International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 857-863 www.ijaem.net ISSN: 2395-5252

Manufacturability Framework for the Production of Ceiling Fan With Autonomous Capability

Oigbochie. D, Adeyeri M.K
[1,2,3]Department of Mechanical Engineering, The Federal Polytechnic, Ado-Ekiti
[*1]Correspondence Author

Date of Submission: 25-08-2025 Date of Acceptance: 05-09-2025

ABSTRACT
Fans are electrical appliances meant used to maintained a suitable air condition within a confined space of human occupancy. Most times these fans when not properly managed, leads to unhealthy and polluted air being generated and circulated to their users. In a bid to ensure the cleanliness and autonomousity for users handling and control, a manufacturability framework for the production of autonomous ceiling fans is herein presented in this work. In this paper, a manufacturability framework for the assembly procedures, and its smart technology integration are being discussed thoroughly. Design analysis for the cleaning module of the appliance was done using appropriate design equations. Injection molding and casting procedures were employed for the manufacturing of the mechanical components, while the electrical components were implemented using standard practice involving sensors selection, programming of microcontroller and their integration.
KEYWORDS: Autonomous, Fan, Framework, Production

I. INTRODUCTION

The integration of autonomous capabilities into everyday consumer products, such as ceiling fans, represents a significant leap forward in the field of smart home technologies and the Internet of Things (IoT). Traditional ceiling fans have been used for decades as a simple means of regulating indoor air circulation, primarily relying on mechanical motors, pull chains, and manual switches. However, with advancements in artificial intelligence (AI) and sensor technologies, the demand for "smart" products that can automate functions and respond to environmental inputs is growing (Zhang et al., 2020). A ceiling fan with autonomous capability, which can adapt to changing room conditions such as temperature, humidity, and motion, exemplifies this trend. This paper outlines a manufacturability framework for the production of such an advanced ceiling fan, integrating the principles of design for manufacturability (DFM) with smart, autonomous system requirements.

Manufacturability, in the context of product design and production, refers to the ease with which a product can be manufactured, assembled, and maintained while meeting performance and cost targets (Boothroyd et al., 2014). The inclusion of autonomous capabilities adds layers of complexity to this framework, as it requires careful consideration of additional components such as sensors, microprocessors, and communication modules. These technologies must be seamlessly integrated into the fan's traditional design without compromising its core functionality or increasing the production cost excessively (Li et al., 2019). In the case of a ceiling fan, manufacturability not only involves mechanical considerations like the motor, blades, and housing but also the electrical and software elements necessary for autonomy.

The process of designing a manufacturable ceiling fan with autonomous capabilities begins with identifying the key requirements for both the fan's traditional functions and its smart features. Traditional functions include optimal airflow, energy efficiency, and low noise, while smart capabilities might include real-time environment monitoring, motion detection, and adaptive control based on user preferences or external conditions (Hassan et al., 2021). To meet these requirements, the design must incorporate sensors (such as temperature and humidity sensors), processing units (like microcontrollers or AI-based systems), and communication interfaces

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 857-863 www.ijaem.net ISSN: 2395-5252

(such as Wi-Fi or Bluetooth) that enable the fan to adjust its operation autonomously.

The manufacturability framework must also address the challenges posed by the integration of these new technologies into a space-efficient and cost-effective package. For example, the addition of autonomous sensors and electronics necessitates a rethinking of the fan's housing design to accommodate these components without adding significant bulk or reducing the fan’s aesthetic appeal. It also calls for consideration of the materials used in the housing, ensuring that they are durable, lightweight, and capable of housing delicate electronics without interference or heat buildup (Vermesan et al., 2018). Additionally, the complexity of the manufacturing process increases as new manufacturing technologies, such as 3D printing for custom components or the use of flexible circuit boards, become relevant.

Cost reduction strategies play a significant role in the manufacturability of the ceiling fan with autonomous capabilities. Since the integration of smart technology adds both material and production costs, it is crucial to identify opportunities for cost savings without compromising product quality. One approach is to standardize certain components that can be used across different models, thereby reducing the need for custom parts (Huang et al., 2016). Furthermore, modular designs can be leveraged, where the fan’s smart features are housed in detachable units that can be upgraded or replaced over time without affecting the rest of the product.

Sustainability also becomes a key consideration when designing a manufacturable ceiling fan with autonomous capabilities. The production process must minimize waste and energy consumption, and the materials used should be recyclable or biodegradable wherever possible. Smart products, particularly those with energy-saving features, hold promise for contributing to more sustainable consumption patterns (Bansal et al., 2020).By ensuring that the fan operates efficiently in real time, adapting its speed and power consumption based on room conditions, the product itself can help reduce overall energy usage, contributing to both environmental sustainability and lower operational costs for the end user.

