DEEP LEARNING-BASED BUILDING ENERGY OPTIMIZATION USING BIM DATA & EVALUATING POTENTIAL ENERGY SAVINGS

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PREFACE

This research paper explores the application of deep learning algorithms for optimizing building energy consumption and evaluating potential energy savings. With the increasing emphasis on sustainable practices and energy efficiency in the built environment, there is a growing need for innovative approaches to reduce energy consumption in buildings. Deep learning, a branch of artificial intelligence, has shown great promise in various fields, including energy optimization.

The purpose of this research paper is to investigate the potential of deep learning algorithms in optimizing building energy consumption and uncovering opportunities for significant energy savings. We aim to explore the use of deep learning models, such as Artificial Neural Networks (ANN) and Support Vector Machines (SVM), in analyzing building energy data and developing predictive models. By leveraging the power of deep learning, we strive to enhance the accuracy and efficiency of energy optimization strategies.

Throughout this research paper, we present a comprehensive analysis of the current state of research in the field of deep learning algorithms for building energy optimization. We discuss the underlying principles and methodologies of deep learning and their relevance to energy consumption modeling. Furthermore, we explore the challenges and limitations associated with the application of deep learning algorithms in the context of building energy optimization.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

DEEP LEARNING-BASED BUILDING ENERGY OPTIMIZATION USING BIM DATA & EVALUATING ENERGY SAVINGS POTENTIAL

ABSTRACT

Building energy optimization is a crucial focus in sustainable practices, and Building Information Modelling (BIM) data is an invaluable resource for enhancing energy performance. Deep learning algorithms, a subset of machine learning techniques, exhibit great potential in utilizing BIM data to optimize energy use and assess potential energy savings. This paper reviews diverse studies utilizing different algorithms, including Support Vector Machines (SVM) and Artificial Neural Networks (ANN), to optimize building energy use based on BIM data. The investigations encompass HVAC system performance, orientation, geometry data etc. The findings demonstrate that deep learning algorithms, particularly ANN, offer significant enhancements in building energy efficiency, leading to substantial energy reductions and potential savings. This abstract provides a comprehensive overview of the current state-of-the-art in leveraging deep learning algorithms, with a specific emphasis on ANN's superior performance in optimizing building energy use based on BIM data.

KEYWORDS

Deep learning algorithms, potential energy savings, environmental awareness, building information modelling (BIM), energy consumption modelling, energy optimization, ANN, SVM.

I. INTRODUCTION

1.1 Introduction to Research Background

The rapid increase in energy demand has become a vital concern in recent years due to its profound impact on the environment. Buildings are significant contributors to global energy consumption, making the optimization of their energy use a pressing concern. It is essential to reduce energy use and ozone-depleting substance outflows while maintaining or increasing structure performance due to the growing demand for energy and the growth of natural mindfulness.

Building Information Modeling (BIM) data, combined with deep learning algorithms, has emerged as a promising approach to achieve these goals. This research paper presents a comprehensive review of the state-of-the-art in leveraging BIM data and deep learning algorithms to optimize building energy use.

In light of the environmental challenges such as burning of fossil fuels which leads to releasing of greenhouse gases primarily carbon dioxide that are contributing to global warming and climate change just to meet the energy demands has centered the attention of the environmentalists to the urgent need of addressing the energy consumption patterns and transition towards sustainable and efficient energy systems. Buildings, in particular, play a crucial role in energy consumption, accounting for a substantial portion of global energy usage. From residential homes to commercial complexes, buildings consume energy for heating, cooling, lighting, and powering various appliances and equipment.

Optimizing building energy consumption is a key strategy for reducing energy waste, enhancing energy efficiency, and mitigating environmental impacts. By implementing energy-efficient practices, technologies, and innovative approaches, significant reductions in energy consumption can be achieved, resulting in lower greenhouse gas emissions and reduced strain on energy resources.

1.2 Introduction to BIM

Building Information Modeling (BIM) is an innovative digital approach that revolutionizes the design, construction, and management of buildings. It involves the creation and use of a detailed digital representation of a building, incorporating information about its physical and functional characteristics.

In the context of optimizing building energy consumption, BIM plays a crucial role. By utilizing BIM data, such as geometry, window to wall ratio, orientation, HVAC systems etc. we can perform detailed energy simulations and analysis to identify potential energy-saving opportunities. BIM provides a comprehensive and integrated platform to evaluate building performance, energy usage patterns, and the effectiveness of energy-efficient strategies.

