TPM Vol. 32, No. S3, 2025
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

# EXPLORING 2D AND 3D CAD TECHNIQUES TO ENHANCE SHIP HULL DESIGN AND ARCHITECTURAL VISUALIZATION

[1]ARASU SATHIYAMURTHY, [2]NAGARAJAN
[1]DEPARTMENT OF MARINE ENGINEERING, AMET UNIVERSITY, KANATHUR, TAMILNADU - 603112, arasu@ametuniv.ac.in, 0009-0005-9561-2513
[2]DEPARTMENT OF MARINE ENGINEERING, AMET UNIVERSITY, KANATHUR, TAMILNADU - 603112, nagarajanmuthu3@gmail.com, 0009-0004-6688-3237

**Abstract**
This research addresses the Parametric Design (PD) issue in Ship Hull (SH) constructions.The PD of SH constructions aims to ascertain the size of structural parts that comply with legal requirements.It demonstrates that the issues related to the PD of SH components remain fundamentally unaddressed in all current shipyard Computer Aided Design (CAD) Computer-Aided Manufacturing (CAM) technologies.A contemporary approach for the PD of SH constructions is presented, outlining a framework of concepts for the physical and logical structure of the design procedure, as well as the methodologies and technological resources for executing design processes.The primary scientific elements of PD for SH constructions and other offshore engineering components are delineated:A systematic methodology, modeling as a primary technique for addressing design challenges, and a rational design strategy based on repeated search processes that use the methodological premise of progressively complicating models and processes for structural design.The research examines the architectural and technical underpinnings of the automatic PD framework for SH components (CAD).The method is designed for design studios to develop civil SH constructions, according to the legal requirements set by the Russian Maritime Registry of Ships and the General Regulations for large-capacity carriers, bulk vessels, and container vessels.
**Keywords – Computer Aided Design, Ship Hull, Architecture, Visualization**

## 1. INTRODUCTION
## 2.

DevelopingShip Hull (SH) structures involves creating a geometric, fundamental, parametric, and technical framework description and providing the requisite technical documentation for manufacturing in SH manufacturing settings [1].Structural design is sometimes seen as creating anSH construction using contemporary visualization technologies.The systems primarily facilitate the execution of Computer-Aided Building (CIB) procedures [10].The computer screen simultaneously functions as an "electronic drawing board," since it mostly automates regular graphic operations inside such graphic platforms[4].CIB can only be executed if data regarding structural shape characteristics and the size of its parts is available[2].In this context, SH structure development synthesizes two interconnected procedures: CIB and Parametric Design (PD) [3].CIB aims to generate visual parameterized data regarding the material composition of SH structures and their geometrical and construction principles[6].A job in CIB design involves creating drawings of structures using contemporary office technology[8].Parametric CIB design aims to ascertain the physical dimensions of structural components that comply with legal requirements.
The issue with the PD of SH components is little addressed in current shipbuilding Computer-Aided Design (CAD) [15] and Computer-Aided Manufacturing (CAM) [5]technologies.PD mechanization needs specific software.It is a prevalent belief that building design involves the computation of a structure with technology that employs the Finite Element Method (FEM) [13].To conduct FEM evaluation, comprehensive and accurate data on the building's geometry is essential; yet, such information is often lacking or insufficient during the early design phases.
The literature provides basic details on the parametric configurations of the SH design and interior structures[9].The fundamental concepts of modeling naval structures using an object-oriented methodology are very pertinent to the creation of software.Ship constructions are tangible entities characterized by a complicated

hierarchy framework, well-suited for the development of a data structure as well as processing methodologies in computer systems designed with an object-oriented paradigm[11].
The issue of structural design is framed as a comprehensive computational mathematics issue.The goal of a value often represents a property of the structural mass.Inequality limitations are established based on the regulations for double-SH crude tankers, cargo vessels, and containers.A specialized tool for linear CIB layout of SH buildings, named CAD, has been created based on the suggested approach. This approach employs simplified techniques, computations, and programs for the initial data preparation necessary for design processes.

