent was requested to wear the assigned maternity garment for period long enough to assess key functional attributes in real-life conditions including comfort during movement, breathability, adaptability to body changes and ease of use in daily activities. The garments had incorporated key features such as loose and flowy

silhouettes, breathable fabric textures, elasticated and stretchable elements, adjustable waistlines, maternity leggings/jeggings and wireless bras based on prior survey findings.

Following the trial, participants were asked to rate the acceptability of the garments using a three-point scale, focusing on the following attributes:

- Suitability of Design Features (e.g., fit, silhouette, adjustability)
- Functional Comfort (ease of movement, breathability)
- Practical Utility (ease in wearing/removing, support for body changes)
- Aesthetic Appeal (color, style, overall look) The rating scale used was:

Rating Description	Score Assigned
Highly Satisfactory	3
Satisfactory	2
Unsatisfactory	1

After the post-data survey analysis the responses were evaluated using weighted mean scores along with frequency and percentage calculations for each question. This analysis helped in identifying the garments that performed best in terms of user satisfaction. Among all the garments- the tunic dress, wrap-style dress and smart vest received the highest ratings from the participants. The remaining garments were evaluated on a relatively similar scale indicating consistent performance in terms of comfort, functionality and overall design effectiveness.

3.14.2 Acceptability & Functional Performance

The evaluation focused on several key attributes that were considered essential by the participants during the pre-survey stage. These included:

- **Functionality:** How well the garment supported the physical changes experienced during pregnancy.
- **Fit and Comfort:** The ease of movement and overall wearability of the garment during daily activities.
- **Breathability and Texture:** Whether the fabric felt smooth, breathable and gentle

on the skin.

- **Adjustability:** Suitability of features such as elasticated panels, drawstrings and flexible waistbands that adapt to body changes.
- **Aesthetic Appeal:** The overall look, style, and design elements incorporated into the garment.
- **Serviceability:** Durability and ease of care (washing, maintenance, etc.) of the garments.

Participants rated each garment on the above attributes using the following 5-point scale:

Rating Scale	Score Assigned
Very Good	5
Good	4
Satisfactory	3
Fairly Satisfactory	2
Unsatisfactory	1

The feedback received was then tabulated and analyzed. Mean scores were calculated for each attribute across all garments and ranks were assigned accordingly to identify which designs were the most appreciated by the users. This step was crucial in validating the practical application and effectiveness of the developed maternity garments, ensuring that they truly met the comfort, functional and aesthetic expectations of the expectant women they were intended for.

3.15 Catalogue Development for Visual Documentation

To facilitate a comprehensive and user-centered evaluation of the developed maternity garments, a visually engaging and functionally informative catalogue was designed. This catalogue served not merely as a technical document, but as a practical and intuitive guide to support participants during the post-design data collection phase. Its objective was to ensure that respondents could accurately assess the garments based on

predefined parameters while gaining a clear understanding of the design intentions.

The catalogue included the following elements:

- **High-resolution technical sketches** of each garment.
- **Detailed feature descriptions** covering garment construction, material properties and design highlights.
- **Clear explanations of smart functionality**, such as embedded health-monitoring technologies (e.g., wearable vest and gloves).
- **Sustainable attributes** including eco-friendly fabric choices and low-impact design elements.

Rather than photographing the garments in a professional studio, each item was documented in a warm, home-like environment to evoke a sense of authenticity and reliability. This setting was intentionally selected to help respondents visualize the garments in everyday domestic use. For each design, multiple photographic angles front, side and rear views were captured to ensure a holistic representation of the garment's structure, fit and aesthetic appeal.

3.16 Final Data Processing & Statistical Analysis

Data collected from both the pre-design and post-design surveys were subjected to systematic tabulation and statistical analysis to extract meaningful insights and validate the effectiveness of the developed garments. The target population consisted of pregnant women in their second and third trimesters.

Data Processing

All raw responses were entered into Microsoft Excel and coded appropriately for analysis. Tables and visual charts (e.g., bar graphs and pie charts) were generated to depict trends and preferences in an accessible format. Descriptive statistical tools were employed to summarize the data, including:

- Simple percentages for frequency distribution of responses
- Mean scores for central tendency
- Standard deviations to measure variability in preferences

Scoring and Ranking Methodology

To identify the most preferred garments and design features, a weighted scoring and ranking method was employed. Each evaluation criterion was assigned a numeric score (1 to 5) and the cumulative score across all parameters was calculated for each garment. The design with the highest total score was ranked as the most favoured. This scoring approach provided a comparative framework to assess user satisfaction and functional efficacy.

Inferential Statistical Analysis

To explore relationships between variables such as the association between trimester stage and clothing preferences Chi-square tests were conducted. This helped to determine whether observed patterns in the data were statistically significant or occurred by chance. The inferential analysis validated key assumptions and supported evidence-based conclusions regarding design suitability.

CHAPTER-4

RESULTS & DISCUSSION

Our interest in clothing influences not only our choices but also how clothing affects behavior, how society indirectly regulates dress through customs and folkways, evolution of fashion, the desire to fit in with a certain group or class and most importantly the behaviors we expect from or extend to individuals based on their attire. Keeping in mind the influential role clothing, the present study Design & Development of Smart Maternity Wear to monitor & communicate the health condition of the wearer aimed to assess the performance of the maternity outfits on comfort, function & durability grounds. It is also sought to determine the need for maternity wear with integrated technology for health monitor & communication. These behavioral and emotional dimensions of clothing become even more critical during pregnancy where physical discomfort, emotional vulnerability and health monitoring needs intersect. This reinforces the relevance of developing maternity garments that go beyond aesthetics to actively support maternal well-being through comfort – driven design and integrated health – monitoring technology. The researcher adopted a mixed method approach. The objectives were achieved through intensive data collection, analysis and discussed under the following subheadings:

Section I: Need Assessment and User Insights

Section II: Design and Development of Smart Maternity garments

Section III: Evaluation of Garment Performance

The detailed findings of the study are presented in the following sections. Section

I: Need Assessment and User Insights

4.1 Demographic Profile of Respondents

4.2 Insights on Maternity Clothing Needs

4.3 Common Challenges in Existing Maternity Wear

4.4 Summary of Key Findings for Design Inputs

Section –II Design & Development of Maternity Garments

4.4 Designing, Sketching & Evaluation of Maternity Sketches

4.4.1 Designing & Sketching

- 4.4.2 Evaluation of Designed Maternity Sketches
- 4.5 Material Sourcing for the Maternity Garments
- 4.6 Integration of IoT in Smart Vests & Gloves
- 4.7 Final Construction of Selected Maternity Designs
- 4.8 Cost of Developed Maternity Garments
- 4.9 Development of the Catalogue

Section –III Garment Evaluation

- 4.10 Wear Trials Results of Smart Maternity Wear
- 4.11 IoT Integrated Vests and Gloves
- 4.12 User Feedback Summary
- 4.13 Statistical Analysis of Performance Indicators

Section I- Need Assessment and User Insights

The initial phase of the research involves a comprehensive study of the needs and challenges faced by pregnant women during the second & third trimesters. These stages bring significant physical changes including increased abdominal size, swelling & fluctuating body temperatures which impact comfort & mobility. Further wise the lack of accessible, functional & aesthetically appealing maternity wear with integrated health monitoring features poses a critical gap in the market.

4.1 Demographic Profile of the Respondents

The general information collected about the respondents included age, qualification, occupation, type of family and annual income. The findings related to demographic characteristics of respondents are presented in the afore mentioned paragraphs along with tables.

- 4.1.1 Age:** The age distribution of the respondents ranged from 18 years to above 30 years, as presented in Table 4.1 and illustrated in Figure 4.1. The data indicates that the highest proportion of participants that is 43.3% belonged to the age group of 26 to 30 years, followed by 39.33% who were above 30 years of age. A smaller segment 17.33% fell within the 18 to 25-year age bracket. These findings suggest that the majority of pregnant women surveyed were in their late twenties to early thirties, a period often associated with peak childbearing

age. A population-based study found that women aged 25–30 had the lowest risks of low birth weight, neonatal intensive care unit admissions and perinatal mortality. Similarly, another study reported that women aged 25–29 experienced the lowest odds of maternal complications such as preeclampsia and gestational hypertension (Zhang, 2020).

Table 4.1: Distribution of Respondents by Age

Parameters	Frequency	Percent	Cumulative Percent
between 18 to 25 years	26	17.3	17.3
between 26 to 30 years	65	43.3	60.7
above 30 years	59	39.3	100.0
Total	150	100.0	

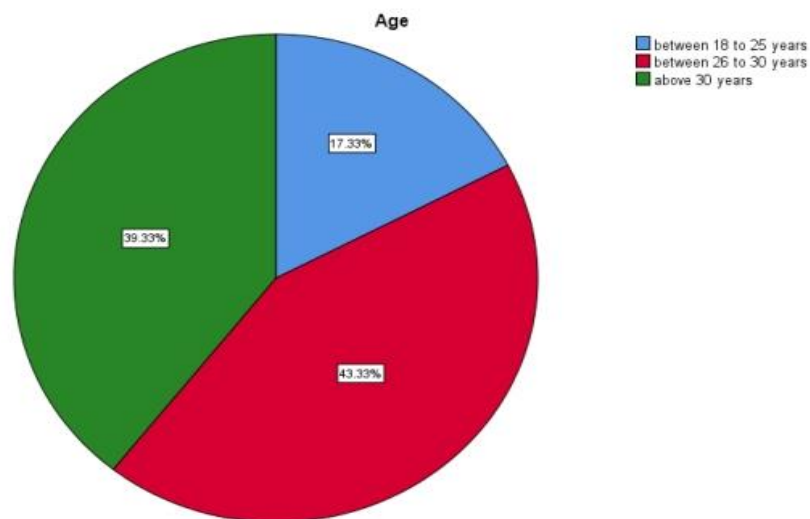


Figure 4.1- Age of the respondents

4.1.2 Qualification: The educational qualifications of the respondents are detailed in Table 4.2 and visually represented in Figure 4.2. The data revealed that a majority of participants (40.67%) held either a Bachelor's or Master's degree followed by 15.33% who had completed secondary school education. A smaller proportion of respondents (2.00%) had attained a diploma qualification, while only 1.33% had earned a Ph.D. This distribution indicated that the majority of

participants possessed a relatively high level of education, implying that they were well-positioned to comprehend the objectives and significance of the present study.

Table 4.2: Distribution of Respondents by Educational Qualification

Parameters	Frequency	Percent	Cumulative Percent
secondary school	23	15.3	15.3
diploma course	3	2.0	17.3
bachelor's degree	61	40.7	58.0
master degree	61	40.7	98.7
Ph.D.	2	1.3	100.0
Total	150	100.0	

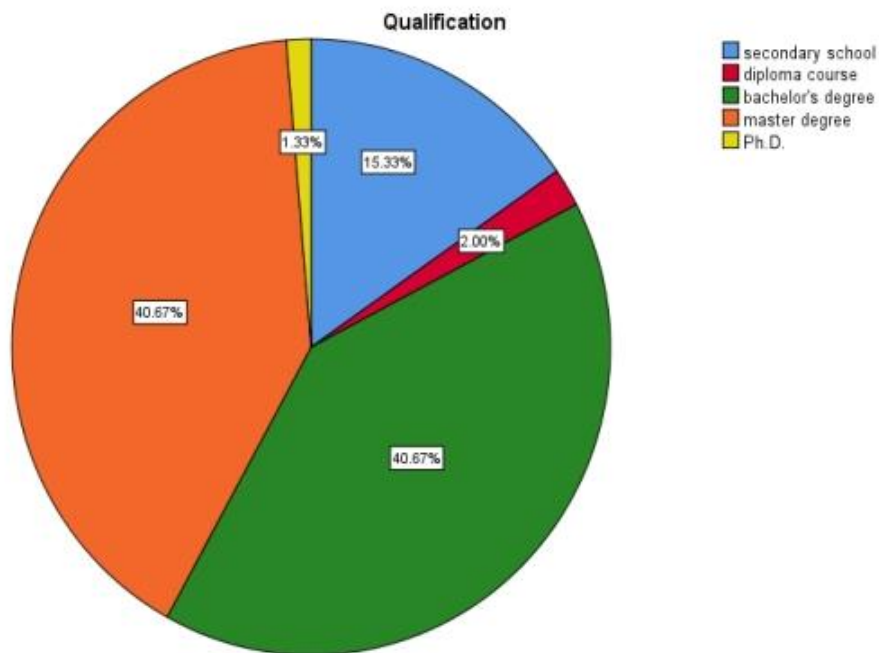


Figure 4.2: Educational Qualification of Respondents

4.1.3 Occupation: the majority of respondents (71.33%) were categorized as non-working, while 28.67% were working as shown in Table 4.3 and Figure 4.3. However, many of those listed as non-working were actually on long term break from their jobs during the data collection phase, as they chose to focus primarily on childbirth and childcare.

Table 4.3: Distribution of Respondents by Occupation

Parameters	Frequency	Percent		Cumulative Percent
working	43	28.7	28.7	
non-working	107	71.3	100.0	
Total	150	100.0		

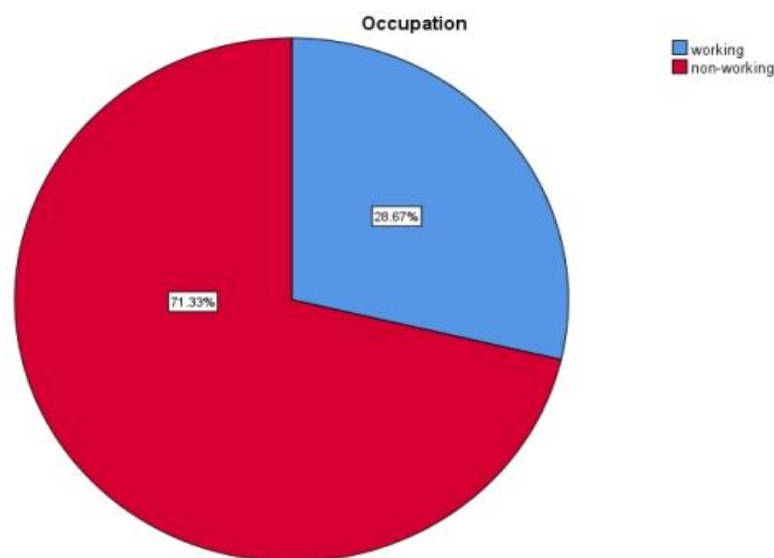


Figure 4.3: Occupation of Respondents

4.1.4 Type of family: The data on family type indicated that a larger proportion of respondents (58.67%) belonged to nuclear families, while 41.33% were from joint families, as presented in Table 4.4 and Figure 4.4. This distribution suggests that most of the participating pregnant women resided in nuclear family setups, which may influence their clothing preferences as well as level

of autonomy in health and lifestyle-related decisions.

Table 4.4: Distribution of Respondents by Type of Family

Parameters	Frequency	Percent	Cumulative Percent
nuclear	88	58.7	58.7
joint	62	41.3	100.0
Total	150	100.0	

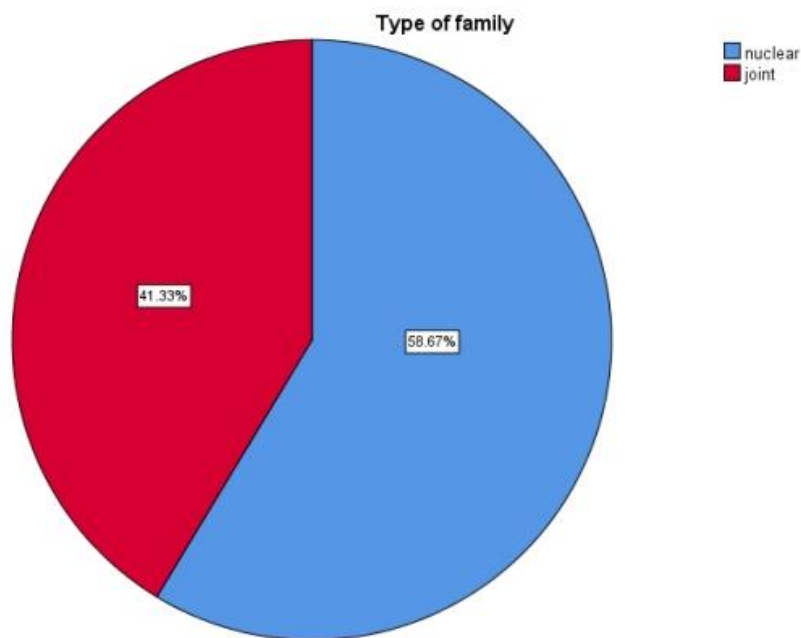


Figure 4.4: Family Type of Respondents

4.1.5 Annual Income: The annual income distribution of the respondents revealed that 40.67% reported earnings of less than ₹5 lakh, followed closely by 39.33% in the ₹5–10 lakh range. Additionally, 15.33% had an annual income between ₹10–15 lakh, while only 4.67% reported earnings above ₹15 lakh. As illustrated in Table 4.5 and Figure 4.5. These findings suggest that a majority of respondents belonged to middle-income households, which may influence their purchasing decisions and preferences for smart maternity wear.

Table 4.5: Distribution of Respondents by Annual Income

Parameters	Frequency	Percent	Cumulative Percent
less than 5 lakh	61	40.7	40.7
between 5 lakh-10 lakh	59	39.3	80.0
between 10 lakh-15 lakh	23	15.3	95.3
above 15 lakh	7	4.7	100.0
Total	150	100	

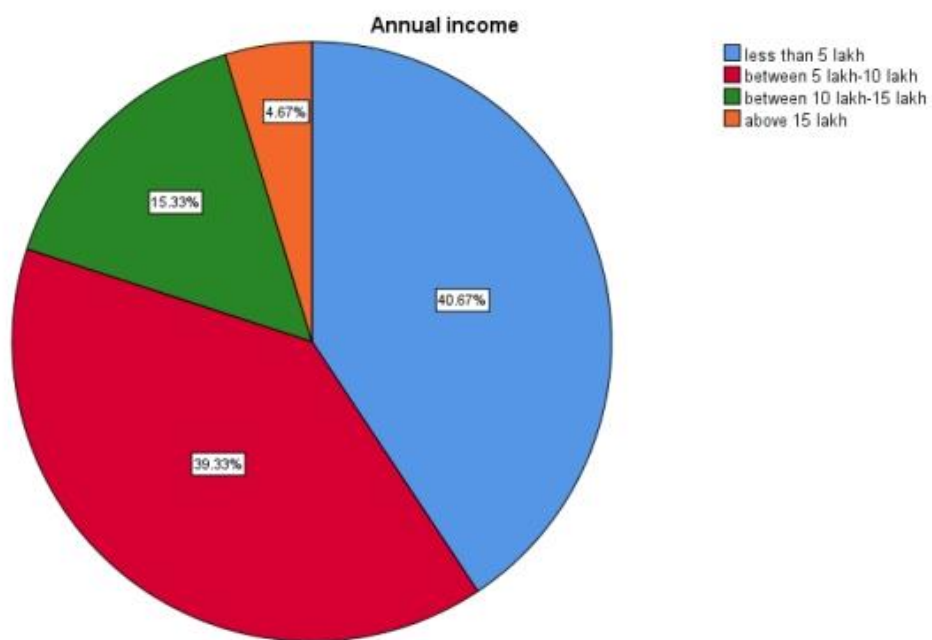


Figure 4.5: Annual Income of Respondents

The demographic profile indicates that the majority of respondents belong to educated, middle – income households and are within the peak childbearing age group. This profile suggests a user base that is likely to be receptive to functional innovation in maternity wear provided the garments align with affordability, comfort and usability expectations.

4.2 Insights on Maternity Clothing Needs

4.2.1 Expecting criteria of the Respondents: All respondents in the study were categorized under the expecting criteria, reflecting a 100% inclusion of pregnant women, as intended for this research. This uniformity aligns with the study's objective of evaluating the preferences and needs of women in their second and third trimesters, as shown in Table 4.6 and Figure 4.6.

Table 4.6: Distribution of Respondents by Expecting Criteria

Parameters	Frequency	Percent	Cumulative Percent
Yes	150	100	100

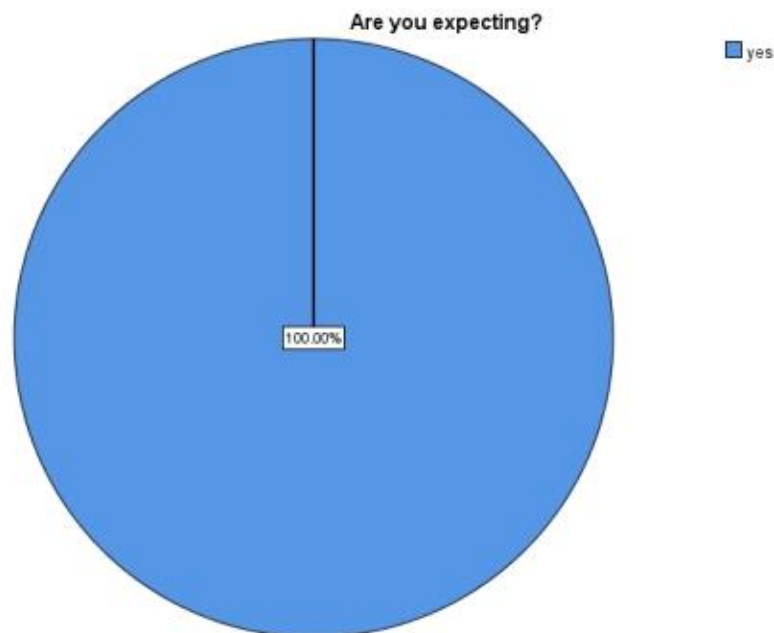


Figure 4.6: Expecting Criteria of Respondents

4.2.2 Age of pregnancy of the Respondents: The data revealed that a majority of the respondents (56%) were in the 6 to 9-month range of pregnancy followed by 31.33% in the 3 to 6-month range and 12.67% in the 1 to 3 month category. This distribution indicates that most participants were in their second and third trimesters aligning with the study's focus on later stages of pregnancy (Table 4.7 and Figure 4.7).