The ability of BIM information to capture the complex nuances of a structure, including its calculation, materials, and frameworks, is what drives the emphasis on BIM information in this explanation of the issue. Using this wealth of data, we can develop high-level energy improvement models and algorithms that take various factors into account when determining how much energy is used.

By utilizing BIM data and applying deep learning algorithms, we aim to harness the power of advanced analytics and machine learning techniques to optimize building energy consumption.

1.3 Research Purpose and Meaning

The objectives of this study are twofold: (1) to propose and evaluate a deep learning algorithm that utilizes BIM data to optimize building energy consumption, and (2) to assess the potential energy savings achieved through this algorithm. BIM data offers a rich source of information, including building geometry, materials, and systems, which can be effectively utilized to train deep learning algorithms for energy optimization. By considering various building parameters and external factors, the algorithm predicts optimal energy consumption patterns.

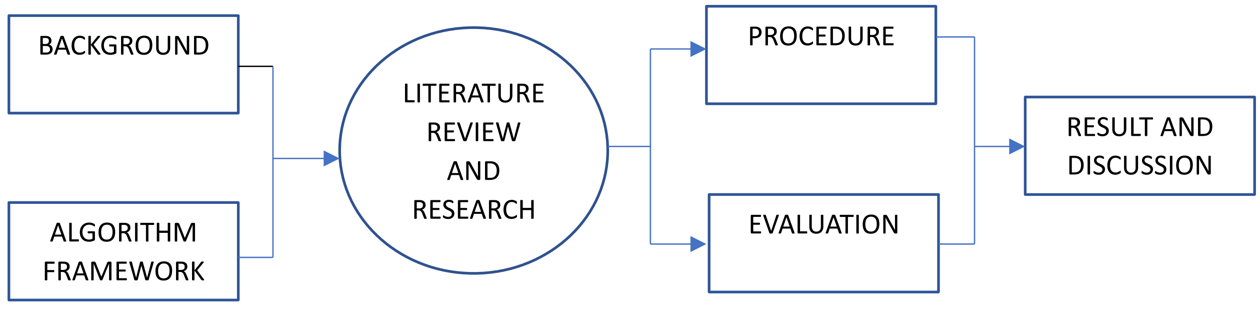

Fig. 1 Flowchart of the Study.

The significance and relevance of this research lie in its potential to advance sustainable building practices and reduce energy costs. The integration of BIM data with deep learning algorithms holds promise for improving building energy efficiency and thermal comfort. This study highlights the importance of accurately predicting energy consumption and identifying potential energy savings in buildings. Furthermore, it emphasizes the need to leverage comprehensive BIM data and overcome challenges associated with its utilization.

Several recent studies have demonstrated the efficacy of BIM data and deep learning algorithms in enhancing building energy efficiency. However, real-world implementation and scalability of these methods warrant further investigation. This paper contributes to the existing literature by providing a comprehensive overview of the current state-of-the-art, outlining the research objectives, and emphasizing the need for additional research to evaluate the effectiveness of these methods in practical settings.

In conclusion, the integration of BIM data and deep learning algorithms offers substantial potential for optimizing building energy use. By leveraging this approach, it is possible to achieve significant energy savings and improve the sustainability of buildings. This research aims to provide valuable insights and recommendations for practitioners and policymakers seeking to enhance energy efficiency and reduce environmental impact in the built environment.

II. LITERATURE REVIEW

The literature review encompasses various research studies that have explored the integration of deep learning algorithms with Building Information Modeling (BIM) data to optimize building energy use and evaluate potential energy savings. This literature review aims to examine the recent research studies that have utilized deep learning. The review provides an overview of the current state of research in this field and identifies the key trends and challenges that need to be addressed to further improve the effectiveness of the deep learning algorithm in optimizing building energy use.

The RenoDSS system was presented by Stefan Fenz (2023) which uses BIM to generate renovation scenarios, calculate energy and sustainability KPIs, and identify the most suitable scenarios based on user preferences and the IFC representation of the current building configuration. The author Haidar Hosamo (2022) improves building design for energy efficiency and cosy comfort by suggesting a framework that combines Building Data Demonstrating (BIM), AI, and the nonruled arranging hereditary calculation II (NSGA II). In light of the design constraints of the building envelope, the Yang Liu (2021) suggests a solution for dealing with anticipated building energy consumption. Through symmetrical testing and energy usage simulations, the creators lay out a structure data model and obtain a dataset. RF model is used to predict how much energy the structure will use and arrange the limit according to the importance, and then use Pearson capacity to measure the relationships between the components.

