iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: XII Month of publication: December 2024

DOI: https://doi.org/10.22214/ijraset.2024.65936

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

Floor space optimization of Molds in Boat Manufacturing using Dynamic programming and optimization algorithm

Vijay Gurav
Brunswick Corporation, University of Texas at Arlington

Abstract: Floor space management in manufacturing of boats requires to be optimized as much as possible and particularly with reference to molds, which are large fixed assets. This article uses dynamic programming to solve the problem of floor space allocation, with particular emphasis on the minimization of unused space and the maximization of mold placement. By specifying the problem as a resource allocation problem, the article naturally considers spatial configurations and operational conditions such as mold size, production timeline, and material transportation. The dynamic programming approach is used to provide a scalable and cost-efficient solution as it is a decomposition of the problem into sub-problems and the global optimum is achieved for layouts. The analysis shows a potential of achieving a high space utilization, the elimination of operational constraints and an improvement of flow rates leading to the formulation of smart manufacturing solutions in the boat industry. This article explains about the analysis of Optimizing Floor Space in Boat Manufacturing, Formulation of the Mold Arrangement Challenge, Key Constraints and Variables in Space Optimization, Dynamic Programming for Mold Layout Optimization, Significance of Efficient Floor Space Utilization and Practical Applications in Boat Manufacturing Facilities were also discussed. In this review article, a total number of 60 papers were choosen from the year 2019 to 2024 accordingly. Moreover, 11 papers were selected from the year 2019, 18 papers were selected from 2020, 13 were selected from the year 2021, 9 papers from the year 2022, 6 papers were selected from 2023 and 3 were from 2024 respectively.
Keywords: *- Floor Space Optimization: Dynamic Programming: Space Efficiency: Boat Manufacturing: Mold Placement*

I. INTRODUCTION

Space management is another important aspect in construction of boats because the manufacturing process involves the use of large floor space molds. The positioning and distribution of these molds determine the productivity rate, cost, and capacity of throughput in the production line [11]. However, the issue of space constraint in managing the limited floor space together with the production schedules and the logistics of the company is a major challenge. The problem of an efficient method to allocate floor space is an important factor to consider in the manufacturing process. Dynamic programming provides a sound methodological setting for management of difficult optimization problems by disassembling them into simpler sub-problems [34]. Therefore, it is easy to assess various placements of the molds with reference to the mold sizes, production priorities, and operational workflows. This approach guarantees that a methodical solution of the mold placement is developed, which will allow using most of the floor space and avoiding large zones that are not occupied by equipment or structures, as well as the intersections of the layout [36].

In this research, the use of dynamic programming in solving the problem of positioning of moulds in boat production is examined. As a result, to overcome these issues, the algorithm is expected to improve the efficiency of this particular industry where the shape of the mold is irregular, the time taken to produce each mold is unpredictable, and floor space is limited. The evaluation for the manufacturing sector is significant, as they provide a practical means of minimising cost and integrating efficient manufacturing processes and floor space utilisation in boat manufacturing and other large scale manufacturing industries.

II. FLOOR SPACE OPTIMIZATION IN BOAT MANUFACTURING

In 2021, Wu, *et al* [1] have proposed the concept of digital twin were recently attracted a lot of focus for connecting the physical and digital domains, but its use in manufacturing is still quite limited. This algorithm surveys the study on the use of digital twin in intelligent manufacturing and presents a new framework for the digital twin-based ship intelligent manufacturing system. The framework comprises five layers: physical, data, model, system, as well as application that will effectively interconnect the digital environment with the physical environment.

Enabling techniques are discussed, and a manufacturing line of pipes and tubes for a pipe machining application supports the analysis. Specific discussions regarding system design, twin modeling, and implementation are given to guide the industry.

In 2021, Yuan *et al* [2] have developed the essential data regarding the fuel consumption of ships is necessary for navigation planning, condition monitoring, and energy management. This approach acquires the real-time status monitoring along with hydrological data of inland ships through multiple sensors and provides approaches for multi-source data processing and real-time fuel consumption computation. An LSTM neural network is trained to forecast fuel consumption rates taking into account navigational and environmental parameters involving water depth, wind speed as well as angle. Validation proves that the proposed LSTM model is more accurate than the traditional regression and RNN models. Also, the Reduced Space Searching Algorithm (RSSA) minimizes fuel and voyage costs, and the fuel consumption and the SOGT models could be incorporated successfully.

In 2020, Kumar *et al* [3] have suggested the leakage from container ships are disastrous to marine life and human beings in that it pollutes the environment. Oil slicks are washed and identified by Autonomous Underwater Vehicles (AUVs) hence the need for efficient path planning to reduce energy utilization. In this article, a new optimization technique, the Whale Cuckoo Search Optimization Algorithm (WCSOA) is developed to find the best paths for AUVs, thus minimizing the search distance. WCSOA improves global search capability, convergence rate, and the scope of search. Performance analysis of the proposed approach reveals that the energy consumption of AUV is reduced by 57% as compared with Boustrophedon and WOA techniques, thereby proving the efficiency of the approach in minimizing search delays and energy utilization.

In 2020, Silva *et al* [4] have developed the Path planning of sailboat robots is a complex problem when sailboat robots are wind-powered and has kinematic limitations. This algorithm focuses on the path planning layer in the N-Boat project for global path planning that could navigate the boat with a start and target position when avoiding obstacles and taking into consideration the wind dead zone. A reinforcement learning approach Q-Learning has been utilized along with a reward matrix and adaptive actions based on wind direction to derive the possible routes including straight and zigzag. The algorithm is safe, robust, and efficient, enabling an extension of the degree of automation of sailing. When combined with an existing local planner, it allows full autonomy of the N-Boat.

In 2020, Tarelko & Rudzki [5] have identified the artificial neural networks (ANN) are used to design ship speed and fuel consumption and estimate fuel usage and travel time for the commanded outputs such as the shaft speed and pitch of the propeller. Since the environmental conditions change, it is difficult to identify the right level of outputs, and this is solved by a decision support system. The system employs ANN models for performance and fuel consumption estimation of ships. Procedures of sea trials were performed to collect the required data, and the approach also describes the stages of ANN models creation, such as data collection, data preprocessing, model selection, and model validation. The above structure were intended to develop decision making with management of ship operations.

In 2020, Yan *et al* [6] have examined the effective inspection of ships at the ports is important in as far as compliance to safety and environmental standards. Three two-step approaches are proposed in this article in order to make the best out of scarce inspection resources in order to detect the most deficiencies in ships. The first method forecasts the number of deficiencies per ship and allocates the number of inspectors by integer optimization. The second approach predicts the deficiencies that the inspectors could identify and applies the same optimization model. The third approach is a semi-SPO method where the loss function is modified to optimize its performance. Simulation studies reveal more than four percentage points of gain in inspection efficiency, while the sensitivity analysis validates the approaches.

In 2022, Abebe *et al* [7] have discussed the near-future ship trajectory prediction for collision-free planning, this research suggests a combined ARIMA-LSTM model depend on AIS data. The AIS data is then pre-filtered by a moving average filter to divide it into linear and nonlinear parts, with LSTM and ARIMA used to design the trajectory. The accuracy and computational performance of model is checked and the model is compared with the existing ARIMA, LSTM and a combination of both. The results of collision-avoidance simulations show that the suggested model could be used for accurate prediction of the trajectories and estimation of the collision risks, thus providing the opportunity to make the appropriate decisions in time to avoid collision. The findings reveal its efficiency in enhancing the safety of the ships. In 2023, Li *et al* [8] have explored a systematic evaluation and comparison of twelve ship trajectory prediction methods which include both traditional ML algorithms such as Kalman Filter, Support Vector Regression and deep learning models like Long Short-Term Memory (LSTM), Recurrent Neural Network (RNN), and Transformer. The study utilizes three AIS datasets from different maritime environments: normal channels, complex traffic and port regions. The performance of the methods is measured against six criteria in order to determine how well the methods predict ship trajectories. The findings give an understanding of the effectiveness and drawbacks of each method in different conditions for improving safety in maritime transport and creating autonomous shipping solutions.

In 2020, Wang *et al* [9] have determined an efficient method for optimizing the sailing route and speed of a ship and studying the impacts of the interrelated factors and environmental conditions. The optimization model is formed by developing an energy consumption model which considers several environmental parameters. An algorithm has been proposed to help solve the coordination decision problem of route and speed. A investigation confirms in which the proposed method is able to minimize fuel consumption and CO2 emissions by about 4% in the conditions of varying environmental parameters. The findings suggest that there is a scope for improving efficiency and environmental performance with context of maritime activities.

In 2022, Qian *et al* [10] have investigated a new GA-LSTM approach for the prediction of ship's trajectory for improving collision risk in inland waterways. AIS data were preprocessed and some of the normal trajectories were used for real time prediction with LSTM network. In this algorithm, genetic algorithm has been utilized to tune LSTM's hyperparameters to increase its accuracy and efficiency of model. The GA-LSTM model is evaluated against conventional support vector machine (SVM) and LSTM models where the suggested model has better accuracy and faster results. The results reveal the advantage and versatility of the model, which offers a reference for the future study of unmanned ship collision avoidance. The assessment on Floor Space Optimization in Boat Manufacturing has been illustrated by Table 1.