Table 4.7: Distribution of Respondents According to their Age of Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
between 1 to 3 months	19	12.7	12.7
between 3 to 6 months	47	31.3	44.0
between 6 to 9 months	84	56.0	100.0
Total	150	100.0	

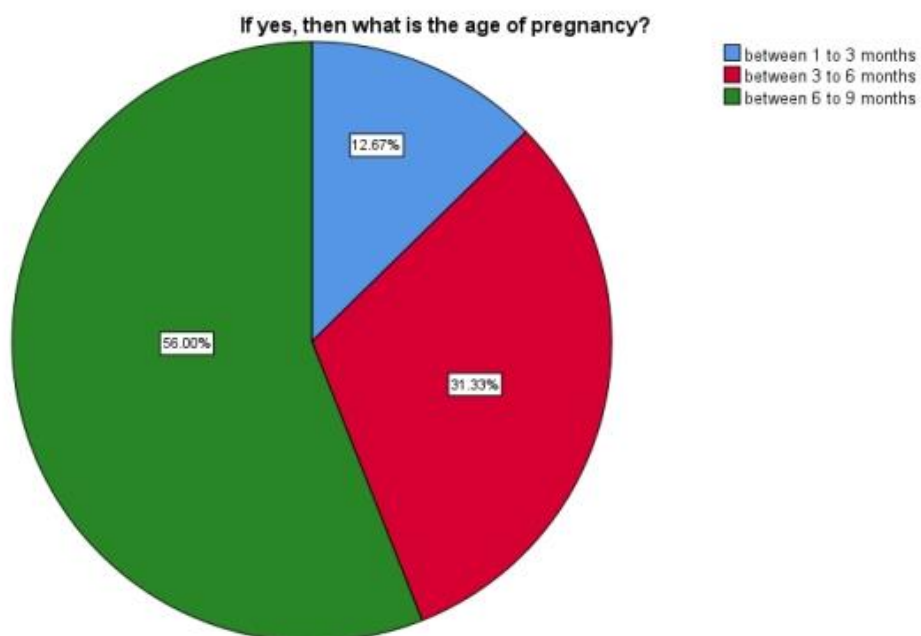


Figure 4.7: Age of Pregnancy among Respondents

4.2.3 Pregnancy Confirmation by the respondents: The findings indicated that 78.67% of respondents confirmed their pregnancy through self-testing followed by a visit to a doctor. Additionally, 14.67% identified their pregnancy after experiencing physical discomfort and subsequently consulting a doctor. A smaller portion, 6.67%, used both methods for confirmation. This trend suggested that the majority of participants were comfortable utilizing modern tools and technology to manage their reproductive health (Table 4.8 and Figure 4.8).

Table 4.8: Distribution of Respondents by Pregnancy Confirmation Method

Parameters	Frequency	Percent	Cumulative Percent
self-testing followed by doctor visit	118	78.7	78.7
felt physical discomfort followed by doctor visit	22	14.7	93.3
self-testing followed by doctor visit, felt physical discomfort followed by doctor visit	10	6.7	100.0
Total	150	100.0	

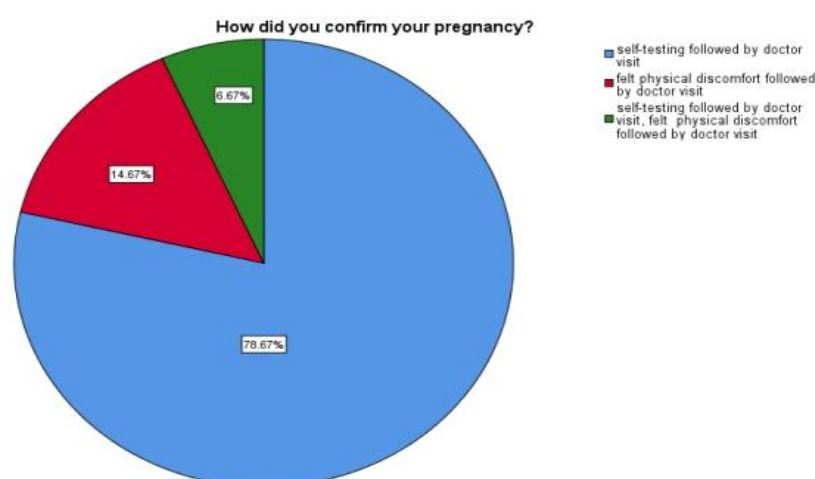


Figure 4.8: Pregnancy Confirmation Method Used by Respondents

4.2.4 Physiological Changes Experienced by Respondents: The data highlighted a wide range of physiological changes experienced by pregnant women, with responses grouped into categories based on the frequency and combination of symptoms reported. A significant portion of the respondents (44%) reported experiencing an extensive combination of changes, including hormonal imbalance, body weight gain, swollen breasts and feet, cramping, frequent urination, headaches, breathlessness, acidity, nutritional deficiencies, and morning sickness. Another 25.33% cited a combination of hormonal imbalance, weight gain, and breast/feet swelling, along with cramping and frequent urination. Approximately 10% experienced hormonal shifts, cramping, and breast/feet discomfort, accompanied by frequent urination, dehydration, and vaginal discharge.

In smaller segments, 7.33% of respondents reported symptoms such as frequent headaches, nutritional deficiencies, and nausea/vomiting, along with breathing difficulties and gastric acidity. Another 6.67% experienced a more severe set of symptoms including headaches, acidity, breathlessness, as well as nutritional deficiencies, sickness, blood pressure issues, temperature fluctuations and vaginal discharge. These findings reflected the multifaceted nature of physiological transformations during pregnancy (Table 4.9 and Figure 4.9).

Table 4.9: Distribution of Respondents by Physiological Changes Experienced

Parameters	Frequency	Percent	Cumulative Percent
hormonal imbalance, body weight gain, swollen breasts/feet, cramping, frequent urination	38	25.3	25.3
frequent headaches, nutritional deficiencies, nausea & vomiting, breathing problems, gastric acidity	11	7.3	32.7
hormonal, weight, breasts/feet, cramping, urination/headaches, breathe/acidity, deficiency, sickness	66	44.0	76.7
hormonal, weight, cramping, breasts, BP, temperature, dehydration, discharge	10	6.7	83.3
headaches, acidity/breathe, deficiency, sickness, BP, temperature, dehydration, discharge	10	6.7	90.0
hormonal, cramping, breasts/feet, urination/dehydration, BP/temperature, discharge, sickness, breathe/acidity	15	10.0	100.0
Total	150	100.0	

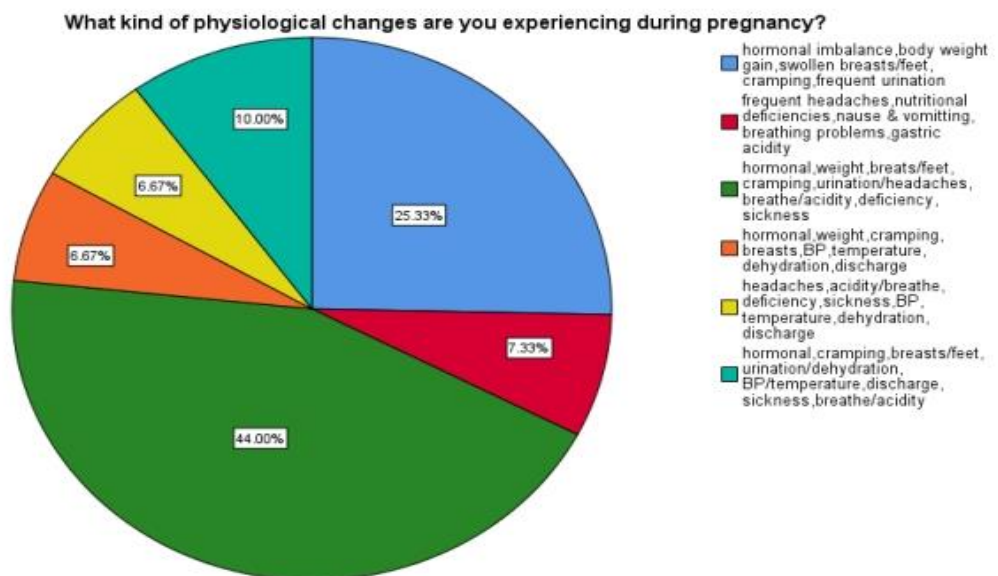


Figure 4.9: Physiological Changes Experienced by Respondents

4.2.5 Check-ups Routine of respondents: An analysis of the frequency of antenatal check-ups among the respondents revealed that 54% reported visiting their healthcare provider every two weeks, while 37.33% attended check-ups once a month, and only 8.67% had weekly visits. These results suggested that a majority of expectant women followed a biweekly prenatal care schedule, which aligned with common medical recommendations for women in their second and third trimesters (Table 4.10 and Figure 4.10).

Table 4.10: Distribution of Respondents by their Check-up Routine

Parameters	Frequency	Percent	Cumulative Percent
visit a month	56	37.3	37.3
visit every 2 weeks	81	54.0	91.3
visit every week	13	8.7	100.0
Total	150	100.0	

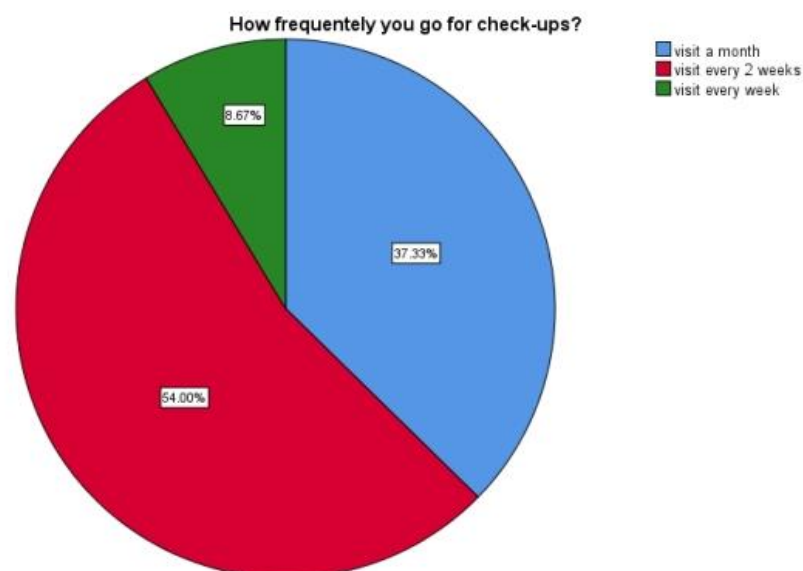


Figure 4.10: Check-up Visits of the Respondents

4.2.6 Symptoms of Emotional Transformation: The data reveals that 68.67% of respondents reported experiencing emotional symptoms during pregnancy while 31.33% did not report such symptoms. This indicates that a significant proportion of pregnant women encounter emotional challenges such as mood swings, anxiety, or irritability which are commonly associated with hormonal changes during pregnancy (Table 4.11 and Figure 4.11).

Table 4.11: Distribution of Respondents by Symptoms Experienced During Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
yes	103	68.7	68.7
no	47	31.3	100.0
Total	150	100.0	

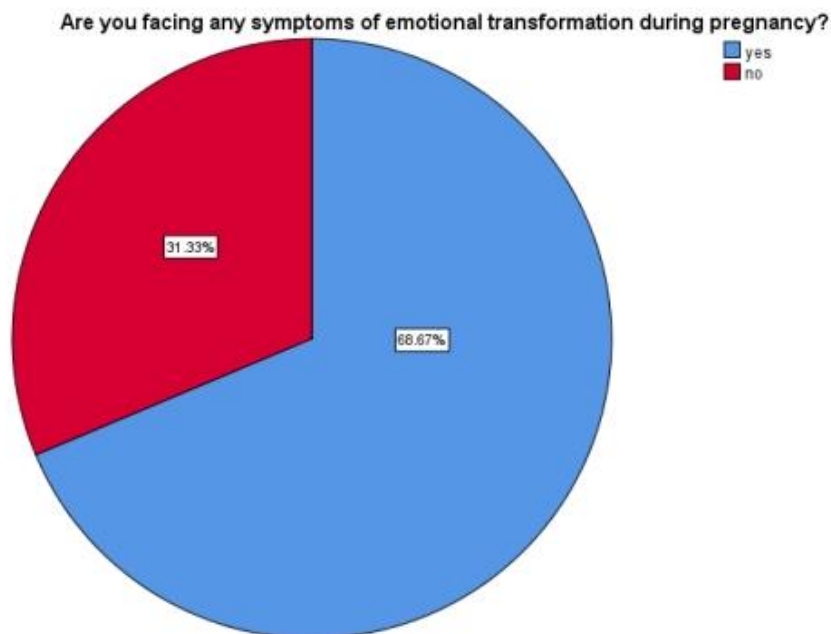


Figure 4.11: Symptoms of Emotional Transformation During Pregnancy

4.2.7 Different Types of Emotional Transformation: A significant proportion of respondents 66.67% reported experiencing emotional changes such as mood swings, forgetfulness, negative body image, weepiness category^l. About 31.33% of the respondents reported no emotional symptoms, while a small percentage 2% experienced more severe issues including weepiness, fear/anxiety, depression, personality/compulsive disorder^l present the distribution of various emotional symptoms experienced during pregnancy (Table 4.12 and Figure 4.12).

Table 4.12: Distribution of Respondents by Type of Emotional Transformation During Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
mood swings, forgetfulness, negative body image, weepiness	100	66.7	66.7
none	47	31.3	98.0
mood swings, forgetfulness, weepiness, fear/anxiety, depression, personality/compulsive disorder	3	2.0	100.0
Total	150	100.0	

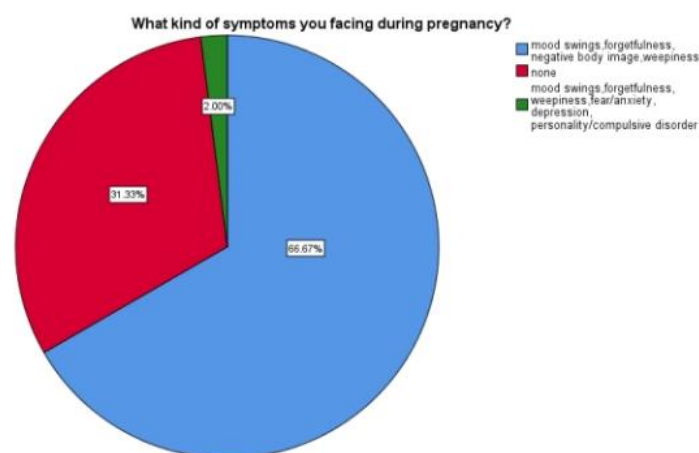


Figure 4.12: Different Types of Emotional Transformation

The high prevalence of combined physiological and emotional symptoms highlights the complex and continuous stress experienced during pregnancy. These findings emphasize the need for clothing solutions that are not only physically comfortable but also psychologically reassuring. Continuous and non- intrusive monitoring systems embedded into everyday maternity garments could support early identification of physiological stress and emotional discomfort without adding burden to the wearer.

4.2.8 Sharing of Health - Related Problems: In the survey 92.67% of respondents gave a positive response YES to experiencing health-related issues, while 7.33% responded negatively NO. This indicates that a significant majority of pregnant women are encountering health concerns during their second & third trimesters. The question was designed to evaluate the prevalence of health related problems among expectant mothers in these stages of pregnancy.

Table 4.13: Distribution of Respondents Based on Sharing of Health- Related Problems

Parameters	Frequency	Percent	Cumulative Percent
yes	139	92.7	92.7
no	11	7.3	100.0
Total	150	100.0	

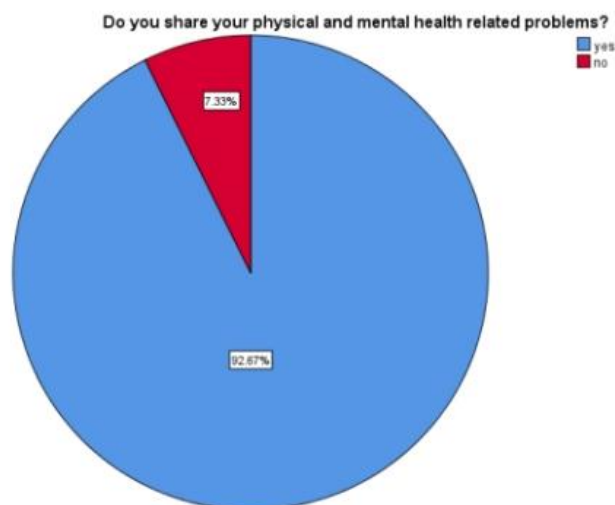


Figure 4.13: Sharing of Health -Related Problems

4.2.9 Health Problem Sharing with Family: A majority of respondents 94% reported discussing their health issues with their spouse and family members indicating strong reliance on familial support systems. In contrast 6% of the participants stated that they do not share their health related problems with anyone. Table 4.14 and Figure 4.14 present the distribution of individuals with whom respondents shared their health-related concerns.. This question was intended to assess the primary emotional and practical support systems available to pregnant women during the second & third trimesters.

Table 4.14: Distribution of Respondents based on Whom they Share their Health Related Concerns With

Parameters	Frequency	Percent	Cumulative Percent
spouse and family	141	94.0	94.0
none	9	6.0	100.0
Total	150	100.0	

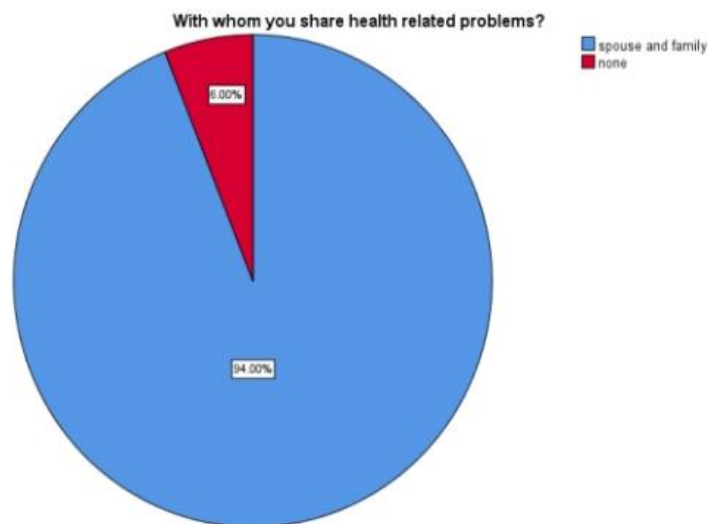


Figure 4.14: Health Related Concerns Sharing With their Family

4.2.10 Special Preparations during the Maternity Period: Among the respondents, 48% reported undertaking special preparations, while 52% indicated that they had not made any. Table 4.15 and Figure 4.15 present the distribution of responses concerning special preparations made during pregnancy. The question was designed to evaluate the extent to which pregnant women actively engage in planning and preparations to support their health and well-being during the maternity period.

Table 4.15: Distribution of Respondents Based on Awareness of Special Preparations During Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
yes	72	48.0	48.0
no	78	52.0	100.0
Total	150	100.0	

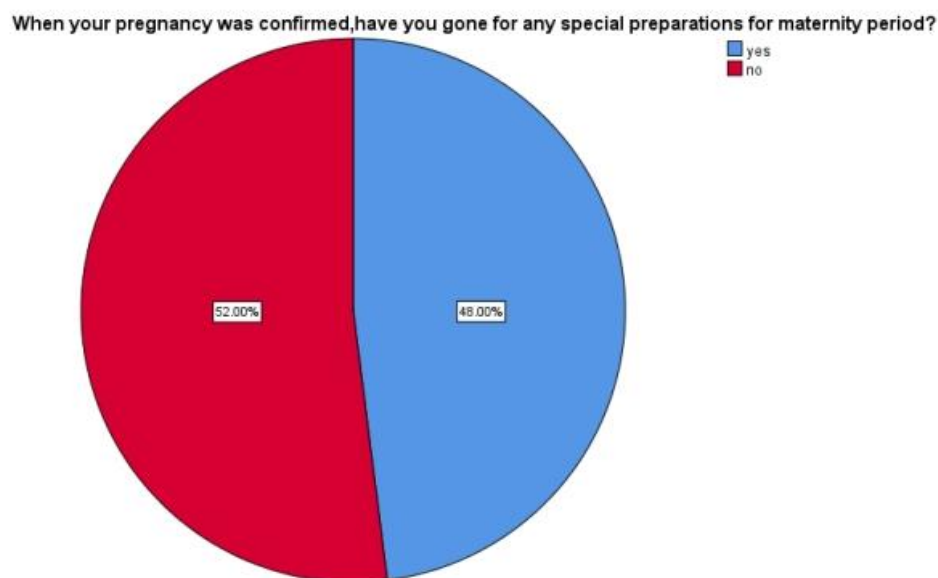


Figure 4.15: Special Preparations During Pregnancy

4.2.11 Types of Special Preparations During Pregnancy: A majority of the respondents, 52.67% reported not making any specific preparations. Meanwhile, 44.67% indicated that they had purchased maternity wear, new mom's essentials, personal care products and comfortable footwear. Additionally 2% of respondents more extensive preparations including maternity wear, personal care items, maternity accessories, baby essentials, and pregnancy and parenting books. A smaller group 0.67% mentioned preparing maternity support accessories, baby items and educational material on pregnancy and parenting. Table 4.16 and Figure 4.16 illustrate the different types of special preparations made by respondents during their maternity period. The question aimed to explore the variety of efforts undertaken by pregnant women to enhance their comfort, readiness and well-being during pregnancy.

