THE ENGINEER STORY
e-ISSN: 3009 - 0792 Volume 8, 2024, 15-23

PARAMETRIC DESIGN APPROACH FOR COST-EFFECTIVE DRONE SOLUTIONS IN COVID-19 INSPECTION AND MONITORING

Tunji John Erinle [1,*], Adekunle Samuel Fatona [2], Koleola Ebenezer Ojaomo [3]
[1] Department of Mechanical Engineering, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria.
[2] Department of Mechanical Engineering, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria.
[3] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Skudai 81310, Johor Bahru, Malaysia.
[*] Corresponding author: erinle_tj@fedpolyado.edu.ng

ABSTRACT

This study presents a parametric design approach for a cost-effective, efficient, medium-sized quadcopter drone for COVID-19 infection inspection and monitoring. The drone includes crucial components such as brushless motors, propellers, servo motors, electronic speed controllers, and other accessories. The parametric design process systematically evaluates factors, resulting in improved drone performance and cost-effectiveness. The analysis emphasises the positive impacts of drones in healthcare operations, including cost savings, enhanced communication, safer working conditions, and more accurate data. The parametric design method assists with developing healthcare operations and technologies.

KEYWORD

COVID-19, Drone, Healthcare operations, Infection inspection, Parametric design

INTRODUCTION

The drone is a type of aircraft known as an unmanned aerial vehicle or unmanned airborne vehicle (UAV), which may be remotely controlled or autonomous and can collect geographical data by flying over certain locations, as demonstrated in Figure 1 (Lutkevich, 2024; Mahadevappa et al., 2020; Chamberlain, 2017). The drone is a flying robot that uses GPS to navigate; it may be commanded remotely or fly autonomously using software-controlled flight plans in its embedded systems (Islam et al., 2021; Bloise et al., 2019). The drone is categorised based on the number of propellers, size, and range as presented in Table 1.

Table 1: Categorisation of Drones (Bohra, 2018)

Based on the Number of propellers	Based on Size	Based on Range
Tri-copters Drones	Nano Drones	Very close-Range Drones
Quad-copters Drones	Mini Drones	Close Range Drones
Hexa-copters Drones	Regular Size Drones (Medium Size)	Short Range Drones
Octa-copters Drones	Large Drones	Mid-Range Drones
		Endurance Range Drones


Figure 1: Some Developed Drones (DroneDeploy, 2018)

IMPORTANCE OF UTILIZING DRONES

Drones are potentially important tools with a wide range of applications (Design Shack, 2024). Drones are rapidly being used in various industries, including agriculture, construction, mining, insurance, media, and telecommunications, exhibiting amazing progress in engineering and technological devices (Sculpteo, 2022; Mairaj et al., 2019). The drone might be used to collect accurate data about objects to inspect. Drones are most commonly utilised in military services. However, it is also utilised for weather monitoring, firefighting, search and rescue, surveillance, and traffic control (BRAC University, 2024; Sudhakar et al., 2020; Zhou et al., 2018). Unmanned aerial vehicles (UAVs), sometimes known as drones, can be used to handle a wide range of operational issues in reducing the spread of COVID-19 in society. This fast-increasing technology, along with developments in big data and artificial intelligence, is set to impact healthcare operations; because airborne drone intelligence provides numerous major benefits, including making inspections safer and assisting the health business in complying with regulatory standards while saving money on labour, safety equipment, and health worker safety (Chaturvedi et al., 2019).

Drones can aid health operations by reducing costs, improving communication, creating a safer work environment, and providing more accurate data. Drones have the potential to impact workflows in the healthcare sector (AeoLogic, 2022).

Cost-effective Inspections

Drones offer cost-effective and weather-resistant inspections for COVID-19 patients, reducing the risk of transmission. They can monitor medical professionals, minimising safety costs and missing work hours. This technology additionally reduces medical expenses and insurance costs (DroneDeploy, 2018).