In addition to these factors, ease of assembly and maintenance is a crucial element of manufacturability. The autonomous ceiling fan must be designed with consideration for both assembly line efficiency and future repairability. For example, modular components and standardized connectors could simplify the assembly process and reduce the risk of errors during production. Furthermore, the fan’s electronics and sensors should be easily accessible for maintenance or replacement if needed (Salvia et al., 2018). A robust system of diagnostics could be integrated into the fan’s software, allowing it to self-diagnose issues and communicate with the user via a mobile app or other interface.

Testing and validation also form an essential part of the manufacturability framework. Autonomous systems are prone to failures due to the complexity of their software and hardware components. Thus, rigorous testing procedures must be in place to ensure that the fan’s smart features work reliably in diverse real-world conditions. This includes stress testing the fan's sensors under varying temperatures, humidity levels, and airflow conditions. Furthermore, the software must be thoroughly tested for bugs, ensuring that the autonomous controls adjust the fan’s behavior accurately in response to environmental data (Zhang et al., 2020).

II. MATERIALS AND METHOD

This flow chart represent the operation involved in the manufacturability framework for the production of ceiling fan with autonomous capabilities such as the raw material, casting operation, forging operation, assembly, extrusion operation.

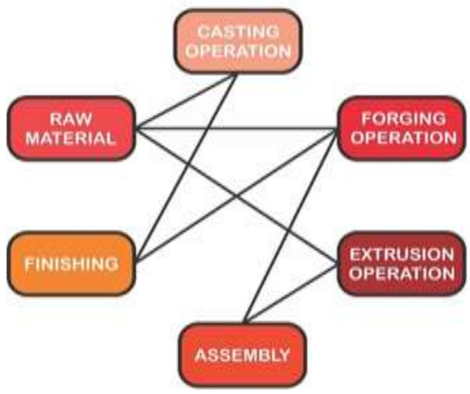


Fig 3.1 flow chart operation.

2.1 FLOW CHART PROCESS

This flow chart presents the process or stages in the manufacturability framework for the product of ceiling fan with autonomous capability such as, the identification of parts, manufacturing process, assembling and, product fitting

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 857-863 www.ijaem.net ISSN: 2395-5252

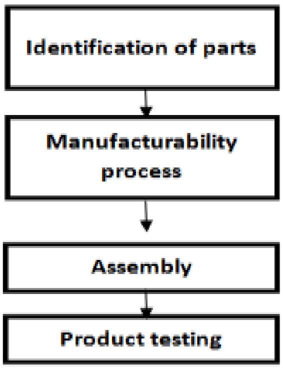


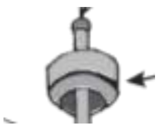
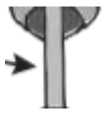
Fig 3.2 flow chart process

2.2 THE MANUFACTURABILITY PROCESS FOR THE COMPONENT OF CEILING.

The identified component as well as their proposed respective production process as tabulated below in table 3.1

The manufacturability process for the component of fan

Table 3.1:The identified component as well as their proposed respective production process is as tabulated

S/N	COMPONENT/ NAME	PICTORIAL VIEW OF THE COMPONENT	CHOICE OF MATERIAL	PRODUCT PROCESS
1.	FAN BLADE		STEEL	Injection moulding machine,Punch press machine, bending machine/ sheet cutting, punching, Blade angle setting, and Blade shank riveting, Painting
2.	CANOPY		Plastic	Injection molding
3.	DOWNROD		Steel pipe	Blast furnance/extrusion method

4	MOTOR HOUSING		Iron metals	Induction furnance/die casting

2.3 IDENTIFICATION OF PARTS THAT ARE INTO VARIOUS MANUFACTURING PROCESS

Parts that make up the manufacturability framework for the product of ceiling fan with autonomous capability are: metal, plastic, electrical component, insulation material and other components

2.4 DESIGNING THE ELECTRICAL SYSTEM FOR THE FAN

2.4.1 SystemArchitecture

The heart of the system is the System Intelligent Unit (SIU), Asshown in Figure 1. The SIU receives inputs from the temperaturesensorandthecameraandusedthereceive dinputdatatoautomatically regulate the speed of the fan via a special speedcontrol circuitry. This process is summarized in the system blockdiagramshown in Figure2.