Table 4.16 Distribution of Respondents Based on the Types of Special Preparations Undertaken During Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
purchase maternity wear, new mom's essentials, maternity personal care, purchase comfy footwear	67	44.7	44.7
maternity support accessories, baby essentials, pregnancy & parenting books	1	.7	45.3
none	79	52.7	98.0
maternity wear, mom's essentials, personal care, footwear, accessories, baby essentials, pregnancy & parenting books	3	2.0	100.0
Total	150	100.0	

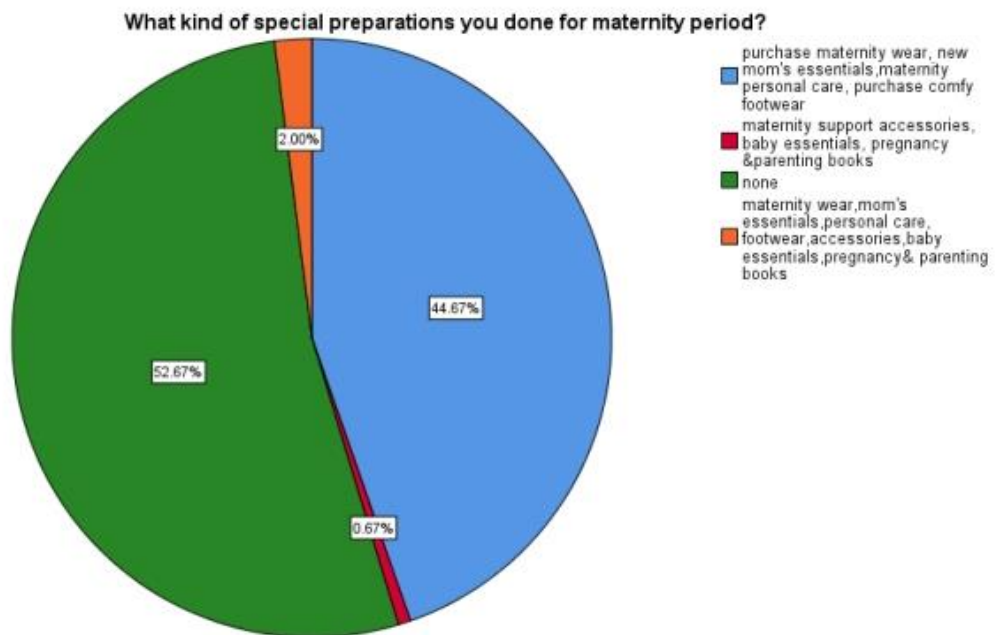


Figure 4.16: Types of Special Preparations During Pregnancy

Although most respondents shared health concerns with family members and attended regular antenatal check-ups, the reliance on periodic clinical visits indicates gaps in continuous health monitoring. This reinforces the relevance of smart maternity wear as a supplementary solution capable of providing real time insights between hospital visits, particularly for managing stress, discomfort and minor health fluctuations.

4.2.12 Special Clothing to Support the Maternity Period: A clear majority 83.33% agreed that dedicated maternity clothing is essential during pregnancy, while 16.67% felt it was not necessary. Table 4.17 and Figure 4.17 summarize respondents opinions on the necessity of specialized maternity wear. This question was designed to gauge the perceived importance of purpose built garments for comfort and support throughout the maternity period.

Table 4.17: Distribution of Respondents Based on the Requirement for Special Clothing During the Maternity Period

Parameters	Frequency	Percent	Cumulative Percent
yes	125	83.3	83.3
no	25	16.7	100.0
Total	150	100.0	

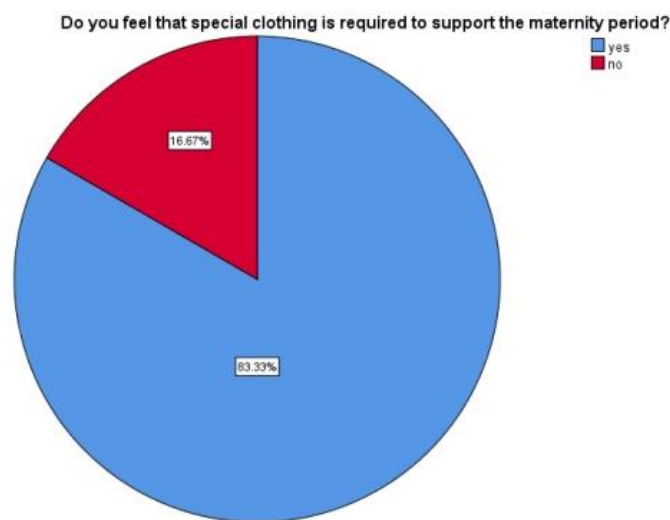


Figure 4.17: Special Clothing to Support the Maternity Period

4.2.13 Preference for Maternity Clothing During and Post Pregnancy: A significant majority of 96.67% expressed a preference for maternity dresses & skirts, ethnic wear, nursing/sleep wear, and tops & bottom wear including lingerie. A smaller portion 3.33% preferred a more comprehensive selection which also included personal care items and maternity support accessories in addition to the aforementioned clothing types. Table 8.18 and Figure 8.18 present the preferences of respondents regarding categories of maternity clothing. This question was designed to understand the specific types of maternity wear that women consider most useful during and after pregnancy.

Table 4.18: Distribution of Respondents Based on their Preference for Maternity Clothing

Parameters	Frequency	Percent	Cumulative Percent
maternity dresses & skirts ethnic wear, nursing/sleep wear, tops & bottom wear, lingerie	145	96.7	96.7
maternity dresses&skirts,ethnic,nursing/sleepwear,tops&bottom ,personal care,support accessories	5	3.3	100.0
Total	150	100.0	



Figure 4.18: Preference of Maternity Clothing During and Post Pregnancy

4.2.14 Special Features Preferred in Maternity Clothing: A significant majority 93.33% favoured garments with loose and breathable, flowy silhouettes, smooth textures, a comfortable fit and adjustable elements. Additionally 5.33% of respondents preferred a more comprehensive sets of features that included the above along with leggings/jeggings, maternity bras and stretchable materials. A smaller portion 0.67% specifically mentioned preferences for leggings/jeggings, bras, elastic/stretch materials, and drawstrings, in combination with core features of breathability, comfort and adjustability. The aim of this question was to understand which design attributes

pregnant women consider most important for ensuring both comfort and functionality during the maternity period. Table 4.19 and Figure 4.19 present the respondents preferences for special features in maternity clothing during pregnancy.

Table 4.19: Distribution of Respondents Based on Preferences for Special Clothing Features During Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
loose & breathable,flowy silhouettes,smooth cloth texture, proper fit according to comfort, adjustable features	140	93.3	93.3
loose/breathe,silhouettes,texture,comfort, adjustable,leggings/jeggings,bras,elastic/s	8	5.3	98.7
tretch			
leggings/jeggings, bras,elastic/stretch,drawstrings	1	.7	99.3
loose/breathe,silhouettes,texture,comfort, adjustable,legging/jegging,bras,elastic/str	1	.7	100.0
etch,drawstrings			
Total	150	100.0	

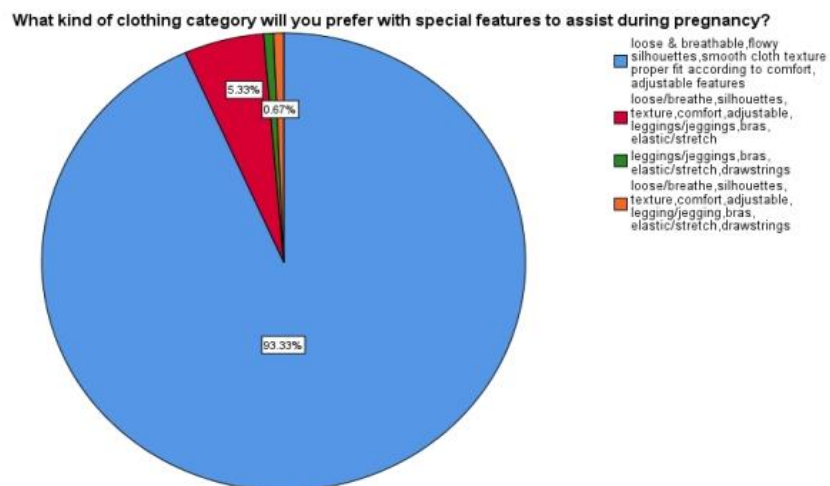


Figure 4.19: Special Features for maternity Clothing During Pregnancy

4.2.15 Mode of Shopping: A majority of 56% reported using both offline and online channels for their purchases indicating a balanced approach to shopping. Meanwhile, 26.67% preferred shopping exclusively through offline stores, and 17.33% favoured online platforms. This question aimed to evaluate the preferred shopping methods among pregnant women, offering insights into their purchasing behavior and accessibility to maternity products. Table 4.20 presents the shopping preferences of the respondents during pregnancy.

Table 4.20: Distribution of Respondents for Mode of Shopping

Parameters	Frequency	Percent	Cumulative Percent
offline	40	26.7	26.7
online	26	17.3	44.0
both	84	56.0	100.0
Total	150	100.0	

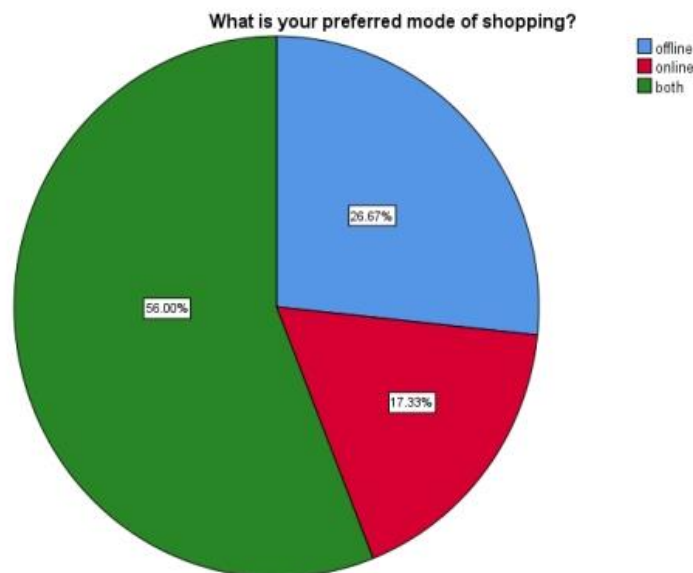


Figure 4.20: Preferred Mode of Shopping of Respondents

4.2.16 Pay Criteria for Maternity Clothing or Products: A majority of 59.33% indicated a willingness to pay between Rs. 1000 and 5000, while 33.33% were comfortable spending between Rs. 500 and 1000. Additionally 6% of respondents were open to paying between Rs. 5000 and 10,000, and a small portion 1.33% were willing to spend above Rs. 10,000. This question aimed to assess the budget range by pregnant women for maternity related purchases providing valuable insights into market affordability and pricing strategies. Table 4.21 and Figure 4.21 present the respondents' willingness to spend on maternity clothing and related products.

The strong preference for breathable fabrics, adjustable features and flowy silhouettes directly informed the design decisions adopted in the developed maternity garments ensuring alignment between user expectations and product outcomes.

Table 4.21: Distribution of Respondents Based on Willingness to Pay for Maternity Clothing and Products

Parameters	Frequency	Percent	Cumulative Percent
Rs. 500-1000	50	33.3	33.3
Rs. 1000-5000	89	59.3	92.7
Rs. 5000-10,000	9	6.0	98.7
Above Rs. 10,000	2	1.3	100.0
Total	150	100.0	

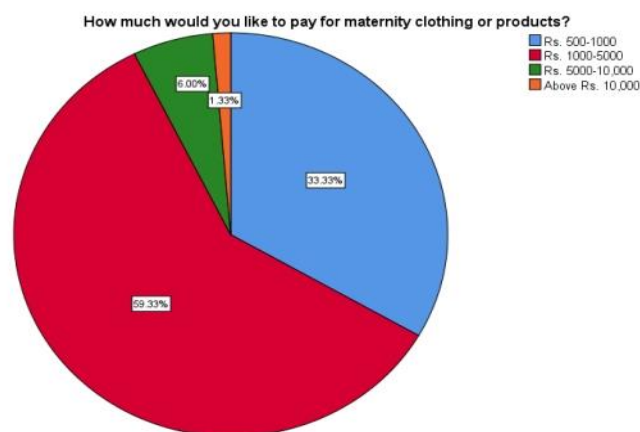


Figure 4.21: Paying criteria for maternity clothing or products

4.2.17 Awareness About Smart Maternity Clothing: A total of 54.67% of the respondents reported being aware of such products while 45.33% indicated a lack of awareness. This question was intended to evaluate the level of familiarity among pregnant women regarding the availability and concept of smart maternity wear and related innovations. Table 4.22 and Figure 4.22 present the data on respondents' awareness of smart maternity clothing or products.

Table 4.22: Distribution of Respondents for Awareness About Smart Maternity Clothing

Parameters	Frequency	Percent	Cumulative Percent
yes	82	54.7	54.7
no	68	45.3	100.0
Total	150	100.0	

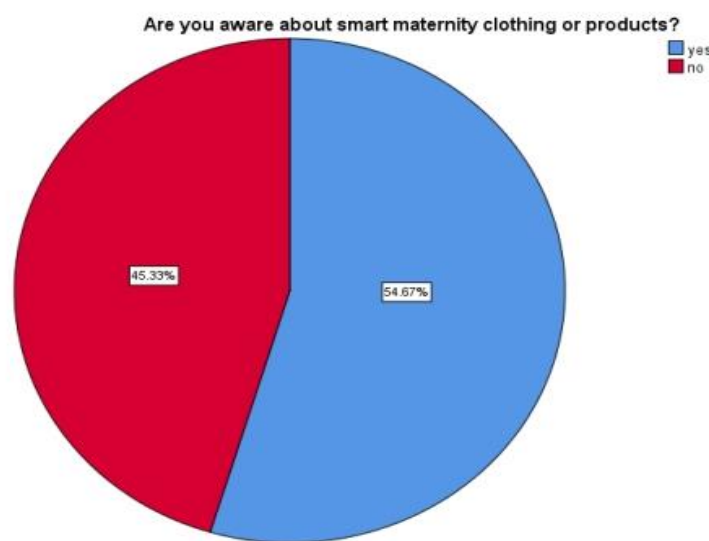


Figure 4.22: Awareness about Smart Maternity Clothing

4.2.18 Preference for Technology in Maternity Clothing: Among the participants 66% expressed interest in wearing technologically enhanced garments while 34% indicated no such preference. This question aimed to evaluate the acceptance and willingness of pregnant women to adopt maternity wear that incorporates innovative technological features to enhance comfort, monitoring or functionality. Table 4.23 and Figure 4.23 illustrate the respondents' preferences regarding the integration of technology into maternity clothing.

Table 4.23: Preference of Smart Maternity Clothing Beyond Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
yes	101	67.3	67.3
no	49	32.7	100.0
Total	150	100.0	

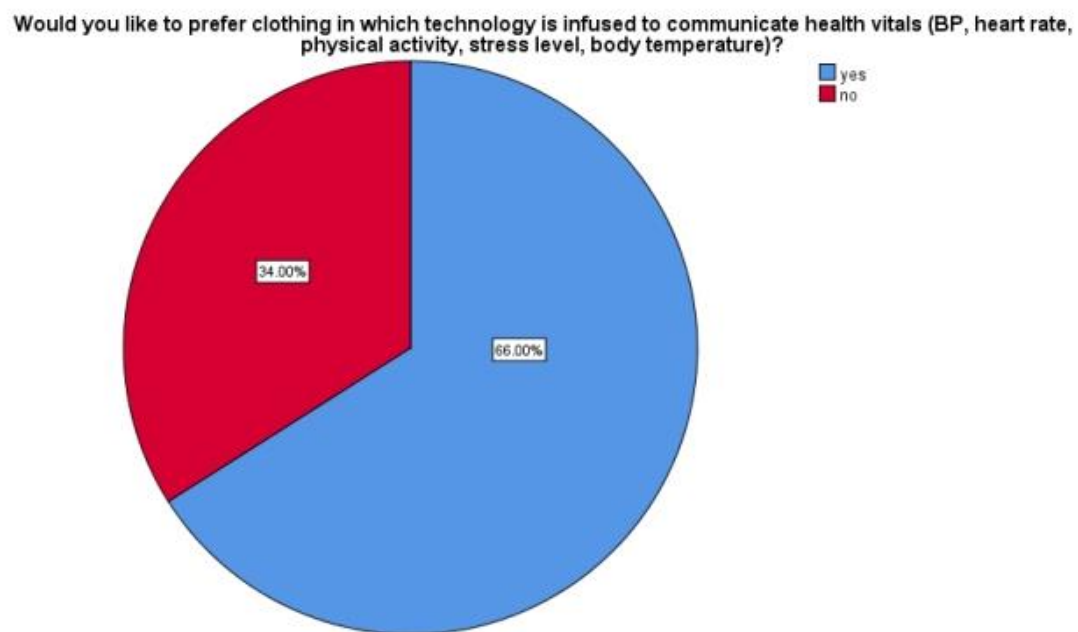


Figure 4.23: Preference for Smart Maternity Clothing of Respondents

Preference for Smart Maternity Clothing Beyond Pregnancy: A majority of 67.33% expressed interest in maternity wear that can be worn post-pregnancy while 32.67% indicated no such preference. This question aimed to assess the demand for versatile maternity garments that offer extended functionality and comfort beyond the gestational period. Table 8.24 and Figure 8.24 present the respondents' preferences regarding the usability of maternity clothing beyond the pregnancy period. While awareness of smart maternity clothing was moderate the high willingness to adopt technology integrated garments indicates a latent demand rather than resistance. This gap between awareness and acceptance highlights the need for user – centric smart maternity solutions that are familiar in appearance yet technologically supportive.

Table 4.24: Distribution of Respondents Based on Their Preference for Smart Maternity Clothing Beyond Pregnancy

Parameters	Frequency	Percent	Cumulative Percent
yes	101	67.3	67.3
no	49	32.7	100.0
Total	150	100.0	

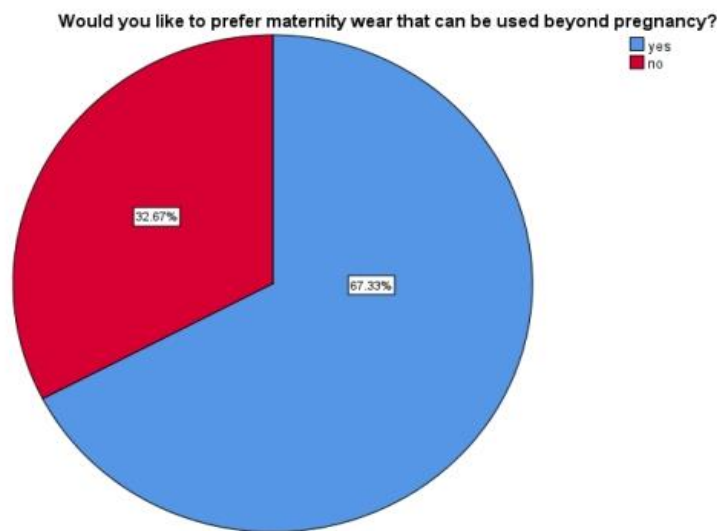


Figure 4.24: Preference for Smart Maternity Clothing Beyond Pregnancy

4.3 Statistical Summary and Data Analysis

This section provides a statistical overview of the key variables studied, summarizing respondent's demographic details, pregnancy experiences, and preferences regarding maternity clothing (Table 4.25).

Table 4.25: Summary Distribution of Respondents across Key Study Variables

Descriptive Statistics					
	N (sample size)	Minimum	Maximum	Mean	Std. Deviation
Age	150	1	3	2.22	.722
Qualification	150	1	5	3.11	1.044
Occupation	150	1	2	1.71	.454
Type of family	150	1	2	1.41	.494
Annual income	150	1	4	1.84	.852
Are you expecting?	150	1	1	1.00	.000
If yes, then what is the age of pregnancy?	150	1	3	2.43	.709
How did you confirm your pregnancy?	150	1	12	1.88	2.737
What kind of physiological changes are you experiencing during pregnancy?	150	1	123	20.38	34.873
How frequently you go for check-ups?	150	1	3	1.71	.617
Are you facing any symptoms of emotional transformation during pregnancy?	150	1	2	1.31	.465
What kind of symptoms you facing during pregnancy?	150	1	12	1.85	1.725
Do you share your physical and mental health related problems?	150	1	2	1.07	.262
With whom you share health related problems?	150	1	3	1.12	.477

When your pregnancy was confirmed, have you gone for any special preparations for maternity period?	150	1	2	1.52	.501
What kind of special preparations you done for maternity period?	150	1	12	2.28	1.707
Do you feel that special clothing is required to support the maternity period?	150	1	2	1.17	.374
What kind of maternity clothing will you prefer during and post pregnancy?	150	1	12	1.37	1.981
What kind of clothing category will you prefer with special features to assist during pregnancy?	150	1	123	2.55	10.355
What is your preferred mode of shopping?	150	1	3	2.29	.863
How much would you like to pay for maternity clothing or products?	150	1	4	1.75	.623
Are you aware about smart maternity clothing or products?	150	1	2	1.45	.499
Would you like to prefer clothing in which technology is infused to communicate health vitals (BP, heart rate, physical activity, stress level, body temperature)?	150	1	2	1.34	.475
Would you like to prefer maternity wear that can be used beyond pregnancy?	150	1	2	1.33	.471
Valid N (list wise)	150				

According to descriptive statistics, pregnant women have practical and emotional clothing needs during pregnancy. While most are not yet familiar with smart maternity wear, they expressed a strong desire to use wearable devices that provide health-monitoring benefits. This research emphasizes the market potential and practical need for producing smart maternity wear that combines comfort, style and health support.