Georgios Gourlis and Iva Kovacic (2022) proposes a holistic modeling and simulation framework for optimizing energy and resource efficiency in existing industrial facilities through digitalization and integrated analysis. The focus of the review is on locating the required structure level of consideration, describing connections with the rest of the virtual climate, and suggesting a semi-automated work process for BIM-based creation of the structure model inside a comprehensive DT biological system. A thorough analysis of Building Data Demonstrating (BIM) capabilities was presented during the design phase of green constructions by Yu Cao (2022). The authors find that BIM has significant advantages in terms of project quality enhancement, executives' capacity for lifecycle information, collaborative effort enhancement, planning, and schedule administration advancement during the creation phase of green structures.

Giulia Spiridigliozzi1(2019) focussed on the ability of using BIM-based programming to improve the demonstrating and replication stages of achieving NZEB (net zero energy building) capability for the study. The evaluation identifies the key data set needed for energy inquiry and to obtain accurate energy recreation outcomes with the least amount of information loss. Wang, W. (2022) explores the use of Building Information Models (BIM) to create energy efficient Building Digital Twins (BDTs). The authors examine key techniques for creating BDTs, including BIM's energy-saving design, energy consumption analysis, and improved data fusion algorithms using Wireless Sensor Networks (WSNs). Wu, X. (2022) focuses on the multiobjective advancement of almost zero energy utilisation building (NZEB) execution, the paper suggests a wise streamlining system that combines Building Data Demonstrating DesignBuilder (BIM-DB) and arbitrary timberland nondominated arranging hereditary calculation III (RF-NSGA-III).

Chen, B. (2021), in order to focus on building energy usage and come up with the optimal plan, the study suggests a structure that coordinates Building Data Demonstrating (BIM) with LSSVM and NSGA-II. Rathnasiri, P. (2023) explores the use of Green Structure Data Displaying (Green BIM) for already-existing green structures is the subject of research. In order to assess Green BIM practises and information requirements, the authors first conduct a writing evaluation and conduct a contextual analysis and a poll review, which help to decipher information accessibility.

Guida, C.G (2021) proposes a methodology that integrates sensors with Building Information Model (BIM) to optimize electrical consumption in public environments. The research focuses on a case study of a university classroom with sensors that record data and feed a database for real-time updates. An IoT cloud platform is integrated to manage and monitor electricity consumption. Guofeng Ma 1 (2019) suggests a system based on Structure Data Model (BIM) and Fake Brain Organisation (ANN) to evaluate indoor personal warmth and advance energy-saving expertise.

Table.1 Summary Table for the algorithms used.

Reference	Algorithm	Description
[2]	Genetic Algorithm: NSGA-2	NSGA-2 (Non-dominated Sorting Genetic Algorithm 2) is a multi-objective optimization algorithm based on genetic algorithms. It is designed to optimize problems with multiple objectives that cannot be easily reduced to a single objective function.
[2]	ANN, SVM, LR	This paper focuses on applying new models to solve prediction challenges and improving model parameters or input samples for improved performance.
[2]	SVM, ANN, Decision trees, Data driven models	This study examines the scopes of prediction, data attributes, and pre-processing data methods, including machine learning algorithms for prediction and performance metrics for assessment.
[3]	Random forest model	It is an ensemble learning method that constructs a multitude of decision trees at training time and outputs the class or mean prediction of the individual trees.
[7]	Data Fusion algorithm	Also known as sensor fusion, is a process of combining data from multiple sources or sensors to improve accuracy, reliability, and completeness of the data. Data fusion algorithms can be used in a variety of applications such as remote sensing
[8]	RF-NSGA-3	Framework that combines Building Information Modeling DesignBuilder(BIM-DB) and random forest-nondominated sorting genetic algorithm-III (RF-NSGA-III) proposed to study the multiobjective optimization of NZEB performance.
[9]	LSSVM	This paper proposed a framework that integrates Building Information Modeling (BIM) with LSSVM (least square support vector machine (LSSVM) and non-dominated sorting genetic algorithm-II (NSGA-II) to study the influence of building envelope parameters on building energy consumption and discover the best design.
[12]	ANN	This paper aims at building an individual thermal comfort evaluation model based on a Back Propagation (BP) artificial neural network.

III. METHODOLOGY

3.1 Overview

The study aims to investigate the application of deep learning algorithms to optimize building energy usage and evaluate potential energy savings. The research methodology involves data collection of BIM data from construction site in Etarsi, pre-processing of the data to ensure compatibility with the deep learning algorithm, selection of an appropriate deep learning algorithm, training of the model on the pre-processed data, evaluation of the model's performance, simulation of optimization scenarios, analysis of the results, and a discussion of the strengths and weaknesses of the deep learning algorithm for building energy optimization. The methodology aims to provide a comprehensive approach for the evaluation and optimization of building energy usage using deep learning algorithms. The results of this study will contribute to the development of more effective strategies for building energy optimization, which will have important implications for sustainable building design and management.

