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Smart Umbrella: An Innovation in Design, Manufacturing, and Assembly for Modern Users

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ABSTRACT: The integration of technology into everyday objects has led to the development of multifunctional devices that enhance user experience while meeting modern demands for sustainability and efficiency. This article presents the design, manufacturing, and assembly of a smart umbrella equipped with innovative features, including a solar panel, rechargeable battery, LED lights, and a USB port. By merging protection against weather conditions with energy portability, the smart umbrella provides a practical solution for outdoor environments such as parks, beaches, and open-air events.

The design process employed the Design Thinking methodology, emphasizing user-centered solutions through stages of empathy, definition, ideation, prototyping, and evaluation. The project also leveraged Design for Manufacture and Assembly (DFMA) to optimize the product's manufacturing and assembly, reducing complexity, costs, and environmental impact. Materials were selected for durability, recyclability, and weather resistance, aligning with sustainability goals.

Prototypes were created using CAD tools, tested for functionality, stability, and user comfort under diverse conditions. Feedback from users informed iterative improvements to ensure performance and usability. The smart umbrella demonstrates how innovation and interdisciplinary approaches can transform traditional products into versatile, eco-friendly solutions. This design represents a significant step toward integrating advanced technology into everyday life, addressing modern challenges in energy access and sustainability.

KEYWORDS: Smart Umbrella, Design Thinking, Design for Manufacturing and Assembly, Quality Function Deployment (QFD), Sustainable Design, User-Centered Design.

I. INTRODUCTION

In today's world, the development of innovative and functional products has become essential for improving users' quality of life while meeting the increasing demands of the technological market. The integration of technology into everyday objects has enabled the creation of devices that not only fulfill their basic function but also offer additional features that enhance their value to users. This article provides a detailed study on the design, manufacturing, and assembly of a smart umbrella equipped with multiple functionalities. Among these are an integrated solar panel, rechargeable battery, LED lights, and a USB port, transforming this object into a portable energy source that provides protection against sun and rain while enabling the charging of electronic devices anywhere.

Technology has progressively entered domains where it was once deemed unnecessary, and products like the smart umbrella exemplify how innovation can enhance user experience by solving multiple problems simultaneously. The proposed umbrella not only offers protection against weather conditions but also addresses one of the most prevalent needs of modern life: constant access to energy for electronic devices such as mobile phones, tablets, and other gadgets. This solution is particularly useful in outdoor settings like beaches, parks, and open-air events where energy sources are often limited.

Beyond its technological functionalities, designing products like the smart umbrella also presents significant challenges in terms of manufacturing and assembly. Here, the Design for Manufacturing and Assembly (DFMA) methodology plays a fundamental role. DFMA is an essential approach in modern product development, aimed at simplifying product design to facilitate its fabrication and assembly. This methodology reduces costs, improves the final product's

quality, and optimizes resource use. For this project, the smart umbrella leverages DFMA, ensuring that the manufacturing process is efficient, cost-effective, and environmentally friendly.

One of the primary benefits of applying DFMA in product design is reducing complexity. This approach helps identify unnecessary or redundant components that can be eliminated or integrated, simplifying both the design and assembly processes. For the smart umbrella, the solar panel is directly integrated into the structure, eliminating additional parts that could increase weight and assembly difficulty. Similarly, the placement of cables connecting the solar panel to the battery has been optimized, concealing them within the umbrella's shaft. This not only improves the design's aesthetics but also protects electronic components from potential damage caused by weather exposure.

DFMA also offers significant cost-saving advantages. Simplifying the design and reducing the number of components decreases the time and effort needed for production. This directly impacts production costs, making the smart umbrella more competitive in the market. Furthermore, DFMA promotes early collaboration between design and manufacturing teams, which is crucial to incorporating manufacturing considerations during the initial design stages. This avoids costly redesigns and delays later in the product development process. For the smart umbrella, engineers and manufacturing teams worked together from the start, ensuring that technological components like the solar panel, battery, and LED lights were easy to integrate during assembly without compromising functionality or aesthetics.

Another key aspect addressed by DFMA is sustainability. In a world increasingly conscious of environmental impact, DFMA encourages efficient use of materials and manufacturing processes that generate less waste. For the smart umbrella, durable and weather-resistant materials were selected, which are also recyclable, contributing to a more sustainable product lifecycle. As a result, the umbrella not only provides a practical technological solution but also aligns with current demands for environmental responsibility.