Major Findings from The Survey:

1. The major physiological changes experienced by pregnant women were hormonal changes, body weight gain, nausea and frequent urination.
2. Most preferred garments were dresses and skirts, tops and bottom wear, nursing/sleepwear and ethnic wear.
3. Most preferred features included loose and breathable fabrics, flowy silhouettes, adjustability, comfortable fabric, elastic/stretchable materials.

These descriptive trends collectively validate the study's premise that pregnant women seek maternity wear that integrates comfort, adaptability and health support. The findings provide a quantitative foundation for advancing smart maternity garments as a viable and necessary innovation.

Section II Design & Development of Maternity Garments

4.4 Designing and Sketching of Garments

4.4.1 Designing & Sketching

Based on the identified physiological, emotional and clothing related needs, the study progressed toward the design and development of maternity garments that translate user insights into functional wearable solutions. Maternity clothes were specially designed to match the comfort level required by pregnant women during pregnancy. Comfort was supplemented with aesthetic appeal as attractive clothing played a significant role in boosting the confidence of expectant mothers, helping them feel beautiful in garments tailored specifically for them.

Building upon insights gathered from problem analysis; the research progressed to the conceptualization and design of smart maternity outfits. These designs aimed to address not only the comfort, functionality and aesthetic needs of pregnant women but also

integrated health-monitoring technologies to support maternal well-being throughout pregnancy.

Based on the existing clothing practices of expectant mothers the issues they encountered with their current garments and insights drawn from the reviewed literature, a total of 11 preliminary design sketches were created. These initial raw illustrations captured the essential design and functional preferences identified through research. Out of these 9 designs were further developed with specific design codes, incorporating features that prioritized both comfort and practicality. Among these 9, seven designs included maternity dresses, tops and bottoms and cord sets, while the remaining two were smart vests integrated with IoT-based health monitoring features. The refined versions of these sketches were later digitally rendered using CorelDRAW as discussed under a separate subheading.



Figure 4.25 (a) Flowy and elegant silhouette having gathers at bust area which allows room for the growing belly, ensuring comfort.

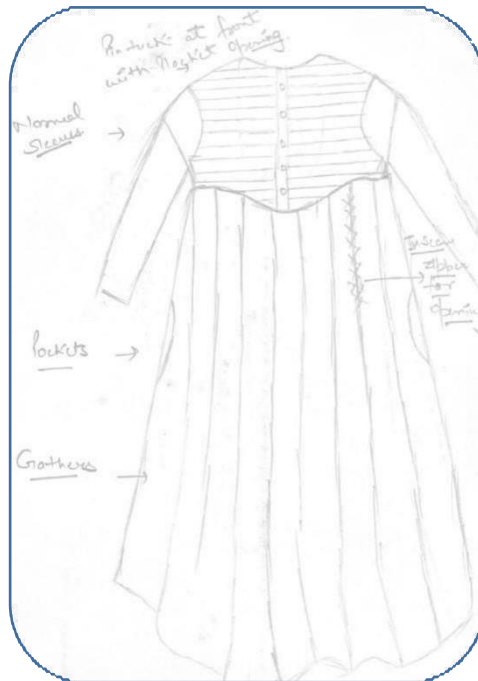


Figure 4.25 (b) This maternity dress design features a front yoke with pleats and a placket opening, normal sleeves, gathered skirt with side pockets, and an in-seam zipper for added functionality.

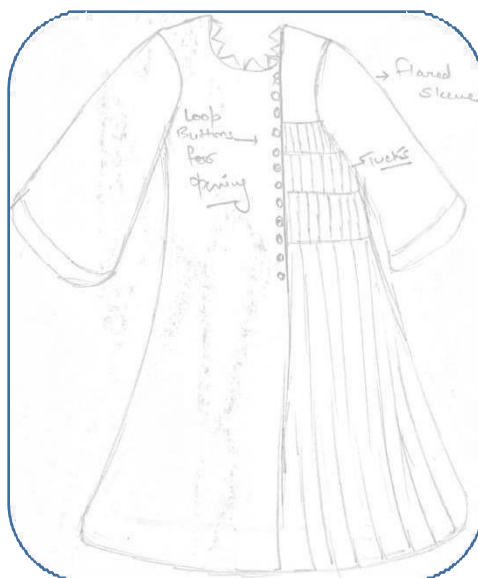


Figure 4.25 (c) This maternity garment design features loop buttons for front opening, flared sleeves for ease and style, and neatly arranged tucks on one side of the bodice extending into the skirt for added volume and comfort.



Figure 4.25 (d) This A-line tunic maternity design features puffed sleeves, an in-seam pocket, loop buttons for front opening and a side knot to adjust the fit and loosen the garment as needed.

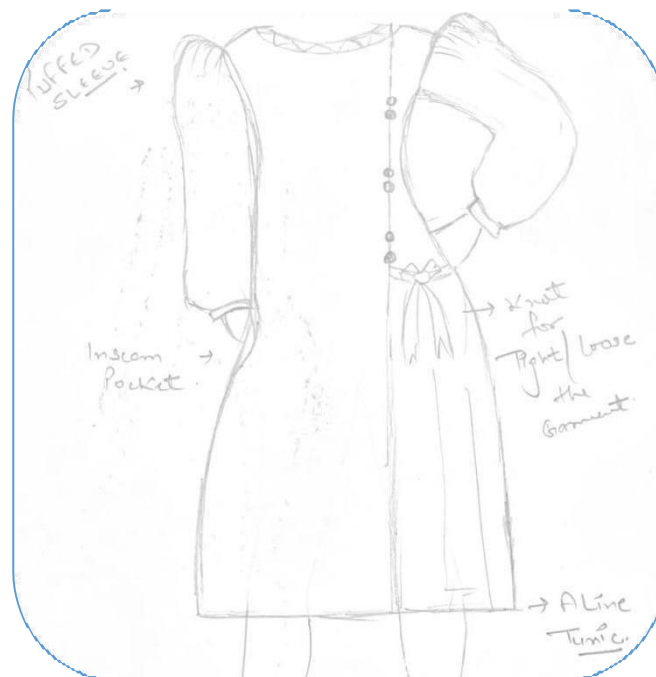


Figure 4.25 (e) This wrap-style maternity tunic features a diagonal front opening with buttons, 3/4th sleeves with contrast bands and a side pocket for added functionality.



Figure 4.25 (f) This flowing maternity dress features layered flared sleeves, a square neckline with decorative trim a drawstring below the bust for adjustable fit and a soft gathered skirt for added comfort and style.



Figure 4.25 (g) This T-shirt dress design features a front button-down closure, gathered drawstring detailing under the bust, patch pockets on the chest and cuffed full sleeves combining casual style with adjustable comfort.



Figure 4.25 (h) This balloon-hem dress design features a front placket opening, in-seam zipper access, side gathering for flexibility, full sleeves with buttoned cuffs and multiple functional pockets for practicality and ease.



Figure 4.25 (i) This sleeveless wrap-style dress features a V-neckline, a concealed zipper for easy opening, a front tie belt for adjustable fit and two large front patch pockets for added convenience and functionality.



Figure 4.25 (j) This full-sleeve dress design features puffed sleeves with cuff details, a front button placket for closure, a waist tie-belt for knotting to enhance fit and a patch pocket on one side for added utility.

Figure 4.25 (a-j): Design Sketches of Maternity Garments

4.4.2 Evaluation of Sketches by Experts

A comprehensive range of maternity garments including maxi and midi dresses, tunics, cord sets, tops and a vest-style waistcoat was developed as part of this study. These designs were tailored to meet the specific needs of pregnant women with careful attention to functionality, comfort and aesthetic appeal. To assess the effectiveness and suitability of the garments an expert evaluation was carried out.

A panel of five experts from the field of Fashion and Textiles evaluated the sketched designs through a systematic visual inspection process. The evaluation involved both qualitative assessment and design validation based on practical relevance and user-centric features. Key analytical details from the expert review included:

4.4.2.1 Qualitative Assessment Criteria:

The designs were assessed on multiple parameters including:

1. Comfort and fit suitability during different stages of pregnancy.
2. Functional features such as nursing access points, adjustability and fabric selection.

3. Aesthetic appeal, silhouette, color balance and garment layering.
4. Practical aspects of wearability, including ease of wear, garment length and freedom of movement.

4.4.2.2 Visual Inspection:

Experts visually examined all 11 preliminary sketches to evaluate how well the designs aligned with the research findings regarding the needs and preferences of expectant mothers.

4.4.2.3 Recommendations and Minor Modifications:

Based on the expert feedback, minor yet crucial design adjustments were suggested:

1. Adjustment of nursing access points for better usability.
2. Length modification of dresses to avoid floor-touching lengths and enhance walking comfort (e.g., calf-length or ankle-length recommendations).
3. Refinements in adjustable features (e.g., side panels, elastic bands) to accommodate body size changes.
4. Emphasis on soft, breathable fabrics to improve overall comfort and skin compatibility.

4.4.2.4 Final Design Range Selection

After incorporating expert recommendations and making necessary refinements, a final range of 11 smart maternity wear designs was selected for prototype development. These included:

1. **7 designs** comprising maternity dresses, tops & bottoms, and cord sets.
2. Two **smart vests** integrated with IoT for health monitoring.

This expert panel assessment served as a critical step in validating the practicality, aesthetics and user alignment of the proposed maternity wear.

4.5 Material Sourcing for the Maternity Garments

In designing the maternity wear range, careful attention was given to selecting materials and components that support both functionality and comfort for pregnant and postpartum-phase. The sourcing process focused on fabrics, fasteners, trims and sewing supplies that would enhance the wearability, flexibility and longevity of each garment. Fabrics were

primarily sourced from the local market of Ludhiana known for their wide variety of affordable and quality knit, stretch and woven fabrics. These fabrics were chosen for their softness, breathability and stretch to accommodate the changing body during pregnancy. Lightweight and comfortable textiles were prioritized to ensure ease of movement and all-day comfort.

To ensure smooth and durable construction, high-quality sewing threads were used including smocking thread for decorative and functional elasticity. Smocking was applied in selected areas to gently shape the garment and allow flexibility without tightness or discomfort.

- ✓ Soft, breathable pure cotton was chosen for its skin-friendly properties ideal for sensitive pregnant skin. Cotton blends such as cotton-rayon were used to enhance drape and flexibility, offering a gentle feel with added durability. Knitted fabrics provided the necessary stretch, especially useful for tunics and gloves that required ease of movement. To bring visual interest, printed fabrics were incorporated while plain fabrics were used to create balance and complement the overall design.
- ✓ Concealed zippers were strategically placed in various garments to allow discreet and convenient nursing access. These zippers maintain a clean stylish look while supporting practical needs during and after pregnancy.
- ✓ Snap buttons were added to the front yokes of some outfits particularly tops and tunics to simplify breastfeeding access. These snaps provide a neat finish and are easy to use.
- ✓ Standard buttons were included not only for their functional role in closures but also as design details to enhance the overall aesthetic of dresses and tops.
- ✓ To support adjustability drawstrings and adjustable belts were integrated into several garments. These features help expectant mothers modify the fit as their body changes throughout different stages of pregnancy.
- ✓ A buckle belt was added to the vest-style waistcoat allowing for a snug supportive fit that can be easily adjusted for comfort and shape.
- ✓ Velcro was also incorporated into select functional areas for ease of use and quick adjustability.
- ✓ In the smart vest design, ribbons were cleverly used to conceal sensor wires maintaining the garment's clean appearance while enabling the integration of wearable health technology.

By thoughtfully sourcing these materials and components, the maternity wear range supports ease of wear, nursing functionality and adaptability. These elements extend the garment's usefulness across pregnancy, postpartum and nursing stages while upholding style and sustainability.

4.6 Integration of IoT in Smart Vests and Gloves

As part of this study, smart vests and gloves were thoughtfully designed to help monitor key health parameters in a simple, wearable form for pregnant women. The smart vest featured an ECG sensor gently placed at chest level to track heart rate with soft conductive wires linking it to a small micro controller tucked neatly into a side pocket making it easy to wear without disrupting daily activities. The smart gloves were fitted with tiny pulse and mood sensors at the fingertips, connected through insulated stitching inside the fabric to ensure comfort. Both garments used Bluetooth technology to transmit real-time health data to a mobile device offering expectant mothers a convenient and non-intrusive way to stay informed about their well-being. This integration aimed to support maternal health, particularly in settings where regular medical access might be limited blending ease, comfort and functionality into everyday maternity wear. In the present study, these technological capabilities were translated into a wearable maternity vest designed to function seamlessly within daily clothing routines thereby avoiding the intrusiveness commonly associated with standalone medical devices.

4.7 Final Construction of Selected Maternity Designs

On the basis of existing clothing practices of expectant mothers, problems they faced with their existing clothing and literature reviewed, nine maternity outfits were designed and sketched with design code ranging from MG-1 to MG-7 (Plate 1 to 7) and for smart vest ranging from SMV 1 & SMV 2 (Plate 8 &9) keeping in mind the preferred designing and functional features.

All the designs were illustrated with the help of software CorelDraw which was very beneficial during stitching and after stitching. The illustrations of the maternity outfits which were developed with the help of software CorelDraw along with detailing were mentioned above.

4.7.1 DESIGN NO.1



Figure 4.26: Maternity Garment (MG-1)

4.7.2 DESIGN NO -2



Figure 4.27: Maternity Garment (MG-2)

4.7.3 DESIGN NO -3



Figure 4.28: Maternity Garment (MG-3)

4.7.4 DESIGN NO -4



Figure 4.29: Maternity Garment (MG-4)

4.7.5 DESIGN NO -5



Figure 4.30: Maternity Garment (MG-5)

4.7.6 DESIGN NO -6

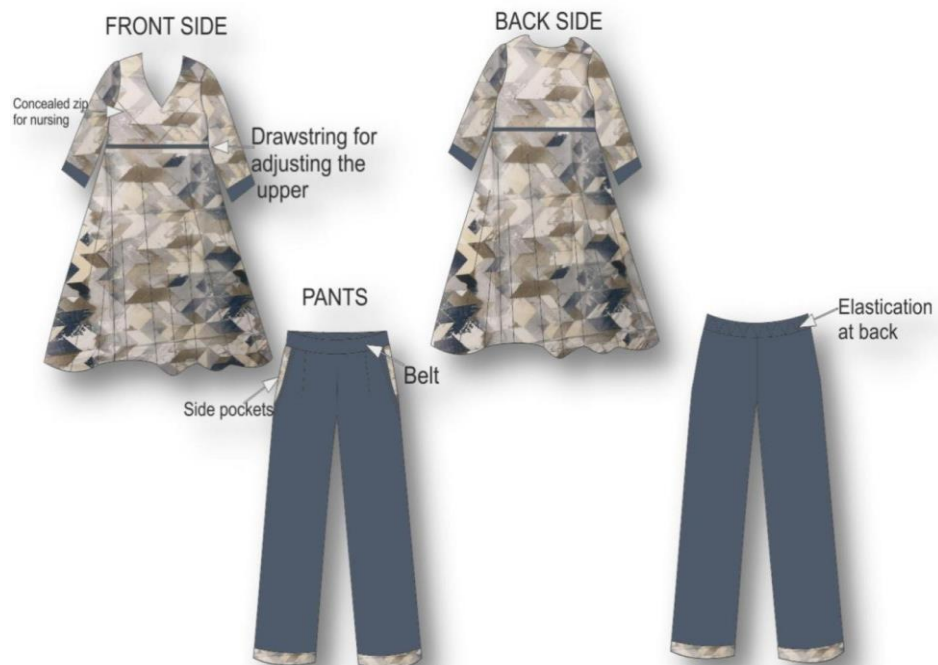


Figure 4.31: Maternity Garment (MG-6)

4.7.7 DESIGN NO -7

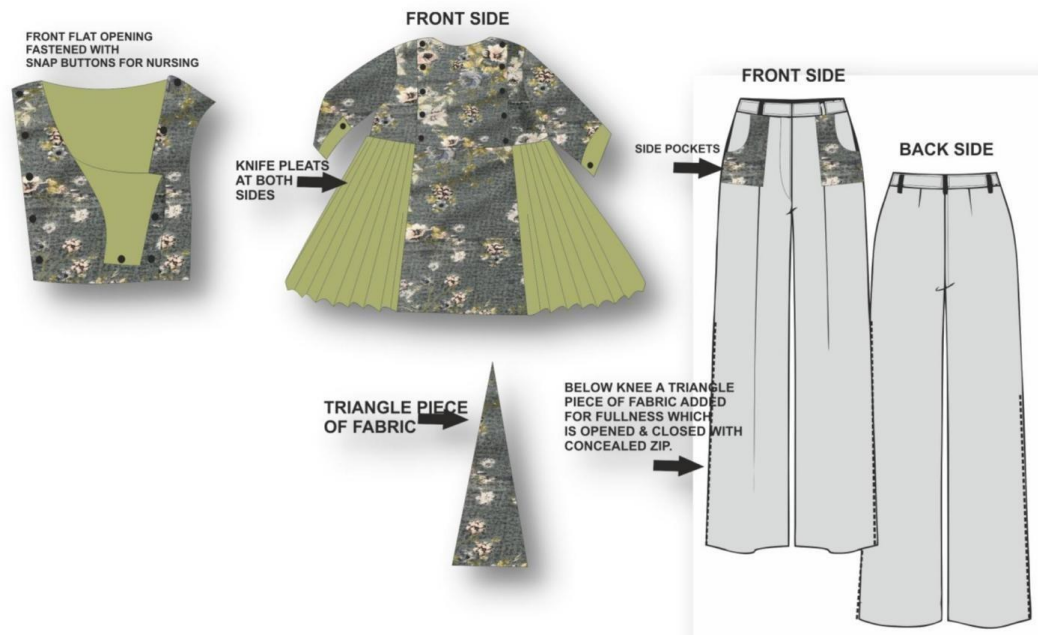


Figure 4.32: Maternity Garment (MG-7)

4.7.8 DESIGN NO -8



Figure 4.33: Maternity Garment (MG-8)

4.7.9 DESIGN NO -9



Figure 4.34: Maternity Garment (MG-9)

All the smart maternity garments developed in this study were thoughtfully designed to support the comfort, daily needs and changing body of pregnant women. Soft, breathable fabrics such as cotton, cotton blends and stretchable knits were carefully selected to ensure ease of movement and a gentle feel against the skin. Across the collection, common features included adjustable tie-ups, elasticated waistbands and front openings with concealed zippers allowing each garment to adapt as the pregnancy progressed. Discreet nursing access points, integrated through side zips, plackets or layered panels made the garments practical for continued use after childbirth. The silhouettes were relaxed yet modern, spanning a variety of styles such as dresses, tunics, tops with bottoms, and cord sets suitable for both at-home wear and casual outings. For the technology-enabled garments such as the smart vest and gloves sensors were seamlessly embedded in the fabric, maintaining comfort and flexibility. Overall, the designs represented a thoughtful balance of aesthetics, functionality and technology, catering to the evolving needs of mothers during and beyond pregnancy.

4.8 Cost Analysis of Developed Garments

To assess the affordability and market suitability of the developed maternity garments, the cost of each item was carefully calculated. This analysis aimed to determine whether the garments fell within the price range preferred by the majority of expectant mothers, as identified during the initial survey.

The costing process took into account several key components:

- ✓ Fabric cost used in the construction of each garment
- ✓ Cost of embellishments and design elements
- ✓ Stitching and tailoring charges

These elements were combined to estimate the total cost of producing each maternity apparel. The detailed cost breakdown for all constructed garments is presented in Table 4.30 and Table 4.31.

The cost analysis and pricing estimates presented in this study are based on the respondents willingness to purchase and their perceived affordability of the developed smart maternity garments. Since the garments were developed as research prototypes, the proposed prices reflect participant's purchase intention rather than actual market transactions or long term consumer purchasing behaviour. Therefore, these findings provide an initial indication of consumer acceptance and pricing expectations. Future studies may further validate these estimates through commercial product trials, market testing and evaluation of actual purchasing behaviour following product commercialization.

4.9 Development of the Catalogue

To collect the post feedback for the maternity outfits based on comfort, function and durability grounds; catalogue was created and the information regarding the whole catalogue was mentioned in the Chapter -3. The catalogue was comprised of all the photographed maternity outfits wearing by the model shown in the figures. Each outfit titled differently with its unique name which represents its own identity of the whole range.



