

ADS Project

P18-Equans-P1


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Title : Resource Planning for Construction Projects

Introduction

This project is a collaboration with **Equans**, a well-known construction company operating in the United Kingdom, to develop a **human resource allocation management system**. Equans aims to utilise existing project data to forecast future project resource allocation. The main focus of the project includes establishing a comprehensive resource planning framework for construction projects in Wales, England, and Scotland, including the allocation of staff such as engineers, project managers and mechanical supervisors.

This collaboration will help Equans to achieve **optimization of human resource management** and **streamlining of decision-making processes**, which will lead to increased project efficiency and productivity. In addition, the project represents a pioneering endeavour at the intersection of construction management and data science.



Project Goals

Resource optimization

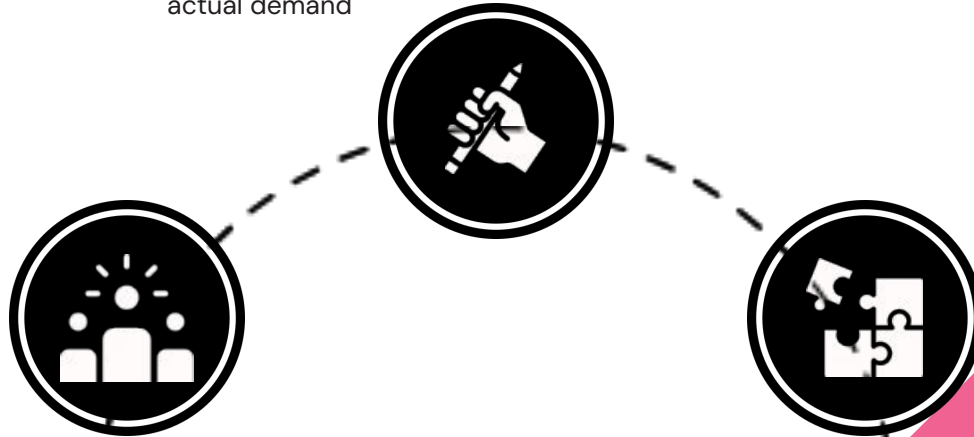
Develop a system that can predict the staff resources required for a project to optimize resource allocation, reduce waste, and improve efficiency

Real-time Adjustment

The prediction is implemented in stages, and the results can be flexibly adjusted according to the latest situation of the project to ensure that the forecast is close to the actual demand

Decision-making Support

The prediction results will provide decision-makers with insights into resource allocation, help formulate human resource plans, and improve decision quality.



Data Overview

Features	Description
Duration_hours	The total number of hours allocated to a project
Total_order_intake	The total value or volume of orders received for a project.
Num_of_Departments	The number of different departments involved in a project.
Duration_days	The total number of days from the start to the completion of a project.
Number_of_JobTitles	The total number of job titles.
Number_of_Tasks	The count of distinct job titles associated with a project.
Work_Intensity	The intensity of work per day.
Department_diversity	The variety of departments within a project.
JobTitle_diversity	The diversity of job titles within the project.
Average_work_quantity_per_department	The average hours assigned to each department within a project.
Average_Work_Quantity_per_Task	The average amount of work (in hours) expected for each task within a project.
Num_of_Employees	The total number of employees allocated to a project.
Duration_to_Employees_Ratio	the ratio of the project's duration in days to the number of employees involved.

Data Pre-processing

By using the project name, combined customer order data and employee hours data to form a new comprehensive dataset.

Merging Datasets

Duplicate time records are removed to ensure that only one total time record is kept for each employee on each project, improving data accuracy.