The paper is organized as follows. Section II provides an overview of the Design Thinking methodology applied to the development of the smart umbrella, detailing the five stages: Empathize, Define, Ideate, Prototype, and Evaluate. Section III describes the use of the Design for Manufacture and Assembly (DFMA) methodology, highlighting how it was used to optimize the product's design for cost-effective and sustainable manufacturing. Section IV presents the results, including the QFD analysis, the identified design features, and the product's evaluation against competitors. Finally, Section V concludes the study, summarizing the achievements and emphasizing the smart umbrella's innovative contribution to multifunctional product design.

II. LITERATURE SURVEY

The development of smart products has become a key trend in the design and manufacturing industry. Umbrellas, traditionally conceived as weather protection tools, are evolving into multifunctional devices through the integration of advanced technology. This concept aligns with a global context where user needs extend beyond comfort and basic functionality to include solutions incorporating sustainability, energy efficiency, and connectivity.

One example of this evolution is Oombrella, an umbrella equipped with environmental sensors that notify users of imminent weather changes. This product illustrates how technology can be integrated into everyday objects to enhance functionality and user experience. Another innovative design is KAZbrella, an inverted umbrella that prevents water from dripping when closed, showcasing how design advancements can effectively solve common issues.

The integration of features such as solar panels, rechargeable batteries, LED lights, and USB ports transforms umbrellas into innovative tools that not only protect against weather conditions but also provide portable energy solutions. This approach allows users to enjoy a multifaceted experience that combines protection with access to renewable energy while promoting sustainable and efficient designs.

Moreover, developing products like the smart umbrella poses significant challenges in terms of manufacturing and assembly. This is where methodologies like Design for Manufacturing and Assembly (DFMA) become essential tools. DFMA simplifies designs, optimizes resources, and reduces costs by eliminating redundancies in components and processes. According to experts in the field, DFMA encourages early collaboration between design and manufacturing teams, ensuring that final products are more efficient, accessible, and sustainable.

In the design field, DFMA has been recognized for its ability to optimize product development processes. Walter Pack emphasizes that this methodology allows for a systematic evaluation of designs to ensure their feasibility and avoid unnecessary costs during manufacturing. This simplification is also evident in everyday products like smart umbrellas, where the number of components is minimized, making assembly more efficient and reducing costs.

Finally, the use of Design Thinking as a user-centered design methodology ensures that the products developed are not only technically efficient but also aligned with the real expectations and needs of consumers. This iterative approach, applied in the stages of empathy, definition, ideation, prototyping, and evaluation, enables the generation of innovative solutions that balance functionality, sustainability, and aesthetics.

Technological advancements in products such as the smart umbrella highlight a convergence between industrial design, technological innovation, and sustainability principles. These innovations not only enhance the user experience but also address contemporary challenges in energy efficiency and environmental care, paving the way for the development of more responsible and multifunctional products.

III. METHODOLOGY

Design Thinking is a methodology widely used in the development of innovative products as it focuses on deeply understanding user needs and creating practical, effective solutions. It is characterized by being a flexible, iterative approach oriented towards problem-solving. During the design process of the smart umbrella, the five fundamental stages of Design Thinking were employed: Empathize, Define, Ideate, Prototype, and Evaluate. Each of these stages was crucial to ensuring that the final product not only met user expectations but was also functional, aesthetically pleasing, and viable in terms of manufacturing and assembly. These five stages are illustrated in figure 1.

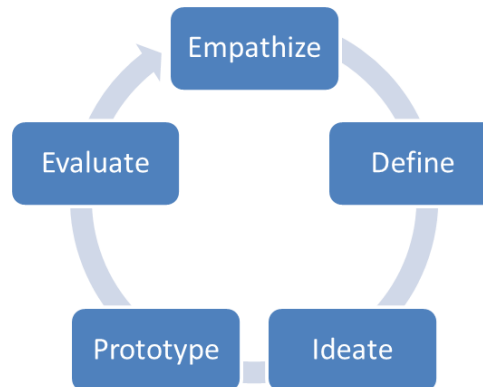


Figure 1. Stages of Design Thinking methodology

1. Empathize: Understanding User Needs

The first stage of Design Thinking focuses on empathizing with the end users of the product, which involves deeply understanding their needs, desires, and frustrations. For the smart umbrella, this phase included qualitative and quantitative research, such as interviews with potential users, online surveys, and direct observation of how people use umbrellas in urban and rural contexts.