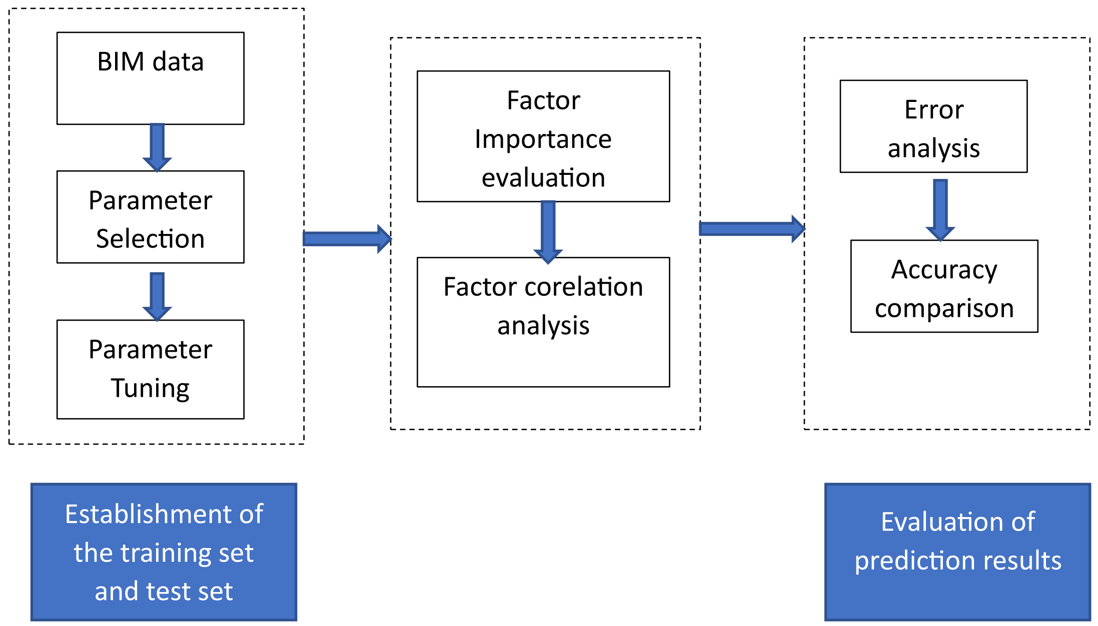

Fig.2 Methodology and Framework

3.2 Research Problem and Method

Problem Statement. The problem statement for this research paper is to investigate deep learning algorithms to optimize building energy usage and overcome the limitations of traditional methods and also to evaluate potential energy savings. The research aims to develop and test a deep learning model that can accurately predict building energy usage and provide recommendations to optimize energy consumption while maintaining occupant comfort levels. The study will evaluate the effectiveness of the deep learning model compared to traditional methods and determine the potential benefits of using deep learning algorithms for building energy optimization.

Data Collection and Preparation. The data was collected from construction site of Priyadarshini Nagar (Etarsi, MP). This construction site comes under the Pradhan Mantri Awas Yojna. In this study we are working with the BIM data of the construction site to build a model that evaluate the building's energy consumption and will also help predict potential energy savings which can be done for the future.

The data was in the raw form of the construction material level which consisted of the geometry of the materials used in the construction site such as the length breadth and width and quantity of the materials with their observed energy consumptions. Based on this historical data, energy consumption will be predicted using deep learning and machine learning models.