## 2. BACKGROUND
## 3.

The translation of data across CAD, CAM, and Virtual Reality (VR) tools is a highly regarded and extensively debated research subject in several sectors. It is characterized by its complexity and time consumption [7].In ship constructions, which are among the most intricate engineering constructs, the amalgamation of planning, evaluation, and assessment is crucial for reducing the design process.The objectives of integrating components include enhanced structural performance, increased interoperability, and improved reliability of designs.Investigators have suggested numerous options, including framework integration strategies.
In the maritime and offshore apparatus sectors, geometric drawings in neutral style are transformed into VR models or regenerated 3D models using software like 3dsMAX[12].Modifications to the CAD model render the procedure arduous, time-intensive, and costly to replicate[14]. By analyzing disparities across different 3D model forms, the study established a streamlined system interface to translate the kinematic data in the CAD design into the VR environment. Compared to CAD, reducing the complexity of Finite Element Analysis (FEA) information to support simulations in real applications remains a formidable challenge.A real-time FEM framework was developed to analyze ultra-large cargo ships' bending and twisting under various maritime circumstances[16].To quickly and effectively create a virtual library of ship designs, the study investigated the process for the conversion of 3D renderings from an unaltered standard to the OpenFlightstandard[18].
The integrative method using the neutral platform employs CAM analysis findings to modify the geometric method, often aimed at optimizing the iterative design process [8].A collaborative study established an impartial framework with model design parameters to preserve the correlation between CAD and CAM.The research used MATLAB Simulink as an intermediary platform to enable CAD model revisions and CAM, aiming to minimize mistakes and enhance the design processes [17].A multi-objective optimizing system using commercially available software integrates an automatic CAD of the shipping container ship latching bridge with information rules, linking the architectural and model simulations via standard characteristic variables.The interface between CAD and CAM technologies is governed by an impartial platform facilitating product optimization and development.Conversely, these methodologies sometimes need bespoke growth, entailing considerable time and expense for implementation.
The layout and evaluation of ship constructions require intricate and varied subject expertise.Knowledge-based administration and reutilization significantly enhance design efficiency and quality.A CAD-CAM-VR integrating tool employing multi-domain feature mappings is suggested, distinguishing itself from conventional integrating approaches that rely on quantitative geometrical model data and topology knowledge of ship structures.

## 3. INTERACTIVE DESIGN METHOD
## 4.

The design environment is examined via subjective human assessments during the design process.This approach guarantees the integration of human intuition while avoiding explicitly including human imperfections in the design procedure.This procedure is executed via user-friendly interfaces or optimizers inside those interfaces to semi-automate research.In this technique, designers actively participate in every attempt to direct the study of prospective areas.A randomly selected design population is created, from which the buyer picks one according to their requirements.The optimizer then iterates to produce designs akin to the selection; however,it does so with enhanced performance, whereby similarities across designs are assessed using a distance-based measurement.This adaptive and collaborative approach continues until the client's favored design is realized.
The layouts produced at each optimization iteration rely on designer choices from the preceding iteration; hence, beginning the procedure with unplanned designs impedes optimization.Modern distance-oriented design-space exploration techniques propel the optimizer towards swift convergence on analogous designs while inadequately investigating the design field.The interactive ModiYacht procedure starts with designs produced, which are evenly dispersed and include virtually all potentialities within the specified area.Rather than using a distance-based measure to guide the collaborative method towards the customer-preferred answer, the research usesa technique to identify and eliminate non-potential regions based on the chosen designs, generating a much reduced space for a design that minimizes computing expenses.During every interaction, designs are generated via the parametric

modeling technique, whereby physical attributes are shown.The user then chooses a design according to the preferred aesthetics and functionality, and the design area is further enhanced.This process keeps going until the ideal design is attained.Fig.1 depicts this methodology inside a two-dimensional design environment. The design area established in the prior contact diminishes with every conversation according to the latest user-selected style.The area of interest to the customer is more thoroughly examined.