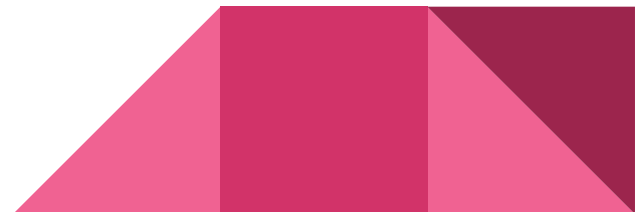
Handling Duplicates

Coded categorical variables and derived new features such as project duration, number of employees and work intensity, etc. from the original data to enrich data dimensions

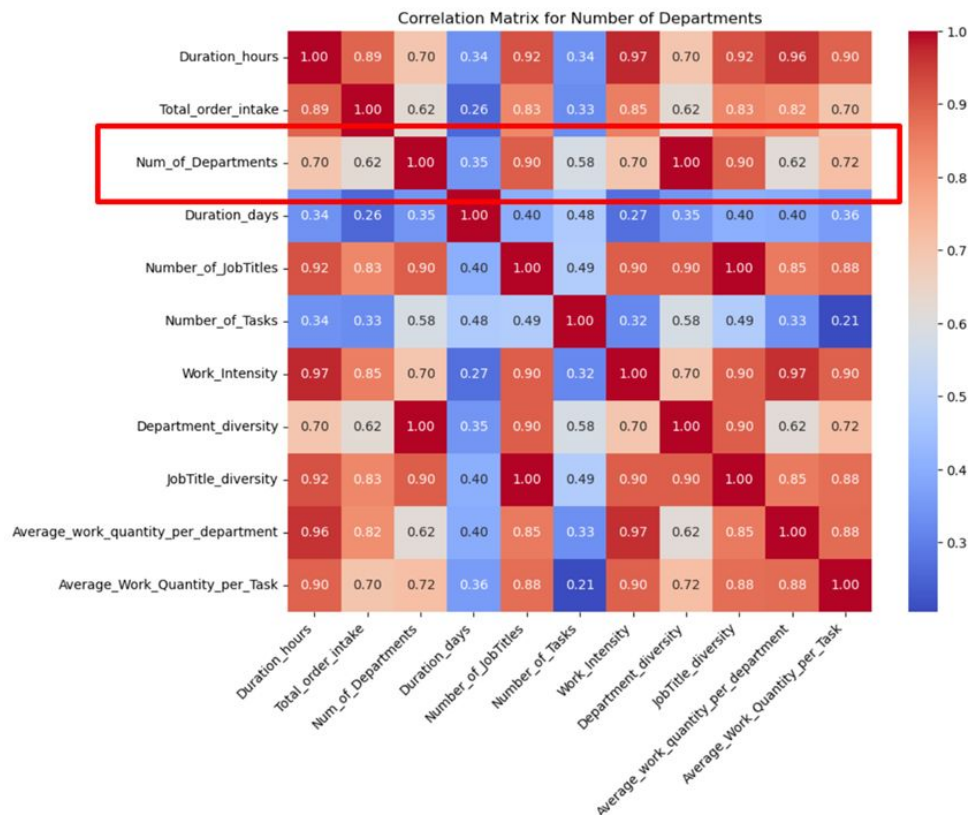
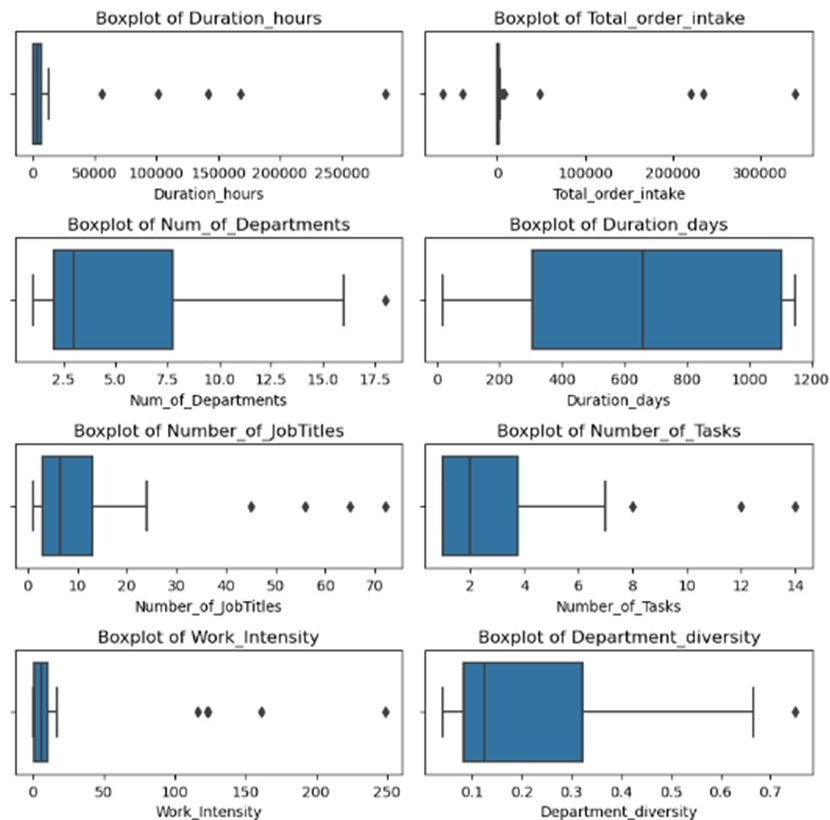
Feature Engineering