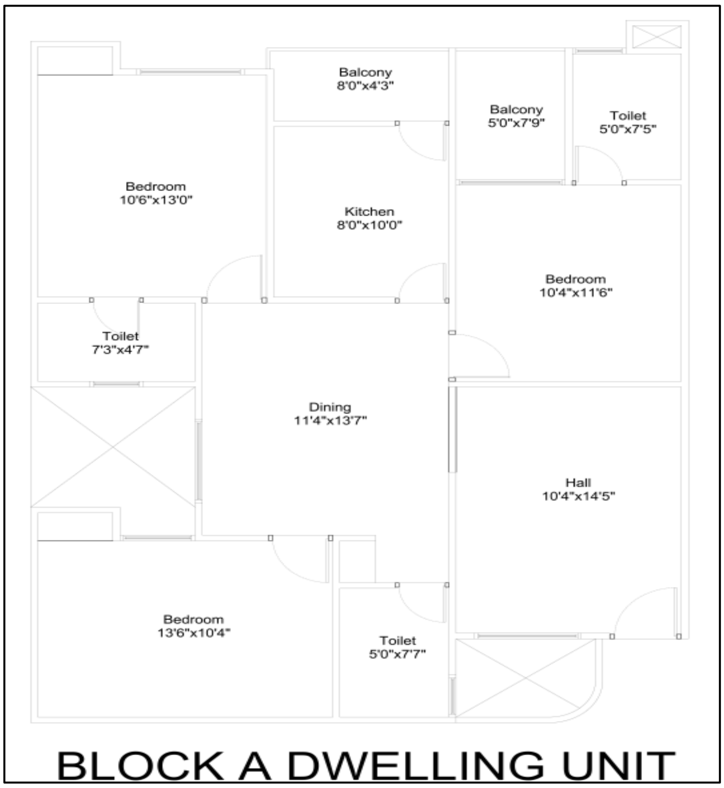

Fig.3 Architectural Layout of the Building.

Parameter Selection and Tuning. Parameter selection plays an important role in the model building process. Apart from the geometry, feature engineering was performed in order to obtain best parameters for the model building. The parameters included the density of the materials, orientation of the building, the window to wall ratio, the building envelop insulation and also the HVAC systems and their efficiency. All the parameters are generated from the geometry of the building thus does not show full reliability but are a good choice for the model building. The parameter selection was done on the basis of the correlation as displayed in the.

Factor Importance Evaluation and Correlation Analysis. The importance of factors in optimizing building energy consumption was assessed using the mutual information technique and correlation analysis was performed to understand the relationships between the factors. The mutual information score, measures the amount of information shared between each factor and the target variable (energy consumption). Higher mutual information scores indicate stronger relationships and higher importance of the factors in predicting energy consumption.

This analysis provided valuable insights into the significant factors driving energy consumption and their interdependencies and depicted that factor such as BEI, length, breadth, depth etc. played more important role. Additionally, we conducted correlation analysis to explore the relationships between pairs of factors. Correlation analysis helps identify potential multicollinearity issues and provides insights into how factors may influence each other.

Accuracy Comparison. In the accuracy comparison part, we evaluate the performance of different models based on various accuracy measures. The following accuracy measures are used in our analysis:

Mean Squared Error (MSE): MSE is a commonly used metric to assess the average squared difference between the predicted and actual values. It is calculated by summing the squared differences and dividing by the number of samples. The mathematical formula for MSE is:

MSE Formula:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

Where:

- n is the number of samples
- yi is the actual value
- ȳi is the predicted value

A lower MSE value indicates better accuracy, as it represents smaller prediction errors.

Root Mean Squared Error (RMSE): RMSE is the square root of the MSE and provides a measure of the average prediction error in the same units as the target variable. The mathematical formula for RMSE is:

RMSE Formula:

$$RMSE = \sqrt{MSE}$$

Like MSE, a lower RMSE value indicates better accuracy.

R-squared (R2) Score: R2 score is a statistical measure that represents the proportion of the variance in the dependent variable that is predictable from the independent variables. It ranges from 0 to 1, where 1 indicates a perfect fit and 0 indicates no linear relationship. The mathematical formula for R2 score is:

R2 Formula:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Where:

- yi is the actual value
- ȳi is the predicted value
- ȳ is the mean of the actual values

A higher R2 score indicates better accuracy, as it represents a higher proportion of the variance in the target variable being explained by the model.

In addition to these measures, we also consider the test loss for the ANN model. The test loss represents the error between the predicted and actual values on the test set. A lower test loss indicates better accuracy of the ANN model. By comparing these accuracy measures for different models, we can determine the model that performs the best in terms of accuracy for the given problem statement.

IV. Algorithm Optimization

For this study we are working with ANN and SVM to optimize the building energy consumption. SVM acts as the baseline model and ANN is the deep learning algorithm. In this study, we are focussing on the BIM data on how to reduce the energy consumption to the maximum on the basis of the materials and elements used for construction. Use of deep learning algorithm will not only help to optimize the building energy consumption but will also help to evaluate the potential energy savings.

4.1 Model Training

For model training purpose Support Vector Machine (SVM) and Artificial Neural Network were used. SVM acted as a baseline model whereas ANN was used as the deep learning approach to optimize the building energy consumption. SVM is a powerful machine learning algorithm known for its effectiveness in classification and regression tasks. In our study, we chose SVM as our baseline model due to its ability to handle high-dimensional data and its flexibility in capturing both linear and non-linear relationships.