Table 1: Assessment on Floor Space Optimization in Boat Manufacturing

Authors [Citation]	Technique Used	Dataset Used	Performance Metrics	Major Objectives	Limitations
Wu *et al.* [1]	Digital Twin Framework	Pipe and tube manufacturing data	None explicitly mentioned	Develop a five-layer digital twin-based framework for intelligent manufacturing	Limited to pipe machining; applicability to other industries not discussed
Yuan *et al.* [2]	LSTM, RSSA	Multi-sensor ship data	Forecast accuracy, fuel cost minimization	Real-time fuel consumption monitoring and computation using LSTM, navigation and energy management	Focuses on inland ships; generalization to other ship types not addressed
Kumar *et al.* [3]	WCSOA	Simulation data	Energy consumption reduction (57%)	Optimize AUV path planning to minimize energy utilization	Applicability to real-world scenarios with environmental complexities not verified
Silva *et al.* [4]	Q-Learning	N-Boat simulation data	Path efficiency, safety	Enable wind-powered sailboat robots to navigate autonomously while avoiding obstacles	Wind dead zone handling might not generalize across all wind-powered vessels
Tarelko & Rudzki [5]	ANN	Sea trials data	Fuel consumption and travel time estimation	Improve ship operation management through ANN-based decision support systems	Dependence on accurate environmental inputs and limited scope for dynamic updates

Yan *et al.* [6]	Integer Optimization, Semi-SPO	Port inspection data	Inspection efficiency gain (>4%)	Enhance ship inspection processes to comply with safety and environmental standards	Limited discussion on scalability to larger port environments
Abebe *et al.* [7]	ARIMA-LSTM	AIS trajectory data	Trajectory prediction accuracy	Predict near-future ship trajectories for collision-free planning	Model complexity and computational cost might limit real-time applications
Li *et al.* [8]	Kalman Filter, SVM, RNN, LSTM, Transformer	AIS datasets from varied environments	Prediction accuracy, computational efficiency	Compare 12 ship trajectory prediction methods for improving maritime safety	Certain methods might underperform in specific environmental conditions
Wang *et al.* [9]	Energy Consumption Optimization Model	Case study data	Fuel consumption and CO2 emission reduction (~4%)	Optimize sailing routes and speed to improve environmental performance	Focused primarily on minimizing environmental impact rather than operational constraints
Qian *et al.* [10]	GA-LSTM	AIS data	Prediction accuracy, model efficiency	Improve ship trajectory prediction for inland waterways using a hybrid GA-LSTM approach	Limited to inland waterways; global applicability not demonstrated

III. FORMULATION OF THE MOLD PLACEMENT PROBLEM

In 2019, Krieger *et al* [11] have explained a simple and cost-effective method of creating microneedle moulds using a desktop SLA 3D printer. It does not require sophisticated structures or the skilled use of microfabrication as do other techniques. The two-step “Print & Fill” process results in high aspect ratio, fine needles that could penetrate through tissue. Accordingly, the design parameters are tuned to fabricate needles in tip radii ranging from 20 µm to 40 µm and aspect ratio higher than 10. These microneedle arrays are then used to make silicone female master molds through which functional microneedle arrays could be made. This method provides an effective and cheap way of making microneedle and fine tuning it within the company.

In 2019, Post *et al* [12] have introduced the application of a large-scale manufacturing technology known as Big Area Additive Manufacturing (BAAM) in creating a 10.36 m catamaran boat hull mould is discussed. The research was to directly print the mould which didn’t need thick layers. The mould was printed in 12 sections in 5 days, then the critical surfaces of mould were CNC milled and the mould assembled. A final hull has been made with the help of the printed mould. The successful completion of this project shows that the use of BAAM with the manufacturing of large and complex moulds is more time and cost effective. This approach holds great promise for effective mass production in boat making.

In 2021, Paquet *et al* [13] have presented a new FAM process for building large boat hulls for the shipping market. Compared with CNC machining or handicrafts, FAM allows for the direct patterning of molds and masters though 3D printing.

The approach contrasts the conventional and additive manufacturing techniques using an industrial application case to demonstrate the benefits of FAM. Using FAM, a 2.5 m boat hull mold was produced which showed substantial reduction in time and cost. This approach could thus be used as an effective way of manufacturing large and complex molds in the manufacturing industry.

In 2021, Lee *et al* [14] have provided the structural design and evaluation of a composite boat hull manufactured through the RTM process. RTM is chosen because it delivers better product quality than hand lay-up techniques while using less resources than autoclave. Different aramid fibers and polyester resin mechanical properties has been determined. Therefore, structural design employing aramid fiber and polyester was done as indicated in the analysis. Resin infusion analysis further supported the fact in which the designed resin injection and outlet location were ideal for production. This research also explains the benefits of RTM in the manufacturing of composite boat hull.

In 2020, Korsmik *et al* [15] have described the design and manufacturing of metal ship propellers based on the topological optimization techniques. The geometry of the original propeller model was modified and the stress-strain state of improved version was analyzed and compared with that of the initial solid cast model. The optimized propeller design has 20% less weight and has similar reliability features to the initial design. An LMD manufacturing program was designed and simulated robotically using the optimized 3D model, while control samples were fabricated and tested for mechanical properties and showed results similar to those of cast and rolled metals. The strength properties of the built-up propeller were very close to that of the control samples.

In 2021, Terekhov *et al* [16] have analyzed the development and characteristics of binders (or tackifiers) employed with fabrication of composite materials by LCM techniques with emphasis on the function of stabilizing preforms during the laying-up and impregnation process. Epoxy, polyester and other resin binders improve fracture toughness and are essential in decreasing the cost of fabricating fibers by allowing for automated fiber placement. The work focuses on the effects of binders on preforming process of the features like stability, compaction, and permeability and their effect on the properties of the resultant composites. It also looks at the benefits and drawbacks of having LCM technology.

In 2020, Barsotti *et al* [17] have studied the recent advances in the evaluation of limit states and design methodologies for marine composites employed in ship structures, offshore platforms, and marine accessories. This underlines the significance of material characterization and structural assessment at the initial stage and during the different stages of the ship’s life cycle. The algorithm gives an insight of the current design practice and rules with emphasis on pleasure crafts, yachts and navy ships. They describe inter-ply and intra-ply failure mechanisms as well as the suggested evaluation methods. Other aspects related to the enhanced mechanical properties of marine composites, including the three-dimensional failure modes, fire resistance, and hybrid joining techniques are also described.

In 2019, Chebil *et al* [18] have proposed the simulation method for 3D resin flow in laminated preforms with multiple layers having several permeabilities. To overcome the computational difficulties associated with the use of solid elements for thin-walled structures, the multi-layered shell elements are adopted for 3D flow simulation. The mathematical description of the multi-layered shell element method is established to include via thickness and planar velocities. The efficiency of the method is discussed with the help of two new dimensionless criteria – the preform permeability ratio and the size of the shell element. Simulation results also show that this approach could save considerable computation time compared with other methods.

In 2021, Wang *et al* [19] have developed the impact of outrigger positioning on the wave resistance of trimarans with slender ship theory used for wave resistance determination. In order to increase accuracy, the NURBS method is employed to model the hull surface and the 3D color maps of the interference resistance depending on the speed and displacement ratio are created. The research shows that there is only one valley point for interference resistance on each map, which indicates the best layout. The steepest descent method is used for the best placement of outriggers with least wave interference in the process of layout optimization. The method described in this research shows high accuracy and enhanced computational performance compared to the conventional enumeration methods.

In 2022, Stiles *et al* [20] have examined the photopolymer materials for LM AM of tooling in aerospace industry with reference to Bis-EMA. The modifications of Bis-EMA by incorporating PETIA enhanced surface hardness and through thickness cure characteristics. An 80:20 Bis-EMA/PETIA blend possessed the highest hardness and thermal stability with the Tg values raised from 154°C to 172°C after thermal cycling. The UV-cured demonstration tooling made from this blend demonstrated almost no geometry change and no change in hardness after five oven cure molding cycles. This research shows that Bis-EMA/PETIA blends are viable for oven/autoclave capable tooling in large scale AM. Table 2 represents the analysis on Formulation of the Mold Placement Problem.