Used random oversampling to address data imbalance, replicating a few categories of data to enhance model understanding of their patterns.

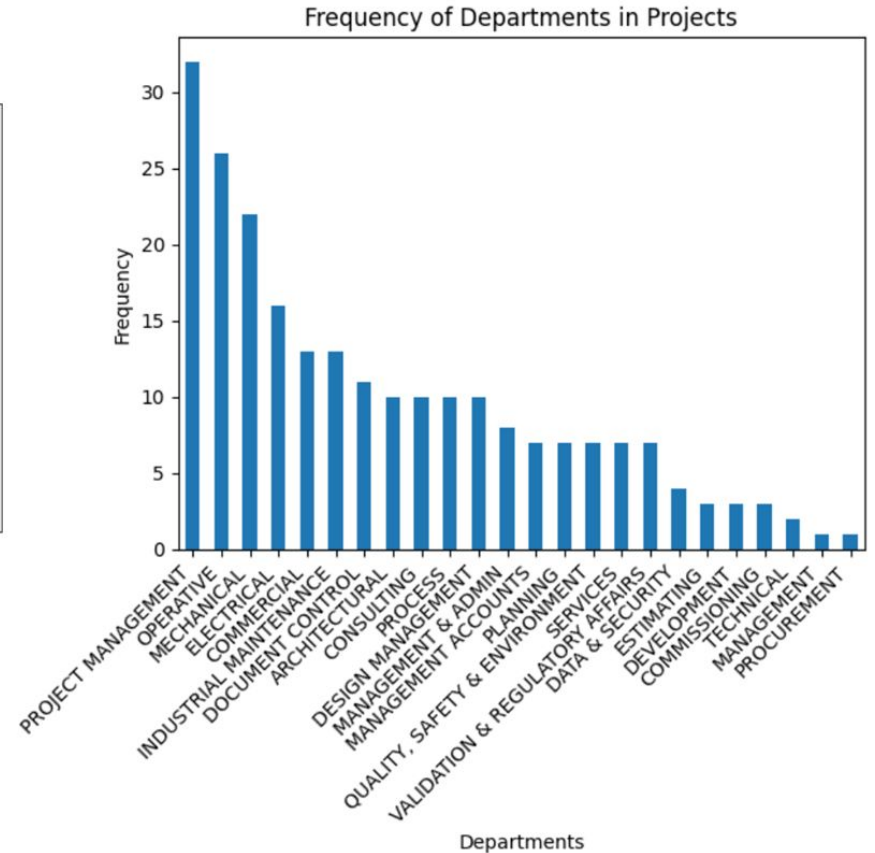
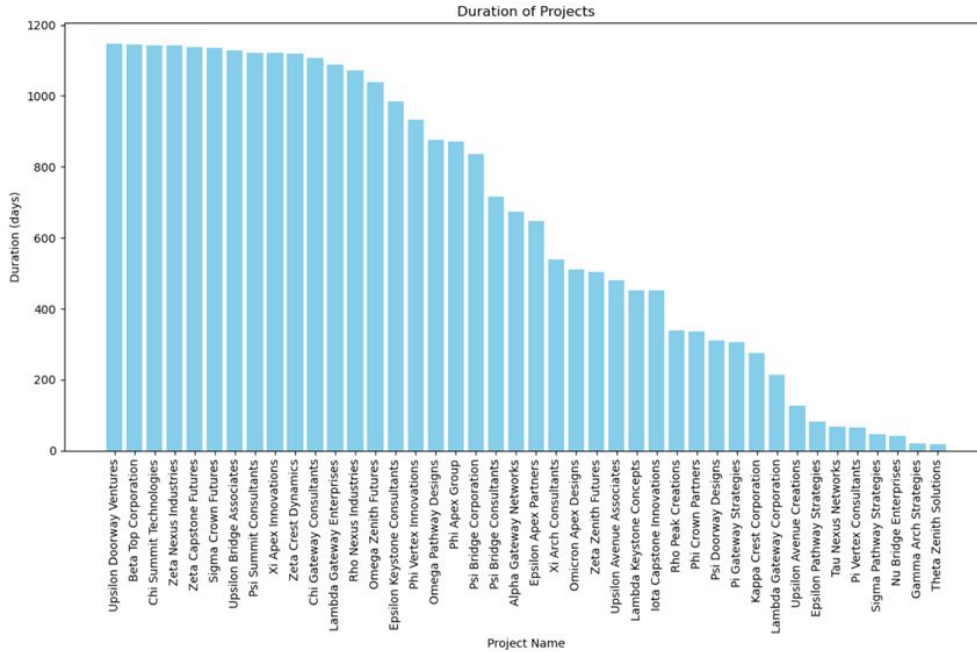
Data Oversampling