Safer Work Environments

Drone inspections are a safer, more cost-effective, and more efficient alternative to manual infrastructure inspections, especially in remote areas where ground crew deployment is difficult, expensive, or dangerous (DroneDeploy, 2018).

Faster and More Accurate Data Collection

Drones offer a versatile platform for cameras and sensors to capture real-time data for COVID-19 health assessments, facilitating informed decision-making and reducing infection risks, ultimately improving inspection and monitoring operations (DroneDeploy, 2018).

Superior Communication

Drones are enhancing healthcare operations by allowing local health professionals to fly over the area and upload data to the cloud, allowing back-office medical directors and monitoring teams to conduct inspections and follow-ups without leaving their workplaces. They can also be combined with software to mark up maps and annotations in real time, resulting in more efficient and effective healthcare operations (Khan et al., 2020; DroneDeploy, 2018).

OVERVIEW OF THE PARAMETRIC DESIGN APPROACH

Parametric design enables systematic evaluation of parameters such as aerodynamics, propulsion systems, and material properties to enhance performance and cost-effectiveness. Using parametric design principles, designers may systematically analyse possibilities for design by specifying and modifying parameters (Erinle et al., 2020). Parametric design may optimize numerous elements of drone performance, including aerodynamics, propulsion systems, and structural design (Li & Gu, 2014). These approaches demonstrate the importance of parametric design, as illustrated in Figure 2.

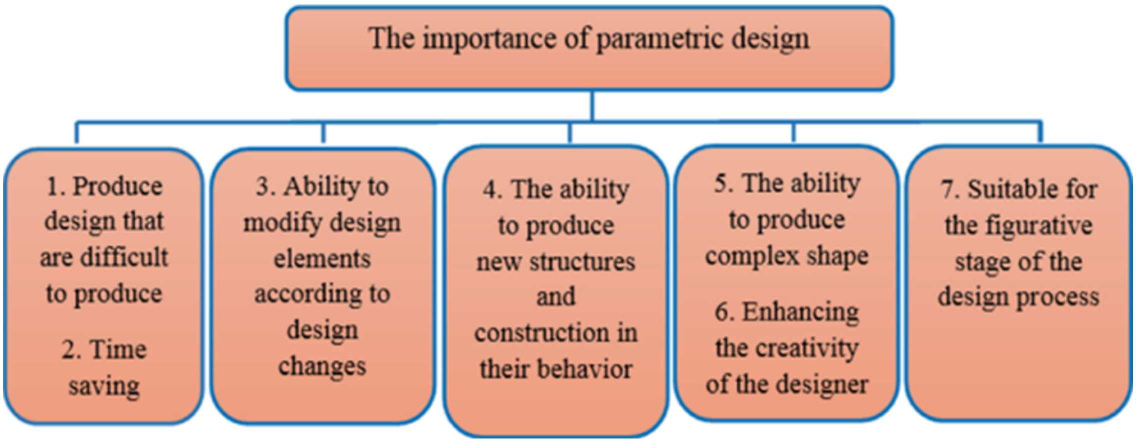


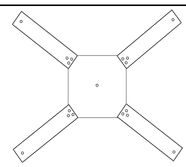
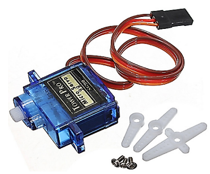
Figure 2: Parametric Design Approach (Abdelhady et al., 2022)

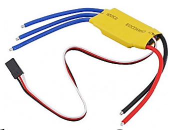
MATERIAL AND METHODOLOGY

Materials

The materials to be adopted for the parametric design of the drone for COVID-19 infection inspection and monitoring would be a Frame (Aluminium plate), Brushless DC motors, Propellers, Servo motors, Electronic Speed Controller (ESC), Flight Controller Board, Lithium Polymer (Li-Po) battery, Battery charger, Transmitter and receiver pair, Landing gear, Global Positioning System (GPS), and IP camera as presented in Table 2. Quad-copter regular-size (medium size), and very close-range drone would be parametrically designed for assembly.