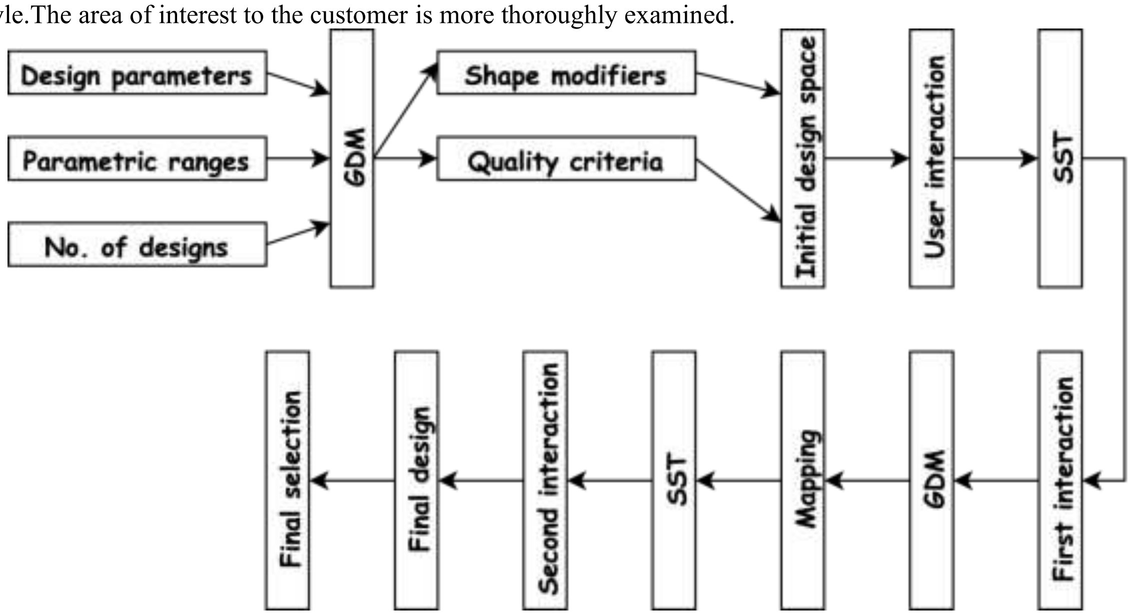


Fig. 1. Workflow of the interactive design

3.1 Unified Mesh Database (UMD) for Virtual Representation

In recent years, "effective cooperation" has been thoroughly examined within the engineering discipline. Compared to CAD, collaboration and dissemination of FEA information in practical scenarios remain problematic.The primary impetus for the virtual representation of FEA knowledge is to optimize the valuable information derived from simulation outcomes (Fig. 2).Significant disparities exist among the data formats of calculation output files from various proprietary CAM applications, most of which are not freely available. Storing instances, analytical procedures, components, material characteristics, nodes, stresses, and displacements inside the data file is more intricate than anticipated.Design semantic matching establishes the linkage of significant feature variables in models across many domains and their visual presentation outcomes.