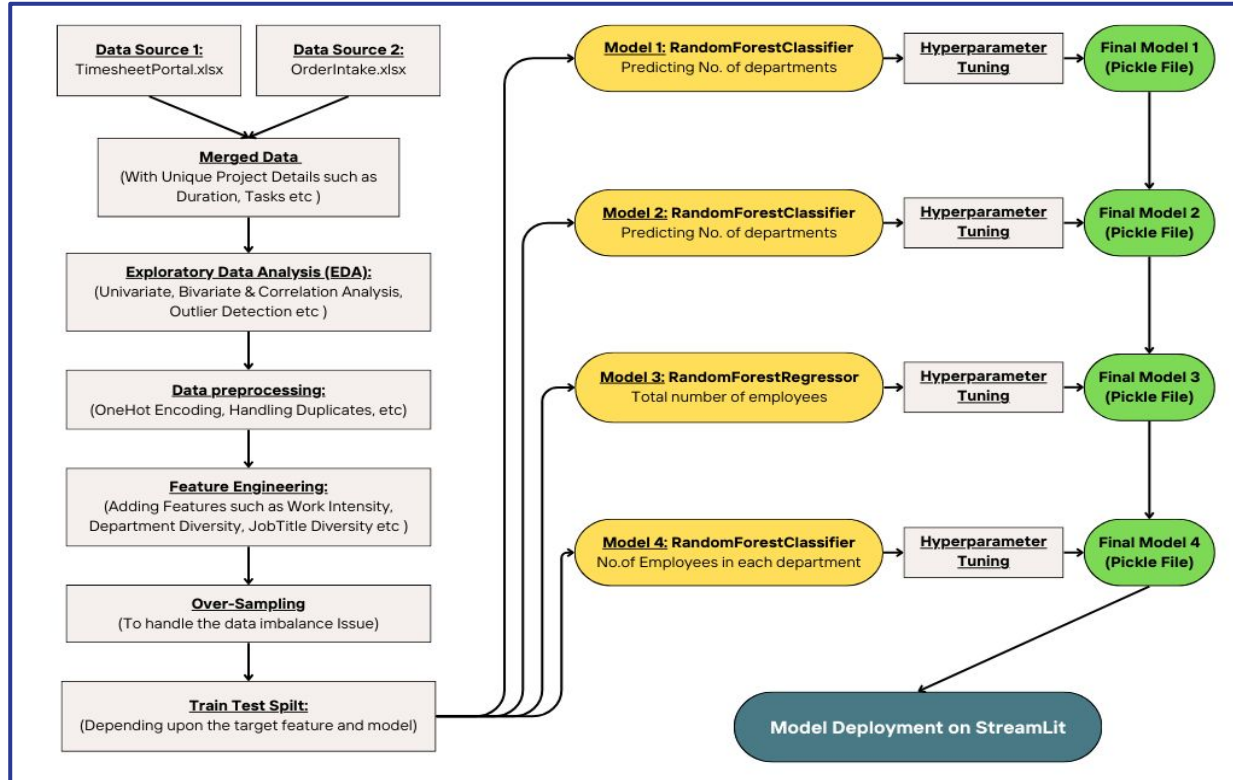
Data — EDA



Data — EDA



Methodology



Results & Outcomes

Model 1 Results : Upcoming Project Department Count Prediction

- Utilised random forest classifier for department count prediction.
- Initial evaluation on imbalanced data set with low test accuracy of 33.33%.
- Transitioned to oversampled data set, improving testing accuracy to 94.44%.
- The parameter tuning using optional enhanced model efficacy.
- Achieved training accuracy of 97.92% and **testing accuracy of 97.22%**.

Model 2 Results: Upcoming Project Department Names Classification.

- Integrated multi output classifier with Random forest classifier.