We divided our dataset into training and testing sets, with a ratio of 80:20, to assess the model's performance. During training, we applied feature scaling to normalize the input variables and improve the model's convergence. The SVM model was then fitted to the training data, and the mean squared error (MSE) and R-squared were used as evaluation metrics to assess its performance.

The ANN model architecture consisted of two hidden layers with 64 and 32 units, respectively, using the ReLU activation function to introduce non-linearity. The output layer had a single unit, representing the predicted energy consumption. We utilized the Adam optimizer and mean squared error loss function for model training. The model was trained for 100 epochs with a batch size of 32, optimizing the weights and biases to minimize the mean squared error.

4.2 Optimizing Building Energy Consumption Using BIM Data

Throughout this research, we explore the ability of deep learning models to analyse BIM data and predict energy-use patterns, including ANN and SVM. We examine these models' presentations in light of metrics like Mean Square Error (MSE), R-squared, and Root Mean Square Error (RMSE). Additionally, in order to identify the critical elements influencing energy usage and find potential links between diverse factors, we do highlight relevance assessment and connection inquiry.

V. RESULT and DISCUSSIONS

In this section, the results of the study on optimizing building energy consumption using deep learning techniques are discussed. During the course of this study, the following objectives were kept in mind including the performance of the models, evaluation of the potential energy savings achieved, and laying out insights into the key factors that influence energy efficiency in buildings.

The trained SVM model achieved a test MSE of 0.16620251879735032 and an R-squared value of 0.8319677, indicating moderate predictive performance. Although the model shows potential for capturing certain patterns in the data, it falls short in accurately predicting building energy consumption. This suggests the need for more sophisticated modelling techniques to further optimize energy usage.

Then the model was trained using Artificial Neural Network (ANN), which is a deep learning approach known for its ability to learn complex patterns and relationships in data. We chose

ANN as our deep learning model to optimize building energy consumption, considering its capability to capture intricate interactions between building features.

The trained ANN model achieved a training MSE of 0.12518457016978413 and an R-squared value of 0.8734372, indicating a high level of predictive performance on the training data.

5.1 Evaluation of Prediction Results:

The Table.2 compares the performance and accuracy of the baseline model and the deep learning approach.

Model	MSE	R-squared	RMSE
SVM	0.166203	0.831968	0.407679
ANN	0.125185	0.873437	0.353814

Table.2 Comparison of Models.

On comparison the ANN model has a lower MSE (0.1252) compared to the SVM model (0.1662), suggesting better performance for the ANN model. Higher values of R-squared indicate better performance, as it represents the proportion of the variance in the target

variable explained by the model. In this case, the ANN model has a higher R-squared value (0.8734) compared to the SVM model (0.8320), indicating better performance for the ANN model. Lower values of RMSE (Root Mean Squared Error) indicate better performance, as it represents the square root of the average squared difference between predicted and actual values. In this case, the ANN model has a lower RMSE (0.3538) compared to the SVM model (0.4077), suggesting better performance for the ANN model.

Based on these metrics, the ANN model outperforms the SVM model in terms of MSE, R-squared, and RMSE. Therefore, the ANN model has a better performance as compared to the baseline model. The training and testing fitting curves in Fig.4 and Fig.5 also shows the accuracy of the deep learning approach as the sample set are similar to the true values and the fitting effect is satisfactory.