Table 2: Analysis on Formulation of the Mold Placement Problem

Authors [Citation]	Methodology	Dataset Used	Performance Metrics	Research Scope	Limitations
Krieger *et al.* [11]	SLA 3D Printing for microneedle molds	Desktop SLA printer design parameters	Tip radius (20-40 µm), aspect ratio (>10)	Cost-effective and accessible manufacturing of microneedle molds	Limited material variety for molds and focused only on SLA printers
Post *et al.* [12]	Big Area Additive Manufacturing (BAAM)	10.36 m catamaran hull	Time (5 days), cost, mold quality	Efficient large-scale mold production for marine applications	Requires post-processing (CNC milling) and assembly
Paquet *et al.* [13]	Fused Additive Manufacturing (FAM)	Industrial boat hull mold data	Cost and time reduction	Demonstrate benefits of FAM in boat hull mold production	Limited size application compared to larger hulls
Lee *et al.* [14]	RTM process with aramid fiber and polyester resin	Mechanical property data of aramid composites	Resin infusion quality, structural performance	Structural design of composite boat hulls with improved quality and efficiency	Focus on RTM; excludes broader composite manufacturing techniques
Korsmik *et al.* [15]	Topological optimization, LMD additive manufacturing	Optimized propeller design simulation data	Weight reduction (20%), mechanical strength	Design and manufacturing of lightweight, reliable ship propellers	Limited analysis of performance under real-world operating conditions
Terekhov *et al.* [16]	Binder development for LCM techniques	Experimental data on preform stabilization	Fracture toughness, process stability	Enhance composite material fabrication by optimizing binders for automated processes	Focuses on binder properties but lacks a holistic approach to composite system improvements
Barsotti *et al.* [17]	Composite evaluation methodologies	Marine composites design and testing data	Failure mechanisms, material properties	Design methodologies for marine composites focusing on mechanical properties and durability	Generalized conclusions; lacks specific case studies for validation
Chebil *et al.* [18]	Multi-layered shell element for resin flow simulation	Simulation data for laminated preforms	Computation time, simulation accuracy	Efficient 3D resin flow simulation for laminated composite structures	Model assumes constant properties; might not capture dynamic real-world variability
Wang *et al.* [19]	Outrigger optimization with slender ship theory	NURBS model data for trimaran hulls	Wave resistance accuracy, computational performance	Optimize outrigger placement for least wave resistance	Limited to slender ship theory; excludes broader hydrodynamic effects
Stiles *et al.* [20]	Bis-EMA/PETIA photopolymer blend for LM AM tooling	Bis-EMA/PETIA material property data	Hardness, thermal stability, geometry retention	Develop tooling materials for aerospace capable of withstanding autoclave environments	Limited focus on aerospace tooling applications

IV. CONSTRAINTS AND VARIABLES IN SPACE OPTIMIZATION

In 2020, Samanipour & Jelovica [21] have introduced a basic strategy for repair of non-dominance based genetic algorithms especially for problems with many constraints. The method recognizes factors that affect constraint and substitutes the violating values with solutions that exist within the current population. In NSGA-II, the approach is adopted and the ship hull girder optimization problem with 94 decision variables and 376 nonlinear constraints is used to validate the method. The new method results in faster convergence, lesser function evaluations, and better distribution of non-dominated front. The suggested algorithm shows better outcomes than the existing constraint handling techniques and MOEA/D approach in terms of hypervolume values.

In 2021, Liu *et al* [22] have focused the short-term berth allocation and ship scheduling for an active seaport with channel constraints where at most one big or two small vessels could pass at a time. An inbound, outbound, and shifting ship movement logistics MILP model is created to address the problem. To enhance the efficiency of the solution, the MILP is reformulated as a set-partitioning model and a CG algorithm is developed. The experiments performed on MATLAB reveal that the CG algorithm is more efficient than other methods, solving large problems in less than ten minutes with small gaps to optimality. Some recommendations are given to port managers who are confronting with the same issues.

In 2021, Nyanya *et al* [23] have suggested the use of renewable energy sources in a ship's power system through wind sails and solar energy. Two models were used: one was designed to adjust the wind sail angle depending on the prevailing conditions, the other focused on the distribution of deck space for wind and solar power. An investigation on a bulk carrier revealed that wind and solar power could cut the CO2 emission by 36%. Also, slowing the speed of the ship to 56% enabled the ship to be run solely on renewable energy. The presented methodology could be used in design phase as well as in operational phase for different types of ships.

In 2019, De *et al* [24] have developed a sustainable ship routing problem that considers time windows and bunker fuel. The model's objective is to assign vessels to several ports to ensure service quality and minimize carbon footprint. To address the problem, a hybrid particle swarm optimization in variable neighborhood search is developed. The algorithm offers better results than Cplex and other algorithms with the average cost deviation of 5.99% by the optimal solution. This approach increases sustainability in the marine transport sector through improving the routing of vessels and managing the fuel.

In 2019, Szlapczynska *et al* [25] have presented a tradeoff-based EMO approach for WR of ships with objectives involving passage time, fuel consumption, and safety while meeting navigational constraints. The approach also uses configurable weight ranges for objectives, to enable the user to influence the optimization process. This preference-based EMO method restricts the Pareto set to solutions that meet the user's pre-specified preferences only. Based on the comparison with the r-dominance method, the applicability and competitiveness for developed model are higher for solving multi-objective WR problems and providing better support for the user's decision-making.

In 2020, Wang *et al* [26] have developed a quadratic optimization genetic algorithm for an automatic ship route planning where the motion characteristics and maneuvering constraints were taken into account. This sets up a turning and speed reduction model to compute precise algorithm states with the own ship and target ships. A detection approach depend on quadtree method examines the position of the route with respect to the land objects like islands and rocks. The double-cycling genetic algorithm presented in this article deals with the obstacles' avoidance of both static and moving types. The effectiveness of the algorithm is shown by applying it to a fireboat; the experimental results indicate the applicability of the proposed approach to dynamic ship routing.

In 2019, Li *et al* [27] have examined the many-to-many maritime collision avoidance scheme is based on a distributed coordination strategy. It involves two phases: First, the prediction of the ship trajectory and assessment of the probability of collisions under different rudder angles, and second, the determination of the most effective rudder angles and their operating time to minimize the total time for collision avoidance. This is important to underline that the optimization is in fact to determine the best plan for the movement of each ship. The efficiency of method, and the communication and computation costs are illustrated through simulation experiments. The approach is aimed at solving real-world problems of multiple vehicle interactions in many-to-many collisions that have not been studied enough in prior research.

In 2022, Das *et al* [28] have offered a model for container vessel shipping in response to the fluctuating demand and supply at the ports with a given time horizon under fuzzy environment. They include speed optimization, performing loading and unloading operations in parallel and the use of load factors to reduce fuel consumption, and thereby carbon emissions. To model realistic scenarios with inexact cost parameters, introduced a risk factor and use the Triangular Fuzzy Numbers (TFN). The design is solved using a modified genetic algorithm, and the usefulness of approach is illustrated through numerical examples. The approach deals with the problem of uncertainty of cost parameters in real world ship routing.

In 2020, Li *et al* [29] have discussed the carbon footprint of Floating Production Storage and Offloading (FPSO) in deep-sea oil as well as gas fields through Life Cycle Assessment. At the operational stage, 88.2% of carbon emissions are recorded mainly in fuel combustion. A distributed energy system is introduced to minimize emissions by improving the utilization of energy. The present work proposes a Multi-objective Mathematical Programming model with the objective of minimizing cost and carbon footprint while fulfilling energy demand. The model was proved by an example where cost savings of 14.6% and reduction of emissions by 4.53% could be achieved. The sensitivity evaluation shows which cost responds more sensitively to natural gas prices.

In 2020, De *et al* [30] have explored the dynamic ship berth allocation problem in container ports, taking into account the ship waiting time caused by berth and crane downtime. A mixed integer linear programming model is then formulated with fuel costs of waiting and operational times. Quay crane hiring and berth allocation are included in the model for sustainability. A chemical reaction optimization algorithm is presented and results were compared with genetic algorithms as well as particle swarm optimization. The findings of the computational experimentation on a real Indian port case indicate that the proposed model enhances the utilization of port resources and availability of berths. The assessment on Constraints and Variables in Space Optimization has been determined by Table 3.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

Table 3: Assessment on Constraints and Variables in Space Optimization

Authors [Citation]	Aim	Technique Used	Performance Metrics	Limitations
Samanipour & Jelovica [21]	Improve repair strategy for genetic algorithms in ship hull girder optimization	Non-dominance based genetic algorithms (NSGA-II)	Hypervolume values, convergence speed, function evaluations	Limited to ship hull girder optimization and not tested on other multi-objective problems
Liu *et al.* [22]	Optimize berth allocation and ship scheduling in constrained seaports	MILP reformulated as a set-partitioning model, CG algorithm	Solution time (<10 min), gap to optimality	Assumes static channel constraints and simplified port operations
Nyanya *et al.* [23]	Integrate renewable energy in ship power systems	Wind sail and solar energy optimization models	CO2 emission reduction (36%), energy sufficiency	Focused only on bulk carriers; applicability to other ship types needs validation
De *et al.* [24]	Develop sustainable ship routing to reduce emissions and costs	Hybrid particle swarm optimization (PSO)	Cost deviation (5.99%), carbon footprint	Focuses on static time windows; excludes real-time adaptability
Szlapczynska *et al.* [25]	Provide user-influenced optimization for weather routing	Preference-based EMO approach	Passage time, fuel consumption, safety	User preferences might limit exploration of broader solution space
Wang *et al.* [26]	Automate ship route planning considering dynamic obstacles	Quadratic optimization genetic algorithm	Route efficiency, obstacle avoidance	Limited testing scope; mainly validated on a fireboat case study
Li *et al.* [27]	Develop a maritime collision avoidance scheme for multiple ships	Distributed coordination strategy	Collision avoidance time, rudder angle efficiency	Requires robust communication systems; assumes accurate trajectory prediction
Das *et al.* [28]	Address demand-supply fluctuations in container vessel shipping	Modified genetic algorithm with TFN	Cost savings, fuel reduction	Relies on fuzzy inputs; results might vary with uncertain data
Li *et al.* [29]	Minimize carbon footprint of FPSOs using energy optimization	Multi-objective mathematical programming	Emission reduction (4.53%), cost savings (14.6%)	Sensitivity to fuel price fluctuations; limited generalizability to other offshore operations
De *et al.* [30]	Enhance dynamic berth allocation in container ports	Chemical reaction optimization algorithm	Resource utilization, berth availability	Focused on a single port case study; scalability to global applications not demonstrated

V. DYNAMIC PROGRAMMING APPROACH FOR MOLD LAYOUT DESIGN

In 2020, Solís *et al* [31] have explored a lot-sizing and scheduling problem to solve for the maximum profit in a plastic injection production context. It deals with finished products where pieces are processed through different molds and machines, all of which have different production capacities. A two-stage iterative heuristic is developed: The first of them defines lot-size and the mold-machine allocation, while the second verifies possible schedules without overlapping. If this fails, restrictions are added, to narrow down the solution until the solution is feasible. The methodology is applied to real company data and random instances and the results are comparable in terms of quality and running times.