- Average accuracy of 89.10% through cross validation.
- Training accuracy and F1 score reached 100% indicating overfitting. **Test accuracy of 92%, an F1 of 99%.**
- Micro-averaged ROC AUC of 1.00 showcasing outstanding discriminatory capability.

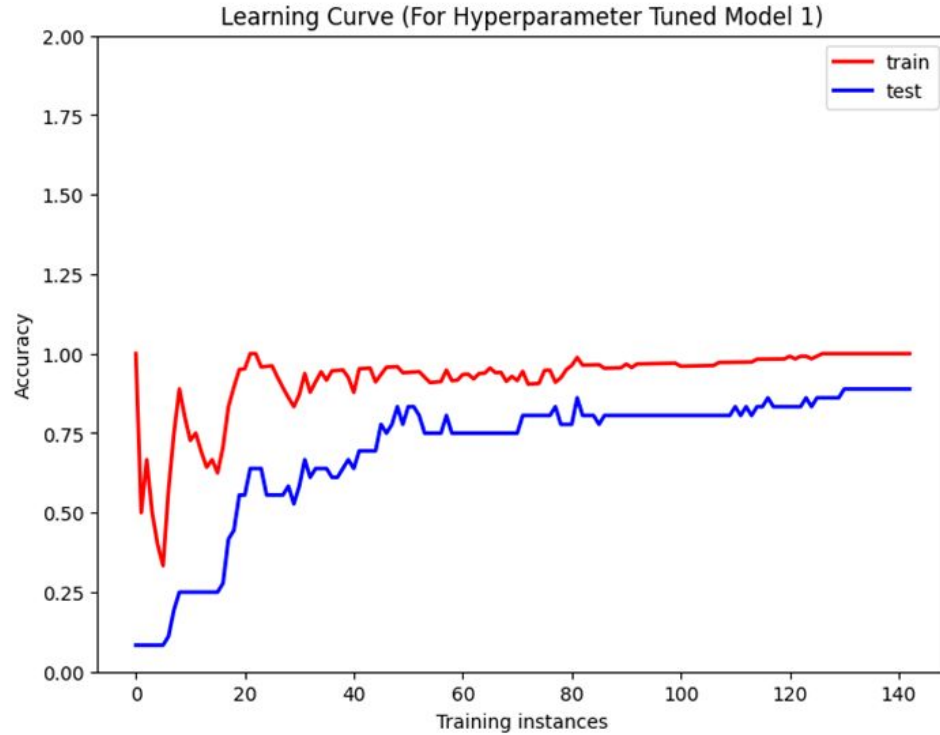
Model 3 Results: Upcoming Project Total Staff Count Prediction.

- Integrated multi output classifier with Random forest classifier.
- Average accuracy of 89.10% through cross validation.
- Training accuracy and F1 score reached 100% indicating overfitting. **Test accuracy of 92%, an F1 of 99%.**
- Micro-averaged ROC AUC of 1.00 showcasing outstanding discriminatory capability.