Table 2: Drone for COVID-19 Infection Inspection and Monitoring Materials

Materials	Functions	Features
Aluminium Plate for the Frame	The drone frame size depends on specifications, with a compact frame being optimal for manoeuvrability, accommodating all drone components, including landing gears.	 Drone Frame
Motors (Brushless)	The weight of the drone determines which motor to use. The brushless DC motor type A2212 is suited for medium-sized quadcopters with 10-inch propellers, offering excellent performance, power, and efficiency. It has a constant velocity of 2200 KV, 1200 g of force, and a 239-watt outrunner motor with a shaft speed of 2200 RPM/volt.	 Brushless Motor
Propellers (Made with High Strength Plastic Material)	The drone's function depends on its propeller type, which is made of high-strength plastic material. A set of 2 x 1045 propellers, including one clockwise and one counter-clockwise rotating, with 2 x propeller shaft adapters, can be used with brushless motors with a 2200 kV rating, 10-inch diameter, and 4.5-inch pitch (Electron Components, 2024).	 Propellers
Servo Motor	The Tower Pro SG90 Servo Mini/Micro Servo Motor, with a 4.8V~6.0V operating speed and 9 g weight, can tilt brushless motors at 180 degrees. A 90^{o} rotation is required for vertical take-off or landing.	 Servo Motor

Battery	The drone's Lithium Polymer rechargeable battery has a capacity of 2200 mAh, a voltage of 11.1 V, and a weight of 160 g, giving a perfect mix of weight, power, and performance for its brushless DC motor.	 Battery
Battery Charger	The B3 Lithium Polymer (LiPo) Battery Charger, is a simple charger for charging batteries.	 Battery Charger
Transmitter-Receiver Pair	The FlySky FS-i6 is a low-cost 6-channel 2.4GHz transmitter and receiver suited to quadcopter pilots. It employs AFHDS spread spectrum technology to operate the drone's flying system, which includes brushless DC and servo motors that can move forward, backward, right, and left.	 Transmitter-Receiver Pair
Electronic Speed Controllers (ESCs)	The Electronic Speed Controller (ESC) is a device that controls the speed and direction of a drone's motor. It connects to the receiver's throttle channel and has been designed for quadcopters. The 30A BLDC ESC is developed for brushless motors and is compatible with A2212 (2200 KV) motors (Wire Blueprint, 2024).	 Electronic Speed Controller
Flight Controller (Multi-Rotor Control Board)	A flight controller, pre-programmed and attached to electrical components such as gyroscopes and accelerometers, controls the movement of many rotors in a quad-copter drone. The controller, which includes a KK 2.1.5 Multi-Rotor LCD Flight Control Board, stabilises the drone by processing inputs from onboard gyroscopes and delivering control signals to the Electronic Speed Controller (ESC). The drone's controls make use of mathematical functions such as proportional-integral-derivative (PID) control and the thrust-to-weight ratio.	 Flight Controller (Multi-Rotor Control Board)
Landing Gear	Flexible plastic landing gear enhances safe landings by transmitting pressure, preventing crashes, and providing additional protection for the flying platform and other crucial components.	 Landing Gear
Internet Protocol (IP) Camera	The drone will feature an IP camera for airborne surveillance, with a 360-degree view of a target or position. This digital security camera captures and compresses video material before delivering it wirelessly over a WiFi network. The camera is constructed of plastic and can be rotated 360 degrees.	 Internet protocol (IP) camera

Infrared Thermometer	An infrared thermometer detects temperature using heat radiation, allowing distance measurements without touch. This non-contact thermometer is appropriate for all ages and can measure body, surface, and ambient temperatures. It also sends an alarm if the temperature exceeds the specified range. A Bluetooth forehead thermometer with a mild vibration sensor is being used to identify COVID-19 infection, with up to 99 readings available on smartphones through iHealth's free iOS and Android apps.	 Infrared Thermometer
Global Positioning System	The Global Positioning System (GPS) is a global navigation satellite system that provides location, navigation, and timing services to users (NASA, 2024). It gives geolocation and timing information to GPS receivers near Earth that have an unobstructed line of sight to four or more satellites. GPS can show the Earth's precise position at any time, weather, or place.	 Global Positioning System (GPS)