Figure 4.35: Boho Grace



Figure 4.36: From Bump to Bloom



Figure 4.37: Empowered Motherhood



Figure 4.38: The Everyday Mama



Figure 4.39: Wrapped In Motherhood



Figure 4.40: Graceful Co-ord

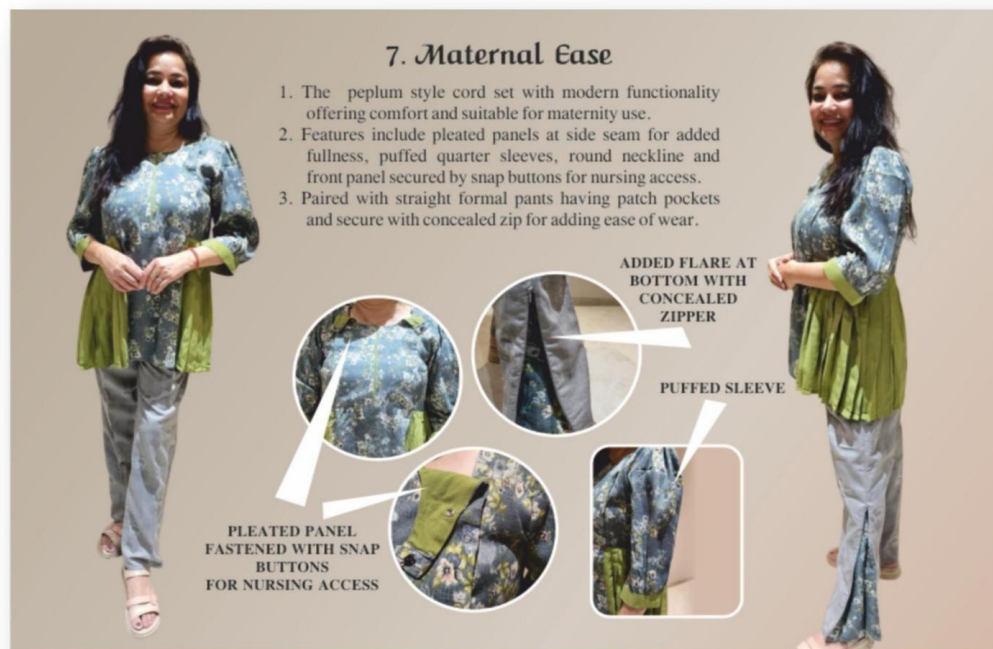


Figure 4.41: Maternal Ease



Figure 4.42: Mother's Rhythm



Figure 4.43: Tech Comfort Vest



Figure 4.44: Glove Tech

Section III: Garment Evaluation and Feedback

A group of 15 pregnant women in their third trimester was carefully selected to obtain feedback on the developed range. To establish a context, they were first asked to respond to a few basic questions related to clothing importance and preference during pregnancy before moving on to the trial phase. This group was distinct from those who participated in the initial survey, as the purpose here was to obtain hands-on feedback through practical usage rather than general opinion-based input. The decision to limit the sample size to 15 participants was intentional. A smaller group enabled more focused attention, closer monitoring and meaningful interaction with each respondent during the garment trial. One specific reason for keeping the sample size limited was the advanced stage of pregnancy of the participants and the nature of the trial, which required a sufficient amount of time for each wearer to comfortably and safely put on and take off the garments, ensuring a respectful and patient centered assessment process.

4.10 User Perceptions Towards Maternity Clothing

Prior to conducting the garment wear trials, participants were engaged to understand their perceptions and expectations regarding maternity clothing. This inquiry served as a contextual foundation before introducing smart maternity wear for practical testing.

4.10.1 Importance of Clothing During Pregnancy

The responses to this question clearly revealed a shared perspective among all 15 participants. Every single respondent agreed that clothing plays a vital role during pregnancy. This unanimous response reflected just how important it was for maternity wear to provide comfort, support and functionality throughout this unique and often challenging phase of life.

The feedback highlighted that thoughtfully designed garments can make a meaningful difference in the everyday experience of expectant mothers. From feeling confident in their appearance to managing the physical changes more comfortably, the right clothing can truly support a woman's journey through pregnancy and beyond. These findings affirmed the core purpose of this research to develop maternity wear that not only fit well but also adapts to changing body needs, offering nursing access and thoughtfully integrate smart and sustainable elements for better usability and care.

Table 4.26: Summary Distribution of Maternity Garments

N		Minimum	Maximum	Mean	Std. Deviation
RESPONDENT	15	1	15	8.00	4.472
MG1 COMFORT	15	3	5	4.33	.816
MG2 COMFORT	15	4	5	4.33	.488
MG3 COMFORT	15	4	5	4.47	.516
MG4 COMFORT	15	3	5	3.93	.594
MG5 COMFORT	15	4	5	4.80	.414
MG6 COMFORT	15	3	5	4.07	.799
MG7 COMFORT	15	3	5	4.33	.617
MG1 FIT	15	4	5	4.40	.507
MG2 FIT	15	3	5	4.27	.961
MG3 FIT	15	3	5	4.00	.845
MG4 FIT	15	3	5	4.00	.845
MG5 FIT	15	4	5	4.67	.488
MG6 FIT	15	3	5	3.93	.704
MG7 FIT	15	3	5	4.27	.704
MG1 DESIGN FEATURES	15	3	5	4.33	.724
MG2 DESIGN FEATURES	15	3	5	4.33	.724
MG3 DESIGN FEATURES	15	3	5	3.93	.704
MG4 DESIGN FEATURES	15	4	5	4.53	.516

Table 4.27: Distribution of Respondents for Preference of Importance of Clothing During Pregnancy Period

Frequency		Percent	Cumulative Percent
	5	33.3	33.3
Comfort and Ease of Movement, Boosting Confidence and Body Image	10	66.7	100.0
Total	15	100.0	

4.10.2 Clothing Preferences During Pregnancy

All 15 respondents wholeheartedly agreed that clothing held significant importance during pregnancy. Comfort and ease of movement were universally valued, with every participant identifying them as essential. Moreover, two-thirds of the group also felt that the right clothing positively impacted emotional and psychological well-being during this transformative phase.

Table 4.28: Distribution of Respondents for Preference of Clothing During Pregnancy

Response (n=15)	Frequency	Percentage (%)
Yes	15	100.0
No	0	0

4.10.3 Willingness to Try Smart Maternity Wear

All 15 respondents gave their consent to try out the range of the smart maternity outfits within their everyday environment. The garments were worn for a full day during routine activities to stimulate real life usage to evaluate comfort, functionality and ease of use. Participants were encouraged to provide honest feedback based on their personal

experiences, which offered valuable insights into the practical relevance and user acceptance of the designs.

Table 4.29: Distribution of Respondents for Preference to Try the Smart Maternity Wear Range Developed for Study

Response (n=15)	Frequency	Percentage (%)
Yes	15	100.0
No	0	0

4.11 Wear Trials Evaluation of Smart Maternity Wear

Each woman was provided with sample garments to wear and test in their everyday environments, reflecting real-life usage scenarios. They were asked to evaluate all the seven smart maternity garments based on five key parameters:

- Comfort
- Fit
- Design Features
- Fabric Feel
- Overall Appearance

Each parameters was rated using a 5-point scale; where 1 indicated Poor, 2 Fair, 3 Good, 4 Very Good and 5 Excellent. The consolidated frequency distribution of user ratings is presented in Table 4.26. Notable, none of the participants rated any garment as 1 or 2, which suggests that the garments were well-received. Most feedback fell in the 3 to 5 range, showing a generally favorable response. These responses were analyzed using descriptive statistical methods and proved instrumental in refining the final designs ensuring they were not only functionally effective but also aligned with the real-life expectations and aesthetic choices of pregnant women.

Table 4.30: Frequency Distribution of User Ratings for Maternity Garments Across Evaluation

Garment Code	Comfort					Fit					Design Features					Fabric Feel					Overall Appearance					Mean Scores
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	
MG1	8	4	3	-	-	6	9	-	-	-	7	6	2	-	-	10	5	-	-	-	6	8	1	-	-	4.41
MG2	5	10	-	-	-	9	1	5	-	-	7	6	2	-	-	9	5	1	-	-	10	3	2	-	-	4.40
MG3	7	8	-	-	-	5	5	5	-	-	3	8	4	-	-	11	4	-	-	-	3	7	5	-	-	4.20
MG4	2	10	3	-	-	5	5	5	-	-	8	7	-	-	-	12	3	-	-	-	3	1	2	-	-	4.27
MG5	12	3	-	-	-	10	5	-	-	-	1	5	-	-	-	2	10	3	-	-	6	5	4	-	-	4.44
MG6	5	6	4	-	-	3	8	4	-	-	9	3	3	-	-	6	8	1	-	-	6	9	-	-	-	4.23
MG7	6	8	1	-	-	6	7	2	-	-	3	10	2	-	-	4	8	3	-	-	5	9	1	-	-	4.20

- In the trial assessment, MG5 emerged as the top-performing garment with the highest overall average rating of 4.64 making it the most preferred choice among participants.
- MG1 and MG2 also received strong feedback, with close average scores of 4.41 and 4.40 reflecting a high level of satisfaction.
- MG3 and MG7 followed with solid ratings of 4.20 while MG6 and MG4 showed good performance particularly in aspects like fabric feel though their overall scores were slightly lower in comparison.

4.12 Feedback on IoT Integrated Vests and Gloves

The positive evaluation outcomes demonstrate the feasibility of integrating health – monitoring technology into maternity garments without comprising comfort or aesthetics establishing the developed smart maternity wear as a novel hybrid between apparel and healthcare support. Based on feedback from 15 respondents, SMV1 emerged as the most well-received smart maternity vest with consistently high ratings in functionality (4.40), silhouette (4.40) and comfort (4.47). SMV2 followed with moderate scores across parameters indicating decent performance but slightly lower user preference. The G1-G2 garment set showed generally positive results though it received the lowest ratings overall particularly in maintenance (3.47). Overall, all garments were rated between 3 and 5 reflecting a satisfactory level of user approval.

Table 4.31: Frequency Distribution of User Ratings for Smart Vest and Gloves Across Evaluation Parameters

Smart Vest Code	Functionality					Silhouette					Comfort					Maintenance					Mean Scores
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	
SMV 1	7	7	1	-	-	6	9	-	-	-	7	8	-	-	-	12	3	-	-	-	4.27
SMV 2	2	10	3	-	-	2	7	6	-	-	4	6	5	-	-	9	6	-	-	-	3.80

Gloves	Functionality					Comfort					Maintenance					Mean Scores
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	
G1-G2	2	9	4	-	-	3	8	4	-	-	-	7	8	-	-	3.76

- Among the three garments evaluated SMV1 emerged as the most preferred option receiving the highest overall mean rating of 4.27.
- SMV2 followed with a respectable average of 3.80 indicating moderate user satisfaction.
- The G1-G2 garments while rated slightly lower at 3.76 still reflected a generally positive response from the participants.

In addition to the quantitative evaluation, qualitative feedback obtained during the wear trial indicated that a few participants perceived the external rechargeable power bank as adding slight bulk to the smart maternity vest during prolonged use. However, this did not significantly affect the overall functionality or user acceptance of the developed prototype. The detachable power bank was intentionally incorporated to facilitate charging, maintenance and garment washability. Nevertheless, some participants suggested that a more compact power source could further enhance comfort and ease of movement. Future research may focus on integrating miniaturized or textile- based energy storage technologies to improve the overall wearability and user experience of smart maternity garments.

4.13 Pricing Acceptability

4.9.2.5 Price Consideration for Maternity Wear

The responses regarding the price range of Rs. 1200/- to Rs. 1800/- for maternity maxi/midi dresses revealed thoughtful consumer perspectives. About 33.3% of the respondents stated they would be very likely to purchase maternity wear at this price while 46.7% noted their decision would depend on the quality and features offered. Another 20% indicated they would be somewhat likely to consider the purchase. Interestingly, none of the participants selected

Not likely, showing a general openness to the pricing with an emphasis on value for money and garment functionality. This suggests that while affordability matters, quality and thoughtful design are key decision-making factors for expectant mothers.

Table 4.32: Distribution of the Respondents on the Preference of Purchasing the Maternity Wear

Response (n=15)	Frequency	Percentage (%)
Very likely	05	33.3
Somewhat likely	03	20.0
Not likely	0	0
Depends on quality/features	07	46.7
Total	15	100.0

4.9.2.6 Price Consideration for Maternity Co-ord Sets

The feedback on the pricing of maternity cord-sets ranging between Rs. 1200/- and Rs. 1500/- shows encouraging interest from the respondents. One-third (33.3%) expressed they would be very likely to purchase at this price point while 46.7% preferred to base their decision on the quality and features of the garments. Another 20% indicated they would be somewhat likely to consider buying them. Importantly, no respondents chose Not likely, which signals a general acceptance of the price range again emphasizing that comfort, functionality and value-added design elements strongly influence purchase intent.

Table 4.33: Distribution of the Respondents on the Preference of Purchasing the Smart Vest

Response (n=15)	Frequency	Percentage (%)
Very likely	05	33.3
Somewhat likely	03	20.0
Not likely	0	0
Depends on quality/features	07	46.7
Total	15	100.0

4.14 Practical Adoption & User Confidence

4.9.2.7 Smart Maternity Vest: Adding It to The Everyday Pregnancy Wardrobe

The responses indicate a promising level of interest in the smart maternity vest as part of a regular pregnancy wardrobe. Just over half of the participants 53.3% expressed a willingness to use it regularly while the remaining 46.7% said they would prefer to use it occasionally depending on specific needs or situations such as medical check-ups, travel or periods of discomfort. Notably none of the respondents rejected the idea altogether suggesting that the product holds strong potential for integration into daily maternity wear, especially when comfort and health monitoring are priorities.

Table 4.34: Distribution of Respondents' Preference for Adding Smart Maternity Vest into Their Daily Wardrobe

Response (n=15)	Frequency	Percentage (%)
Yes	8	53.3
No	0	0
Occasionally, for specific situations	7	46.7
Total	15	100.0

4.9.2.8 Smart Vest: A Promising Investment for Comfort, Health Monitoring and Maternity Needs

The feedback from respondents indicates a strong sense of approval regarding the potential of the smart vest in meeting maternity-related needs. A significant 66.7% of participants strongly agreed that the vest is a valuable investment for enhancing comfort and enabling health monitoring during pregnancy. Meanwhile 33.3% of the respondents remained neutral possibly indicating a need for further awareness or hands-on experience with the product. Importantly no negative responses were recorded reinforcing the idea that the vest is perceived positively and holds potential for real-world application among expectant mothers.

Table 4.35: Distribution of Respondents' Preferences Regarding Smart Vest as a Promising Investment for Comfort, Health Monitoring and Maternity Needs

Response (n=15)	Frequency	Percentage (%)
Strongly agree	10	66.7
Agree	0	0
Neutral	5	33.3
Disagree	0	0
Strongly disagree	0	0
Total	15	100.0

Overall the findings confirm that smart maternity wear designed through a user – centric and need based approach can play a meaningful role in enhancing maternal comfort, psychological reassurance and health monitoring thereby contributing to preventive and personalized maternal care.

CHAPTER-5

SUMMARY & CONCLUSION

Pregnancy is a transformative phase marked by significant physiological, emotional and psychological changes which directly influence women's clothing needs and preferences. Expectant mothers are conscious of their appearance while simultaneously prioritizing comfort, mobility and well-being particularly during the second and third trimesters. Clothing that fails to accommodate these evolving needs can adversely affect physical comfort, emotional confidence and overall quality of life. Maternity apparel therefore plays a critical role not only in addressing anthropometric changes but also in supporting psychological reassurance and daily functional ease for pregnant women.

The investigation has provided a useful database about the problem areas and needs of pregnant women, designing of maternity (clothing) outfits, production integrated with technology to monitor & communicate the health condition and awareness about smart maternity clothing, while assessing the comfort, functionality, durability & health monitoring.

The study successfully generated primary, user-centric data that bridged the gap between maternity clothing design and wearable health technology. By integrating insights related to comfort, functionality, durability and health awareness; the research offers a holistic framework for the development of maternity wear that responds to both apparel and healthcare needs.

The present study was therefore planned with the following objectives:

1. To understand the needs and problem areas of pregnant women in the second and third trimesters.
2. To design a maternity range with adaptive silhouettes and a vest based detachable health monitoring module
3. To develop the maternity garments ensuring the longevity of the design & monitoring system.
4. To assess the performance of the maternity garments on comfort, function and durability parameters.

The Summary & Conclusion are described under following heads.

5.1 Limitations of the Study

5.2 Methodology

5.3 Major findings

5.4 Conclusion

5.5 Implications & Recommendations of the study

5.6 Scope for further studies

5.1 Limitations of the Study

1. Limited sample size for testing.
2. Technical challenge in integrating sensors into the maternity clothing.
3. Socio-psychological acceptance barriers for smart wearables.
4. The detachable nature of smart components while enhancing usability and maintenance limited the scope of evaluating fully embedded textile- based systems.
5. The developed smart maternity wear prototype utilized an external rechargeable power bank to operate the embedded electronic components. Although this configuration ensured reliable power supply and simplified charging and maintenance, it slightly increased the bulk of the garment during prolonged use. Future studies may explore miniaturized batteries or textile-based energy storage technologies to improve comfort and wearability.
6. The wear trial and user evaluation of the developed smart maternity wear were conducted with 15 participants. Although this sample size was appropriate for prototype evaluation, future studies involving larger and more diverse populations are recommended to enhance the generalizability and clinical validation of the findings.

5.2 Methodology

The present study combined both exploratory & experimental research design to meet the objectives of the study. The sample was selected according to the non-probability method by following stratified sampling technique. The healthcare institutes or hospital organizations were selected according to the non-probability method. Principal tool used to gather information was an interview cum- observation schedule. Personal interview method was used for data collection. Post data survey was conducted to test

the interview cum observation table. Tools were appropriately modified and used in final data collection. Survey method was used to assess the existing clothing practices of expectant mothers, problems faced, their general attributes and functional as well as designing features of clothing, physiological changes, awareness of smart clothing & sensors. Experimental research design was used for designing, construction, integration, assessment and acceptability of maternity outfits. Collected data were tabulated and analyzed using descriptive as well as inferential statistics via; frequency, percentage, mean score, rank and analysis of variance employed was coefficient of rank correlation and χ^2 (chi square) test. This combined methodological approach ensured that both user perceptions and technical feasibility were systematically addressed, strengthening the validity of the research outcomes.

5.3 Major Findings

During pregnancy women undergo several significant physiological changes including hormonal fluctuations, weight gain, nausea and frequent urination. These changes greatly influence their clothing preferences and comfort needs. As a result, many pregnant women tend to favour garments such as dresses, skirts, tops paired with bottoms, ethnic wear and specialized nursing or sleepwear. In terms of design features, there is a strong preference for outfits that offer comfort and adaptability particularly those with loose and breathable fabrics, flowy silhouettes, elasticated elements, stretchability and adjustable components that can accommodate the body's evolving shape throughout the pregnancy journey.

Building on the insights gained from the problem analysis this research advances toward the conceptualization and creation of smart maternity wear that goes beyond fulfilling basic comfort, functionality, and aesthetic requirements. These garments are thoughtfully designed to incorporate health-monitoring technologies promoting maternal well-being throughout the pregnancy journey. When it comes to designing maternity clothing two primary design philosophies are typically followed. One approach embraces and accentuates the pregnant body, proudly showcasing the baby bump as a celebrated feature. In contrast the second approach aims to downplay the physical changes of pregnancy, helping women maintain a more traditional or conventional look for as long as possible. This latter method often involves the use of

fashion-forward silhouettes and when those become harder to achieve due to physical changes, visual techniques such as strategic use of color, lines and textures are employed to create a more streamlined or slimmer appearance.

Based on the clothing habits of expectant mothers, the challenges they faced with their current wardrobes, and insights gathered from the literature review, a total of nine maternity outfits were thoughtfully designed and illustrated. These included seven regular maternity garments labelled MG-1 to MG-7 (Plate 1 to 7), and two smart vest designs labelled SMV 1 and SMV 2 (Plate 8 & 9) which already given in the Chapter - 4. The designs incorporated the preferred style and functional features identified during the research. All illustrations were created using CORELDRAW software, which proved to be highly effective during the garment construction phase. Following the stitching process, each outfit underwent evaluation and was later featured in a catalogue. This catalogue included professional photo-shoots of the garments, capturing their aesthetics and practicality for presentation and feedback purposes.

Following the design phase, all maternity garments were evaluated by experts from the Textile and Clothing Department to guide the next steps in the development process. The garments were assessed based on key design and functional features that addressed both comfort and adaptability during pregnancy and beyond. Top preferences were given to features such as loose and breathable designs, which help accommodate physiological changes and promote airflow; smooth fabric textures that are gentle on sensitive skin; and the inclusion of elastic and stretchable elements for flexibility and ease of movement. Additionally, garments that were adaptable and functional suitable for both maternity and postnatal use received positive feedback. Flowy silhouettes were also appreciated for offering comfort while maintaining an elegant appearance, while adjustable components like drawstrings, belts, and smocking ensured a personalized fit. A proper and comfortable fit was emphasized as essential, without sacrificing style. In terms of garment types, the most preferred included maxi and midi dresses for their full coverage, graceful appeal, and ease of movement; tops paired with bottom wear for everyday versatility and tunics along with nursing or sleepwear, which were valued for their built-in accessibility features that support breastfeeding and restful wear.

A significant outcome of the study was the positive reception of modular smart

maternity wear. Although initial awareness of wearable health technologies among expectant mothers was limited, acceptance increased substantially once the concept and functionality of detachable smart vests and gloves were introduced. Respondents expressed greater trust in garments that closely resembled conventional maternity wear while offering unobtrusive health monitoring. The modular and detachable design approach enhanced usability by allowing easy maintenance, laundering and optional use of technology without compromising daily comfort, thereby strengthening user acceptance and perceived practicality.

As part of this research, a field survey was conducted in two prominent cities of Punjab Ludhiana and Jalandhar to explore the real-life clothing experiences of pregnant women, the everyday challenges they face, and their level of awareness regarding emerging smart textile technologies. The feedback collected from respondents offered valuable insights. This response highlights the novelty of the present research, which positions maternity clothing not merely as a passive garment but as an active, user – friendly health support system integrated into everyday wear.

A majority of women emphasized that during pregnancy, clothing is more than just a matter of style it plays a crucial role in providing comfort, confidence, and a sense of support. Many participants shared difficulties in finding garments that offer a good fit, feel soft against the skin, allow breathability and adapt to the body's changing shape. Functional elements such as nursing access, adjustable waistlines, and breathable materials were considered essential rather than optional. One of the most notable findings was the enthusiastic reception of smart maternity wear. Although some respondents were initially unfamiliar with wearable health technologies, their interest grew significantly after being introduced to the smart vest and gloves developed during this study. The concept of apparel that could both monitor health and remain comfortable to wear was met with strong approval and curiosity.

5.4 Conclusion

The present study clearly establishes that conventional maternity clothing often fails to adequately address the combined comfort, functional and psychological needs of expectant mothers during pregnancy. The findings confirm that women prefer maternity

garments that are adjustable, breathable, durable and aesthetically pleasing particularly in areas of rapid physical change. These preferences guided the design and development of maternity wear that balances comfort, adaptability and visual appeal.