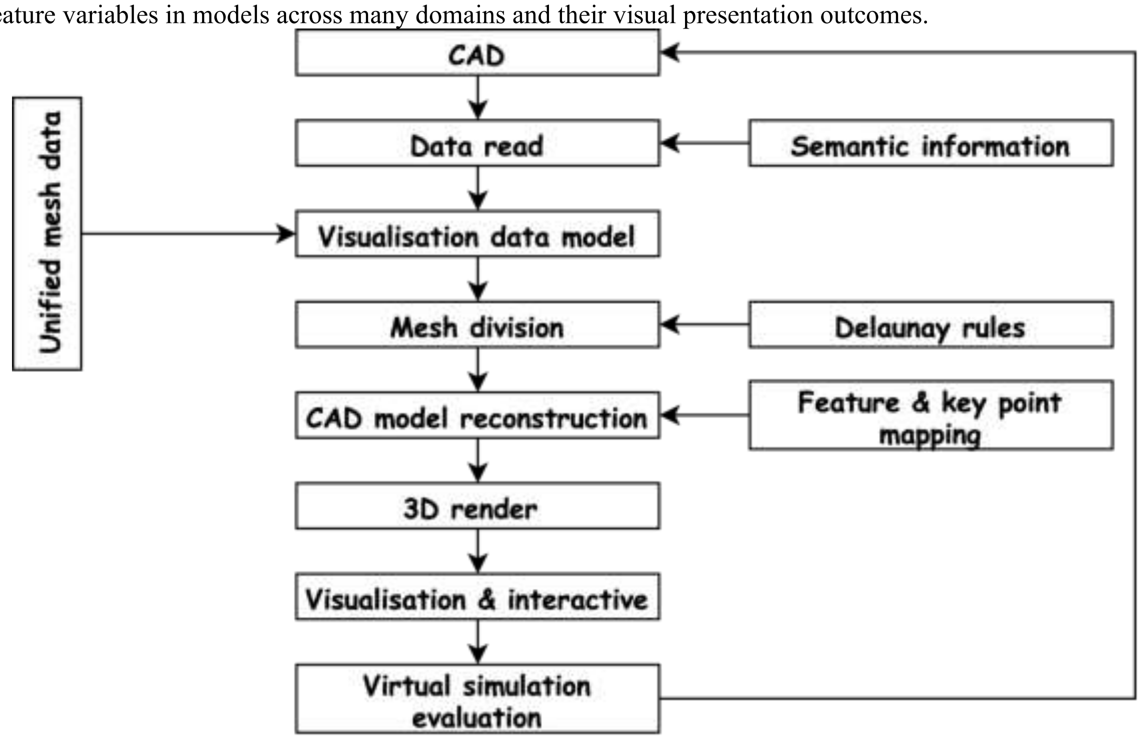

Fig. 2. Visual procedure

A FEM analysis mining technique for duplicated data is built by integrating engineering semantics files and command flows.A separate study finds additional information on minimizing weight FEA data.Nodes, components, topological relationships, emphasizing shifts, and other relevant data inside the binary output file are examined.The model reconstructing and displaying a simulation created with Unity 3D software is limited to triangle models.The understanding rule foundation includes the Delaunay triangle principles as evaluative expressions to achieve optimal visualization.It optimizes the smallest angle of each triangle, fulfilling the essential criteria for model rebuilding.

The industry lacks a standardized file format for FEA data used in visualizations.The presentation efficacy of current data translation and interface creation techniques is comparatively inadequate.This project seeks to effectively show and disseminate concurrent CAD drawings and FEA ship structure information.A cohesive mesh representation of information approach is developed using a set of procedures and functions to provide virtual display and access to geometric designs, FEM designs, and FEM information stored in a single lightweight grid.The graphical outcomes adapt to system shape and simulation parameters.

3.2 Project Database

The knowledge gained from establishing a CIB design platform and addressing several practical issues in ship maintenance and design facilitated the conceptualization of the project vessel database framework (Fig. 3).

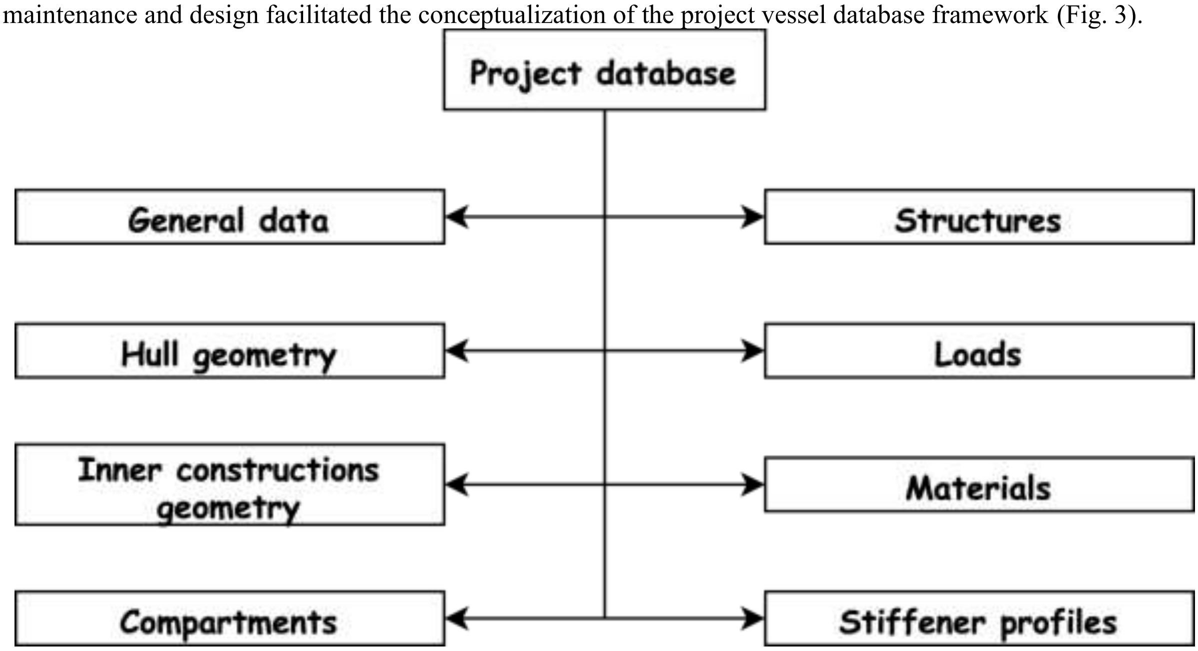


Fig. 3. Structure of the database

General project information, including ship type, ice category, principal dimensions, coordinate system property, and spacing table, is included in many text files.