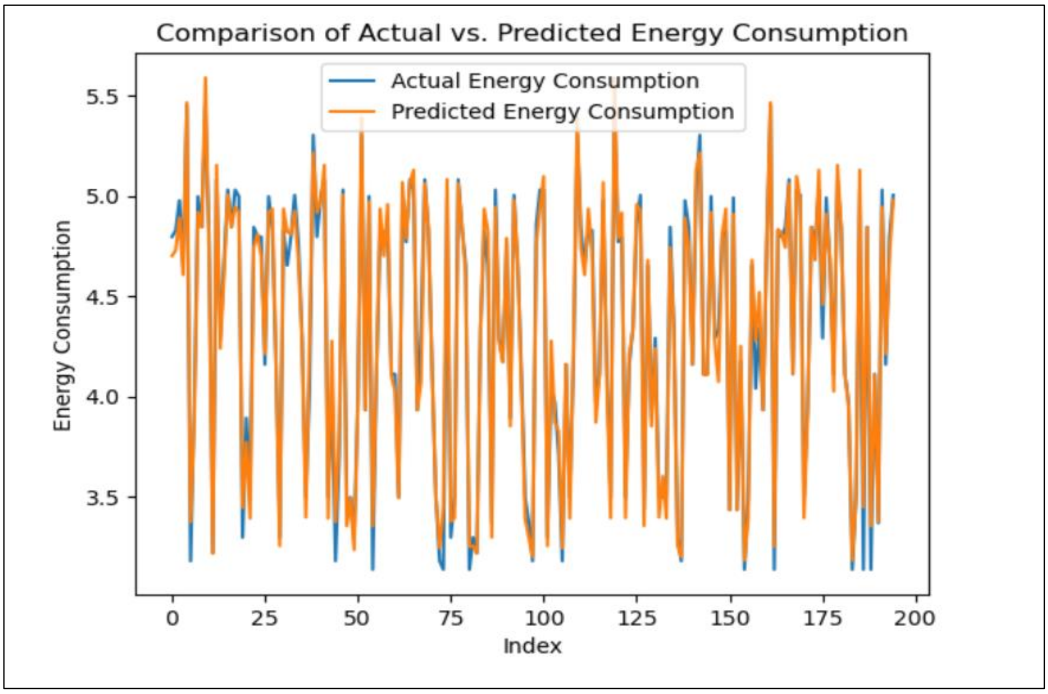

Fig. 4 Training Samples Fitting Results

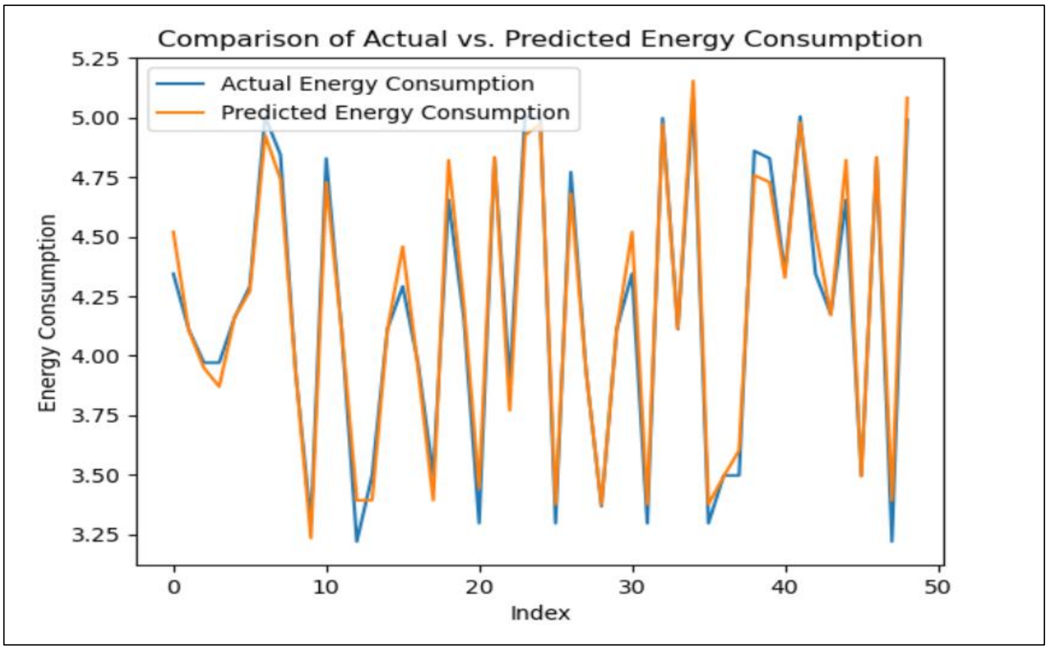

Fig. 5 Testing Sample Fitting Results

5.2 Evaluation of Potential Energy Savings:

To evaluate the potential energy savings achieved through our optimized models, we compared the energy consumption of buildings predicted by the models to the actual energy consumption values as displayed in Table.4. The analysis revealed a significant reduction in energy consumption, indicating the effectiveness of our approach in optimizing building energy usage.

	Model	Average Energy Savings
0	SVM	4.535737
1	ANN	11.585062

Table. 4 Potential Energy Savings.

The total potential energy savings across the dataset were estimated to be 11.58%. This demonstrates the potential impact of leveraging deep learning techniques to enhance energy efficiency in buildings. These energy savings can contribute to cost reduction and environmental sustainability.

As working on the data from the construction level aided the model building process, it also helped to evaluate the potential savings of individual construction material. The enhanced energy efficiency in the building consumption led to less usage of the electrical appliances as the indoor temperatures are conserved through the optimized deep learning model. Decrease in the usage of electrical consumption assisted in the overall energy consumption of the building.