In 2023, Hu *et al* [32] have determined the integrated production scheduling and maintenance planning for machine that receives random jobs. The emphasis is made on the necessity to load particular molds before the job starts, an aspect that is frequently excluded from other investigations. Maintenance is best described by using reliability/availability frameworks. The objective is to minimize total cost and maximum unavailability of machine. A new DE-GA is presented for this purpose and is supported by a solution refinement method. The performance analysis proves that DE-GA has a better solution than Gurobi solver and four other algorithms in different test problems.

In 2020, Lee *et al* [33] have investigated the mold production scheduling in the context of the injection mold industry is discussed where deep RL is employed to fulfill customer delivery dates. A mathematical modeling of the scheduling problem is described, and an MDP framework for RL is used. Thus, the deep Q-network algorithm is used to reduce total weighted tardiness. The outcomes of the experiment indicate which the use of a deep RL approach is superior to conventional dispatching rules. This approach provides a viable and rational way to address the challenges of mold manufacturing. The findings show that it could be applied successfully in production settings characterized by change.

In 2022, Heydar *et al* [34] have explained an approximate dynamic programming solution to an energy-constrained scheduling problem involving unrelated parallel machines. Jobs come in at any time while ready and processing times are only available when orders are placed.

The objective is to reduce a weighted sum of makespan and total energy consumption for machine switching, processing, and idle time. At every level of dynamic program, a binary program is employed to solve the problem. The experimental findings reveal which the suggested method attains better accuracy and shorter time in comparison with offline integer linear programming and prior heuristics.

In 2021, Allah *et al* [35] have developed an approach of dynamic programming (DPA) combined with intuitionistic fuzzy set (IFS) to solving multi-objective optimization problems (MOOP). DPA produces efficient solutions, and IFS deals with the conflict between objectives using satisfaction and dissatisfaction concepts. A new closeness strategy-based distance function is presented for evaluating the quality of solutions.

The method is then employed on the IEEE 30-bus power system, and results are compared with other methods to establish its effectiveness. The DPA-IFS methodology is very useful in handling of conflicting objectives and closely related decisions inherent in engineering design. Actual examples in numbers support its viability in practice.

In 2024, Chen *et al* [36] have formulated the security-constrained unit commitment with AC power flow constraints (AC-SCUC), an NP-hard problem, as a decomposable problem in the space-time domain. To solve the problem, an improved dynamic programming (IDP) algorithm has been developed, which can prune the state space by identifying the start and end periods of every consecutive status. As with other forms of dynamic programming, improvements to existing algorithms are made with IDP through a closed-form solution instead of iterations. Examples were provided to determine the use of algorithm and to compare the results with more conventional approaches.

In 2023, Ghaleb & Taghipour [37] have developed the dynamic shop-floor scheduling in the thermoplastic industry, where real-time events such as mold failure need to be taken into account. The problem of batch processing, machine dependency, and maintenance considerations is modeled in a mixed-integer programming model to minimize tardiness and operating costs. A predictive-reactive schedule is developed depend on a modified simulated annealing (SA) algorithm. The method includes the event-driven rescheduling policy and the problem-specific solution assessment. Experimental analysis proves which the developed SA-based algorithm decreases tardiness by 26.1% and total cost by 6.99 % against dispatching rules, an iterated greedy algorithm, and the Tabu Search algorithm.

In 2020, Mei *et al* [38] have described the effects in managing and scheduling the large-scale one-of-a-kind production (OKP) systems in 2020 especially in the context of shipbuilding industry where design variability, disruption in workforce distribution, and intricate production network make real-time control challenging. The paper develops a cost dynamic control and optimization method depend on MLHPP model to establish a PERT-Petri net closed-loop production control system. This approach solves the problem of different working hours, fluctuations in resource availability and the relationships between tasks. The applicability of the proposed method is then confirmed by the real industrial implementation in the shipbuilding interim production system to show the proper structuring and controlling of the systems.

In 2019, Zhang *et al* [39] have presented the theoretical analysis of lean production, particularly in the light of smart manufacturing and Industry 4.0. The authors present a new theory known as the Lean-Oriented Optimum-State Control Theory (L-OSCT), which combines lean methods and tools with optimum-state control theory. This approach employs synchronizing methods to realise global-wide leanness in large-scaled systems. L-OSCT offers protection and control of dynamic processes in industrial networking. The effectiveness of suggested algorithm is further supported by the investigation with a large paint manufacturing firm in China.

In 2020, Sivasankaran *et al* [40] have considered the machine capacity planning in production shifts, with the focus on the fact that machine performance impacts organizational wellbeing. It solves the problem of how to assess the utilization of machines in the course of each shift.

The study formulates a mathematical model for determining capacity utilization by comparing actual production of machines with the potential production during a given period.

The model also considers variations in production capacity with respect to demand. In this approach, a linear programming model is utilized to represent the optimal capacity planning. The proposed model is solved by using LINDO software so that it can be applied practically in industrial organizations. The analysis on Dynamic Programming Approach for Mold Layout Design has been illustrated by Table 4.

Table 4: Analysis on Dynamic Programming Approach for Mold Layout Design

Authors [Citation]	Technique Used	Dataset Used	Performance Metrics	Major Objectives	Limitations
Solís *et al* [31]	Two-stage iterative heuristic	Real company data and random instances	Feasibility, quality, and running times	Optimize lot-sizing and scheduling to maximize profit in plastic injection production.	High reliance on iterative refinement; scalability with larger datasets is not fully addressed.
Hu *et al* [32]	DE-GA with solution refinement	Random test problems	Total cost, machine unavailability	Integrate production scheduling and maintenance planning for mold loading in random jobs.	Does not consider multi-machine interactions or real-time dynamics comprehensively.
Lee *et al* [33]	Deep Reinforcement Learning (Deep Q-network)	Simulated mold production schedules	Total weighted tardiness	Improve scheduling in mold production to meet delivery deadlines efficiently.	Limited application scope to specific industries; computational intensity in large-scale scenarios.
Heydar *et al* [34]	Approximate Dynamic Programming	Simulated data	Makespan, total energy consumption	Address energy-constrained scheduling for unrelated parallel machines in dynamic environments.	Limited focus on real-world adaptability; assumes perfect knowledge of job arrivals.
Allah *et al* [35]	Dynamic Programming with Intuitionistic Fuzzy Set (IFS)	IEEE 30-bus power system dataset	Satisfaction and dissatisfaction concepts	Solve multi-objective optimization problems in engineering design using intuitive decision metrics.	Limited experimentation on diverse MOOP scenarios; higher computational requirements for IFS processing.
Chen *et al* [36]	Improved Dynamic Programming (IDP)	Example datasets for AC-SCUC problems	Pruned state space, running time	Solve security-constrained unit commitment (SCUC) with AC power flow efficiently.	Focused on energy sector applications; limited scalability with highly dynamic or larger problem spaces.
Ghaleb & Taghipour [37]	Modified Simulated Annealing (SA)	Thermoplastic industry dataset	Tardiness reduction, cost minimization	Develop dynamic shop-floor scheduling incorporating real-time events like mold failure.	Performance dependent on problem-specific calibration; limited scope in cross-industry applications.
Mei *et al* [38]	Cost dynamic control with MLHPP model	Shipbuilding interim production systems	Efficiency in structuring and controlling	Manage scheduling in one-of-a-kind production (OKP) systems in shipbuilding with real-time controls.	Complex implementation; challenges in adapting to other domains with less variability.
Zhang *et al* [39]	Lean-Oriented Optimum-State Control Theory (L-OSCT)	Paint manufacturing firm case study	Synchronization, leanness improvement	Combine lean methods with optimum-state control for global-wide industrial process efficiency.	Requires extensive synchronization; applicability limited to systems with existing lean practices.
Sivasankaran *et al* [40]	Linear programming for capacity planning	Industrial machine capacity datasets	Machine utilization rates	Optimize machine performance and capacity planning in production shifts for better organizational output.	Simplistic linear modeling may not capture non-linear demand variations or complex capacity constraints.