The SH shape is preserved in a text file structure that delineates the shape of a series of segments or anSH "wireframe".The SH geometry is seen in a specialized edition in two-dimensional and 3D formats.

The morphology of internal frameworks is preserved in text files that include data on internal building control portions and the variable values that define the contours of these buildings inside a specificSH segment.The outcomes of geometric modeling for the longitudinal firewall of an ice-class tanker are shown as a case study.

- Compartments: The undertaking's compartments and tanks are documented in a text file structured as a hierarchical tree.Every compartment has its hierarchy code.
- The settings of all stated divisions are compiled in a text file as information blocks, each beginning with a distinct compartment identifier.This document includes the data needed for the calculation of designs.
- SH Composition:This is the most intricate data element.The text files are located in the "SHShip_Structures" project directory.
- Lightweight and Changing Loads:Lighter ship elements and changeable dead weight elements are stored in text files, and the quantity corresponding to the loading possibilities is evaluated.
- Directory of project resources:The essential data, acquired per the technique outlined in point 3, is stored in a text file.

- Profiling: Data on the standard dimensions of profiles utilized throughout the tasks, acquired using the technique,is preserved in a text file.

## 4. CONCLUSION

The design of SH structures synthesizes two interconnected processes: CIB and PD.The construction aims to provide visible parameterized data regarding the structural design makeup of SH buildings and their geometric and building principles.One of the architect's responsibilities is the creation of structural models with contemporary office supplies.Parametric CIB design aims to ascertain the size of structural components that comply with regulatory standards.The PD of SH constructions uses the stipulations of categorization societies and structural strength norms.

Many computations are conducted while designingSH components at the design bureau.Typically, highly skilled professionals are engaged to execute them.The PD method is cyclical.The SH design undergoes several alterations, necessitating modifications in the proportions of structural components and, therefore, the reiteration of design computations.The computerization of PD, via specialist software, is very significant.

The authors' extensive experience, exceeding 30 years, in scientific studies and in addressing practical challenges related to the creation of SH buildings, floating docks, and surface vessels has enabled them to conceptualize the overarching framework of parametric CIB design, which consists of functional software modules, the detail degree of the design item (ship or offshore framework SH) outline, and the theoretical basis for its advancement.The extension of the acquired representation is as follows:

The architecture of the CIB platform is defined by a collection of soft units and their interconnections, the functional category of each block (the aggregate of issues to be addressed), and the order of program method execution.

A shared database is essential for the parametric CIB for SH structural design.The shared database contains data that is, by means, applicable to ships across all projects.

A shared database and specific software facilitate the creation of project databases, enhancing the ease and streamlining the creation of functional software elements and managing the PD processes.

Catalogs (or classifications) of ship constructions, compartmentsof the SH, material information, and characteristics are of significant practical value.

It is essential to establish a specialized method for encoding the components of the SH construction and the spaces inside the SH.The data is necessary for constructing the program code for the CIB system components.

## REFERENCES

1. Dodero, M., Bertagna, S., Braidotti, L., Marinò, A., & Bucci, V. (2022). Ship design assessment through virtual prototypes. Procedia Computer Science, 200, 1227-1236.
2. Ziwei, M., & Han, L. L. (2023). Scientometric Review of Sustainable Land Use and Management Research. *Aquatic Ecosystems and Environmental Frontiers*, *1*(1), 21-24.
3. Ryumin, S., &Tryaskin, V. (2022). Computer-Aided System for Parametric Design of Ship Hull Structures—CADS-Hull. Machines, 10(4), 262.
4. Petrova, E., & Kowalski, D. (2025). Energy-Efficient Microalgae Filtering and Harvesting Using an Extremely Low-Pressure Membrane Filter with Fouling Control. *Engineering Perspectives in Filtration and Separation*, *2*(1), 25-31
5. Feldhausen, T., Heinrich, L., Saleeby, K., Burl, A., Post, B., MacDonald, E., ...& Love, L. (2022). Review of Computer-Aided Manufacturing (CAM) strategies for hybrid directed energy deposition. Additive Manufacturing, 56, 102900.
6. Nallasivamani, P., Nishanth, R., Rameshkrishnan, M., Soundar, M., & Mounika, S. (2023). Clothing Recommender System using Deep Learning. *International Journal of Advances in Engineering and Emerging Technology*, *14*(1), 58–63
7. de Freitas, F. V., Gomes, M. V. M., & Winkler, I. (2022). Benefits and challenges of virtual-reality-based industrial usability testing and design reviews: A patents landscape and literature review. Applied Sciences, 12(3), 1755.
8. Musa, K. M., &Alshemary, K. K. H. (2024). The Role of Nanoparticles in Sunscreen: UV Protection and Particle Size. *International Academic Journal of Science and Engineering*, *11*(1), 153–164. https://doi.org/10.9756/IAJSE/V11I1/IAJSE1118
9. Veerappan, S. (2023). Designing voltage-controlled oscillators for optimal frequency synthesis. National Journal of RF Engineering and Wireless Communication, 1(1), 49-56. https://doi.org/10.31838/RFMW/01.01.06