Fig 3.16.System Architecture

2.4.2 System Block Diagram

The system consists of several parts, i.e. sensor unit, fan speed control, system intelligent unit, AUX Port and CF Port, as shown below

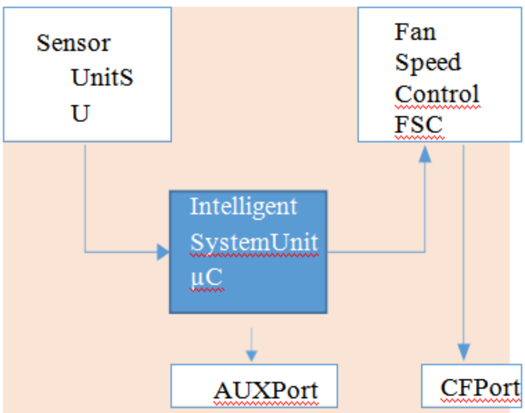


Fig 3.17. System Block Diagram Each of these parts is described below:

i. Sensing Unit

The sensing unit comprises of two main sensors: temperature and Humidity sensor.

ii. Temperature Sensor

The popular techniques to control temperature consist of the Nose-Hoover thermostat, Anderson thermostat, Berendsen thermostat, and Langevin (stochastic) thermostat. A thermostat is so important for ensuring that the HVAC system installed in your house works optimally. This gadget is set to turn on or off an air conditioning, balances the heat of a system, and also allows you to dictate what the temperature should be set. This article discusses electronic thermostat circuit working, types and its applications

iii. System Intelligent Unit

The system intelligent unit is the main controlling circuitry of the project. The processor used is a Raspberry Pi3 Model B+. The Pi 3 Model B+ is a powerful single-board computer developed by the raspberry foundation. It has a 64-bit ARM Cortex-A53quad-coreprocesso rat a clock speed of1.4GHz.This Model has a 1GB LPDDR2

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 857-863 www.ijaem.net ISSN: 2395-5252

SDRAM with an extended 40-pin GPIO header allowing form any connections. It operates with a5Vdirect voltage.

iv. Speed Control Unit

The speed control unit is designed to regulate the speed of the fan based on the signals from the system intelligent unit. This is achieved through PWM by varying the duty cycle of the input pulse signal from the SIU. A buffer circuit is built with an NPN transistor and Scotty diode to protect the SIU pins.

v. Control Mechanisms

The system has 4 speed control levels: Off, Low, Medium, and High. Each of this level is selected based on the occupancy detection and room temperature. The fan is set to OFF when occupancy is not detected but room temperature goesup.Table1showstheconditionsnecessary for each level to be selected.

2.4.3 Electrical System Workflow

The logical representation of the software code has been presented in the flowchart shown in Figure 4.