VI. IMPORTANCE OF OPTIMIZING FLOOR SPACE

In 2021, Wang *et al* [41] have suggested an improved taboo search genetic algorithm (ITSGA) to enhance the layout for multi-deck ship compartments (SMCL). The problem includes a number of restrictions, for example, the location of functional cabins, deck passages, and staircases. An optimization model is formulated that considers layout, relative and absolute position, and ergonomics. TABU search principles are incorporated in to the genetic algorithm to improve the local search ability of ITSGA. To ensure that the cabin sequence is preserved during genetic operations, a new coding method is developed. Computational experiments confirm the applicability and efficiency of suggested algorithm in solving the problem of the layout of ship compartments.

In 2021, Fan *et al* [42] have established that there is need to increase the speed optimization in order to develop energy efficiency in ship, which in turn has economic and environmental impacts. It establishes a multiple-stage speed-optimal model using dynamic programming with total fuel consumption as the target and the main engine speed as the control parameter. A real case of a Yangtze River ship is described, and actual operational data collected with the help of onboard sensors are used to model the dependence of fuel consumption on the speed of the ship using regression analysis. The analysis proves in which the velocity and direction of water flow influence the ship speed control, and the proposed approach is suitable for long-range and varying conditions sailing. To sum up, this study provides practical assistance to the improvement of navigation in the maritime industry.

In 2023, Xing *et al* [43] have proposed the fishing behavior supervision in the East China Sea to enhance the sustainable fishery resource exploitation. In the paper, it investigates three types of fishing boats based on AIS data and cubic spline interpolation for trajectory optimization. A new coding method with the Geohash algorithm divides the sea into grids and maps the ship trajectories onto the grids. The trajectory sequence is embedded by the CBOW model and transformed into trajectory vectors used in training with LightGBM model. The model is refined using the Bayesian optimization with the F1 score of 0.925, which is higher than XgBoost and CatBoost. The method shows high relevance and efficiency in the context of fishery management.

In 2022, Rudzki *et al* [44] have introduced the pressures towards lowering operating costs, especially fuel, in vessels. Selection of the right ship propulsion parameters depends on the operator's experience and knowledge, and this might not always be the best decision-making process. For enhancement of this, the article suggests the implementation of a decision support system with the form of an expert system. The system employs the two-criteria optimization model to rationally control the fuel consumption and navigation time. This model helps ship operators to determine the optimum propulsive power settings. The approach is useful in reducing operational costs and improve decision making. The proposed system offers a better approach to Ship performance as compared to the conventional methods.

In 2024, Liu *et al* [45] have provided the impact of ship delivery delays because of welding quality, which contributes about 45% of the total delays. This suggests a digital twin-based capacity assessment and scheduling enhancement system for the ship welding production line (WPL). The model creates a digital twin ship component Workload Prediction and Loading (DTM-WPL) to enable data mapping and models for dynamic simulation. The optimization model involves processing time, equipment failure rate, and buffer storage capacity for sequencing of equipment. A synchronous mapping technique for welding quality prognosis and control is presented. The approach enhances production efficiency by 7.27%, according to real-world tests. It improves the welding processes and the production capacity with the organization.

In 2019, Li *et al* [46] have presented a genetic algorithm optimization process for the model of the level of service (LOS) for building evacuation planning. LOS, a qualitative measure of pedestrian movement intensity, is widely employed to set network characteristics in the evacuation models. The authors' goals are to identify better values of these LOS parameters for improved evacuation networks. Every chromosome is a complete evacuation network, and fitness is evaluated by minimum clearance time based on the Capacity Constrained Route Planner (CCRP). An example of a three-story building proves that the optimized LOS gives an 11% improvement of clearance time. The approach is also scalable, as evidenced by the testing performed on a twelve-deck cruise ship. It might be useful in the creation of proper emergency management procedures.

In 2020, Barone *et al* [47] have investigated about the energy saving in the contemporary cruise vessels. These dynamic simulations are conducted in TRNSYS where ship envelopes and energy systems are modeled with specific weather inputs for goals such as maximum saving and minimum payback. The use of waste heat recovery systems to power thermally activated devices is well illustrated by a case of an LNG-fueled cruise ship operating in the Mediterranean and Caribbean. They show that fuel consumption could be saved between 0.1–1.9 kt/year and cost possibly decrease up to €615k/year with decrease in emissions. Payback periods are less than five years, and the data presented provide useful information for ship designers and operators.

In 2019, Claridge *et al* [48] have identified that while whole building simulation was used in system design, it has gradually shifted to use in system operations. Optimisation during the operation of the calibrated simulations that have been created during the commissioning process.

These simulations are critical in fault detection and diagnosis that improves energy management and decreases costs and operational problems. Current BMS and data management technologies enable accurate calibrated simulation-based, real-time, and detailed fault detection at a reasonable cost. This approach guarantees the continued energy conservation and optimisation of operations, and provides more than the commissioning phase.

In 2022, Moradi *et al* [49] have identified the target for CO2 emissions is 0, ship route optimization is important besides other measures such as alternative fuels to improve the efficiency of the operation. This method applies RL for the ship routes, and utilizes ANNs to estimate the fuel utilization. These employed RL methods include DQN, DDPG and PPO through which speed and the heading angle are optimized. Out of them, DDPG gives the best performance for continuous action space and saves 6.64% fuel in no-time-limit scenario against the 1.07% by DQN. This approach reveals a great promise for sustainable shipping.

In 2021, Pang *et al* [50] have developed the new developments in digital twin and digital thread for industrial design and manufacturing. These are some of the technologies critical to Industry 4.0 but are limited in their ability to handle big data. A new framework is presented to improve the current digital twin and digital thread concepts for data management and innovation and enhance the procedures. The framework consists of behavior simulation, physical control, and integration to enable the flow of information. This includes the architecture and layout of the organization, security measures, requirement for databases and hardware and software solutions. This framework is especially useful for improving operational performance and transparency in Industry Shipyard 4.0 settings. The assessment on Importance of Optimizing Floor Space has been illustrated by Table 5.

Table 5: Assessment on Importance of Optimizing Floor Space

	Methodology	Dataset Used	Performance Metrics	Research Scope	Limitations
Wang *et al* [41]	Improved Tabu Search Genetic Algorithm (ITSGA)	Simulated ship compartment layouts	Efficiency, applicability	Optimize multi-deck ship compartment layouts considering ergonomics and constraints.	Limited to ship compartment layouts; applicability to other layout optimization problems untested.
Fan *et al* [42]	Dynamic programming with regression analysis	Yangtze River ship operational data	Total fuel consumption	Optimize ship speed to develop energy efficiency and minimize fuel consumption.	Focused on specific case study; limited generalizability to other waterway conditions.
Xing *et al* [43]	CBOW and LightGBM with Bayesian optimization	AIS data for fishing boats	F1 Score (0.925)	Supervise fishing behavior and enhance sustainable fishery resource exploitation in East China Sea.	Requires comprehensive AIS data; performance might vary with incomplete trajectory data.
Rudzki *et al* [44]	Decision Support System with two-criteria model	Hypothetical vessel data	Fuel consumption, navigation time	Optimize ship propulsion settings to reduce operating costs and improve decision-making.	Relies on operator input; effectiveness varies with operational conditions.
Liu *et al* [45]	Digital Twin Model for Welding Production Line	Real-world shipyard welding data	Production efficiency (+7.27%)	Improve welding quality and reduce delays in shipbuilding production lines.	High dependence on digital infrastructure and real-time data accuracy.
Li *et al* [46]	Genetic Algorithm for Evacuation Planning	Building evacuation and ship data	Clearance time (-11%)	Optimize evacuation network parameters to improve safety and reduce evacuation times.	Limited focus on evacuation scenarios; scalability beyond tested environments not fully explored.
Barone *et al* [47]	Dynamic simulation in TRNSYS	LNG cruise ship data	Fuel savings (0.1–1.9 kt/year)	Evaluate energy-saving measures for cruise ships using waste heat recovery systems.	Payback period calculations might vary based on regional regulations and ship designs.
Claridge *et al* [48]	Calibrated simulation for fault detection	Whole building simulation data	Energy conservation, fault detection	Enable real-time fault detection and energy management during operations of complex systems.	Requires high-quality BMS and data management systems; cost might be prohibitive for smaller setups.
Moradi *et al* [49]	RL (DQN, DDPG, PPO) with ANN-based fuel estimation	Simulated ship route data	Fuel savings (DDPG: 6.64%)	Optimize ship routes for fuel efficiency and environmental sustainability.	Limited scope to simulated routes; real-world implementation challenges not fully addressed.
Pang *et al* [50]	Digital Twin and Digital Thread Framework	Industrial shipyard data	Operational performance, transparency	Enhance data management and process innovation in Industry Shipyard 4.0 settings.	High dependency on advanced digital infrastructure and integration capability.

VII. APPLICATION IN A BOAT MANUFACTURING FACILITY

In 2022, Pamungkas & Iskandar [51] have examined the Failure Mode, Effect and Criticality Analysis (FMECA) and fishbone methods to enhance the quality of wooden fishing boats manufactured by WahanaKarya in West Aceh, Indonesia. From the FMECA, it was realized that some of the areas of concern included the following: quality of wood cutting for bow and hull installation. The fishbone diagram investigated the root causes under human, machine, material, and method elements. They are; better quality of raw material, better quality of worker supervision and training, better quality of Standard Operating Procedures (SOPs), better quality of worker shift, and better quality of machinery. Such measures are helpful to reduce such defects such as gaps and conducting several surveys useful to improve the quality of boats and the satisfaction of customers.