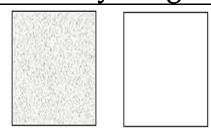
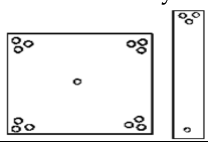
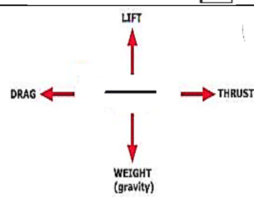
Methods

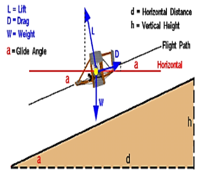
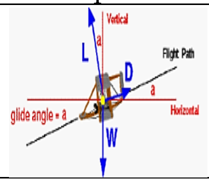
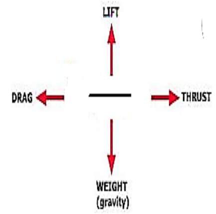
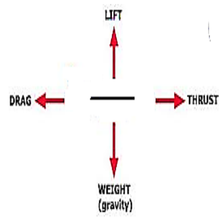
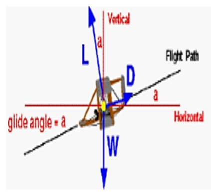
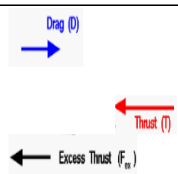
The methods to be implemented for the design and manufacture of the drone for COVID-19 infection inspection and monitoring will be design analysis and cost analysis to ensure the device's effectiveness and efficiency.

Design Analysis

The design analysis is focused on a medium-sized quadcopter drone with four brushless motors and four propeller modules. This straightforward design is appropriate for a variety of applications and provides effective control of roll, pitch, yaw, and movement as presented in Table 3. The X frame design, together with the X framework arm design, improves camera vulnerability while being powerful, user-friendly, and dependable.

Table 3: Details of the Design Analysis for the Drone Parametric Design

Parameters	Equations	Free Body Diagram
Frame	$\text{Volume} = \text{lenght} \times \text{breadth} \times \text{thickness}$ $\text{Volume}, V = \text{length}, l \times \text{breadth}, b \times \text{thickness}, t$ $V = \frac{\pi \times d^2}{4} \times t$ $\text{Mass}, m = \text{Density}, \rho \times \text{Volume}, V$ $W = m \times g$ Net Weight of the Frame = 6.4	 Plate for the Payload 
Forces Acting on the Drone	**Lift Force:** $\text{Lift}, L = \frac{1}{2}\rho v^2 C_L A$ **Drag Force:** $\text{Drag}, D = \frac{1}{2}\rho v^2 C_D A$ **Thrust Force, F:** $\text{Thrust}, F = ma$ **Gravity Force, W:** $\text{Weight}, W = mg$	 Forces Acting on the Drone