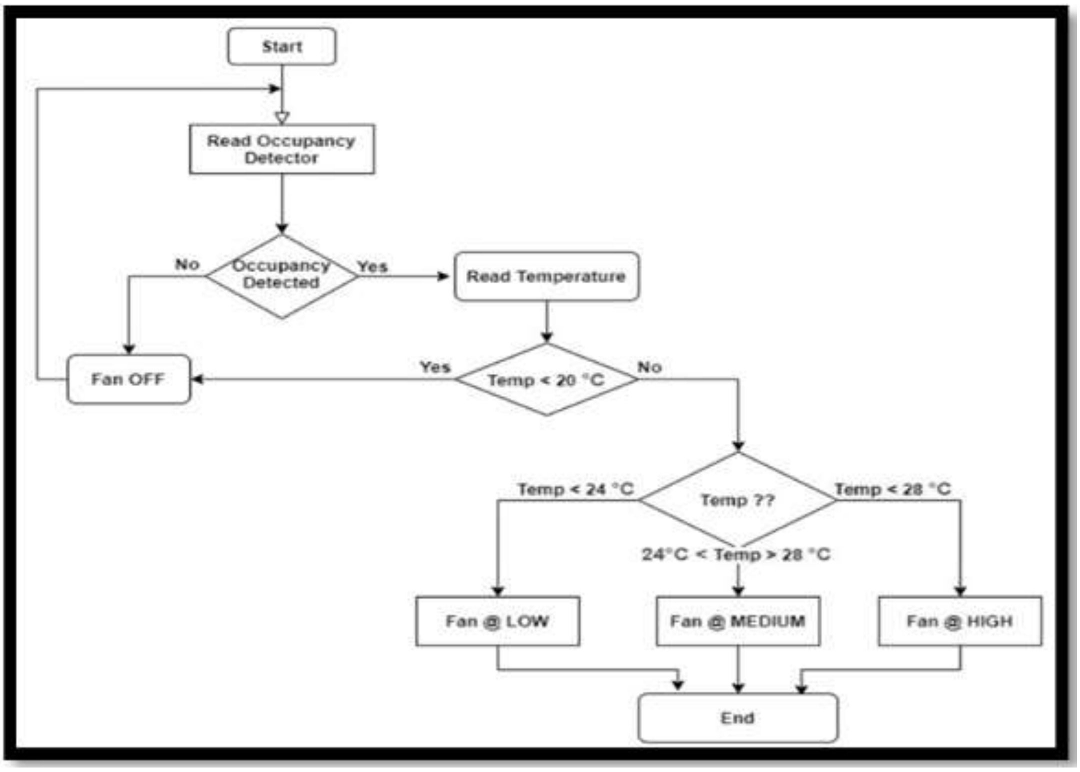


Fig 3.17System Flow Chart

Firstly, the occupancy detector is run to check the feeds from the camera for room occupancy. If no occupancy is detected, the Fanisturned OFF. If occupancy is detected, the SIU reads the room temperature from the Si7021 temperature sensor. The fan remains OFF if the temperature is below 20 ºC. However, the fan is turned ON if the temperature is more than 20ºC. The speed control circuitry has three(3) speed levels which are triggered based on the temperature.

The fan's speed is set to LOW if the room temperature is between 20 and 24ºC. It is set to Medium when the temperature falls within 24 ºC to 28 ºC. The fan speed is set HIGH for temperatures higherthan28 ºC.

2.4.4 Determine the Efficiency of the fan

The output= 31^{o}C

The input= 45 ^{o}C

Efficiency $= \frac{\textbf{output}}{\textbf{input}} \times \mathbf{100}$

Efficiency $= \frac{31}{45} \times 100 = 69\%$

III. RESULTS AND DISCUSSION

To test the sensivity and air humidity of the product. The infrared thermometer and hygrometer were used. The temperature and air humidity at specific time interval were taken for seven occupants in a standard room. The fan speed was observed and all the values tabulated in table

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 857-863 www.ijaem.net ISSN: 2395-5252

Table 3.1

No of occupancy	Relay control	Temperature range	Time lapse	Fan speed	Air humidity	Infrared
1	3	Less than 26^0C	12:00pm	OFF	45%	31.18^0C
2	3	Less than 26^0C	12:10pm	OFF	46%	32.51^0C
3	3	Less than 26^0C	12:20pm	OFF	44%	32.62^0C
4	1	26^0C - 28^0C	12:30pm	Medium speed	42%	32.74^0C
5	1	26^0C - 29^0C	12:40pm	Medium speed	44%	32.84^0C
6	1	26^0C - 30^0C	12:50pm	Medium speed	45%	32.81^0C
7	2	31^0C - 40^0C	1:00pm	Full speed	46%	32.78^0C

3.2Deployment of the Developed Fan

After completion of the integration module the complete autonomous fan was deployed into a standard/office room. For better determination of the various integrated components into the system an infrared thermometer and hygrometer were positioned to serve as control devices for the deployed ceiling fan.

Also seven subject as/occupants were used in which they were introduced into the office room in an incremental number starting from one to seven at specific time intervals. It was observed that the number of occupants was a determinant factor for the temperature fan speed and air humidity.

3.3 Discussion

The temperature increases as the number of occupancy increases due to the respiration of the occupancy and motion. When there is inhale and exhale of the occupancy according to the numbers of the occupancy, the temperature increases, which is been triggered by the three relay. Relay 1 shows that the speed of the fan is at medium speed mode displaying the temperature ranges from 26^oC – 30^oC. While relay 2 show and triggered the speed of the fan to full speed mode displaying the temperature from 31 ^{o}C and above. While relay 3 triggered the fan to OFF when the temperature is below 26 ^{o}C and when there is no motion.

IV. CONCLUSION AND RECOMMENDATIONS

Based on result obtained from this research a summary of the key findings from the work on the manufacturability framework for the autonomous ceiling fan, along with recommendations for future improvements. The contributions of the project to the fields of smart home automation, product design, and manufacturability are also discussed, and potential future work is outlined

This has paper has successfully developed a framework for designing and manufacturing a ceiling fan with autonomous capabilities, specifically integrating temperature and motion sensing for automatic control. The removal of the manual regulator in favor of a microcontroller-based system with three relays greatly improved the fan's energy efficiency and user convenience. The fan demonstrated real-time adjustments to room temperature and motion conditions, with a **16x2 LCD** displaying both temperature readings and motion status.