In 2022, Peterson [52] have discussed that AM, Fused Filament Fabrication (FFF) in particular, opens new opportunities for yacht design and production of small boats despite the issues with speed, scalability, and materials. There are some participants in the marine industry that are already applying AM technologies but their application to large vessels has challenges of water resistance, surface finish, structural strength, and reinforcement incorporation. Current research and development of AM is directed to address the material and mechanical requirements of the marine sector. Achievements in this area could dramatically change the boat manufacturing industry by allowing new designs and more efficient production.

In 2020, Manalo *et al* [53] have explored the Glass-fiber-reinforced-polymer (GFRP) bars are used to replace the steel bars for reinforced-concrete structures in marine environment because of its low maintenance and long service life. This research investigated the manufacturing and structural characteristics of precast-concrete boat-ramp planks reinforced with GFRP or galvanized steel. They also found that GFRP-reinforced planks needed less man and machinery power during construction of planks and serviceability as well as structural performance. These advantages paved way for the adoption of a new plank design incorporating GFRP bars to be used in Australian boating infrastructure projects due to its economical and engineering efficiency.

In 2019, Abdullah *et al* [54] have presented a small, automated trash collector boat for cleaning small streams, lakes, and drainage areas and the health risks that come with manual cleaning. The boat is also built to capture and contain floating waste during the operation, and the waste is then physically removed afterwards. The design was then fine-tuned by developing a 3D model following engineering design methodologies and by using Autodesk Inventor 2009. Fabrication used right materials to optimize efficiency and testing checked on the performance, monitoring and load bearing capacity of the system. It found out that the boat could pick up to 6 kg of trash per operation, hence being suitable for small scale water cleaning operations.

In 2020, Fitriana *et al* [55] have introduced the activity to clean reservoirs of waste and sediment, developing a garbage and sediment cleaning boat using SketchUp Pro 3D, and building the boat from used plastic barrels. This research project took place in Purwosekar Village, Malang Regency and employed qualitative research methods and descriptive analytical research design. The outcomes include a functional boat prototype and product design, aiming at improving the tourism attractiveness of the reservoir area. It is believed that with the help of this measure, local inventions will be encouraged, people will be proud of their village, and the village's economy will be developed due to the creation of viable prospects for sustainable development.

In 2024, Golbabaei *et al* [56] have developed that the EOL management of boats especially those made from fiber-reinforced plastic will be an environmental and sustainability concern due to its low recyclability and reuse possibilities. This study of 101 studies focuses on abandoned and derelict vessels (ADVs), with regards to sustainable disposal, material reuse, and recycling. This highlights areas of legal void in regulations, utilization of low-cost approaches, and development of effective and environmentally friendly technologies of end-of-use recycling processes while advocating for collective efforts and centralization of recycling services. They include: deconstruction and reuse, repurposing, engagement of the industry and funding for research to advance circular economy solutions for the marine industry.

In 2023, Bodaghi *et al* [57] have developed a new concept for design of efficient boat-fendering systems with increased energy dissipation and memory shape characteristics. The fender panels are designed with re-entrant, honeycomb, and chiral auxetic metamaterials, and their thermo-mechanical characteristics are investigated using tests and simulations. Compressive behaviors are studied using finite element modeling (FEM) while shape memory polymers are thermo-mechanically 4D-printed. These fenders are revealed to be capable of energy absorption, plastic deformation, heat, and cycling loads with excellent mechanical property recovery. This could greatly enhance sustainability in marine transport as a novel design.

In 2019, Martin *et al* [58] have suggested the role that activities and interactions that consumers engage in throughout the use phase play in explaining differences in environmental sustainability effects, from a practice theory perspective. It shows how people are governed by institutional frameworks and culture in the consumer decisions they make, with regard to sustainability. This study also examines how conventional products and the new products in the market provide the chances for sustainability. Also, it analyses the place of consumer competence in influencing environmental impacts.

The paper connects macromarketing with consumer culture theory, with an emphasis on the role of regulatory compliance and the consumer's commitment to the best practices to enhance sustainability.

In 2023, Saputra *et al* [59] have proposed a modified LoRaWAN-based boat monitoring system equipped with GPS and a mobile device to enhance the boat monitoring in shallow water. The system integrates BLE and LoRaWAN networks to solve problems in monitoring boat traffic, particularly in noisy conditions such as shallow waters and delta rivers. Field tests done in real-time demonstrate that the system minimizes signal noise and interferences and facilitates accurate data transmission. The results obtained are compared to the reference system and a high correlation is observed. The proposed model has possibilities for implementation in large scale and for commercial use as it provides an efficient solution for boat monitoring in different environments.

In 2021, Pintér *et al* [60] have identified how small electric boats could be used to store energy at Lake Balaton in Hungary to mitigate distribution network issues because of demand growth and integration of renewable energy. The study also reveals that V2G technology where electric boats could act as storage capacities to balance power supply is gradually emerging. The storage capacity for small electric boats with the region could rise from 4.8 MWh in 2016 to 15.6 MWh by 2030. The innovation of the study is in viewing these boats as energy storage facilities that could provide new flexibility services to the micro-grids and contribute to the Hungarian energy plan for 2030. The Table 6 represents the analysis on Application in a Boat Manufacturing Facility.

Table 6: Analysis on Application in a Boat Manufacturing Facility

Authors Name [Citation]	Methodology	Performance Metrics	Limitations
Pamungkas & Iskandar [51]	FMECA and Fishbone techniques for quality enhancement in wooden fishing boats	Identification of root causes and improvement measures for boat manufacturing quality	Focused on specific case study in West Aceh; generalizability to other manufacturing setups not tested.
Peterson [52]	Additive Manufacturing (AM) with FFF for yacht design and production	Potential for new designs and efficient production	Limited scalability, challenges with water resistance, surface finish, and structural strength.
Manalo *et al* [53]	Use of GFRP bars in precast-concrete boat-ramp planks	Reduced manpower, structural and serviceability efficiency	Focused on Australian marine infrastructure; long-term performance of GFRP not fully explored.
Abdullah *et al* [54]	Automated trash collector boat design and testing	Trash collection capacity (6 kg/operation)	Limited to small-scale cleaning operations; scalability to larger bodies of water not studied.
Fitriana *et al* [55]	Development of garbage and sediment cleaning boat from recycled materials	Functional prototype for reservoir cleaning	Focused on specific local project; potential for larger-scale applications untested.
Golbabaei *et al* [56]	Study of EOL management and recycling of fiber-reinforced plastic boats	Identification of sustainable disposal and recycling approaches	Lack of universal regulations; cost and scalability challenges for recycling methods.
Bodaghi *et al* [57]	Design of boat-fendering systems with auxetic metamaterials	Enhanced energy absorption and recovery properties	Focused on prototype designs; real-world implementation and durability require further testing.
Martin *et al* [58]	Practice theory perspective on consumer sustainability in boating	Analysis of consumer competence and sustainability effects	Conceptual study; lacks practical testing and direct application.
Saputra *et al* [59]	Modified LoRaWAN-based boat monitoring system	Accurate data transmission and noise minimization	Limited to shallow water environments; scalability for diverse conditions requires exploration.
Pintér *et al* [60]	Small electric boats as energy storage and V2G technology	Increased storage capacity (4.8 MWh to 15.6 MWh)	Focused on Lake Balaton; scalability and cost of implementation in other regions not examined.

VIII. RESEARCH GAPS

However, the application of floor space management as a concept in the boat manufacturing industry has not been researched in detail despite the development of various optimization techniques. Previous research in the area of space optimization has been conducted predominantly with regards to generic manufacturing processes without considering some of the peculiarities of managing large, irregular shaped molds used in boat manufacturing. Present approaches fail to incorporate time-varying parameters like production rates, different sizes of molds, and limitations in managing the part, which is important in this sector. Furthermore, lack of specific algorithms which could effectively solve such problems in real time prevents construction of practical and efficient solution for floor space allocation in such specific manufacturing contexts.

In addition, the integration of optimization models with the modern manufacturing technologies like automated mold handling, and the real-time monitoring systems is not well developed. Static optimization is the dominant paradigm in most research, while dynamic environments are typical for production spaces where priorities of molds and space requirements could change frequently. There is also a lack of comparative studies which compare the performance of dynamic programming with other optimization methods in this regard. Closing these gaps through the creation of context-sensitive optimization models might thus greatly improve efficiency and define a new benchmark in the use of space on boats.

IX. CONCLUSION

Floor space management is an important factor in the boat manufacturing process since molds are large and complex. This article shows that it is possible to use dynamic programming to solve these problems and determine the best positions for the molds at the same time taking into consideration the operational conditions and production requirements. As a result, dynamic programming optimizes space by subdividing the problem into more easily solved sub-problems and guarantees globally optimal solutions, minimizes the number of operations, and scales manufacturing processes. For analysis, a total of 60 papers were choosen from the year 2019-2024 which deliberates the techniques, performance, dataset and also the limitations present in the existing studies. This study highlights the efficacy of future complex optimization methods in transforming the current floor space planning in the boat industry as well as their readiness for integration of real-time systems and adaptive production systems.