Through this process, several common problems faced by users were identified: extreme heat, lack of access to outdoor energy sources, and the need for protection against adverse weather conditions. Additionally, there was a growing demand for sustainable and multifunctional products that combine protection and technology. This knowledge served as the basis for guiding design decisions, ensuring that the smart umbrella not only provides shade but also offers other important utilities, such as charging mobile devices using solar energy.

2. Define: Delimiting the Problem and Objectives

Once user needs were understood, the next stage was to clearly define the problem to be solved and the project objectives. During this phase, the design team focused on synthesizing the findings from the empathy stage and formulating a clear vision of the product.

The identified problem was the need for a multifunctional umbrella that provides solar protection while efficiently and sustainably offering portable energy. Based on this, several key objectives were defined:

- Technological integration: Incorporate an efficient solar panel, a high-capacity rechargeable battery, LED lights for nighttime illumination, and a USB port for charging electronic devices.
- Aesthetic and functional design: Ensure the umbrella is visually appealing and easy to use, including a smooth opening and closing mechanism.
- Durability and sustainability: Use weather-resistant and recyclable materials to extend the product's lifespan and minimize its environmental impact.
- User comfort: Ensure the umbrella is lightweight, easy to transport, and stable, even under windy conditions.

This stage allowed the team to focus on the most important aspects for users and set the foundation for the ideation and prototyping phases.

3. Ideate: Generating Innovative Solutions

In the ideation phase, the team dedicated itself to generating a wide range of ideas to address the problems identified in the previous stage. This process involved brainstorming sessions, sketching concepts, and discussing different approaches to integrate the various technological functionalities into the umbrella's design.

During this stage, multiple possibilities were explored for integrating the solar panel, batteries, and electrical circuits in a way that would not compromise the product's weight or portability. Lightweight yet durable materials, such as aluminium alloys for the structure and weather-resistant plastics for the canopy, were also discussed.

Proposed solutions in this phase included:

- Integrating the solar panel into the top of the umbrella to optimize solar energy capture during the day.
- Concealing wiring within the umbrella shaft for a clean aesthetic and protection against damage.
- Strategically placing LED lights along the ribs to provide illumination without affecting the visual design.
- Designing a modular system for easy assembly and disassembly, facilitating transport and maintenance.

4. Prototype: Building Models

The prototyping phase involved turning the ideas generated in the previous stage into reality by creating physical or virtual models to experiment with the proposed solutions. In this project, computer-aided design (CAD) tools were used to develop 3D digital prototypes, which were later 3D-printed into physical models for feasibility testing.

Using CAD software allowed for quick design adjustments, such as optimizing the size of the solar panel or the placement of LED lights. Simulations were also conducted to evaluate how the umbrella would respond to various weather conditions, such as strong winds or prolonged sun exposure.

The prototype was tested for weight, stability, and functionality. It was confirmed that the solar panel captured enough energy to charge a moderate-capacity battery and power devices connected via the USB port. During this phase, improvements were identified for subsequent design iterations, such as reinforcing the opening mechanism to ensure greater durability.

5. Evaluate: Testing and Feedback

The final stage of the Design Thinking process is evaluating the finished product by testing prototypes in real-world conditions and collecting user feedback. For the smart umbrella, outdoor tests were conducted in parks and plazas where users could directly experience the product. Additional simulations were performed to ensure the design met safety and durability standards.

During the evaluation, valuable insights into user experience were gathered. For instance, some users preferred a lighter umbrella, prompting the team to explore alternatives to reduce weight without compromising stability. The energy efficiency of the solar panel was also assessed, leading to adjustments to improve performance under varying solar radiation levels.

In the case of the smart umbrella, QFD (Figure 2) helped identify essential features considered indispensable by users, such as the integration of a solar panel to capture renewable energy, a high-capacity rechargeable battery for energy storage, a USB port for charging electronic devices, and LED lights for nighttime illumination. Additionally, other key aspects emerged related to aesthetics and functionality, such as a modern and attractive design, smooth opening and closing mechanisms, and the use of weather-resistant and recyclable materials aligned with current sustainability demands.

The QFD methodology also involves constructing the "House of Quality," a matrix that links customer needs with the technical capabilities required to meet them. At this stage, critical technical parameters are identified for the engineering team to ensure that the final product aligns with user expectations. For example, to guarantee product durability, materials resistant to extreme temperature and humidity conditions were selected, and integrated electrical systems were designed to ensure optimal performance under various environmental conditions.

Another important aspect of QFD is its ability to continuously evaluate the product in relation to competitors. In this project, the smart umbrella's specifications were compared with similar products available in the market. This analysis revealed key opportunities to differentiate the design, such as including additional features like a modular system that facilitates transportation and assembly, as well as the ability to integrate a mobile application to monitor battery charge and solar panel efficiency.

The use of the QFD methodology at this stage of development allowed the transformation of user expectations and needs into clear and actionable technical specifications. This approach not only ensures that the final product meets customer expectations but also optimizes the design and manufacturing process by prioritizing features that truly matter, resulting in a functional, competitive design aligned with current market trends.

According to the QFD analysis, the following design features were determined to be essential:

- A modern and attractive structure made of weather-resistant materials.
- An easy and smooth deployment mechanism.
- A solar panel integrated into the upper tip to capture solar energy.
- A power bank or rechargeable battery located in the handle for energy storage.
- Hidden wiring within the umbrella shaft connecting the solar panel to the battery for recharging.
- LED lights integrated into the ribs for nighttime illumination, powered by the battery.
- A USB port in the handle to charge mobile devices using the battery.
- A protective case to prevent wear and tear during transport.

Similarly, the following project limitations must be considered:

1. Energy Efficiency:

- Solar Panels: The efficiency of solar panels depends on the amount of direct sunlight they receive. The shadow created by the umbrella may reduce panel efficiency.
- Batteries: High-capacity batteries are needed to store the collected energy, but they can add weight and bulk to the umbrella.

2. Weight and Portability:

- Solar panels and batteries can significantly increase the umbrella's weight, making it harder to transport and assemble.
- Balancing the structure is crucial to prevent tipping, especially in windy conditions.

3. Durability and Weather Resistance:

- Electronic components must be well-protected from rain, dust, and humidity to avoid damage.
- The umbrella must be resistant to windy conditions to prevent damage or tipping.

4. Maintenance:

- Electronic components may require additional maintenance or eventual replacement over time.
- Batteries have a limited lifespan and will need to be replaced periodically.

5. Component Integration:

- The integration of solar panels and the USB charging port must be both aesthetic and functional, without compromising the appearance or usability of the umbrella.
- Wires and connections must be well-managed and protected to avoid damage and ensure safety.

Additional Considerations:**1. Device Compatibility:**

- Ensure the USB charging port is compatible with a wide range of devices and provides fast, efficient charging.

2. Control and Monitoring:

- Develop a mobile app that allows users to monitor battery charge and the status of the solar panels.

3. Sustainability:

- Use recyclable and sustainable materials in the umbrella's manufacturing to attract environmentally conscious consumers.

DFMA is a critical methodology aimed at optimizing product design to facilitate manufacturing and assembly, reduce costs, and improve process efficiency. The following steps and principles are key for applying DFMA to the design of the multifunctional umbrella with integrated gadgets:

- **Component Analysis:** Review the umbrella design to eliminate unnecessary parts or combine functions into a single component, such as integrating the solar panel directly into the structure without additional parts.
- **Design Simplicity:** Design the umbrella shaft with built-in channels to conceal wires connecting the solar panel to the battery, avoiding the need for additional cable management parts.
- **Material Standardization:** Select commonly available materials for the structure and electronic components, such as aluminium for the shaft and weather-resistant plastics for the canopy.
- **Ease of Manufacturing:** Choose the manufacturing processes with fewer steps, such as plastic injection parts and extrusion for the shaft.
- **Minimized Fasteners:** Use fewer screws and clips in assembly, favouring snap-fit designs where possible, ensuring fastener points are accessible and easy to manage.
- **Modular Design:** Divide the umbrella into main modules, such as the handle with the battery, the shaft with the wiring, and the canopy with the solar panel, to simplify assembly and maintenance.
- **Single-Direction Assembly:** Ensure all umbrella components are assembled from a common direction to simplify the process and reduce assembly time.