4.1 RECOMMENDATIONS

To further refine the product and manufacturability framework, the following recommendations are made:

1. **Design Refinement for Mass Production**:
   - **Component Consolidation**: Simplify the electronics by using integrated modules for relays and sensors to reduce assembly complexity and production costs.
   - **Fan Blade Optimization**: Consider using **aerodynamically optimized blade designs** and **lighter materials** to improve airflow efficiency and reduce material costs.

2. **Advanced Autonomous Features**:
   - **Machine Learning for Predictive Maintenance**: Incorporating machine learning algorithms could allow the fan to predict maintenance needs, such as motor wear, or suggest cleaning cycles based on dust accumulation. This would enhance its longevity and reduce maintenance costs.
   - **Smart Connectivity**: Adding **Wi-Fi or Bluetooth modules** would enable integration with smart home systems, allowing users to

control the fan remotely via smartphones or voice-activated assistants (e.g., Amazon Alexa, Google Home).

3. **Enhanced Energy Efficiency**:
- Use of **variable-speed motor controllers** instead of capacitors could improve the efficiency of the fan's speed regulation, allowing smoother transitions and reduced power consumption.

REFERENCES

[1]. **Bansal, R., Sharma, R., & Srivastava, S. (2020).** Sustainable smart technologies for home automation: A comprehensive review. Energy Reports, 6, 1749-1765. https://doi.org/10.1016/j.egyr.2020.06.020

[2]. **Boothroyd, G., Dewhurst, P., & Knight, W. (2014).**Product design for manufacture and assembly (3rd ed.). CRC Press.

[3]. **Hassan, M. M., Mohamed, M., & Anwar, F. (2021).** Smart home automation with artificial intelligence: Applications and future trends. International Journal of Automation and Computing, 18(4), 359-375. https://doi.org/10.1007/s11633-021-1271-3

[4]. **Huang, G. Q., Mak, K. L., & Zhang, Y. F. (2016).** Mass customization and modular product design. International Journal of Advanced Manufacturing Technology, 87(5-8), 1513-1535. https://doi.org/10.1007/s00170-016-8886-7

[5]. **Li, X., Liu, Y., & Zhang, J. (2019).** Integration of IoT and AI in smart home applications: Challenges and opportunities. Journal of Industrial Information Integration, 15, 1-9. https://doi.org/10.1016/j.jii.2018.11.004

[6]. **Salvia, G., Gatti, A., & Perini, G. (2018).** Design for disassembly and modularity in product development: A review. Procedia CIRP, 72, 896-901. https://doi.org/10.1016/j.procir.2018.03.113

[7]. **Vermesan, O., & Friess, P. (2018**). Internet of things: Converging technologies for smart environments and integrated ecosystems (1st ed.). River Publishers.

[8]. **Zhang, Y., Zhang, Y., & Zhao, Y. (2020).** Autonomous systems for smart homes: Design, integration, and future prospects. *Sensors,

[9]. **Bansal, R., Sharma, R., & Srivastava, S. (2020).** Sustainable smart technologies for home automation: A comprehensive review. Energy Reports, 6, 1749-1765. https://doi.org/10.1016/j.egyr.2020.06.020

[10]. **Boothroyd, G., Dewhurst, P., & Knight, W. (2014).**Product design for manufacture and assembly (3rd ed.). CRC Press.

[11]. **Hassan, M. M., Mohamed, M., & Anwar, F. (2021**). Smart home automation with artificial intelligence: Applications and future trends. International Journal of Automation and Computing, 18(4), 359-375. https://doi.org/10.1007/s11633-021-1271-3

[12]. **Huang, G. Q., Mak, K. L., & Zhang, Y. F. (2016).** Mass customization and modular product design. International Journal of Advanced Manufacturing Technology, 87(5-8), 1513-1535. https://doi.org/10.1007/s00170-016-8886-7

[13]. **Li, X., Liu, Y., & Zhang, J. (2019).** Integration of IoT and AI in smart home applications: Challenges and opportunities. Journal of Industrial Information Integration, 15, 1-9. https://doi.org/10.1016/j.jii.2018.11.004

[14]. **Salvia, G., Gatti, A., & Perini, G. (2018**). Design for disassembly and modularity in product development: A review. Procedia CIRP, 72, 896-901. https://doi.org/10.1016/j.procir.2018.03.113

[15]. **Vermesan, O., & Friess, P. (2018).** Internet of things: Converging technologies for smart environments and integrated ecosystems (1st ed.). River Publishers.

[16]. **Zhang, Y., Zhang, Y., & Zhao, Y. (2020).** Autonomous systems for smart homes: Design, integration, and future prospects. Sensors, 20(12), 3489. https://doi.org/10.3390/s20123489