REFERENCES

[1] Wu, Q., Mao, Y., Chen, J., & Wang, C. (2021). Application research of digital twin-driven ship intelligent manufacturing system: Pipe machining production line. Journal of Marine Science and Engineering, 9(3), 338.
[2] Yuan, Z., Liu, J., Zhang, Q., Liu, Y., Yuan, Y., & Li, Z. (2021). Prediction and optimisation of fuel consumption for inland ships considering real-time status and environmental factors. Ocean Engineering, 221, 108530.
[3] Kumar, S. V., Jayaparvathy, R., & Priyanka, B. N. (2020). Efficient path planning of AUVs for container ship oil spill detection in coastal areas. Ocean Engineering, 217, 107932.
[4] Silva Junior, A. G. D., Santos, D. H. D., Negreiros, A. P. F. D., Silva, J. M. V. B. D. S., & Gonçalves, L. M. G. (2020). High-level path planning for an autonomous sailboat robot using Q-Learning. Sensors, 20(6), 1550.
[5] Tarelko, W., & Rudzki, K. (2020). Applying artificial neural networks for modelling ship speed and fuel consumption. Neural computing and applications, 32(23), 17379-17395.
[6] Yan, R., Wang, S., & Fagerholt, K. (2020). A semi-“smart predict then optimize”(semi-SPO) method for efficient ship inspection. Transportation Research Part B: Methodological, 142, 100-125.
[7] Abebe, M., Noh, Y., Kang, Y. J., Seo, C., Kim, D., & Seo, J. (2022). Ship trajectory planning for collision avoidance using hybrid ARIMA-LSTM models. Ocean Engineering, 256, 111527.
[8] Li, H., Jiao, H., & Yang, Z. (2023). AIS data-driven ship trajectory prediction modelling and analysis based on machine learning and deep learning methods. Transportation Research Part E: Logistics and Transportation Review, 175, 103152.
[9] Wang, K., Li, J., Huang, L., Ma, R., Jiang, X., Yuan, Y., ... & Yan, X. (2020). A novel method for joint optimization of the sailing route and speed considering multiple environmental factors for more energy efficient shipping. Ocean Engineering, 216, 107591.
[10] Qian, L., Zheng, Y., Li, L., Ma, Y., Zhou, C., & Zhang, D. (2022). A new method of inland water ship trajectory prediction based on long short-term memory network optimized by genetic algorithm. Applied Sciences, 12(8), 4073.
[11] Krieger, K. J., Bertollo, N., Dangol, M., Sheridan, J. T., Lowery, M. M., & O'Cearbhaill, E. D. (2019). Simple and customizable method for fabrication of high-aspect ratio microneedle molds using low-cost 3D printing. Microsystems & nanoengineering, 5(1), 42.
[12] Post, B. K., Chesser, P. C., Lind, R. F., Roschli, A., Love, L. J., Gaul, K. T., ... & Wu, S. (2019). Using Big Area Additive Manufacturing to directly manufacture a boat hull mould. Virtual and Physical Prototyping, 14(2), 123-129.
[13] Paquet, E., Bernard, A., Furet, B., Garnier, S., & Le Loch, S. (2021). Foam additive manufacturing technology: main characteristics and experiments for hull mold manufacturing. Rapid Prototyping Journal, 27(8), 1489-1500.
[14] Lee, H., Jung, K., & Park, H. (2021). Study on structural design and analysis of composite boat hull manufactured by resin infusion simulation. Materials, 14(20), 5918.
[15] Korsmik, R. S., Rodionov, A. A., Korshunov, V. A., Ponomarev, D. A., Prosychev, I. S., & Promakhov, V. V. (2020). Topological optimization and manufacturing of vessel propeller via LMD-method. Materials Today: Proceedings, 30, 538-544.

[16] Terekhov, I. V., & Chistyakov, E. M. (2021). Binders used for the manufacturing of composite materials by liquid composite molding. Polymers, 14(1), 87.

[17] Barsotti, B., Gaiotti, M., & Rizzo, C. M. (2020). Recent industrial developments of marine composites limit states and design approaches on strength. Journal of Marine Science and Application, 19, 553-566.

[18] Chebil, N., Deleglise-Lagardere, M., & Park, C. H. (2019). Efficient numerical simulation method for three-dimensional resin flow in laminated preform during liquid composite molding processes. Composites Part A: Applied Science and Manufacturing, 125, 105519.

[19] Wang, S. M., Duan, W. Y., Xu, Q. L., Duan, F., Deng, G. Z., & Li, Y. (2021). Study on fast interference wave resistance optimization method for trimaran outrigger layout. Ocean Engineering, 232, 109104.

[20] Stiles, A., Kobler, W., Yeole, P., & Vaidya, U. (2022). Photopolymer formulation towards large scale additive manufacturing of autoclave capable tooling. Additive Manufacturing, 50, 102571.

[21] Samanipour, F., & Jelovica, J. (2020). Adaptive repair method for constraint handling in multi-objective genetic algorithm based on relationship between constraints and variables. Applied Soft Computing, 90, 106143.

[22] Liu, B., Li, Z. C., Wang, Y., & Sheng, D. (2021). Short-term berth planning and ship scheduling for a busy seaport with channel restrictions. Transportation Research Part E: Logistics and Transportation Review, 154, 102467.

[23] Nyanya, M. N., Vu, H. B., Schönborn, A., & Ölçer, A. I. (2021). Wind and solar assisted ship propulsion optimisation and its application to a bulk carrier. Sustainable Energy Technologies and Assessments, 47, 101397.

[24] De, A., Wang, J., & Tiwari, M. K. (2019). Hybridizing basic variable neighborhood search with particle swarm optimization for solving sustainable ship routing and bunker management problem. IEEE Transactions on Intelligent Transportation Systems, 21(3), 986-997.

[25] Szlapczynska, J., & Szlapczynski, R. (2019). Preference-based evolutionary multi-objective optimization in ship weather routing. Applied Soft Computing, 84, 105742.

[26] Wang, L., Zhang, Z., Zhu, Q., & Ma, S. (2020). Ship route planning based on double-cycling genetic algorithm considering ship maneuverability constraint. Ieee Access, 8, 190746-190759.

[27] Li, S., Liu, J., & Negenborn, R. R. (2019). Distributed coordination for collision avoidance of multiple ships considering ship maneuverability. Ocean Engineering, 181, 212-226.

[28] Das, M., Roy, A., Maity, S., Kar, S., & Sengupta, S. (2022). Solving fuzzy dynamic ship routing and scheduling problem through new genetic algorithm. Decision Making: Applications in Management and Engineering, 5(2), 329-361.

[29] Li, Z., Zhang, H., Meng, J., Long, Y., Yan, Y., Li, M., ... & Liang, Y. (2020). Reducing carbon footprint of deep-sea oil and gas field exploitation by optimization for Floating Production Storage and Offloading. Applied Energy, 261, 114398.

[30] De, A., Pratap, S., Kumar, A., & Tiwari, M. K. (2020). A hybrid dynamic berth allocation planning problem with fuel costs considerations for container terminal port using chemical reaction optimization approach. Annals of Operations Research, 290, 783-811.

[31] Ríos-Solís, Y. Á., Ibarra-Rojas, O. J., Cabo, M., & Possani, E. (2020). A heuristic based on mathematical programming for a lot-sizing and scheduling problem in mold-injection production. European Journal of Operational Research, 284(3), 861-873.

[32] Hu, C., Zheng, R., Lu, S., Liu, X., & Cheng, H. (2023). Integrated optimization of production scheduling and maintenance planning with dynamic job arrivals and mold constraints. Computers & Industrial Engineering, 186, 109708.

[33] Lee, S., Cho, Y., & Lee, Y. H. (2020). Injection mold production sustainable scheduling using deep reinforcement learning. Sustainability, 12(20), 8718.

[34] Heydar, M., Mardaneh, E., & Loxton, R. (2022). Approximate dynamic programming for an energy-efficient parallel machine scheduling problem. European Journal of Operational Research, 302(1), 363-380.

[35] Rizk-Allah, R. M., Abo-Sinna, M. A., & Hassanien, A. E. (2021). Intuitionistic fuzzy sets and dynamic programming for multi-objective non-linear programming problems. International journal of fuzzy systems, 23, 334-352.

[36] Chen, J., Zhu, J., Zhuo, Y., Ye, H., Wang, Z., & Liu, H. (2024). An improved dynamic programming algorithm for security-constrained unit commitment under spatial-temporal decomposition framework. International Journal of Electrical Power & Energy Systems, 155, 109652.

[37] Ghaleb, M., & Taghipour, S. (2023). Dynamic shop-floor scheduling using real-time information: A case study from the thermoplastic industry. Computers & Operations Research, 152, 106134.

[38] Mei, Y., Zeng, Z., & Ye, J. (2020). A computing model: the closed-loop optimal control for large-scale one-of-a-kind production based on multilevel hierarchical PERT-Petri net. IEEE Transactions on Engineering Management, 68(6), 1637-1649.