Similarly post pregnancy mothers also preferred this maternity range with hidden for discrete nursing without removing the layers of clothes. Concealed zipper in vertical, snap buttons in placket opening passing through bust point, were the most preferred features. Floral prints, lines, plains, texture kind of patterns were preferred.

Importantly, the study demonstrates that modular and detachable smart maternity wear offers a practical and user- acceptable approach to integrating health monitoring into daily clothing. By avoiding fully embedded systems, the developed prototypes ensure ease of maintenance, flexibility of use and higher acceptability without compromising comfort or aesthetics. The research therefore contributes a novel, user – centric model for smart maternity wear that aligns fashion design with preventive maternal healthcare.

5.5 Implications & Recommendations of the Study

1. The present study is imperative for ready to wear industries, costume designers & boutique owners to develop special maternity wear to cater the needs of the pregnant women.
2. Study has great commercial potential for whole range in maternity dress and healthcare sector.
3. The developed designs of maternity outfits will be helpful for the designers to adapt innovative styles.
4. The study will serve as a variable source of reference material for clothing and textiles as well as fashion designing students and can be used as teaching aid by teachers.
5. The study provides a foundation for integrating smart maternity wear into preventive maternal healthcare initiatives especially in resource limited or remote settings.

5.6 Scope for Further Studies

This study plays an important foundation in exploring how wearable technology can be meaningfully integrated into maternity wear. While the results are promising there is

still much room to grow and innovate in this field. Future research can take this work further both in terms of refining the technology and enhancing the design of smart garments to better serve expectant mothers.

One key area is the need to include larger and more diverse groups of participants. Expanding the study to women from different regions, age groups, income levels and pregnancy stages could offer a more comprehensive understanding of how smart maternity wear is received and how it functions in real-life scenarios.

There is also a strong opportunity for long-term studies to explore the actual health benefits of these garments over time. How might wearing a smart vest or similar product throughout pregnancy help in early detection of issues or improve overall prenatal care? These are important questions that future studies could address.

Additionally, while this research focused on pregnancy the postpartum phase presents new challenges and needs that smart clothing could address. For instance smart nursing wear could assist with temperature regulation, support lactation tracking or even encourage better posture during feeding.

As technology continues to advance more sophisticated sensors can be integrated into garments to monitor a broader range of health indicators such as fetal movements, hydration levels or even blood sugar. Pairing these capabilities with AI and data analytics could allow garments to provide more personalized insights and alerts, helping mothers and their healthcare providers stay proactive.

Sustainability is another vital consideration. Exploring smart textiles that are eco-friendly, biodegradable or self-cleaning would not only improve comfort and hygiene but also address environmental concerns making maternity fashion smarter in every sense.

On the practical side future work should also look into the economic feasibility of producing and distributing smart maternity wear at scale. Research into pricing strategies and cost-effective materials could help make these garments more accessible to a wider population, including women in rural or underserved areas.

Importantly progress in this field will depend on strong cross-disciplinary collaboration. Designers, healthcare professionals, engineers and software developers

must continue to work together to ensure that these garments are not only functional and safe but also appealing and user-friendly.

5.6.1 Future Commercialization and Clinical Integration

Another important area for future research is the clinical testing and commercialization of smart maternity wear. Before such garments can be introduced into routine healthcare practice, they should undergo large scale clinical evaluation in collaboration with hospitals, obstetricians and healthcare professionals to establish their safety, reliability and clinical effectiveness. Future work should also focus on obtaining the necessary medical certifications and regulatory approvals while ensuring compliance with applicable healthcare standards. Furthermore, integration of the developed smart maternity wear with hospital information systems, telemedicine platforms and remote maternal healthcare services could facilitate continuous maternal health monitoring and support its successful adoption in routine prenatal healthcare.

Lastly, understanding the psychological and behavioural aspects of wearing smart clothing such as comfort, trust in technology and privacy concerns

Will be crucial to ensuring that such innovations are embraced by the women they are meant to support.

In conclusion, this research opens multiple pathways for interdisciplinary innovation and with sustained technological advancement and collaborative efforts, smart maternity wear has the potential to redefine maternal comfort, autonomy and healthcare support throughout pregnancy and beyond.

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APPENDIX- I LETTER OF CANDIDACY



Centre for Research Degree Programmes

LPU/CRDP/PHD/EC/20220823/001858

Dated: 28 Jun 2022

Rupika Nanda
VID: 12106195
Programme Name: Doctor of Philosophy (Design)

Subject: Letter of Candidacy for Ph.D.

Dear Candidate,

We are very pleased to inform you that the Department Doctoral Board has approved your candidacy for the Ph.D. Programme on 28 Jun 2022 by accepting your research proposal entitled: DESIGN AND DEVELOPMENT OF SMART MATERNITY WEAR WITH DETACHABLE HEALTH MONITORING MODULES

As a Ph.D. candidate you are required to abide by the conditions, rules and regulations laid down for Ph.D. Programme of the University, and amendments, if any, made from time to time.

We wish you the very best!!

In case you have any query related to your programme, please contact Centre for Research Degree Programmes.

Head
Centre for Research Degree Programmes

Note:- This is a computer generated certificate and no signature is required. Please use the reference number generated on this certificate for future conversations.

Jalandhar-Delhi G.T.Road, Phagwara, Punjab (India) - 144411
Ph : +91-1824-444594 E-mail : drp@lpu.co.in website : www.lpu.in

APPENDIX-II

Questionnaire survey for pre data

Design and Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer

Objective: To understand the need & problem areas of pregnant women in second and third trimesters

Questionnaire survey for pregnant women Section 1: Basic Information

Sr. No.	Characteristics	
1.	Name of the respondent	
2.	Age (tick the option below)	
	a. Between 18 to 25 years	
	b. Between 26 to 30 years	
	c. Above 30 years	
3.	Qualification (tick the option below)	
	a. Secondary School	
	b. Diploma Course	
	c. Bachelor's Degree	
	d. Master Degree	
	e. Ph.D.	
4.	Occupation (specify If working)	
	a. Working	
	b. Non-Working	

5.	Type of family a. Nuclear	
	b. Joint	
6.	Annual Income (tick the option below) a. Less than 5 lakh	
	b. Between 5 lakh- 10 lakh	
	Between 10 lakh – 15 lakh Above 15 lakh	
7.	Contact Number	

Section 2: Questions Regarding Maternity Wear and Care

8. Are you expecting?

a. YES ☐ b. No ☐

9. If yes, then what is the age of pregnancy?

a. Between 1 to 3 months ☐

b. Between ~~2 to~~ 6 months ☐

c. Between 6 to 9 months ☐

10. How did you confirm your pregnancy?

a. Self-testing followed by Doctor Visit ☐

b. Felt physical discomfort followed by Doctor ☐ Visit

11. What kind of physiological changes are you experiencing during pregnancy?

Sr. no.	Physiological Changes (tick the changes)	
1.	Hormonal imbalance	
2.	Body weight gain	
3.	Sore or Swollen breasts	
4.	Cramping	
5.	Frequent Headaches	
6.	Nutritional deficiencies	
7.	Nausea and vomiting (morning sickness)	
8.	Breathing problems	
9.	Gastric acidity	
10	Swollen feet	
11	Sensory changes (vision changes, taste & smell changes)	
12	Changes in the hair, skin and nails	
13	Blood Pressure	
14	Fluctuation in body temperature	
15	Dehydration	
16	Frequent urination	
17	Spotting or Vaginal discharge	

quently you go for check-ups?

- a. Visit a month ☐
- b. Visit every 2 weeks ☐
- c. Visit every week ☐

13. Are you facing any symptoms of emotional transformation during pregnancy?

Complications/ Problems	Place for treatment/consultation	IF NO, why?
Fear & Anxiety ☐	Health professionals ☐	Felt not necessary ☐
Depression ☐	Psychology experts ☐	Tradition ☐
Personality disorder ☐	Private consultants ☐	No time ☐
Obsessive compulsive disorder ☐	Any other ☐	Costly ☐
Mood swings ☐		
Negative body image ☐		
Forgetfulness (short term memory loss) ☐		
Weepiness (frequent cry or tearfulness) ☐		
Any other (please mention) ☐		

- a. YES ☐ b. NO ☐

14. Do you share your physical and mental health related problems?

a. YES ☐

b. NO ☐

IF YES, with whom?

a. Spouse ☐

b. Friends and relatives ☐

c. Any other (specify) ☐

15. When your pregnancy was confirmed, have you gone for any special preparations for maternity period?

a. YES ☐

b. NO ☐

If yes, then tick the mention below options:

1. Purchase Maternity Wear ☐

2. New Mom's Essentials ☐

3. Maternity Support Accessories ☐

4. Baby Essentials ☐

5. Maternity Personal Care ☐

6. Pregnancy & Parenting Books ☐

7. Purchase Comfy Footwear ☐

8. Any other ☐

16. Do you feel that special clothing is required to support the maternity period?

a. YES ☐

b. NO ☐

17. What kind of maternity clothing will you prefer during and post pregnancy?

Product range	Tick the suitable option
1. Maternity dresses & skirts	
2. Maternity ethnic wear	
3. Maternity lingerie	
4. Maternity personal care	
5. Maternity support accessories	
6. Maternity tops and bottom wear	
7. Nursing/Sleep wear	

at kind of clothing category will you prefer with special features to assist during pregnancy? (tick the suitable option)

a. Loose and Breathable ☐

b. Maternity leggings and jeggings ☐

c. Wireless maternity and nursing bras ☐

d. Flowy Silhouettes ☐

e. Smooth ~~Cloth~~h Texture ☐

f. Pants or Skirts fastened with drawstrings ☐

g. Elasticsation and ~~Stretch~~ ability ☐

h. Adjustable features ☐

i. Proper fit according to comfort ☐

j. Any other (please specify) ☐

k.

19. What is your preferred mode of shopping?

a. Offline ☐

b. Online ☐

c. Both ☐

18. W

20. Would you like to pay for maternity clothing or products?

a. Rs. 500- 1000 ☐

b. Rs. 1000-5000 ☐

c. Rs. 5000 to 10,000 ☐

d. Above Rs. 10,000 ☐

21. Are you aware about smart maternity clothing?

a. YES ☐

b. NO ☐

22. Would you like to prefer type of clothing in which technology is infused to communicate you where your health vitals (BP, Heart rate, Physical activity, Stress level, Body temperature) were monitor by your own?

a. YES ☐

If yes, then please specify here –

b. NO ☐

If no, then please specify here -

c. May be ☐

23. Would you like to prefer maternity wear that can be used beyond pregnancy?

a. YES ☐

b. NO ☐

APPENDIX-III

Post-data Collection Questionnaire: Survey on collecting feedback from expecting mothers on developed range of maternity outfits

I Rupika Nanda research scholar from Lovely Professional University under the guidance of Dr.NehaSah and the title of my research is **Design and Development of Smart Maternity Wear to Monitor & Communicate the Health Condition of the Wearer**". I developed a range of maternity outfits for the expecting mothers who are in second and third trimesters. I request you to spare a few minutes to answer the following questions regarding the developed range. I assure you that the data provided by you will be kept confidential and used only for academic research.

Section 1: General Information

Sr. No.	Characteristics	
1.	Name	
2.	Age	
3.	Qualification	
4.	Occupation	
5.	Contact No.	

Section 2 : Specific Questions

6. Does clothing play an important role during the pregnancy period?

a. YES ☐

b. NO ☐

If yes, *what aspects do you find applicable?*

☐ Comfort and ease of movement

☐ Emotional and psychological well-being

☐ Boosting confidence and body image

7. Would you be willing to try the smart maternity wear range developed as part of this study?

a YES ☐

b NO ☐

8. Maternity Garments Evaluation Table

Rating Scale Explanation:

1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent

Garment code	Comfort	Fit	Design features	Fabric feel	Overall Appearance
MG1					
MG2					
MG3					
MG4					
MG5					
MG6					
MG7					

9. Smart Vest Evaluation Table

Rating Scale Explanation:

1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent

Smart Vest code	Functionality	Silhouette	Comfort	Maintenance
SMV 1				

SMV 2				
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10. The price of the maternity maxi/midi dresses ranges approximately between Rs. 1200/- to Rs. 1800/-. How likely are you to consider purchasing such maternity wear at this price point?

1. Very likely
2. Somewhat likely
3. Not likely
4. Depends on quality/features

11. The price of the maternity cord-sets ranges approximately between Rs. 1200/- to Rs. 1500/-. How likely are you to consider purchasing such maternity wear at this price point?

1. Very likely
2. Somewhat likely

3. Not likely

4. Depends on quality/features

12. Would you like to incorporate this smart maternity vest into your pregnancy wardrobe for regular use?

a YES ☐

b NO ☐

c Occasionally, for specific situations ☐

13. Do you think this smart vest is a promising investment for your comfort, health monitoring and maternity needs?

a Strongly Agree ☐

b Agree ☐

c Neutral ☐

d Disagree ☐

e Strongly Disagree ☐

APPENDIX-IV COST SHEETS MG-1

COST SHEET -1

Date	25/4/2025	Style No.	MG-1
Season	SS	Sample Size	Large
Item	Dress	Description	Maxi dress, loose style, flowy silhouette, adjustable belt for fir, front and back view

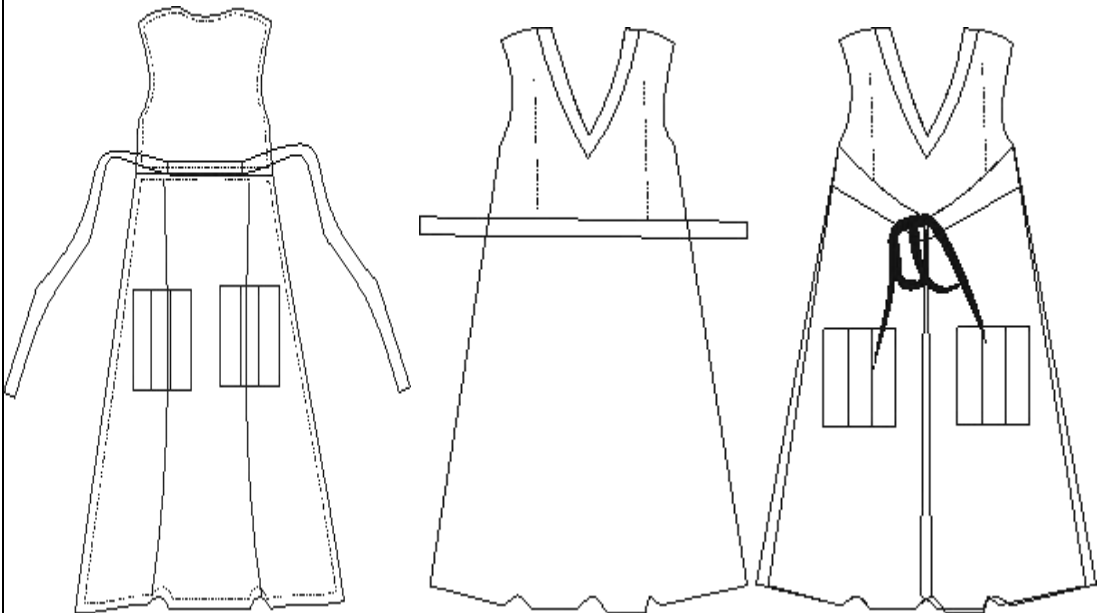


Items	Details	Cost (INR)	Consumption/pc	Cost/pc (INR)
	Cotton fabric	₹150/m	5 m	₹750.00

Fabric	Width 60l			
Trims				
Buttons	18 pcs @ ₹0.60/unit	₹0.60	18 pcs	₹10.80
Thread	Polyester thread (80 Tex)	₹4/spool	4 spools	₹16.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing & Packaging	Includes final pressing, folding, tagging			₹13.00
Total Raw Material + Trims + CMT + Finishing				₹889.80
Overhead charges (8%)	Utilities, wages, admin	8%		₹71.18
Total cost/pc				₹960.98
Profit margin (20%)	On cost price	20%		₹192.20
Retail price (without GST)				₹1153.18
Retail price with GST				₹ 1291.56

(12%)				
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MG-2 COST SHEET -2

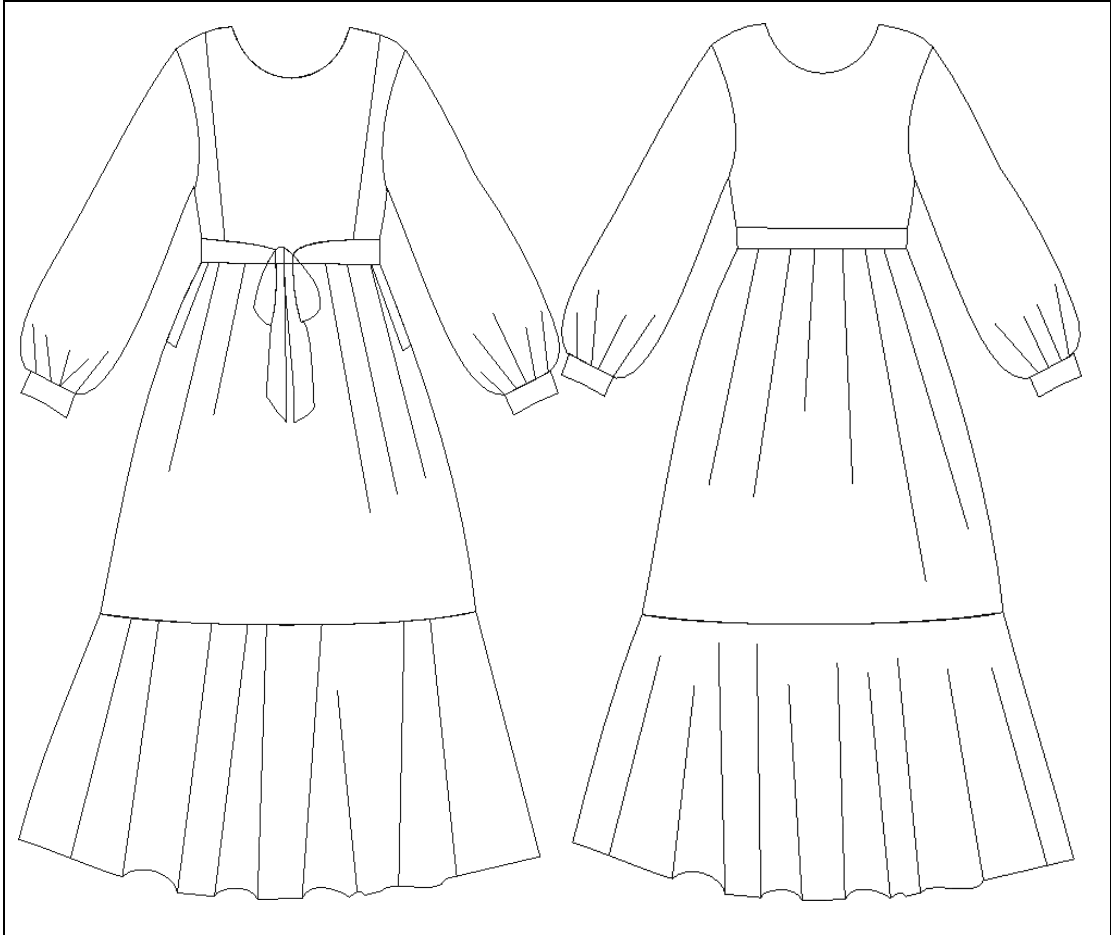
Date	25/4/2025	Style No.	MG-2
Season	SS	Sample Size	Large
Item	Wrapped Dress	Description	Sleeveless wrap up dress, concealed zippers on bust area, Velcro fastening in belt, large pockets for keeping essentials
			

Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Fabric	Cotton fabric	Overall		₹400.00
	Width 39"			
Trims & Accessories				
Concealed Zippers	For sing purpose	₹20/pc	2 pc	₹40.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Velcro	For belt fastening	₹20/m	0.5 m	₹10.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing & Packaging	Final ing, folding, tagging			₹13.00
Total Raw Material				₹563.00

+ Trims + CMT + Finishing				
Overhead charges (8%)	Utilities, wages, admin	8%		₹45.04
Total cost/pc				₹608.04
Profit margin (20%)	On cost price	20%		₹121.61
Retail price (without GST)				₹729.65
Retail price with GST (12%)				₹817.21

MG-3 COST SHEET -3

Date	25/4/2025	Style No.	MG-3
Season	SS	Sample Size	Large
Item	Maxi Dress	Description	Maxi dress with flowing silhouette, front yoke having concealed zipper for nursing access, buttons on cuff , satin belt for fit.



Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric	Cotton for body	₹200/m	4 m	₹800.00
Yoke Fabric	Cotton blend	₹200/m	0.75 m	₹150.00
Satin Belt Fabric	Satin (for belt)	₹150/m	1 m	₹150.00
Trims & Accessories				
Concealed Zippers	For sing purpose	₹20/pc	2 pc	₹40.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Buttons	On cuffs	₹5/pc	4 pcs	₹20.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing & Packaging	Final pressing, folding, tagging			₹13.00
Total Raw Material + Trims + CMT +				₹1303.00

Finishing				
Overhead charges (8%)	Utilities, wages, admin	8%		₹104.24
Total cost/pc				₹1407.24
Profit margin (20%)	On cost price	20%		₹281.45
Retail price (without GST)				₹1688.69
Retail price with GST (12%)				₹1892.14

COST SHEET -4 MG-4

Date	25/4/2025	Style No.	MG-4
Season	SS	Sample Size	Large
Item	A-line Dress	Description	A-line cut & bell sleeved dress with square neckline, patch pockets, concealed zipper for nursing access.

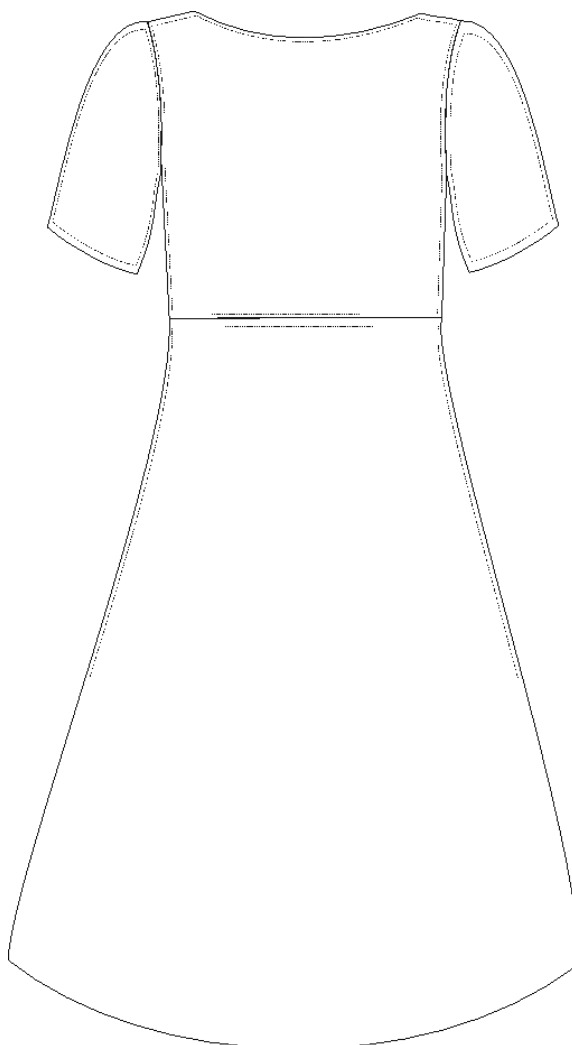


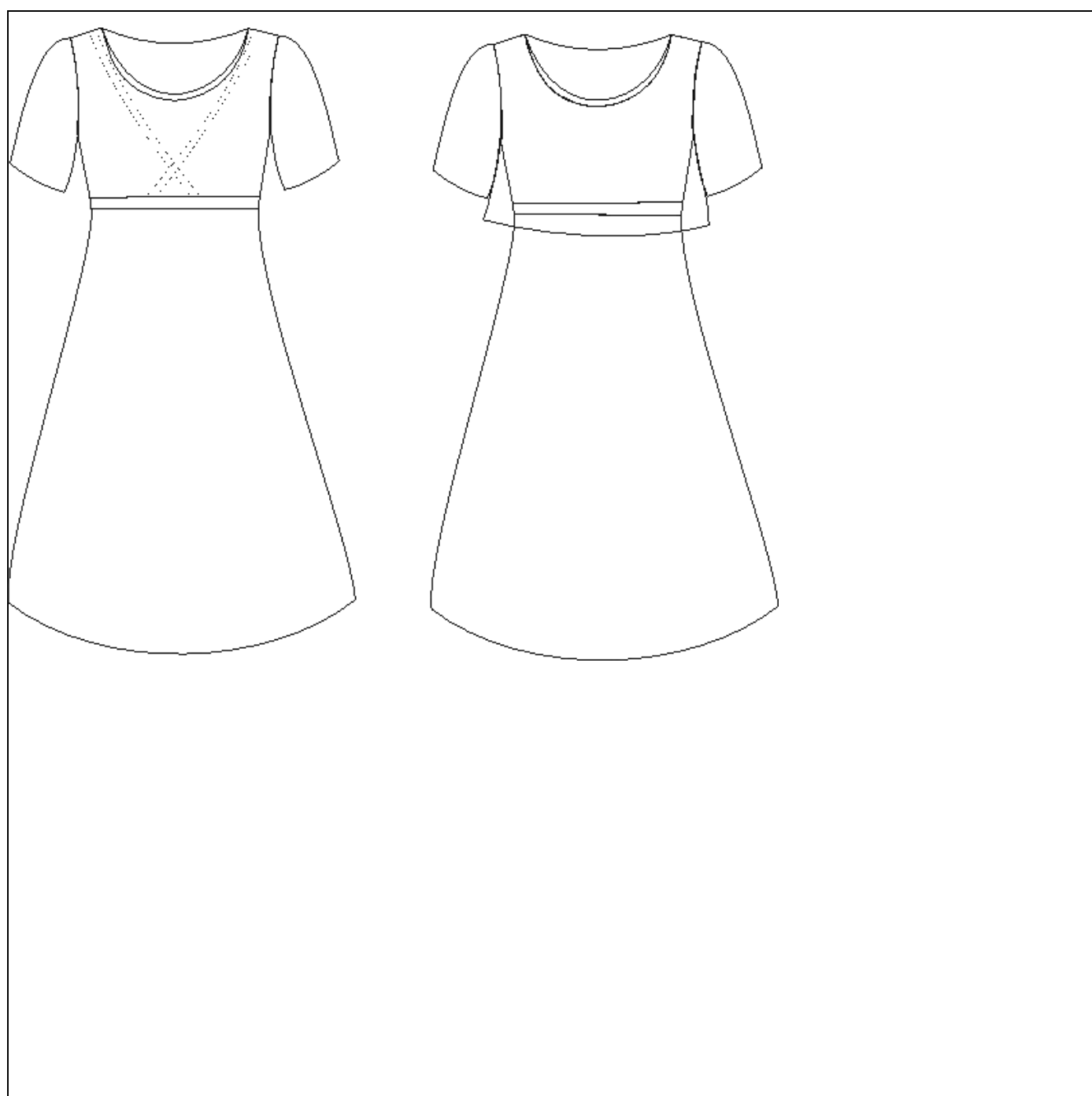
Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric	Cotton for body	₹200/m	3.5 m	₹700.00
Bodice Fabric	Cotton blend	₹100/m	1.5 m	₹150.00
Trims & Accessories				
Concealed Zippers	For nursing purpose	₹20/pc	2 pc	₹40.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Snap rings	For opening mechanism	₹10/pc	10 pcs	₹100.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing & Packaging	Final pressing, folding, tagging			₹13.00
Total Raw Material + Trims + CMT + Finishing				₹1153.00
Overhead charges	Utilities, wages, admin	8%		₹92.24

(8%)				
Total cost/pc				₹1245.24
Profit margin (20%)	On cost price	20%		₹249.05
Retail price (without GST)				₹1494.29
Retail price with GST (12%)				₹1673.60

MG - 5 COST SHEET - 5

Date	25/4/2025	Style No.	MG-5
Season	SS	Sample Size	Large
Item	Tunic Dress	Description	Tunic dress features front flap cover for privacy concealed with snap buttons for nursing access.



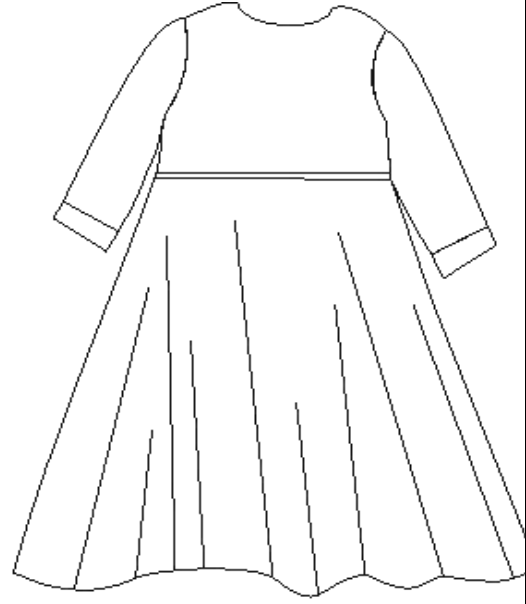
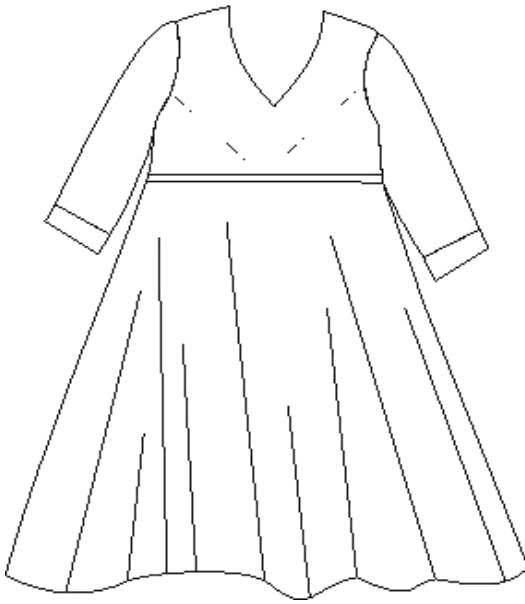


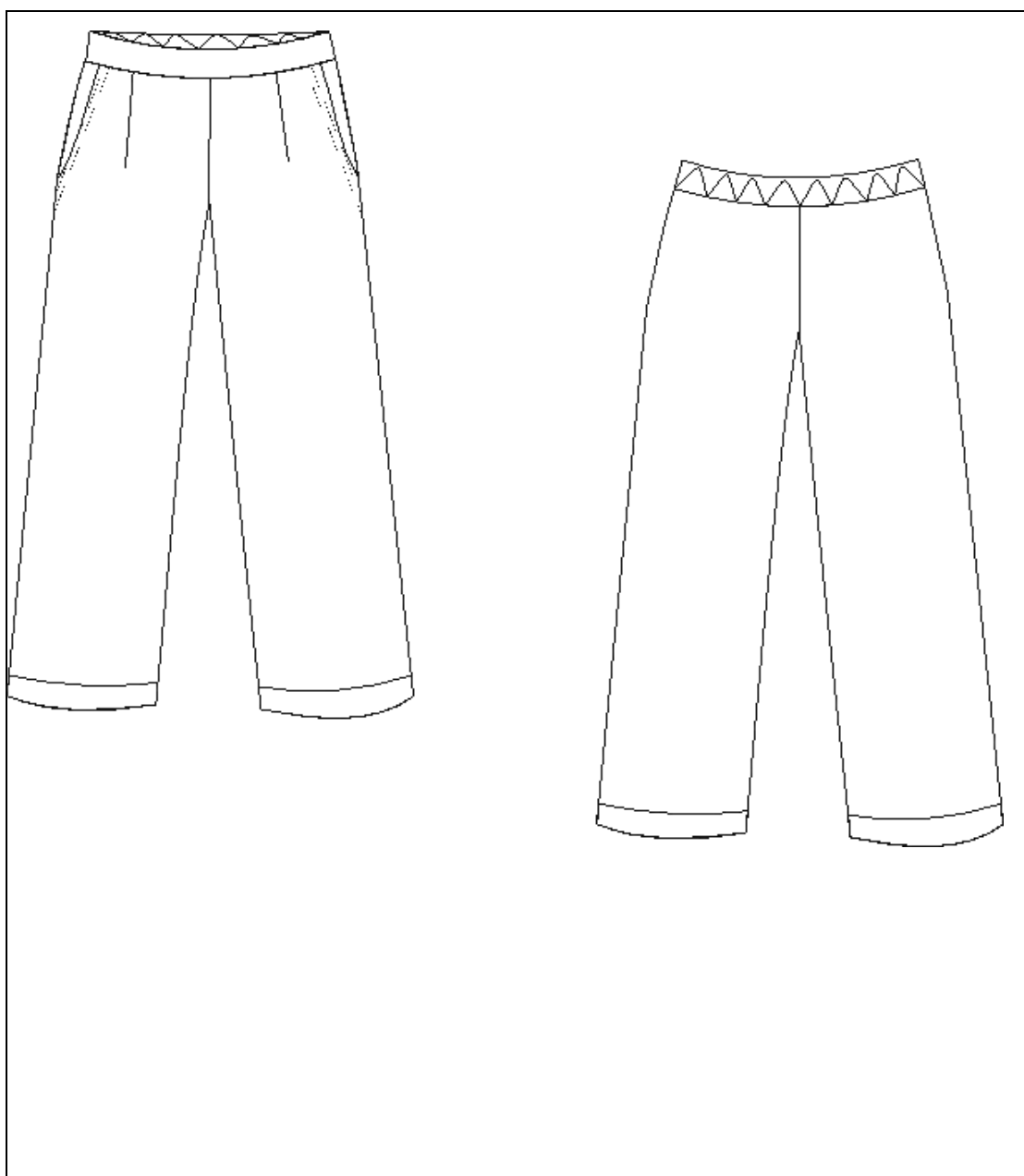
Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric	Cotton for body			₹300.00
Trims & Accessories				
Snap buttons	For nursing purpose	₹10/pc	2 pc	₹20.00
Thread	Polyester thread	₹5/spool	4 spools	
	(80 Tex)			₹20.00
Lace	For detailing	₹25/m	2 m	₹50.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing& Packaging	Final pressing, folding, tagging			₹13.00
Total Raw Material + Trims + CMT + Finishing				₹503.00

Overheadcharges (8%)	Utilities, wages, admin	8%		₹40.24
Total cost/pc				₹543.24
Profit margin (20%)	On cost price	20%		₹108.65
Retail price (without GST)				₹651.89
Retail price with GST (12%)				₹731.82

MG-6 COST SHEET -6

Date	25/4/2025	Style No.	MG-6
Season	SS	Sample Size	Large
Item	Tunic style	Description	A-Line kurti style cord set with soft flare
	Cord set		having drawstrings on waist for fit & concealed zip for nursing access. Plain bottoms having pockets and elasticated.



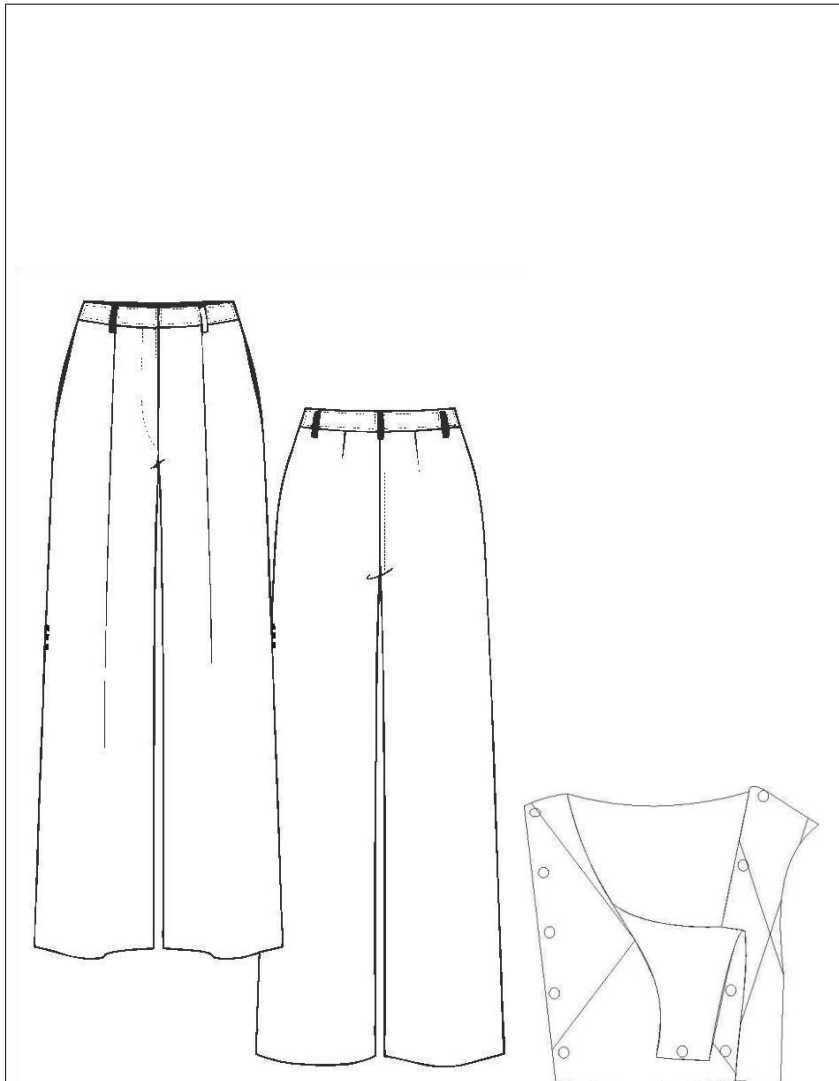


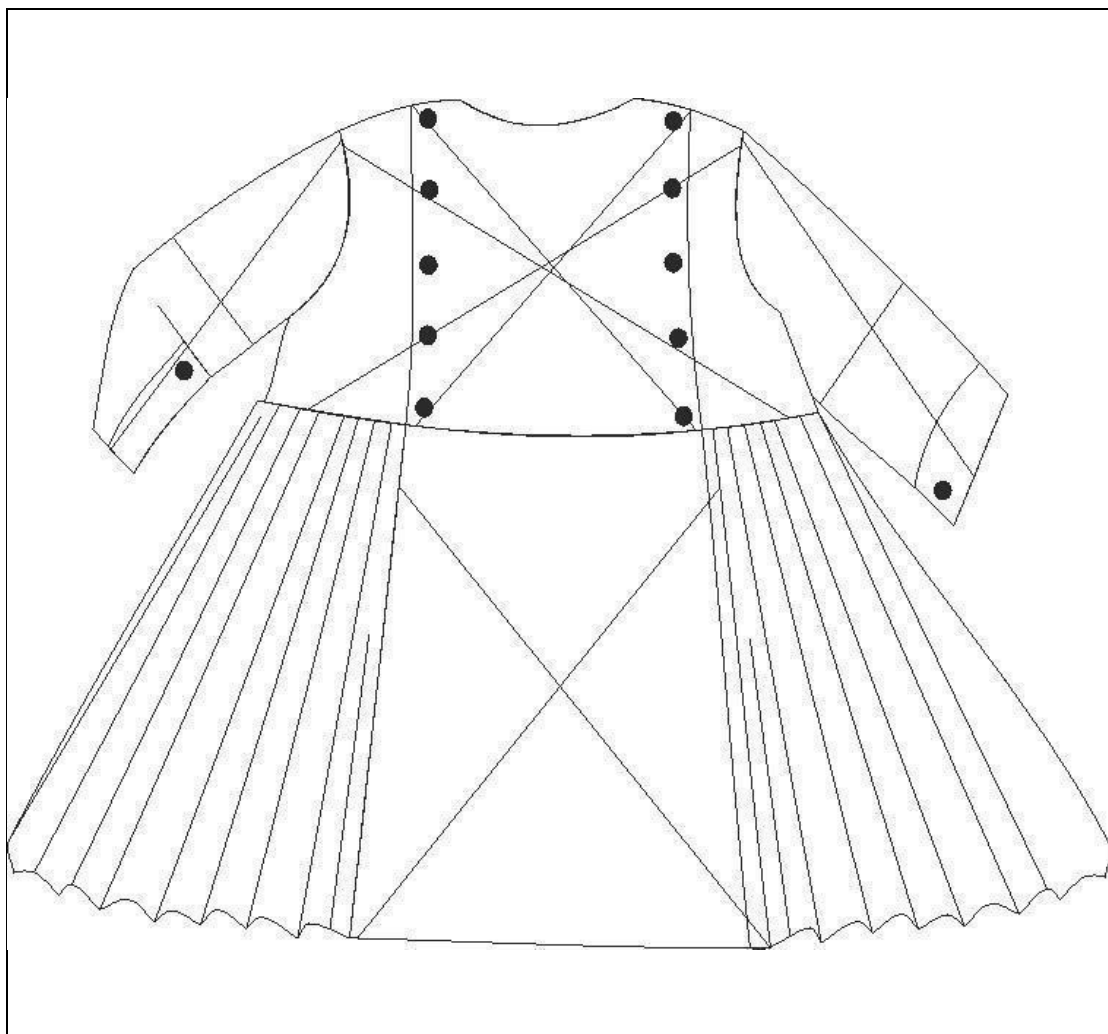
Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Top Fabric	Cotton for body	₹150/m	3 m	₹450.00
Bottom Fabric	Cotton muslin	₹180/m	2.5 m	₹450.00
Trims & Accessories				
Concealed Zippers	For nursing purpose	₹20/pc	2 pc	₹40.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Drawstrings	For fit	₹10/m	4 m	₹40.00
Elastic	Half-inch elastic for bottom waistband			₹30.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing	Final pressing			₹13.00

& Packaging	ng, folding, tagging			
Total Raw Material + Trims + CMT + Finishing				₹1143.00
Overhead charges (8%)	Utilities, cha wages, admin	8%		₹91.44
Total cost/pc				₹1234.44
Profit margin (20%)	On cost price	20%		₹246.89
Retail price (without GST)				₹1481.33
Retail price with GST (12%)				₹1658.09

COST SHEET MG-7

Date	25/4/2025	Style No.	MG-7
Season	SS	Sample Size	Large
Item	Peplum style Cord set	Description	Peplum style Cord set with modern functionality offering comfort and suitable for maternity use, pleated panels, round neckline, snap buttons, concealed zip for nursing access.



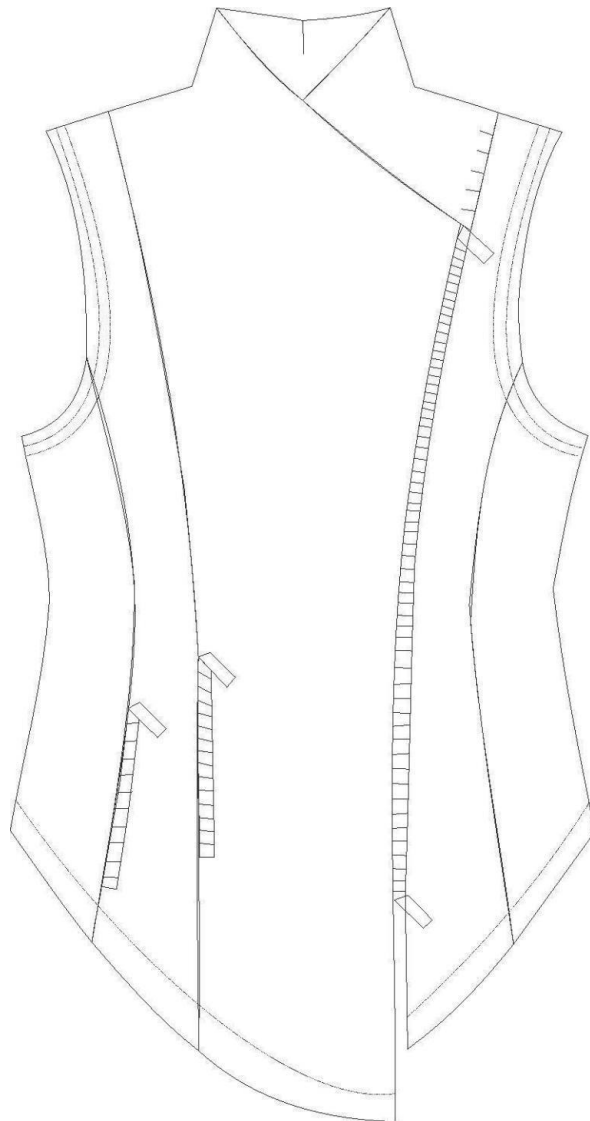


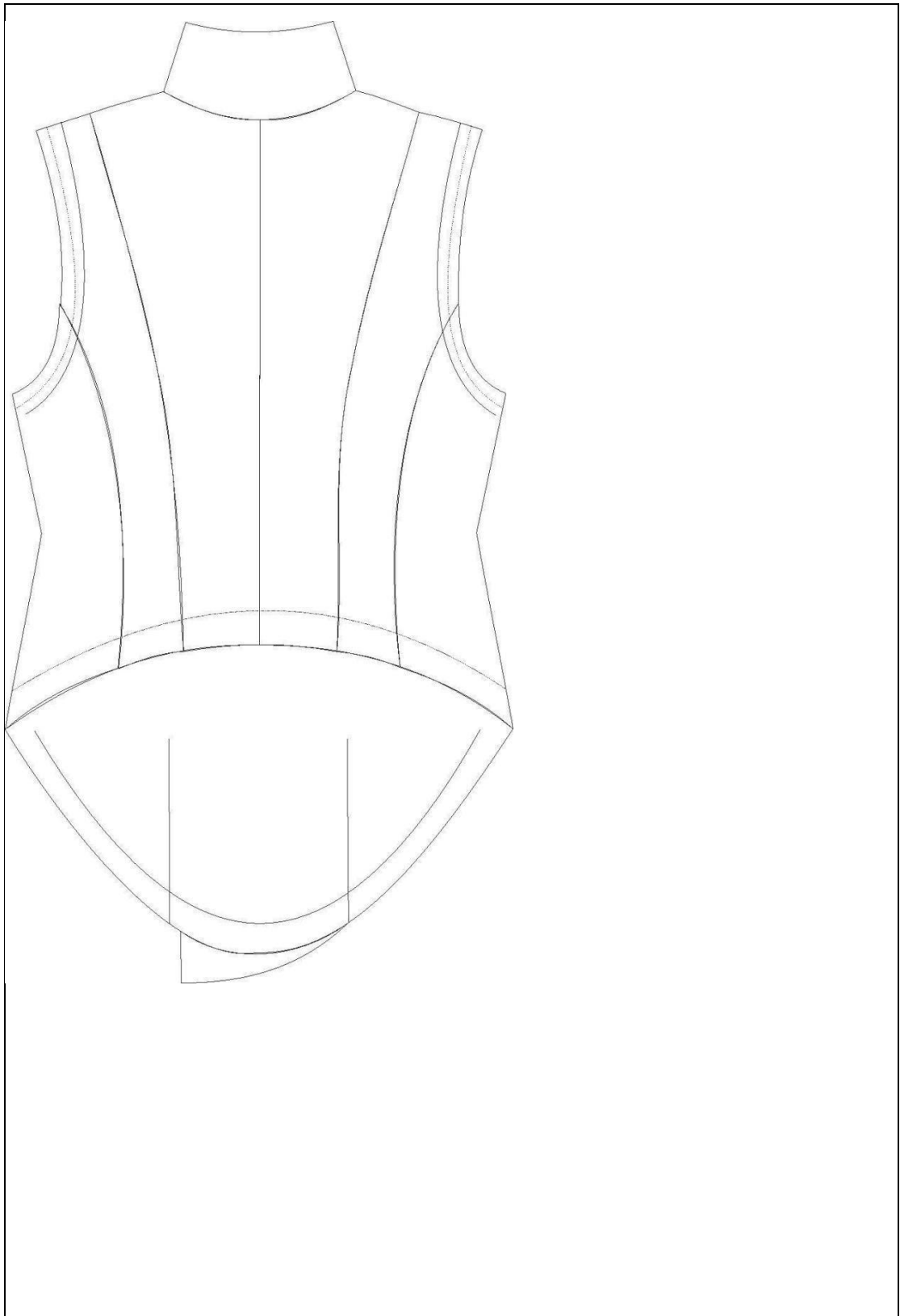
Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric (printed)	Cotton for body	₹100/m	3 m	₹300.00
Bottom Fabric	Cotton muslin	₹250/m	2.5 m	₹625.00
Pleat Fabric	Knife pleats	₹200/m	2 m	₹400.00
Trims & Accessories				
Concealed Zippers	For nursing purpose	₹20/pc	2 pc	₹40.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Snap rings	Opening mechanism	₹10 per pc	12 pcs	₹120.00
Elastic	Half-inch elastic for bottom waistband			₹30.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing &	Final pressing, folding,			₹13.00

Packaging	tagging			
Total Raw Material + Trims + CMT + Finishing				₹1728.00
Overhead charges (8%)	Utilities, wages, admin	8%		₹138.44
Total cost/pc				₹1866.24
Profit margin (20%)	On cost price	20%		₹373.25
Retail price (without GST)				₹2239.49
Retail price with GST (12%)				₹2508.23

SMV-1 COST SHEET -8

Date	25/4/2025	Style No.	SMV-1
Season	SS	Sample Size	Large
Item	Smart Vest	Description	Sleeveless smart vest which monitors ECG through NodeMCU.



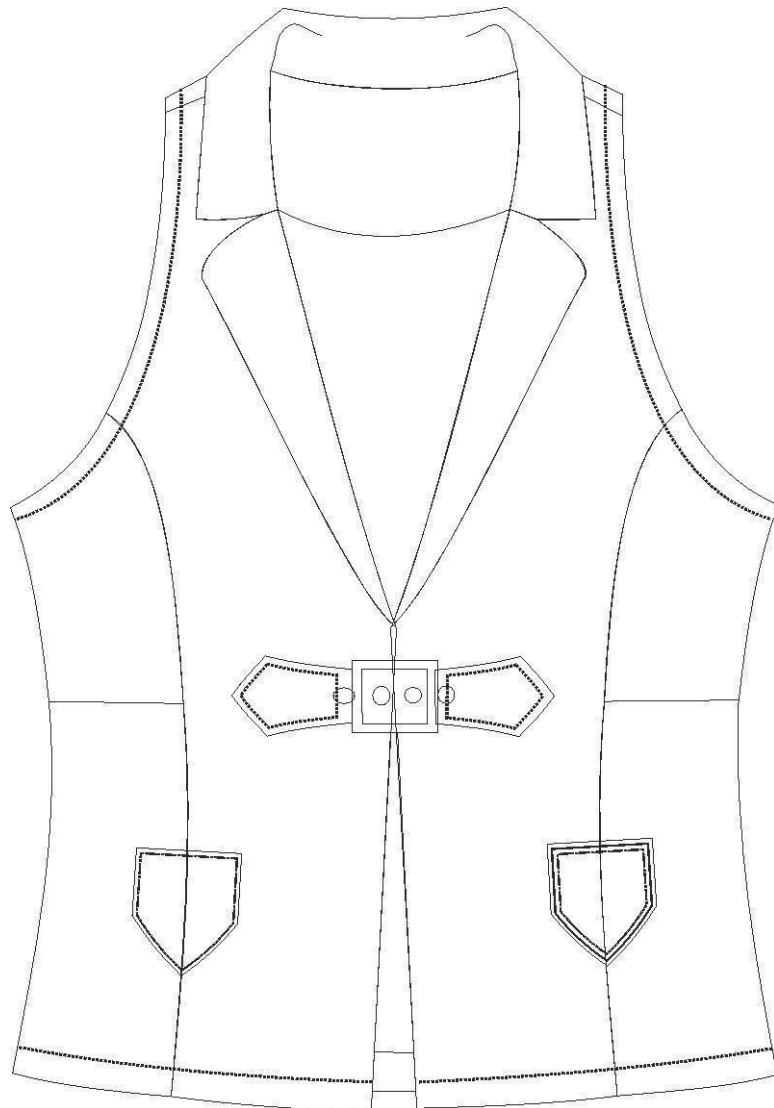


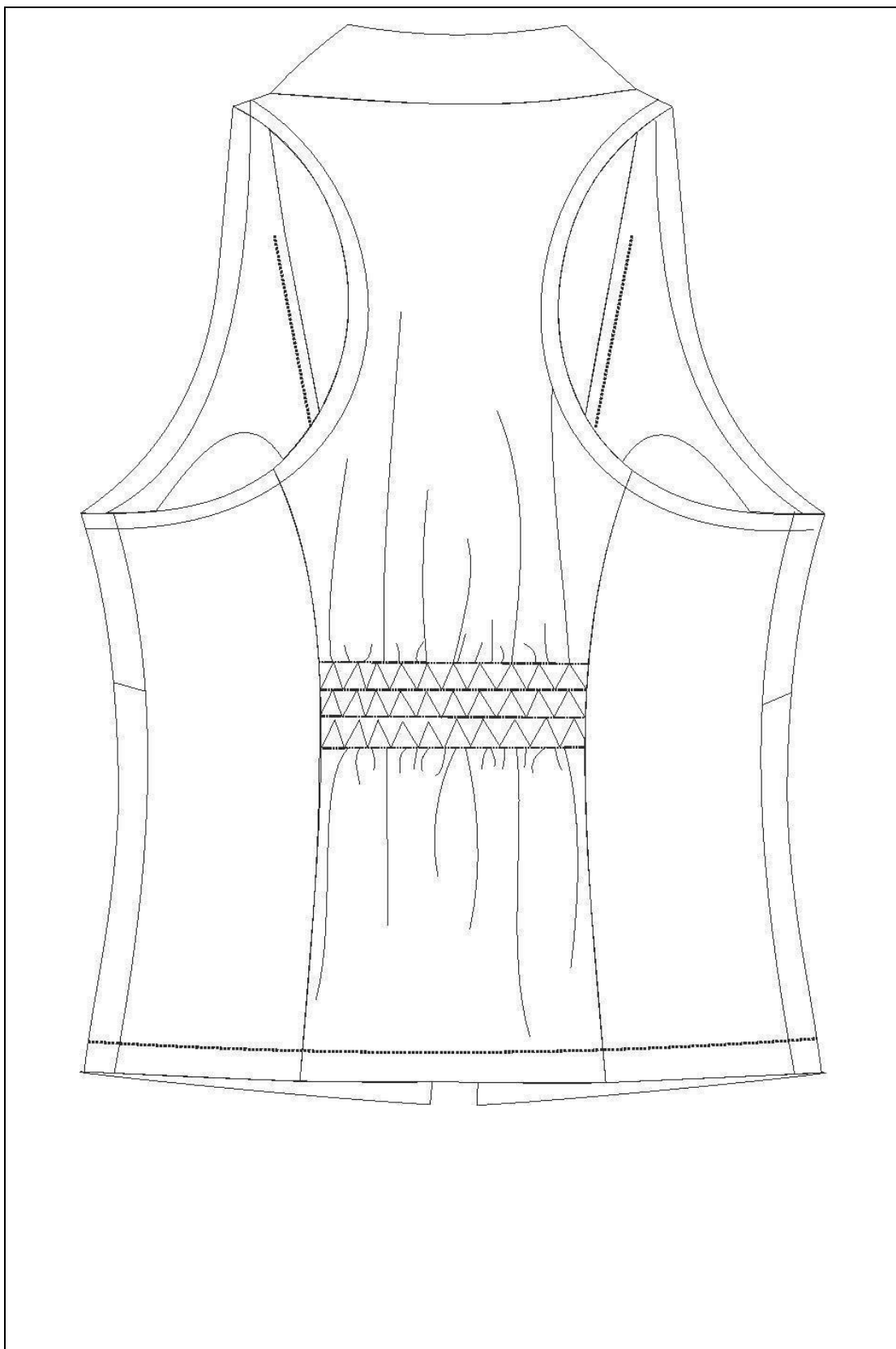
Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric (printed)	Cotton for body	₹100/m	3.5 m	₹350.00
Trims & Accessories				
Concealed Zippers & Metal zipper	For nursing purpose	₹20/pc	3pc	₹60.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Shearing thread	For stretch seams & finish			₹20.00
Sensor Set (ECG NodeMCU)	Complete setup including electrodes, module etc.		1 set	₹2000.00
Ribbon (Sensor casing)	For covering sensor wires	₹40/3m		₹40.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00
Finishing	Final press			₹13.00

& Packaging	ing, folding, tagging			
Total Raw Material + Trims + CMT + Finishing				₹2753.00
Overhead charges (8%)	Utilities, wages, admin	8%		₹220.24
Total cost/pc				₹2973.24
Profit margin (20%)	On cost price	20%		₹594.65
Retail price (without GST)				₹3567.89
Retail price with GST (12%)				₹3995.64

SMV-2 COST SHEET - 9

Date	25/4/2025	Style No.	SMV-2
Season	SS	Sample Size	Large
Item	Smart Vest	Description	Sleeveless smart vest in formal form which monitors ECG through NodeMCU.





Items	Details	Cost (INR)	Consumption /pc	Cost/pc (INR)
Main Fabric	Cotton for body	₹500		₹500.00
Trims & Accessories				
Buckle belt	Waist fit adjustment, stylish function	₹20/pc	3pc	₹250.00
Thread	Polyester thread (80 Tex)	₹5/spool	4 spools	₹20.00
Shearing thread	For stretch seams & finish			₹20.00
Sensor Set (ECG NodeMCU)	Complete setup including electrodes, module etc.		1 set	₹2000.00
Ribbon (Sensor casing)	For covering sensor wires	₹40/3m		₹40.00
Fabrication (CMT)	Cutting, stitching, pressing			₹100.00

Finishing & Packaging	Final pre ssing, folding, tagging			₹13.00
Total Raw Material + Trims + CMT + Finishing				₹3003.00
Overhead c harges (8%)	Utilities, wages, admin	8%		₹240.24
Total cost/pc				₹3243.24
Profit margin (20%)	On cost price	20%		₹648.65
Retail price (without GST)				₹3891.89
Retail price with				
GST (12%)				₹4359.92

APPENDIX-V

Descriptive Statistics and Evaluation Tables

Table 1: Summary Distribution of Respondents across Key Study Variables

Descriptive Statistics					
	N (sample size)	Minimu m	Maximu m	Mean	Std. Deviation
Age	150	1	3	2.22	.722
Qualification	150	1	5	3.11	1.044
Occupation	150	1	2	1.71	.454
Type of family	150	1	2	1.41	.494
Annual income	150	1	4	1.84	.852
Are you expecting?	150	1	1	1.00	.000
If yes, then what is the age of pregnancy?	150	1	3	2.43	.709
How did you confirm your pregnancy?	150	1	12	1.88	2.737
What kind of physiological changes are you experiencing during pregnancy?	150	1	123	20.38	34.873
How frequently you go for check-ups?	150	1	3	1.71	.617

Are you facing any symptoms of emotional transformation during pregnancy?	150	1	2	1.31	.465
What kind of symptoms you facing during pregnancy?	150	1	12	1.85	1.725
Do you share your physical and mental health related problems?	150	1	2	1.07	.262
With whom you share health related problems?	150	1	3	1.12	.477
When your pregnancy was confirmed, have you gone for any special preparations for maternity period?	150	1	2	1.52	.501
What kind of special preparations you done for maternity period?	150	1	12	2.28	1.707
Do you feel that special clothing is required to support the maternity period?	150	1	2	1.17	.374
What kind of maternity clothing will you prefer during and post	150	1	12	1.37	1.981

pregnancy?					
What kind of clothing category will you prefer with special features to assist during pregnancy?	150	1	123	2.55	10.355
What is your preferred mode of shopping?	150	1	3	2.29	.863
How much would you like to pay for maternity clothing or products?	150	1	4	1.75	.623
Are you aware about smart maternity clothing or products?	150	1	2	1.45	.499
Would you like to prefer clothing in which technology is infused to communicate health vitals (BP, heart rate, physical activity, stress level, body temperature)?	150	1	2	1.34	.475
Valid N (list wise)	150				

Table 2: Summary Distribution of Maternity Garments**Descriptive Statistics**

	N	Minimum	Maximum	Mean	Std. Deviation
RESPONDENT	15	1	15	8.00	4.472
MG1 COMFORT	15	3	5	4.33	.816
MG2 COMFORT	15	4	5	4.33	.488
MG3 COMFORT	15	4	5	4.47	.516
MG4 COMFORT	15	3	5	3.93	.594
MG5 COMFORT	15	4	5	4.80	.414
MG6 COMFORT	15	3	5	4.07	.799
MG7 COMFORT	15	3	5	4.33	.617
MG1 FIT	15	4	5	4.40	.507
MG2 FIT	15	3	5	4.27	.961
MG3 FIT	15	3	5	4.00	.845
MG4 FIT	15	3	5	4.00	.845
MG5 FIT	15	4	5	4.67	.488
MG6 FIT	15	3	5	3.93	.704
MG7 FIT	15	3	5	4.27	.704
MG1 DESIGN FEATURES	15	3	5	4.33	.724
MG2 DESIGN FEATURES	15	3	5	4.33	.724
MG3 DESIGN FEATURES	15	3	5	3.93	.704
MG4 DESIGN FEATURES	15	4	5	4.53	.516

MG5 DESIGN FEATURES	15	4	5	4.67	.488
MG6 DESIGN FEATURES	15	3	5	4.40	.828
MG7 DESIGN FEATURES	15	3	5	4.07	.594
MG1 FABRIC FEEL	15	4	5	4.67	.488
MG2 FABRIC FEEL	15	3	5	4.53	.640
MG3 FABRIC FEEL	15	4	5	4.73	.458
MG4 FABRIC FEEL	15	4	5	4.80	.414
MG5 FABRIC FEEL	15	4	6	4.93	.594
MG6 FABRIC FEEL	15	3	5	4.33	.617
MG7 FABRIC FEEL	15	3	5	4.07	.704
MG1 OVERALL APPEARANCE	15	3	5	4.33	.617
MG2 OVERALL APPEARANCE	15	3	5	4.53	.743
MG3 OVERALL APPEARANCE	15	3	5	3.87	.743
MG4 OVERALL APPEARANCE	15	3	5	4.07	.594
MG5 OVERALL APPEARANCE	15	3	5	4.13	.834
MG6 OVERALL APPEARANCE	15	4	5	4.40	.507
MG7 OVERALL APPEARANCE	15	3	5	4.27	.594
Valid N (listwise)	15				

Table 3: Summary Distribution of Smart Vests and Gloves

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
RESPONDENT	15	1	15	8.00	4.472
SMV1 FUNCTIONALITY	15	3	5	4.40	.632
SMV2 FUNCTIONALITY	15	3	5	3.93	.594
SMV1 SILHOUETTE	15	4	5	4.40	.507
SMV2 SILHOUETTE	15	3	5	3.73	.704
SMV1 COMFORT	15	4	5	4.47	.516
SMV2 COMFORT	15	3	5	3.93	.799
SMV1 MAINTENANCE	15	3	4	3.80	.414
SMV2 MAINTENANCE	15	3	4	3.60	.507
G1-G2 FUNCTIONALITY	15	3	5	3.87	.640
G1-G2 COMFORT	15	3	5	3.93	.704
G1-G2 MAINTENANCE	15	3	4	3.47	.516
Valid N (listwise)	15				

APPENDIX-VI

Conference Participation Certificates





CERTIFICATE

THIS IS TO CERTIFY THAT

RUPIKA NANDA

Lovely Professional University, Phagwara

has presented in the Two Day National Conference on
Textiles and Clothing Comfort -NTCC 2024 organized by
Department of Textile & Fashion Technology held at
Kumaraguru College of Technology on 1st and 2nd March 2024.

Mr. A. PAVENDHAN
ASSOCIATE DEAN
TEXTILE CLUSTER

Dr. M. EZHILARASI
PRINCIPAL
KCT



KUMARAGURU
Institutions



REFERENCE NO: WSAD/FTSC/2025/P147



CERTIFICATE OF PARTICIPATION

This is to certify that
RUPIKA NANDA
Research Scholar

presented their paper titled:

MACHINE LEARNING-BASED PREDICTION OF ANTIMICROBIAL PERFORMANCE IN NANOMATERIAL-COATED TEXTILES

at the International Conference, **Fashion as a Tool for Social Change - Innovating the Present, Preserving the Future**,
hosted by School of Arts and Design, Woxsen University (India) on 10TH and 11TH November 2025.

Co - Authored by
NEHA SAH AND D KAMALRAJ

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Woxsen University, India

Dr. Sadhna

Dr. Sadhna
Associate Professor, SoAD
Woxsen University, India

Knowledge Partners



REFERENCE NO: WSAD/FTSC/2025/P169



CERTIFICATE OF PARTICIPATION

This is to certify that
RUPIKA NANDA
Research Scholar

presented their paper titled:

IOT ENABLED SMART MATERNITY VEST FOR REAL-TIME MATERNAL HEALTH MONITORING: DESIGN, DEVELOPMENT AND VALIDATION

at the International Conference, **Fashion as a Tool for Social Change - Innovating the Present, Preserving the Future**,
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