Lift-to-Drag Ratio	$\text{ratio} = \frac{\text{Lift}}{\text{Drag}} = \frac{L}{D} = \frac{C_L}{C_D} = \frac{\text{distance, d}}{\text{height, h}} = \frac{1}{\tan a}$ Drag coefficient, C_D for Flat Plate $= 1.28$ Assume height of flight, h = 30 m Assume distance of flight, d = 400 m $C_L = 17.07$	 Aerodynamic Forces Component
Drag-to-Lift Ratio	$\text{ratio} = \frac{\text{Drag}}{\text{Lift}} = \frac{D}{L} = \frac{C_D}{C_L} = \tan a$ $\text{ratio} = \frac{D}{L} = \frac{C_D}{C_L} = \tan a = 0.0750$ Glide angle or Climb angle, $a = 4.29^0$	
At Cruise	**At Cruise** When the drone travels smoothly at a moderate or economical speed Lift, $L =$ Weight, W Thrust, $F =$ Drag, D Velocity, $v = 3.03\ m/s \approx 3$ m/s Thrust, $F =$ Drag, $D = 1.2$ N Acceleration, $a = 0.75\ m/s^2$ Distance, X in x − direction = 6 m	
Thrust to Weight ratio	$\text{ratio} = \frac{\text{Thrust}}{\text{Weight}} = \frac{F}{W} = \frac{ma}{mg} = \frac{a}{g}$ $V = V_0 + at$ Horizontal Distance, X $X = \frac{at^2}{2} + V_0 t + X_0$ $\text{ratio} = 0.076$ High $\frac{F}{W} =$ High Acceleration = High Climb Rate $\frac{F}{W} > 1.0$ will accelerate vertically If the force remains constant, the acceleration will be constant $t = 4$ seconds Distance, X in x − direction = 6 m The drone will cover 6 metre in 4 seconds	
Forces Component Equations	Vertical Component Equations $L\cos a + F\sin a - D\sin a - W = ma_{Vertical}$ Horizontal Component Equations $F\cos a - L\sin a - D\cos a = ma_{Horizontal}$ $a_{Vertical} = -0.02\ m/s^2$ $a_{Horizontal} = -0.75\ m/s^2$	
Excess Thrust, F_{ex}	Excess Thrust, $F_{ex} = F - D$ $F_{ex} = 0.16$ N $F_{ex} = 0.000148$ N Thrust, $F = 1.36$ N (When moving vertically) Thrust, $F = 1.200148$ N (When moving horizontally)	 Horizontal Forces Acting on the Drone with Excess Thrust

Control and Stability of Drone

A drone rotates around its centre of gravity adopting three distinct axes of rotation as shown in Figure 3.

Roll - The axis of roll in a quadcopter involves controlling the speed of the right motors relative to the left motors, commonly referred to as 'Roll', resulting in a side-to-side motion.

Pitch - The lateral axis, commonly referred to as the pitch axis, controls the speed of rear motors as it relates to front motors. To pitch forward, the rear motors must accelerate, forcing the front motors to pitch down, resulting in forward movement.

Yaw - The axis of yaw, or the normal axis from the cabin to the landing gear, is responsible for a quad-copter's rotation. It occurs when opposing motors accelerate, varying torque and causing the quadcopter to rotate.

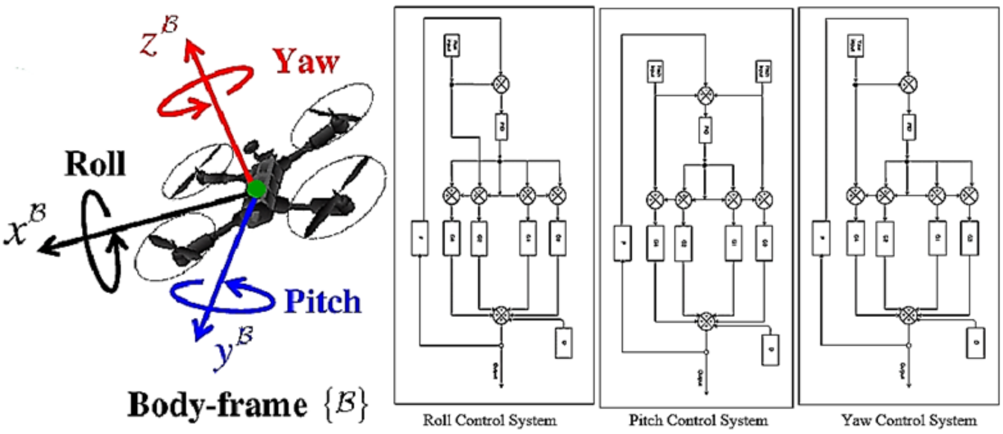


Figure 3: Unique Axes about which the Drone Can Rotate and its Control System (Patrick, 2023; Bowyer, 1992)

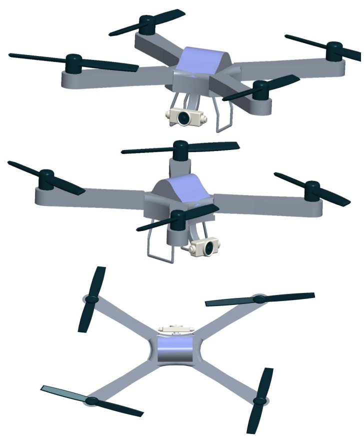
RESULT AND DISCUSSION

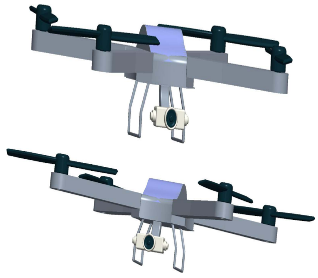
Cost Analysis

The cost analysis includes material, labour, and overhead costs for the drone's development, with figures illustrating the platform and arm, and Table 4 provides estimations.

Table 4: Cost Estimation of the Materials

S/N	Materials/Parts	Quantity /Unit	Mass (g)	Mass (kg)	Price ($)
1	Aluminium Plate for the Frame	1	643.5	0.6435	100
2	Motors (Brushless)	4	60each/240	0.24	5
3	Propellers (Blade) made with high-strength plastic material	4	10each/40	0.04	5
4	Servo Motor	4	9each/36	0.036	15
5	Battery	1	160	0.16	25
6	Battery Charger	1	103	0.103	10
7	Transmitter- Transmitter	1	392	0.392	50



	Receiver pair	Receiver	14.9	0.0149		
8	Electronic Speed Controller (ESC)	1	23	0.023	5	
9	Flight Controller (Multi-Rotor Control Board)	1	20	0.02	20	
10	Landing Gear	4	75each/150	0.15	10	
11	Internet Protocol (IP) Camera	1	100	0.1	30	
12	Infrared Thermometer (wireless)	1	30	0.03	25	
	Material Cost				$300	
	Overhead Cost = 10 % of the Material Cost				$30	
	Labour Cost = Machining Cost + Manufacturing Cost				$20	
	Direct Cost = Material Cost + Labour Cost				$320	
	Total Cost = Direct Cost + Overhead Cost				**$350**	

CONCLUSION

In conclusion, this study explores drones' usage for COVID-19 infection inspection and monitoring in healthcare institutions. It employs a parametric design method for improving drone characteristics, assuring cost-effectiveness and efficiency. The study also examines the practicality of drone deployment for use in medical applications taking into account material, labour, and administrative expenses. Drones can provide cost-effective inspections, better work conditions, faster data collecting, and improved communication capabilities. Future research and developments in drone technology are predicted to improve patient care and public health outcomes.

REFERENCE

Abdelhady, M. I., Abdelgadir, A. K., Al-Araimi, F., & Al-Amri, K. (2022). Using Algorithm in Parametric Design as an Approach to Inspire Nature in Architectural Design. In: Sharma, H., Vyas, V. K., Pandey, R. K., Prasad, M. (eds). Proceedings of the International Conference on Intelligent Vision and Computing (ICIVC 2021). ICIVC 2021. Proceedings in Adaptation, Learning and Optimization, Vol 15. Springer, Cham. https://doi.org/10.1007/978-3-030-97196-0_10.

AeoLogic. (2022). How Drones Will Transform the Healthcare Industry. Drone Technology. Aeologic Technologies https://www.aeologic.com.

Bloise, N., Primatesta, S., Antonini, R., Fici, G. P., Gaspardone, M., Guglieri, G., & Rizzo, A. (2019). A Survey of Unmanned Aircraft System Technologies to Enable Safe Operations in Urban Areas. International Conference on Unmanned Aircraft Systems (ICUAS), IEEE, pp. 433-442.

