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Innovative sustainable Clothing for Teenagers with the Multifunctionality and Zero-Waste concept.

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Abstract-
Children's clothing is an important part of the fashion industry that hurts the environment a lot because kids grow so quickly and need to change clothes all the time. Because of this, more materials are used and more cloth trash is made. To solve these problems, we need new ideas that combine ecology with practicality. This study looks into how to create and make sustainable, multipurpose children's clothing using zero-waste principles in order to reduce the damage to the environment and meet the changing needs of kids. Due to kids growing up so quickly, clothes are often thrown away too quickly, which adds a lot to textile waste. Using old ways to create and make clothes can lead to a lot of fabric waste, which makes environmental problems worse. Because of these worries, sustainable fashion has come up, focused on reducing trash, producing in an ethical way, and using materials that are good for the earth. In particular, zero-waste design, which gets rid of textile trash during the design process, has gotten a lot of attention because it might make making clothes less harmful to the environment. Still, there hasn't been enough study on how to use zero-waste ideas in children's clothing. Adding multifunctionality to kids' clothes can also make them more helpful and help customers in both practical and financial ways. Our study aims to fill these gaps by coming up with zero-waste, flexible, and long-lasting designs for kids' clothes.

Keywords*: Multifunctional, Children wear, Sustainable, Convertible, Zero -Waste.*

1.0 Introduction-

The fashion industry is one of the most significant contributors to global pollution, and children's clothing is particularly problematic due to their frequent replacements and rapid growth. A creative solution to this issue that addresses practical, financial, and environmental concerns is sustainable multipurpose children's apparel with a zero-waste concept. This study examines the integration of sustainable materials, multifunctional design, and zero-waste production procedures in children's apparel to minimize environmental impact and enhance its utility and lifespan. By employing designs that are adaptable, modular, and multipurpose, clothing can evolve in tandem with the child, thereby reducing the necessity for frequent replacements. According to Gong, M & Rahman, O. (2016), a more circular fashion economy can also be achieved by significantly reducing textile waste through the implementation of zero-waste trimming and recycling techniques.

The research aims to highlight the benefits and challenges of implementing these sustainable strategies in the teenager's apparel industry by providing implementable design options that meet both consumer demands and ecological responsibility. The global fashion industry is one of the most resource-intensive and waste-generating industries, as it is characterized by significant environmental hazards, such as excessive water consumption, carbon emissions, and textile waste. Children's clothing, in particular, significantly contributes to this issue due to their rapid development rates, frequent clothing replacements, and brief clothing lifespans. In order to address these concerns, this study explores the concept of zero-waste, sustainable multipurpose children's clothing. This design concept integrates eco-friendly materials, inventive clothing customization, and effective manufacturing methods to significantly reduce the environmental impact.

1.1 The Need for Sustainability in Children's Wear-

Children outgrow their clothes fast, sometimes making clothing outdated in just months. Their fast-paced development causes too much textile waste, financial burden on parents, and more environmental damage. Fabric offcuts and leftovers produced by conventional fashion companies help to fill landfills. Adopting zero-waste approaches—which entail effective fabric use, pattern-cutting processes, and recycling strategies—can therefore greatly reduce pre- and post-consumer waste.

1.2 Multifunctionality in Children's Wear-

For sustainable children's fashion, multifunctional clothes show great promise. Adjustable size, reversible features, removable components, or transformable designs in clothing help to fit a child's development and changing requirements. By cutting unnecessary buying and waste creation, these designs not only improve durability and adaptability but also inspire sustainable consumer behavior.

1.3 Zero-Waste Design Approach-

A zero-waste design approach ensures that every part of the fabric is used efficiently, eliminating material waste during the manufacturing process. This can be achieved through:

- Zero-waste pattern making, where fabric is cut with minimal to no leftover scraps.
- Upcycling and repurposing discarded materials into new garments.
- Closed-loop recycling, where old clothing is transformed into new fabric or apparel.

By integrating sustainability, functionality, and waste reduction, this study aims to present innovative strategies for designing children's wear that help parents and children practically and also aligns with global environmental goals.

1.4 Research Objectives-

This research seeks to:

1. Analyse the environmental impact of conventional teenager's wear and the role of textile waste in pollution.
2. Examine sustainable materials suitable for children's clothing, such as organic cotton, bamboo fiber, and recycled fabrics.
3. Propose innovative and practical design solutions for sustainable multifunctional Teenager's wear.

1.5 Problem statement-

1.5.1 Introduction-

Among the various categories of apparel, teenager's wear presents a unique challenge due to its short lifespan. Children's clothes frequently become unusable within a short period due to rapid growth, wear and tear, and changing needs, leading to high consumption and disposal rates. As a result, parents must frequently purchase new clothing, contributing to textile waste accumulation and unsustainable production cycles.

Moreover, traditional fashion production is inherently wasteful, with fabric offcuts, leftover materials, and unsold stock contributing to massive landfill waste. Zero-waste design has emerged as a potential solution, yet its application in children's fashion remains largely unexplored. At the same time, multifunctional clothing—designed to serve multiple purposes, adapt to different needs, and extend usability—offers an innovative approach to sustainability. However, current children's fashion lacks a cohesive integration of sustainability, Multifunctionality, and zero-waste principles.

1.6 The Need for Multifunctionality in Children's Wear-

A. Challenges of Traditional Children's Clothing-

Most conventional children's clothing follows a rigid, single-function design, meaning each garment serves a single purpose for a specific age range or occasion. For example, separate outfits are needed for playtime, formal events, sleepwear, and outdoor activities. Additionally, seasonal changes require new purchases**,** as winter clothing differs from summer apparel. This results in excessive consumer spending and increased textile waste.

B. Potential of Multifunctional Clothing-

Multifunctional clothing presents an opportunity to reduce the number of garments needed per child by offering designs that:

1. Adjust in size – Clothing that expands or contracts to accommodate a child's growth can significantly extend garment usability.
2. Serve multiple purposes – Convertible garments that can be worn in different ways (e.g., reversible designs, detachable sleeves for all-season use) can reduce wardrobe size and excessive consumption**.**
3. Enhance durability and flexibility – Materials and construction methods that prioritize longevity and adaptability can reduce the frequency of replacements.

Despite its potential, multifunctional design is underutilized in children's wear, and very few brands incorporate adaptive features that could prolong garment life. This research seeks to bridge this gap by exploring how multifunctional designs can contribute to sustainability and reduce textile waste.

2.0 Literature Review -

The fashion industry significantly impacts the environment through waste generation, resource depletion, and carbon emissions. Sustainable fashion design has emerged as a response to these challenges, with a focus on zero-waste concepts and multifunctionality. Children's clothing presents unique challenges and opportunities in sustainable design due to rapid growth rates and changing needs. This literature review examines existing research on sustainable design principles, zero-waste techniques, and multifunctional clothing for children, emphasizing the importance of eco-friendly materials, ethical production, and circular fashion models.

2.1 Introduction-

Textile waste is exacerbated by the frequent replacement of children's apparel as a result of development. Designs that are both sustainable and multifunctional can simultaneously mitigate the environmental impact and offer practical solutions for parents Cunha, J. & Broega (2009). This review investigates the literature on sustainable materials,

multifunctional apparel, and zero-waste fashion in the context of children's clothing. Sustainability in the fashion industry entails the development of garments that are durable and adaptable, the utilization of eco-friendly materials, and the reduction of waste. The significance of sustainable production processes and lifecycle thinking is underscored by the research conducted by Fletcher (2008) and Gwilt (2014). The principles of sustainable children's apparel include ethical manufacturing, recyclability, and longevity. The objective of zero-waste fashion is to eradicate textile refuse during the production process. Rissanen and McQuillan (2016) have investigated zero-waste pattern-making techniques, including modular and tessellated designs. Research suggests that zero-waste methodologies can decrease production waste by as much as 15% (Rissanen, 2013). By incorporating these methods into children's apparel, it is possible to maintain functionality and aesthetic appeal while simultaneously increasing sustainability. Multifunctional garments are designed to fulfil a variety of functions, thereby increasing their longevity and functionality. Research conducted by Niinimäki (2011) and Koo (2016) indicates that transformable apparel can accommodate the rapid development of children, thereby reducing the necessity for frequent replacements. Some strategies employed to enhance the adaptability of apparel include reversible designs, adjustable features, and convertible garments.

In sustainable fashion, children's wear depends critically on sustainable materials. Eco-friendly substitutes abound from organic cotton, bamboo, Tencel, recycled textiles. Studies by Hethorn and Ulasewicz (2015) confirm the usage of biodegradable and non-toxic materials to guarantee safety and sustainability in children's apparel. Moreover, helping to preserve the environment are sustainable dyeing and finishing techniques. Closed-loop manufacturing, upcycling, and recycling are promoted in ethical and circular fashion models. Studies supporting circular economy ideas in clothes design by Ellen MacArthur Foundation (2019) and Webster (2017). Second-hand marketplaces, clothes exchanges, and rental services lengthen the life of children's clothing hence lowering textile waste and consumption. Beyond simple wear, multifunctional clothes may be converted into other useable objects or adapted to fit diverse climates. With an eye toward children's health, zero-waste approaches, material selection, and disassembly design, (Shaharuddin and Jalil 2021) produced four multipurpose children's apparel items. Their designs sought to be recyclable and decomposable at the end of their lifetime, therefore fostering sustainability in the clothing sector. Zero-waste design reduces or does away with fabric waste during garment manufacture. Using the "Jigsaw Puzzle" method for pattern and grading, Jalil and Shaharuddin, (2021) concentrated on zero-waste pattern creation for children's apparel. Their research showed that mass manufacturing of multi-digital grading zero-waste technologies may help the apparel industry both economically and ecologically. Design of sustainable children's apparel depends much on the use of environmentally friendly materials. Focusing on reducing material diversity to enable recycling and safeguard children's health, Shaharuddin and Jalil (2021) underlined utilizing organic cotton and recycled polyester. Their designs guaranteed comfort and safety by following worldwide guidelines for children's clothes. Promoting sustainable behaviors depends on an awareness of designers' points of view. Investigating designers' viewpoints on multifunctional children's clothing, Hatef and Shaari, (2023) found that their design decisions were much impacted by sustainable practices, environmental knowledge, and market environment. The study underlined the need of teaching designers and increasing their expertise to help to increase the acceptance of sustainable children's clothing. Including green design ideas into children's clothes means thinking through post-use processing, user demands, and material choices. According to Shuyan et al. (2023) suggested a conceptual framework stressing optimal design, environmental protection materials, and user requirements to support sustainable development in children's clothing. Children's functional textiles should provide comfort, protection, health, and support for cognitive development. According to study published in the Applied Sciences journal in 2023, the varied nature of children's clothing and functional materials depends critically on an interdisciplinary design approach and complete user comprehension. The study underlined the importance of using researched materials and technology in children's fashion to provide creative and intentional solutions by means of practical application. Within a zero-waste framework, the sustainable, multifarious children's apparel design calls for a comprehensive strategy combining creative design ideas, environmentally safe materials, and a strong awareness of consumer demands. Advancement of sustainability in the children's clothes sector depends critically on ongoing research and cooperation among designers, producers, and customers, Koo, H.S., Dunne, L. & Bye, E., (2014).

3.0 Research Methodology-

Implementing a comprehensive research methodology that incorporates design innovation, material science, and user-centered evaluation is essential for the development of sustainable, multifunctional children's apparel with a zero-waste principle. The methodology outlined below delineates the approach to achieving the research objectives:

3.1 Design and Development-

A. Conceptualization-

Formulate initial design concepts for children's apparel that integrate multifunctionality and zero-waste principles. This entails the exploration of a variety of design possibilities that are consistent with sustainability objectives through ideation sessions and sketching.

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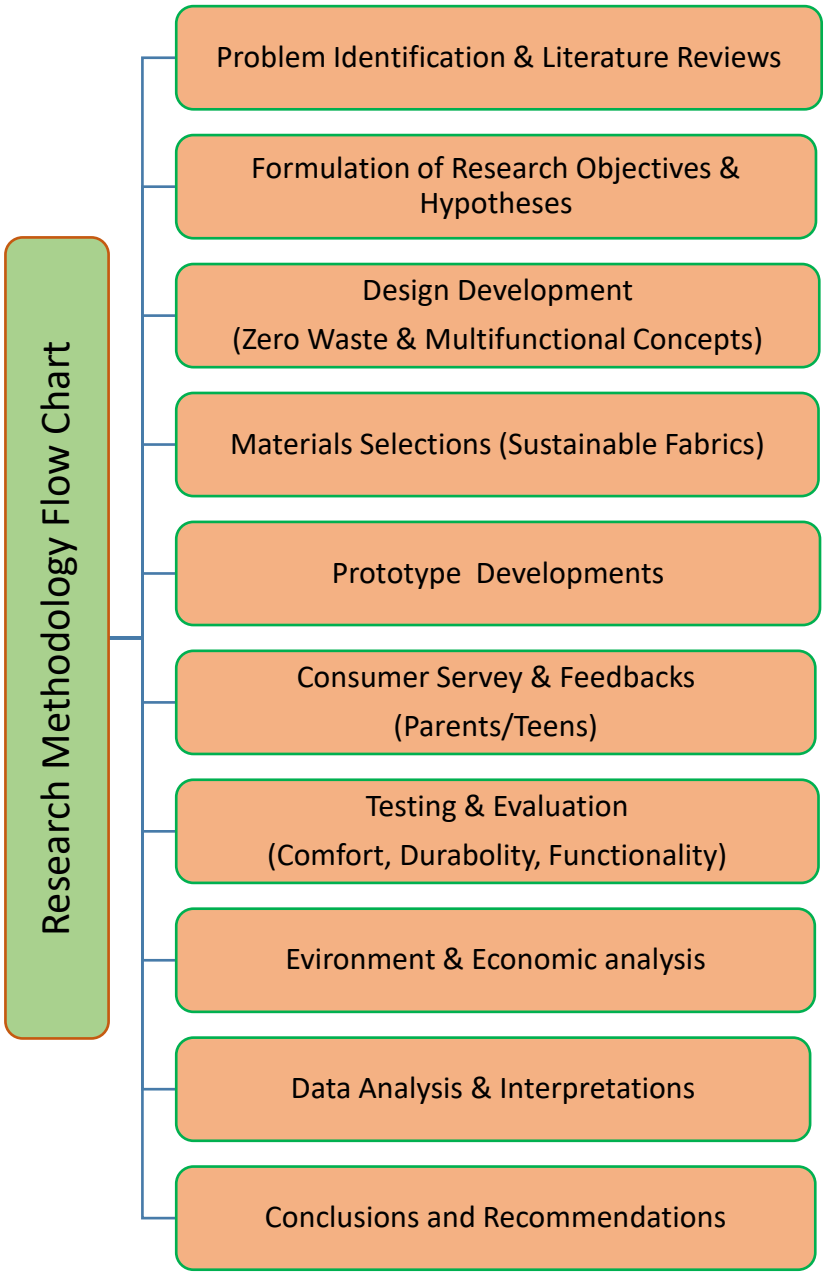

B. Pattern Design-
Eliminate fabric waste by employing zero-waste pattern cutting techniques to develop garment patterns., The Rectangular fabrics cuts, 3D CLO draping and "Jigsaw Puzzle" method have been implemented, which involves the strategic arrangement of pattern parts to optimize the utilization of the entire fabric with minimal to no waste. Precision and efficiency will be enhanced by digital instruments such as Computer-Aided Design (CAD) software.

C. Prototyping-
Utilize sustainable materials, such as organic cotton or recycled fabrics, to develop prototypes of the garments that have been designed. The prototypes will be created to evaluate the designs' feasibility and to implement any required modifications prior to their final production.

3.2 Material Selection-
Identify and choose materials that are durable, non-toxic, and eco-friendly for children's apparel. This encompasses the investigation and procurement of materials that are environmentally friendly and secure for children. Factors such as the environmental impact of material production, recyclability, and biodegradability will be taken into account. In the following table,

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4.0 Representations of Results and Discussion with respect to the Research Objectives-

A. Objective 1 is to understand and learn the consumer's awareness about the multifunctional garments with respect to their understanding about the environmental beliefs and their correlation with each other, following are the calculations of Pearson Correlation Formula with respect to the data obtained from the 330 end-users that includes teens and parents.

(End-Users only: Teens + Parents, (n = 330)

Awareness levels (Category %)

Formula for %:.

- High: 32.1%
- Moderate: 44.2%
- Low: 23.6%

Link to purchase intentions

- Let awareness score = {Low=2, Moderate=3, High=4}
- Purchase Intention measured on a 1-5 scale

Pearson correlation formula:

$$r = \frac{\sum (A_i - \bar{A})(P_i - \bar{P})}{(n-1)\, s_A\, s_P}$$

Calculated: r = 0.702 (Strong and Positive)

Significance test:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \Rightarrow t = \frac{0.702\sqrt{328}}{\sqrt{1-0.702^2}} = \mathbf{17.863},\ df = 328,\ p < 10^{-49}$$

Conclusion: Higher awareness strongly associates with higher purchase intention.

B. Objective 2 of the Research Study is to examine sustainable materials suitable for children's clothing, such as organic cotton, bamboo fiber, and recycled fabrics.

A comparative analysis is shown of various fabrics on the basis of above -mentioned variables considered for finding the best suitable and sustainable raw materials for the teenager's multifunctional garments.

Rank	Fabric	Sustainability (out of 10)	Key Strengths	Key Limitation
1	Hemp	9.5	Low water & pesticide use, soil regeneration, strong durability, biodegradable	Limited availability, slightly higher initial cost
2	Organic Cotton	9.0	No pesticides, safe for sensitive skin, biodegradable, widely available	Still water-intensive, shorter lifespan compared to hemp/linen
3	Linen (Flax)	8.5	Low water input, crop rotation benefits, fast drying, biodegradable	Creases easily, higher cost for fine-quality fabrics
4	Lyocell (TENCEL™)	8.0	Closed-loop eco-friendly processing, renewable wood source, soft & durable	Dependent on certified sustainable wood sourcing
5	Recycled Cotton	7.5	Diverts textile waste, saves resources, compostable if pure	Shorter fiber length often blended, reduced recyclability and durability.
6	Recycled Polyester (r PET)	7.0	Reduces plastic waste, highly durable, low-care energy	Sheds microplastics, non-biodegradable, recycling loops still limited
7	Bamboo (Viscose)	5.5	Fast-growing raw material, soft, biodegradable	Chemical-intensive viscose process unless closed-loop, greenwashing risks

The 100% Organic Cotton has been used to developing the initial designs of the teenager's clothes since it is easily available and softer and more comfortable than coarser hemp and other less sustainable fabrics.

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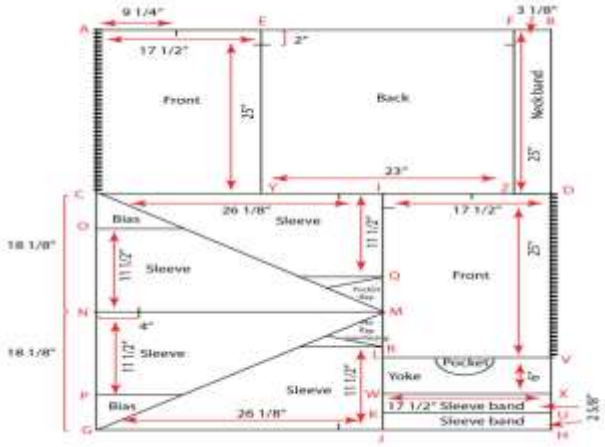
C. The last objective of the research is proposing innovative and practical design solutions for sustainable multifunctional Teenager's wear.

The skirt is designed for the girls (Picture 1A, 1B,) that can also be converted and worn as a full dress also. The pattern was rectangular piece of fabric in two colours, sharp curves were avoided so as to minimise the fabric wastages at the cutting level. Left over fabrics were used to give skirt Belt.

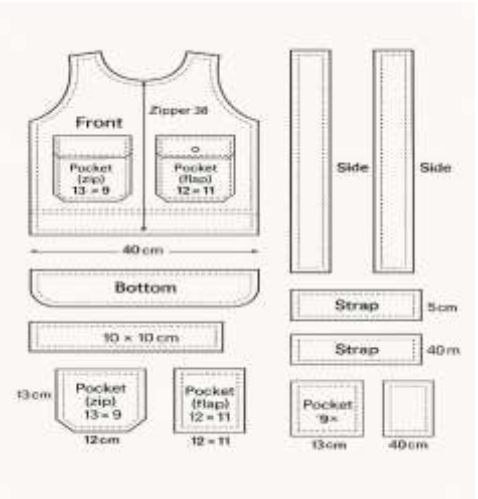


Fig; Rectangular Pattern for the Garment

Pic:1- Long-Skirt 1A **Long Dress 1B**

The other multifunctional outfit for the youth was a boy's vest that can be converted into a travelling bag as shown in the below pictures-2 and it was designed with CAD pattern software.

Pic: 2 Boy's Vest Front & Back View



Pic: 2A CAD Pattern Layout

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The boy's detachable long length jacket as shown below in the picture-3, the boy's jacket can be transformed into a waist length jacket by giving a zipper and size snap buttons. The lower panel of the jacket is detachable and can be reattached by the wearer as and when required according to the occasion or situation.
The jacket was developed with 100% organic cotton twill fabric whereas the inner lining was given of 100% cotton light weight poplin fabric. The filling inside the jacket is also given with the cotton fibre sheet with the quilting technique. Plastic zipper, side snap buttons are also given for closure of the jacket. The garment design is unisex and can be worn by both boys and girls.

Pic:3 Boys Jacket

The Fourth garment is the Girl's dress which can be worn as dress and can be transformed into skirt and tank top, it can be worn as daily wear attire. It is made of 100% printed organic cotton woven cambric fabric. Self-fabric straps, Plastic Buttons and side concealed zipper is used in the dress construction. The techniques of draping on the dress form were applied in giving it final look appearance and fit. The dress is designed with lining fabric 100% cotton voile.

4A (Dress) 4B (Skirt) 4C (Top with adjustable Height)

Picture- 4 Girl's dress can be worn as a dress, skirt, and tank top as shown in images (A B & C)
The complete range of four outfits of the children were developed and created based upon zero waste concept by using eco-friendly recyclable materials. The leftover waste fabric cuts were used in the Top's and dress's straps and strings. In apparel's construction, CAD pattern making and draping techniques were applied to avoid unnecessary wastages in the construction process.

5.0 Conclusion
The aims of the research would be designing and exploring a range of multifunctional children's clothing by transforming different garments with different functions and properties. Different techniques will give versatility to design conversion and design flexibility. The multifunction design approach will encourage people to reuse, recycle garments instead of throwing away. To enhance the garment's flexibility, functionality, user-friendliness characteristics, various designing techniques may be applied such as garment draping, panelling, and folding etc. Suitable cloths for various occasion and functions can be designed with latest fashion and trends. The convertible and detachable garments will provide many

options to the consumer to stylize their cloths as per their functional property. The problem of wastage can be resolved by the wearer by mix-matching the multifunctional garments in different styling.

Multifunctional children's garments could be recycled and brought again in the economic system back instead overthrowing and minimizing landfill space area, carbon footprint on the planet, and have a affirmative outcome on the environment and our coming future. The eco-fashion design norms will help the garment designing team in identifying the recyclable, reusable and less harmful materials cause less harm to the nature and environment. The fashion designers should focus on using recyclable, reusable materials in designing multifunctional clothing for children. The fast fashion brands and their manufactures should focus on designing multifunctional cloths in their wide product assortments and educate and motivate their product's end users about the sustainability and environment protection.

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