10. Wang, H., Xu, P., Sha, H., Gu, J., Xiao, T., Yang, Y., & Zhang, D. (2022, July). BIM-based automated design for HVAC system of office buildings—An experimental study. In Building Simulation (Vol. 15, No. 7, pp. 1177-1192). Beijing: Tsinghua University Press.
11. Rahim, R. (2024). Scalable architectures for real-time data processing in IoT-enabled wireless sensor networks. Journal of Wireless Sensor Networks and IoT, 1(1), 44-49. https://doi.org/10.31838/WSNIOT/01.01.07
12. Sreenivasu, M., Kumar, U. V., &Dhulipudi, R. (2022). Design and Development of Intrusion Detection System for Wireless Sensor Network. Journal of VLSI Circuits and Systems, 4(2), 1–4. https://doi.org/10.31838/jvcs/04.02.01
13. Liu, W. K., Li, S., & Park, H. S. (2022). Eighty years of the finite element method: Birth, evolution, and future. Archives of Computational Methods in Engineering, 29(6), 4431-4453.
14. Uvarajan, K. P. (2024). Advances in quantum computing: Implications for engineering and science. Innovative Reviews in Engineering and Science, 1(1), 21-24. https://doi.org/10.31838/INES/01.01.05
15. Hunde, B. R., & Woldeyohannes, A. D. (2022). Future prospects of computer-aided design (CAD)–A review from the perspective of artificial intelligence (AI), extended reality, and 3D printing. Results in Engineering, 14, 100478.
16. Surendar, A. (2024). Survey and future directions on fault tolerance mechanisms in reconfigurable computing. SCCTS Transactions on Reconfigurable Computing, 1(1), 26-30. https://doi.org/10.31838/RCC/01.01.06
17. Chou, J. R. (2024). An integrative review exploring the development of sustainable product design in the technological context of Industry 4.0. Advanced Engineering Informatics, 62, 102689
18. Arvinth, N. (2024). Integration of neuromorphic computing in embedded systems: Opportunities and challenges. Journal of Integrated VLSI, Embedded and Computing Technologies, 1(1), 26-30. https://doi.org/10.31838/JIVCT/01.01.06
19. Barhoumia, E. M., & Khan, Z. (2025). Predictive analysis of climate change impact using multiphysics simulation models. Bridge: Journal of Multidisciplinary Explorations, 1(1), 23–30.
20. Rahman, F., &Prabhakar, C. P. (2025). From synapses to systems: A comprehensive review of neuroplasticity across the human lifespan. Advances in Cognitive and Neural Studies, 1(1), 28–38.
21. Chen, Z., &Dahal, R. K. (2025). AI-driven big data framework for climate-resilient transportation infrastructure. Journal of Smart Infrastructure and Environmental Sustainability, 2(1), 38–44.
22. Sadulla, S. (2025). Effect of Pranayama on lung function in post-COVID rehabilitation among middle-aged adults: A clinical study. Journal of Yoga, Sports, and Health Sciences, 1(1), 24–30.
23. Abdullah, D. (2025). Topology optimization of composite structures for enhanced crash energy absorption: Mitigating non-uniform stress distributions in crashworthy designs. Advances in Mechanical Engineering and Applications, 1(2), 1–10.
24. Kavitha, M. (2025). Breaking the silicon ceiling: A comparative analysis of women's leadership and participation in AI startups across global innovation hubs. Journal of Women, Innovation, and Technological Empowerment, 1(1), 1–6.
25. Khan, Z., &Soria, F. (2024). Lightweight CNN architectures for next-gen computing applications and edge device inference. Electronics, Communications, and Computing Summit, 2(2), 19–27.