[39] Zhang, K., Qu, T., Zhou, D., Thürer, M., Liu, Y., Nie, D., ... & Huang, G. Q. (2019). IoT-enabled dynamic lean control mechanism for typical production systems. Journal of ambient intelligence and humanized computing, 10, 1009-1023.

[40] Sivasankaran, P., Radjaram, B., & Karthigayan, K. Maximizing Machine Capacity by Improving Efficiency using Linear Programming Model.

[41] Wang, Y. L., Wu, Z. P., Guan, G., Li, K., & Chai, S. H. (2021). Research on intelligent design method of ship multi-deck compartment layout based on improved taboo search genetic algorithm. Ocean Engineering, 225, 108823.

[42] Fan, A., Wang, Z., Yang, L., Wang, J., & Vladimir, N. (2021). Multi-stage decision-making method for ship speed optimisation considering inland navigational environment. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 235(2), 372-382.

[43] Xing, B., Zhang, L., Liu, Z., Sheng, H., Bi, F., & Xu, J. (2023). The study of fishing vessel behavior identification based on ais data: a case study of the east china sea. Journal of Marine Science and Engineering, 11(5), 1093.

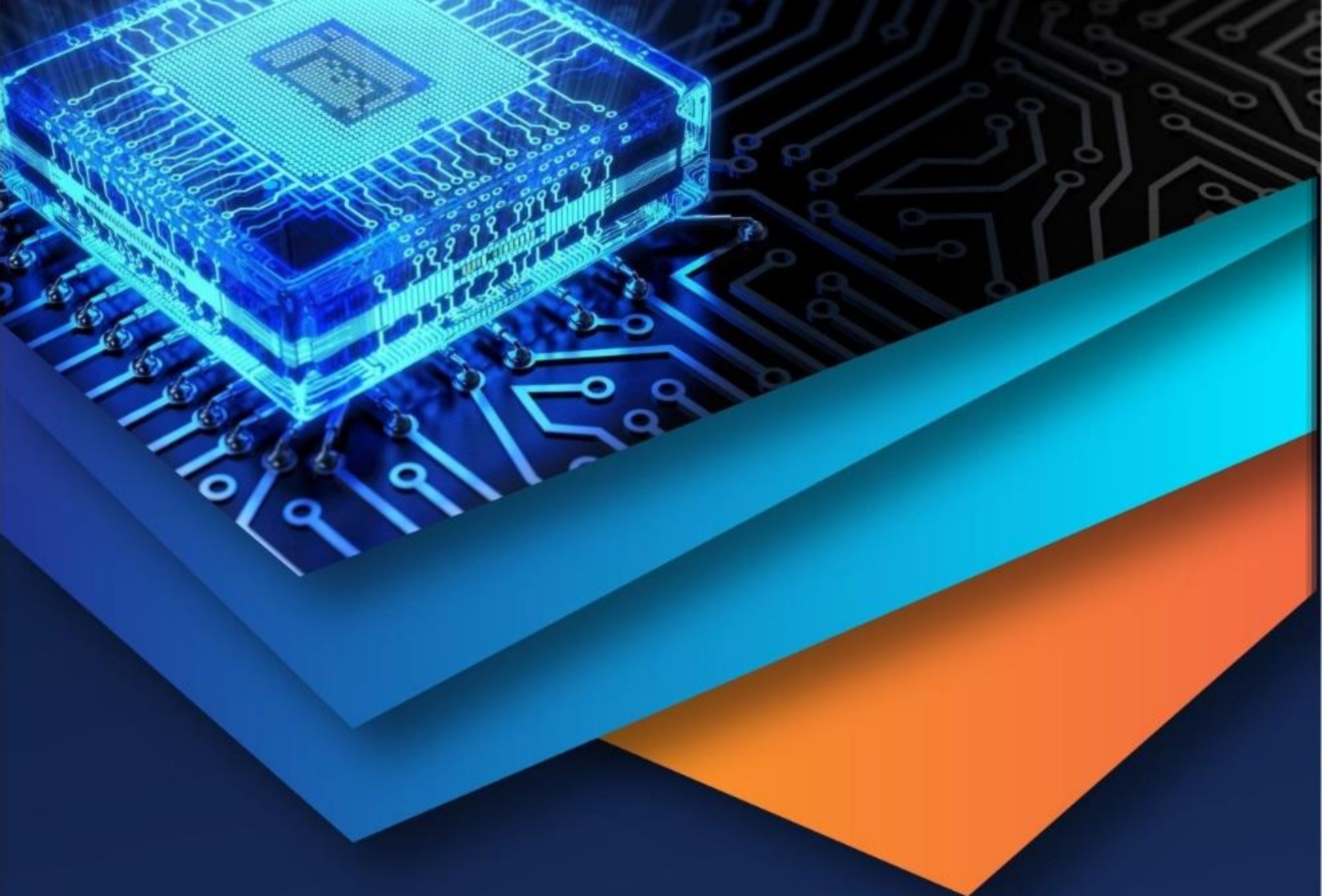
[44] Rudzki, K., Gomulka, P., & Hoang, A. T. (2022). Optimization model to manage ship fuel consumption and navigation time. Polish Maritime Research, 29(3), 141-153.

[45] Liu, J., Ji, Q., Zhang, X., Chen, Y., Zhang, Y., Liu, X., & Tang, M. (2024). Digital twin model-driven capacity evaluation and scheduling optimization for ship welding production line. Journal of Intelligent Manufacturing, 35(7), 3353-3375.

[46] Li, Y., Cai, W., & Kana, A. A. (2019). Design of level of service on facilities for crowd evacuation using genetic algorithm optimization. Safety Science, 120, 237-247.

[47] Barone, G., Buonomano, A., Forzano, C., Palombo, A., & Vicidomini, M. (2020). Sustainable energy design of cruise ships through dynamic simulations: Multi-objective optimization for waste heat recovery. Energy Conversion and Management, 221, 113166.

[48] Claridge, D. E., & Paulus, M. T. (2019). Building simulation for practical operational optimization. In Building performance simulation for design and operation (pp. 399-453). Routledge.
[49] Moradi, M. H., Brutsche, M., Wenig, M., Wagner, U., & Koch, T. (2022). Marine route optimization using reinforcement learning approach to reduce fuel consumption and consequently minimize CO2 emissions. Ocean Engineering, 259, 111882.
[50] Pang, T. Y., Pelaez Restrepo, J. D., Cheng, C. T., Yasin, A., Lim, H., & Miletic, M. (2021). Developing a digital twin and digital thread framework for an 'Industry 4.0'Shipyard. Applied Sciences, 11(3), 1097.
[51] Pamungkas, I., & Iskandar, I. (2022). Defect analysis for quality improvement in fishing boat manufacturing processes through the integration of FMECA and fishbone: A case study. International Journal of Innovative Science and Research Technology, 7(7), 181-188.
[52] Peterson, E. (2022). Recent innovations in additive manufacturing for marine vessels. Maritime Technology and Research, 4(4), 257491-257491.
[53] Manalo, A. C., Alajarmeh, O., Cooper, D., Sorbello, C. D., Weerakoon, S. Z., & Benmokrane, B. (2020, December). Manufacturing and structural performance of glass-fiber-reinforced precast-concrete boat ramp planks. In Structures (Vol. 28, pp. 37-56). Elsevier.
[54] Abdullah, S. H. Y. S., Azizudin, M. M., & Endut, A. (2019). Design and prototype development of portable trash collector boat for small stream application. International Journal of Innovative Technology and Exploring Engineering, 8(10), 350-356.
[55] Fitriana, N., Yuniwati, E. D., Darmawan, A. A., & Firdaus, R. (2020, October). The Application of Waste and Sediment Trader Boat Designs in Reservoir: A Community Empowerment. In International Conference on Community Development (ICCD 2020) (pp. 542-545). Atlantis Press.
[56] Golbabaei, F., Bunker, J., Yigitcanlar, T., Baker, D., Mirhashemi, A., & Paz, A. (2024). Sustainable end-of-life management of abandoned and derelict vessels through the lens of circular economy. Journal of Cleaner Production, 143559.
[57] Bodaghi, M., Namvar, N., Yousefi, A., Teymouri, H., Demoly, F., & Zolfagharian, A. (2023). Metamaterial boat fenders with supreme shape recovery and energy absorption/dissipation via FFF 4D printing. Smart Materials and Structures, 32(9), 095028.
[58] Martin, D. M., Harju, A. A., Salminen, E., & Koroschetz, B. (2019). More than one way to float your boat: Product use and sustainability impacts. Journal of Macromarketing, 39(1), 71-87.
[59] Saputra, D., Gaol, F. L., Abdurachman, E., Sensuse, D. I., & Matsuo, T. (2023). Architectural model and modified long range wide area network (LoRaWAN) for boat traffic monitoring and transport detection systems in shallow waters. Emerg. Sci. J, 7(4), 1188-1205.
[60] Pintér, G., Vincze, A., Baranyai, N. H., & Zsiborács, H. (2021). Boat-to-grid electrical energy storage potentials around the largest lake in central Europe. Applied Sciences, 11(16), 7178.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY