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DESIGN AND DEVELOPMENT OF SMART SANDALS FOR VISUALLY IMPAIRED INDIVIDUALS IN NIGERIA, ENHANCING SAFETY AND LEVERAGING THE VALUE CHAIN

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Design and Development of Smart Sandals for Visually Impaired Individuals in Nigeria, Enhancing Safety and Leveraging the Value Chain

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ABSTRACT

The high prevalence of visual impairment in Africa poses significant challenges to mobility and personal safety, particularly in environments with hazardous terrain. This study presents the design and development of smart sandals equipped with advanced technology to detect and alert users to the presence of sharp objects, thereby enhancing safety and independence for visually impaired individuals. The project adopts a value chain approach unique to Africa, integrating locally sourced materials, community-driven production processes, and innovative technology to create a sustainable and affordable solution. The smart sandals feature embedded sensors and alert systems that proactively warn users of nearby sharp objects, significantly reducing the risk of injuries. Beyond addressing safety concerns, the project fosters socioeconomic development by engaging local artisans, manufacturers, and technology developers. This inclusive approach promotes economic empowerment, job creation, and skill development while ensuring the sandals remain accessible to underserved and marginalized communities. By combining human-centered design principles with a sustainable value chain framework, this initiative underscores the transformative potential of wearable technology to improve quality of life. The project not only mitigates safety challenges for visually impaired individuals but also contributes to broader economic and social advancements across Africa, demonstrating a scalable and impactful model for innovation.

Keywords: Visual impairment, smart sandals, wearable technology, mobility, safety.

1. INTRODUCTION

Visual impairment significantly impacts the daily mobility and safety of affected individuals, particularly in regions with hazardous terrains and limited accessibility infrastructure. In Africa, where a high prevalence of visual impairment exists, the lack of assistive mobility solutions increases the risk of injuries and restricts independence. To address this challenge, wearable technologies have emerged as innovative solutions to enhance mobility for visually

impaired individuals. Smart sandals equipped with advanced sensor technology offer a promising approach to improving safety by detecting sharp objects and alerting users in real time.

Footwear refers to garment worn on the feet, which typically serves the purpose of protection against adversities of the environment such as wear from ground texture and temperature. Footwear in the manner of shoes therefore primarily serves the purpose to ease locomotion and prevent injuries. Footwear can also be used for fashion and adornment a well as to indicate the status or rank of the person within a social structure. Footwear plays a fundamental role in our days to day lives as it a necessary to human being just like (Abraham Maslow's theory of need hierarch) which is physically needs. Robbins, (2001) stated "footwear apparel has been seen as an intimate part of an individual". It is one of the most personal components of daily life, and at the same time, it is an expression of social activities embedded in the culture pattern within a particular era as noted by Barnard (2009). Footwear originally servers as a paramount part of human apparel or fashion in which human cannot do This application is a form of a device implanted in the midsole of the sandals so whenever the user steps on a metal sharp object, a notification will come up from an alarm speaker connected to the instep upper part of the sandals. And may help blind people, a safety lives.

Without Footwear is of different sizes, shape, colures, textures and materials to suit different function and occasion in order to give satisfaction to the user in terms of protection against weather and climate conditions, dangerous animal and plant, infection, diseases etc. (NP kuso,2018).

Therefore, this study explores the design and development of smart sandals tailored for visually impaired individuals in Africa, emphasizing a value chain approach that integrates locally sourced materials, community-driven production, and technological innovation. The project aims to create a sustainable, affordable, and inclusive solution that not only enhances personal safety but also contributes to economic empowerment by involving local artisans, manufacturers, and technology developers. By leveraging Africa's unique value chain, this initiative promotes skill development, job creation, and accessibility while fostering social and economic development.

Additionally, the study highlights the transformative potential of wearable technology in improving the quality of life for visually impaired individuals. By adopting human-centered design principles and ensuring affordability through local production, the smart sandals offer a scalable model for innovation in assistive technology. The subsequent sections provide a review of relevant literature, examining existing assistive mobility technologies, the role of wearable devices in disability inclusion, and the impact of value chain in product development.

2. Literature Review

This literature review explores the history of sandals, the evolution of assistive mobility technologies, focusing on their effectiveness, limitations and potential for adaptation in Africa. It examines traditional mobility aids, smart footwear innovations, and the roles of value chain in developing sustainable solutions. The review also discusses challenges related to accessibility and affordability, emphasizing the need for localized, inclusive technological interventions to enhance mobility and safety for visually impaired individuals.

History of Sandals

Sandals are among the oldest forms of footwear, dating back thousands of years,

with evidence of their use in ancient civilizations across the world. They were originally designed for practicality, providing protection while allowing

ventilation in warm climates. Over time, they evolved in design, materials, and cultural significance. The earliest known sandals date back approximately 10,000 years and were discovered in Fort Rock Cave, Oregon, made from woven sagebrush bark (Pielou, 1994). Similarly, ancient Egyptians wore sandals crafted from papyrus and palm leaves, as seen in hieroglyphic depictions and archaeological findings (Aldred, 1988). Egyptian pharaohs and high-ranking officials adorned elaborate sandals made from leather or gold, signifying status and authority (Wilkinson, 2000).

In Mesopotamia and the Indus Valley civilizations, sandals were commonly worn by nobility, often made of leather and secured with straps (Boucher, 1996). The Greeks and Romans further refined sandal designs, incorporating thick soles and intricate lacing systems. Greek philosophers, such as Socrates and Plato, are frequently depicted wearing simple leather sandals, while Roman soldiers utilized sturdier caligae (military sandals) for durability during long marches (Harlow & Nosch, 2014).

Thereafter, during the medieval period in Europe, sandals became less common due to colder climates and the rise of enclosed shoes (Steele, 2010). However, in warmer regions such as the Middle East, Africa, and parts of Asia, they remained an essential part of daily attire. Traditional Japanese zori and Indian paduka exemplify regional adaptations of the sandal, incorporating wood, leather, and ornamental elements (Guroian, 2005). By the 19th and early 20th centuries, sandals gained renewed popularity in Western fashion, influenced by archaeological discoveries and cultural exchange. The rise of leisure and beachwear in the mid-20th century contributed to the global demand for sandals, with materials such as rubber and synthetic fibers improving affordability and accessibility (Welters & Cunningham, 2005).

Today, sandals serve both aesthetic and functional purposes. Advances in footwear technology have led to the development of orthopedic, sports, and smart sandals designed for comfort and safety. Smart sandals, equipped with sensors for health monitoring or mobility assistance, reflect the integration of technology into traditional footwear (Khan et al., 2022). The incorporation of sustainable materials and ethical production methods is also shaping contemporary sandal manufacturing, particularly in Africa, where locally sourced materials and artisanal craftsmanship are central to footwear production (Moses et al., 2020).

Assistive Mobility Technologies for Visually Impaired Individuals

Mobility is a fundamental aspect of independence for visually impaired individuals, yet navigating environments safely remains a significant challenge. Over the years, assistive mobility technologies have evolved from traditional tools, such as white canes and guide dogs, to advanced electronic travel aids (ETAs) that integrate sensor-based navigation systems. Technological advancements have played a crucial role in improving mobility and safety for visually impaired individuals. Traditional assistive devices such as canes and guide dogs have been widely used, but they present limitations in detecting specific hazards such as sharp objects on the ground (Dakopoulos and Bourbakis, 2010). Recent developments in wearable assistive technologies, including smart footwear, offer enhanced safety features by incorporating sensor-based detection and real-time alert systems (Khan et al., 2022). These innovations demonstrate the potential of integrating sensor-based navigation and obstacle detection systems into wearable devices to provide a more effective solution for visually impaired individuals.

Smart Footwear and Wearable Technology in Mobility Assistance

The blend of smart technology into footwear has gained attention as a viable approach to mobility assistance. Smart shoes and sandals embedded with ultrasonic sensors, haptic feedback mechanisms, and audio alerts have been developed to aid visually impaired users in detecting obstacles and navigating safely (García et al., 2019). Research indicates that wearable

technology, particularly in the form of footwear, enhances user convenience and autonomy compared to handheld or externally mounted assistive devices (Jain et al., 2021). However, many existing smart footwear solutions remain expensive and inaccessible to economically disadvantaged populations, particularly in Africa. This underscores the importance of designing affordable, locally produced smart sandals that leverage existing value chains.

Value Chain Integration in Assistive Technology Development

The value chain approach in product development focuses on optimizing the entire lifecycle of a product, from material sourcing to distribution, to create cost-effective and sustainable solutions (Kaplinsky & Morris, 2001). In the context of assistive technology, integrating local artisans and manufacturers into the production process ensures affordability and accessibility while promoting economic empowerment. Studies have shown that locally produced assistive devices are more sustainable and adaptable to regional needs compared to imported alternatives (Moses et al., 2020). By incorporating community-driven production and using locally available materials, smart sandals can be produced at a lower cost while fostering job creation and skill development in African communities.

Socioeconomic Impact of Inclusive Technology in Africa

Inclusive technology development not only addresses the immediate challenges faced by visually impaired individuals but also contributes to broader socioeconomic advancements. According to World Health Organization (WHO, 2021), disability inclusion in technology enhances independence and economic participation, ultimately improving overall quality of life. Community-based production of assistive technologies has been shown to enhance social inclusion and economic sustainability by creating employment opportunities for marginalized groups (Smith et al., 2018). The design and development of smart sandals in Africa align with these principles by prioritizing affordability, accessibility, and economic integration, making the solution both practical and impactful.

2.1 RESEARCH SAMPLES

A research is the collection of different design sourced from related works and translated into a broad range of design.

Fig 1: Research Page
Source: pinterest.com (2025)

Theme

A theme is a recurrent, underlying objective that ensures consistency in a design of wide range of products. Also, it reflects the proposed idea that the research intends to adopt into a finished product. Theme can be sourced from animals, plants and colors, etc. provided that the principle and the element of design are taken into account artistically. Theme is based on choice of any of a research work, in this work, abstract of an Eagle was chosen, because it has been observed that this animal has the basic element of design which was used on this work on the development of the design

Figure 2: Abstract of an Eagle
Source: wikipedi.org/Eagle (2025)

Targeted Customers

Are the end users of the finished product which cut across different age ranges e.g 18-30, 40-50 and above, and also different social classes, colours and professions.

Fig. 3: targeted customer

Source: Wikipedia.com

1. METHODOLOGY

There are several methods of production which can be employed in the production of footwear depending on the kind and style of footwear in question. These methods are adopted from the design, pattern cutting and through the final production. The cemented type of construction is a method in attaching the sole to the upper part of the shoe. In this method the upper part is placed on a last, which is a plastic form that give the shoe it shapes. Then, a thin layer of adhesive is appealed to the outsole, and the uppers attached to it.

3.1 Materials for Production

Here are the material and quantity purchased for production,

S/N	MATERIALS	PAIRS/ SQUARE FOOT
1	Flexible wire	4 yards
2	1mm cable	6 yards
3	Clock alarm	2
4	Microcellular sole	1 pair
5	Adhesive	60CL
6	Grain upper leather	3sqf
7	Ring	1pair
8	Insole raping synthetic	2pairs
9	Velcro	Half yard
10	Metal plate	One pair
11	Microcellular 2mm	1pair
12	White synthetic leather	1pair
13	Fiber	1 line
14	Welt	1 pair
15	Microcellular 8	1pair
16	White and black thread size 3	2
17	Leather lining	3sqf
18	Microcellular sole	1pair
19	Battery	2pairs
20	Back stiffener	1pair

Table 1

3.2 Equipment and Machines

i. Tack nails
ii. Scissor
iii. Cutting knife
iv. Lasting pincer
v. Filling Machine
vi. Sewing Machine
vii. Sole Attaching Machine

3.3 SEQUENCE OF PRODUCTION

The sequence of production is process involved in production cycle, that is, ranging from design to finishing, just as seen in the list and flow chart below:

i. Design
ii. Pattern making (cutting)
iii. Clicking
iv. Closing (stitching)
v. Lasting,
vi. Finishing,
vii. Packaging.

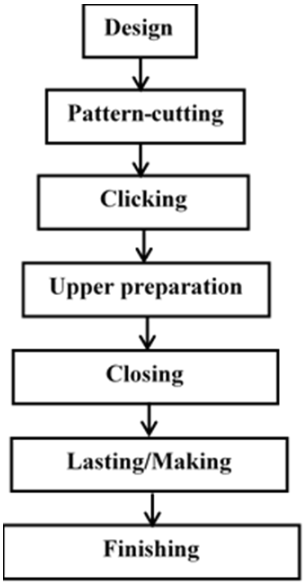

Figure 11: Production flow chat

Source: (Clarks, C.J. 1989)

3.3.1 Design

It can be defined as a detail plan or drawing of a shoe from which it can be made from or the art or process of deciding how something will look like or works etc. by drawing plans and making models. The final design is achieved by extracting different parts of the smart sandals.

Range Development

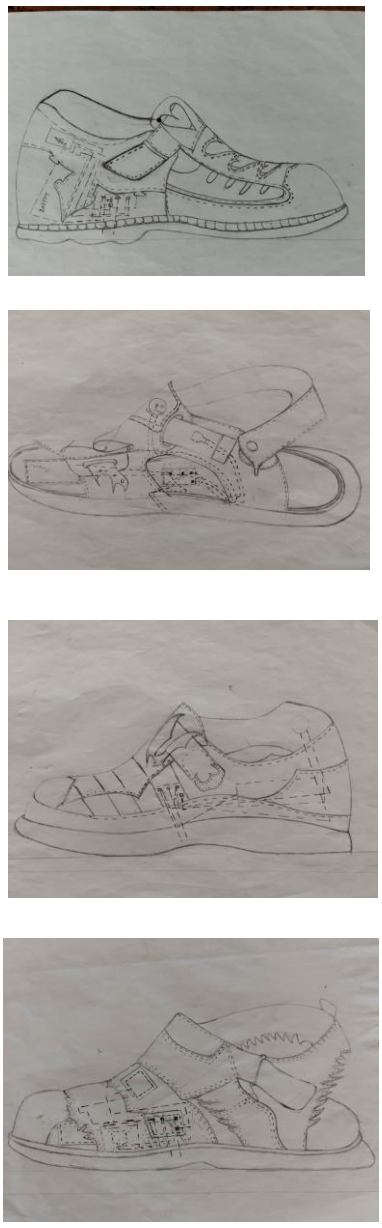

Plate 1: Range Development

These are displayed products with different designs and colors for the intended design from which the final design is developed.

Final Design

The preferred design (final design) was selected from the range development for production.

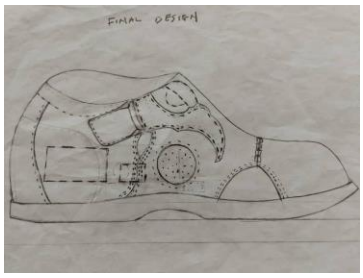

Plate 2: Final Design

3.2 Pattern Cutting

This is a process whereby the designer's ideas are interpreted into pattern and then sectional patterns are produced before transferring it onto the material.

Sequence of Pattern Cutting

There are several different steps involved in the sequence of pattern cutting.

1. Selection of last
2. Last tapping
3. Inn and out forme
4. Mean forme
5. Standard forme
6. Net pattern.
7. Working pattern.
8. Lining pattern.

Selection of Last

A shoe last is a three-dimensional (3D) form that gives the shoe its shape and size. It is usually made of wood or plastic, and it has the shape and dimensions of a human foot. A last of size 42 was selected to aid in the production of the visually impaired footwear

Plate 3: Selected Last

Taped Last

The last was taped completely round the whole body, starting from the feather edge of the last round and afterwards two strip of masking tape placed from the back tip of the last. This is done on both sides of the last for easy removal of the masking tape.

Plate 4 taped last

IN and OUT Forme

The in and out forme is gotten from a taped last, that is after the last have been taped, it is then centralized from the fore part of the last (instep) down to the backpart, (heel edge) of the last. Thereafter, IN and OUT part of the is then removed and placed on a cardboard and cutout from the cardboard following the shape.

Plate 5 IN and OUT Forme

Mean Forme

The mean forme is the average of both the IN and OUT forme and it is achieved by placing the out forme on a card board paper then trace round the topline of the OUT forme also the IN is placed on the same position with the out forme for alignment after which a space is created as result of placing them IN and OUT forms together.

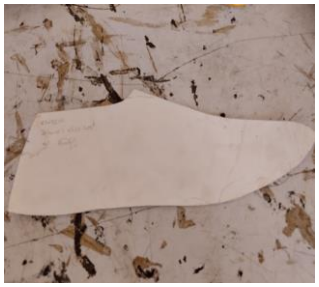

Plate 6: Mean Forme

Standard Making

The standard making is the process of cutting the upper component to the exact standard required by the shoe design. This ensure that the upper will fit perfectly on the last, and it helps to maintain con

Plate 7: Standard

Net Pattern

This is the pattern that has underlay as its only allowance.

Plate. 8: Net Pattern

Working Pattern

Working pattern is gotten from tracing the net pattern and adding 5mm as the folding allowance.

Plate 9: Working Pattern

Lining Pattern

Lining pattern this is the pattern that has underlay allowance and 3mm of trimming allowance.

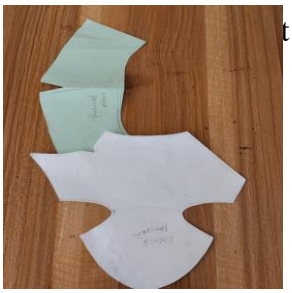

Plate 10: Lining Pattern

3.3 Cut Upper Component

Cut upper component are the part that make up the upper of the shoe.

Clicking

The term clicking is the traditional word for cutting. Clicking room is the Name given to the part of the factory where the different parts of the upper of a shoe are cut from Leather or leatherette.

Assembling

This process involves assembling all cut and skived parts of uppers, assembling together with the aid of adhesive before they are being stitched together.

Closing

Closing is the title given to the operational of fitting together and stitching all the cut (s) components with lining to produce an upper ready for lasting.

Lasting

Lasting is the term given to the process of pulling the upper material over the last and securing it to the bottom of the insole either by tacks or with adhesive, provided that the operations are carried out in the correct way.

This operation is carried out on a closed upper alongside with an insole, that is the upper is pulled over the last temporary with the aid of tacks, afterwards an adhesive is applied round the feather inwardly then the lasting is properly done in order for the shoe to retain the shape of the last.

Attaching: This is one of the steps in footwear production process that involves attaching the upper part of the shoe to the sole.

Sole preparation: This is the process where by all the sole part are been brought together for preparation. For the benefit of this project, this device and this metal plate shown below was buried inside the outer sole, so as to be included as part of the sole preparation.

Plate 11: Sole Preparation

Sole roughing: This is the process whereby the surface of the inward of the feather edge is been roughed round the sole for proper adhesion.

Sole cementing: The surface of the sole is coated with cement, usually (PU) polyurethane or on the other hand Neoprene adhesive in the case of leather sole or microcellular rubber and allowed to dry.

3.4 FINAL PRODUCT.

The final product in footwear production is the finished shoe, ready to be shipped and sold.

IN view

Ku

OUT view

Plate 12: Final Product (OUT and IN view)

4. PRODUCT EVALUTION

Functionality and Performance

The primary function of the smart sandals is to detect sharp objects and provide real-time alerts to users. Embedded sensors detect obstacles and send feedback through vibrations or audio cues. The effectiveness of these sensors in different environments, such as urban and rural terrains, is crucial in determining the sandals' overall performance. Field tests was conducted to assess the sandals' ability to detect small and sharp hazards, such as broken glass, nails, and uneven surfaces, ensuring accurate and timely alerts and aim was achieved.

Usability and Comfort

Usability is a key factor in the adoption of assistive technologies. The sandal is lightweight, easy to wear, and user-friendly. When the sandal was tried on by a Visually impaired individual, he was able to operate the alert system with minimal effort, ensuring independence in mobility. Comfort is also essential, with ergonomic design considerations such as cushioning, breathability, and adjustable straps for a secure fit. based on feedback from user has helped in refining the interface and improved accessibility.

Durability and Environmental Adaptation

Given Africa’s diverse climate conditions, the smart sandals is, durable and resistant to extreme weather, including heat, and rough terrain.

The materials used were robust and sourced locally to ensure cost-effectiveness while maintaining high quality.

3. CONCLUSION

The design and development of smart sandals for visually impaired individuals in Nigeria present a transformative approach to enhancing mobility, safety, and independence. By blending advanced sensor technology, these sandals offer real-time alerts to users, significantly reducing the risk of injuries from sharp objects and hazardous terrain. The adoption of a value chain framework ensures that the production process remains sustainable, leveraging locally sourced materials, skilled artisans, and community-driven manufacturing.

This initiative not only addresses a critical mobility challenge but, also contributes to socioeconomic development by creating employment opportunities and fostering technological innovation within Nigeria's footwear industry. The use of affordable and durable materials further enhances accessibility, ensuring that the sandals remain within reach of underserved populations. However, for long-term success, continuous improvements are necessary. Advancements in battery efficiency, sensor accuracy, and cost reduction strategies will further refine the product. Additionally, stakeholder collaboration including government support, private sector involvement, and advocacy from disability organizations will be crucial in scaling production and increasing awareness.

Ultimately, the smart sandal project highlights the potential of wearable technology in improving the quality of life for visually impaired individuals. By combining human-centered design with a localized value chain approach, this initiative provides a scalable, impactful, and sustainable model for assistive footwear development in Nigeria and beyond.

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