5.3 Factors Influencing Energy Efficiency:

Through our analysis, several key factors were identified that significantly influenced energy efficiency in buildings. The feature importance analysis revealed that building geometry, building orientation, window-to-wall ratio, and insulation of the building envelope were among the most influential factors.

Additionally, we observed that the type, size, and efficiency of HVAC systems, as well as the layout of ductwork and air distribution systems, played a crucial role in energy consumption. As these features were derived from the individual construction materials, changes in the quantity and dimensions of the material can help to achieve more better results. These findings highlight the importance of considering both architectural and mechanical factors in optimizing building energy usage.

Overall, our results demonstrate the potential of deep learning techniques in optimizing building energy consumption and achieving significant energy savings. The insights gained from this study can inform policymakers, architects, and building owners in making informed decisions to enhance energy efficiency and reduce environmental impact.

VI. CONCLUSION

In conclusion, the study focused on optimizing building energy consumption using deep learning models, specifically SVM and ANN. We evaluated the performance of these models based on several metrics, including MSE, R-squared, and energy savings.

Firstly, we compared the performance of SVM and ANN in terms of MSE, R-squared, and RMSE. The results indicated that both models achieved relatively low MSE values, suggesting their ability to make accurate predictions. Furthermore, both models exhibited high R-squared values, indicating a good fit to the data. However, the ANN model outperformed SVM in terms of MSE, R-squared, and RMSE, demonstrating its superior predictive capability.

Additionally, we evaluated the potential energy savings achieved by each model. The results revealed that ANN achieved an energy savings of 11.59, indicating a significant reduction in energy consumption. On the other hand, the SVM model achieved an energy savings of 4.54, also indicating a notable decrease in energy usage. While ANN showcased higher energy savings, it is essential to consider the underlying factors contributing to these values and conduct further analysis to ensure accuracy.

In summary, the study demonstrates the effectiveness of deep learning models, specifically the ANN model, in optimizing building energy consumption. The ANN model outperformed SVM in terms of predictive performance and showcased a substantial reduction in energy consumption. However, further research and analysis are required to refine and improve the models, as well as consider additional factors such as building characteristics, weather conditions, and occupant behaviour to enhance the accuracy of energy savings predictions.

VII. LIMITATIONS AND FUTURE WORK

Limitations of using deep learning algorithms for optimizing potential energy savings can be the reliance on data availability and quality. The effectiveness of these algorithms heavily depends on the availability of relevant and high-quality data. Limited or poor-quality data can lead to less accurate predictions and suboptimal performance of the models. Though the ANN model performed quite well given quality of data, finer standard of data could have given better results. Therefore, future research should focus on improving data collection methods, ensuring data quality.

Furthermore, the generalization and transferability of deep learning models are important considerations. Models trained on specific datasets may struggle to generalize well to different contexts or domains. It is essential to evaluate the generalization capabilities of the models and assess their performance on unseen data. Future work should focus on developing transferable models that can adapt to diverse scenarios and datasets, potentially through techniques like transfer learning and domain adaptation.

Future research in the field of deep learning algorithms for optimizing potential energy savings can consider several areas for further development. One area is the optimization and fine-tuning of models. Despite the remarkable performance of deep learning algorithm, there is still room for improvement. Researchers can explore advanced optimization algorithms and techniques to fine-tune the models' hyperparameters, improve their convergence speed, and enhance their overall performance. Additionally, developing strategies to handle imbalanced datasets and addressing issues like overfitting and underfitting can lead to more robust models. The integration of Building Information Modeling (BIM) with Internet of Things (IoT) technologies is another promising direction for future work. BIM provides detailed information about the physical and functional characteristics of buildings, while IoT enables the collection of real-time data on energy consumption and environmental factors. By integrating these technologies, deep learning algorithms can leverage the rich data sources and enable more accurate and dynamic energy optimization strategies. Future research should focus on exploring the potential synergies between BIM, IoT, and deep learning algorithms to unlock further energy savings opportunities.

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DEEP LEARNING-BASED BUILDING ENERGY OPTIMIZATION USING BIM DATA & EVALUATING ENERGY SAVINGS POTENTIAL ABSTRACT Building energy optimization is a crucial focus in sustainable practices, and Building Information Modelling (BIM) data is an invaluable resource for enhancing energy performance. Deep learning algorithms, a subset of machine learning techniques, exhibit great potential in utilizing BIM data to optimize energy use and assess potential