As part of the validation and testing phase, a 3D design of the product was developed, as shown in figures 3, 4, and 5. The 3D design illustrates the umbrella's structure, including the solar panel at the top, the rechargeable battery, and the USB port in the handle, meeting user specifications. Further tests at both the component and system levels evaluated the product's design to identify potential issues such as defects in component quality, assembly processes, or compatibility. Mitigation strategies such as employee training, process standardization, quality control checkpoints, and preventive maintenance for machinery can minimize these risks.



**Figure 3. Smart umbrella 3D design
(top view)**



**Figure 4. Smart umbrella 3D design
(side view)**



**Figure 5. Smart umbrella 3D design (close-
up handle)**

The proposed multifunctional umbrella is considered a functional, innovative, and competitive design that provides an intelligent solution. It allows users to take advantage of the high temperatures in Mérida, Yucatán, while offering protection from harmful UV rays for those who spend extended periods under the sun.

V. CONCLUSION

The use of DFMA in product development not only optimizes manufacturing and assembly processes but also enhances product quality, reduces costs and production times, and promotes greater sustainability. Implementing this methodology represents a significant competitive advantage in today's manufacturing industry.

The design and development of the smart umbrella proved to be a successful project in integrating modern technology into an everyday product. The application of DFM principles and automation strategies optimized the design for manufacturing and assembly, ensuring a high-quality and functional product. The results highlight the importance of a systematic approach to the development of innovative products, where interdisciplinary collaboration and the use of advanced technologies play a crucial role. The smart umbrella not only provides protection against weather conditions

but also offers portable energy and improves the user experience, marking a significant advancement in the design of multifunctional products.

The implementation of Design Thinking in the development of the smart umbrella was essential to ensure that the final product was not only technically efficient but also aligned with user needs and expectations. Through the five stages of the process, innovative ideas were generated, functional prototypes were built, and their effectiveness was evaluated under real-world conditions. This resulted in a product that efficiently combines technology, functionality, and sustainability.

REFERENCES

- [1] Boothroyd, G., Dewhurst, P., & Knight, W. A. (2010). *Product Design for Manufacture and Assembly*. CRC Press.
- [2] Anderson, D. M. (2014). *Design for Manufacturability: How to Use Concurrent Engineering to Rapidly Develop Low-Cost, High-Quality Products for Lean Production*. CRC Press.
- [3] Ulrich, K. T., & Eppinger, S. D. (2016). *Product Design and Development*. McGraw-Hill Education.
- [4] Dieter, G. E., & Schmidt, L. C. (2012). *Engineering Design: A Materials and Processing Approach*. McGraw-Hill Education.
- [5] Restrepo, C. A., Jaramillo, J. C., & Vásquez, J. D. (2019). Application of the Design for Manufacture and Assembly Method to the Chassis of a Formula SAE Competition Vehicle. *Revista Facultad de Ingeniería Universidad de Antioquia*, 91, 35–45. Retrieved from https://scielo.org.co/scielo.php?pid=S1909-83672019000100035&script=sci_arttext
- [6] Villada, J., & García, M. (2020). Evolution and Strategic Organizational Development of Design for Manufacture and Assembly (DFMA). *Cuaderno Activa*, 8(2), 38–49. Retrieved from <https://ojs.tdea.edu.co/index.php/cuadernoactiva/article/view/424>
- [7] Martínez, C., & López, R. (2021). Design for Manufacture and Assembly. *Revista Información Tecnológica*, 32(2), 5–18. Retrieved from https://revistas.sena.edu.co/index.php/inf_tec/article/view/812
- [8] Xu, J., & Ma, L. (2022). Mixed Reality for Mechanical Design and Assembly Planning. arXiv Preprint. Retrieved from <https://arxiv.org/abs/2209.01252>
- [9] Smith, D., & Brown, K. (2011). A New DFM Approach to Combine Machining and Additive Manufacturing. arXiv Preprint. Retrieved from <https://arxiv.org/abs/1106.3176>
- [10] GizTab. (s.f.). Ombrella: la sombrilla inteligente que te avisa si lloverá. Recuperado de <https://www.giztab.com/ombrella-la-sombrilla-inteligente-que-te-avisa-si-llovera/>
- [11] Vía Tec. (s.f.). Finalmente, un diseño inteligente de sombrilla. Recuperado de <https://viatec.do/finalmente-un-diseno-inteligente-de-sombrilla/>



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