Bohra, D. S. (2018). Introduction to Drones. Drones. Education.

Bowyer, R. (1992). Aerodynamics for the Professional Pilot. Airlife Publishing Ltd., Shrewsbury, UK, pp. 107, ISBN 1853103268, 9781853103261.

BRAC University. (2024). Design and Development of Unmanned Aerial Vehicles (Drone) for Civil Applications. Thesis Project. Department of Electrical & Electronic Engineering, BRAC University, BUET, Dhaka-1000, Bangladesh. https://core.ac.uk/download/pdf/61806036.pdf.

Chamberlain, P. (2017). Drones and Journalism, Vol. 4, Taylor & Francis.

Design Shack. (2024). What is Figma Used for: 10 Examples & Ideas. Compact Creative. https://designshack.net.

DroneDeploy. (2018). Drones in Oil & Gas. Pushing the Boundaries of Aerial Inspection. www.dronedeploy.com.

Electron Components. (2024). Propeller 1045-Clockwise Counter Clockwise Pair Drone. Future Simple Solutions. https://www.electroncomponents.com.

Erinle, T. J., Oladebeye, D. H., & Ademiloye, I. B. (2020). Parametric Design of Height and Weight Measuring System. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE), Vol. 8 (7), ISSN 2321-2004. https://doi.org/10.17148/IJIREEICE.2020.8705.

Islam, N., Rashid, M. M., Pasandideh, F., Ray, B. Moore, S., & Kadel, R. (2021). A Review of Applications and Communication Technologies for Internet of Things (IoT) and Unmanned Aerial Vehicle (UAV) Based Sustainable Smart Farming. Sustainability, Vol. 13 (4), p. 1821.

Khan, N. A., Jhanjhi, N. Z., Brohi, S. N., & Nayyar, A. (2020). Emerging Use of UAVs: Secure Communication Protocol Issues and Challenges Drones in Smart-Cities. Elsevier, pp. 37-55.

Li, Y., & Gu, D. (2014). Parametric analysis of thermal behavior during selective laser melting additive manufacturing of aluminum alloy powder. Materials & Design, ScienceDirect, Elsevier, Vol. 63, pp. 856-867. https://doi.org/10.1016/j.matdes.2014.07.006.

Lutkevich, B. (2024). Drone (UAV): Definition. TechTarget. https://www.techtarget.com

Mahadevappa, R., Virupaksha, T., & Raghavendra, L. N. (2020). A Practical Approach to Enhance the Flight Endurance of a Fixed-Wing UAV. Proceedings of the National Aerospace Propulsion Conference, Singapore, Springer, pp. 297-309.

Mairaj, A., Baba, A. I., & Javaid, A. Y. (2019). Application Specific Drone Simulators: Recent Advances and Challenges Simul. Modell. Pract. Theory, 94, pp. 100-117.

NASA. (2024). Global Navigation Satellite System (GNSS): The Global Positioning System (GPS). https://www.earthdata.nasa.gov.

Patrick, G. (2023). 7 Best Drone Flight Control Systems Enhancing Mission Planning Tactics. Verified Market Research. https://www.verifiedmarketresearch.com.

Sculpteo. (2022). Top Tips for Drone Manufacturing with 3D Printing. Ebooks, Paris, France & Oakland, CA, USA. www. sculpteo.com.

Sudhakar, S., Vijayakumar, V., Kumar, C. S., Priya, V. Ravi, L., & Subramaniyaswamy, V. (2020). Unmanned Aerial Vehicle (UAV) Based Forest Fire Detection and Monitoring for Reducing False Alarms in Forest Fires. Comput. Commun., 149, pp. 1-16.

Wire Blueprint. (2024). Designing an Electronic Speed Controller Circuit: Schematic and Components. https://wireblueprint.com.

Zhou, Z., Irizarry, J., & Lu, Y. (2018). A Multidimensional Framework for Unmanned Aerial System Applications in Construction Project Management. J. Manage. Eng., 34 (3), Article 04018004.