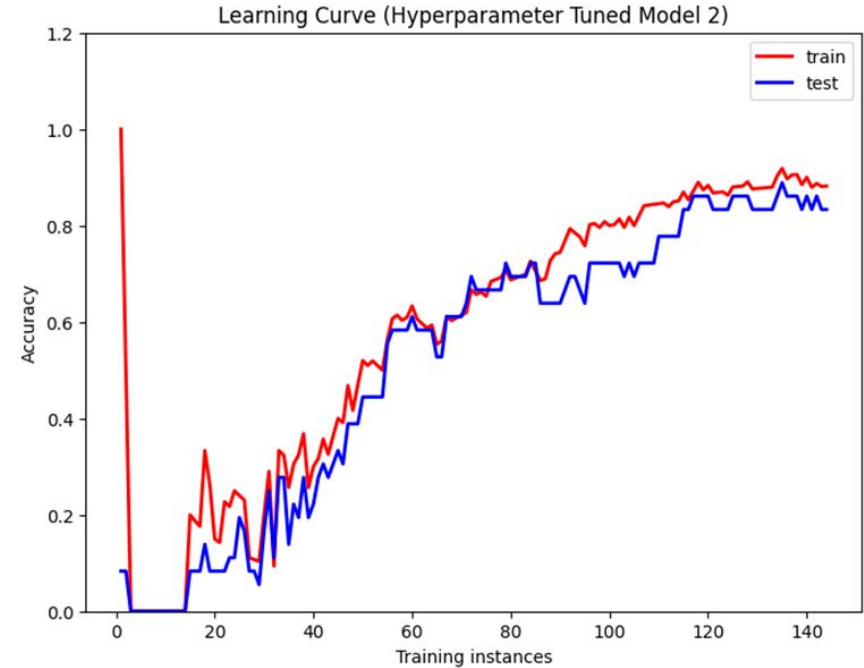
Model 4 Results: Upcoming Project Department-wise Staff allocation Prediction.

- Random Forest Regressor with standard scaler preprocessing.
- Consistent precision with an average negative MSE.
- Training metrics with **low MSE(error) of 0.012** and high R-squared value of 0.997.
- Testing RMSE of 0.22, and R-squared of 0.99.
- Learning curve indicating promising high model performance with convergence to low error values.

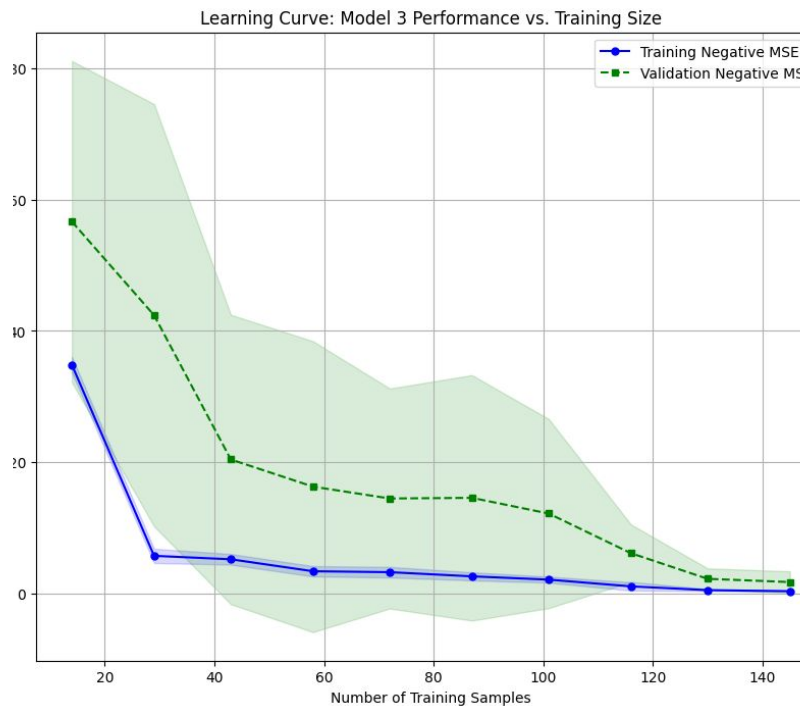
Learning curve of oversampled training and testing dataset on tuned **model 1**



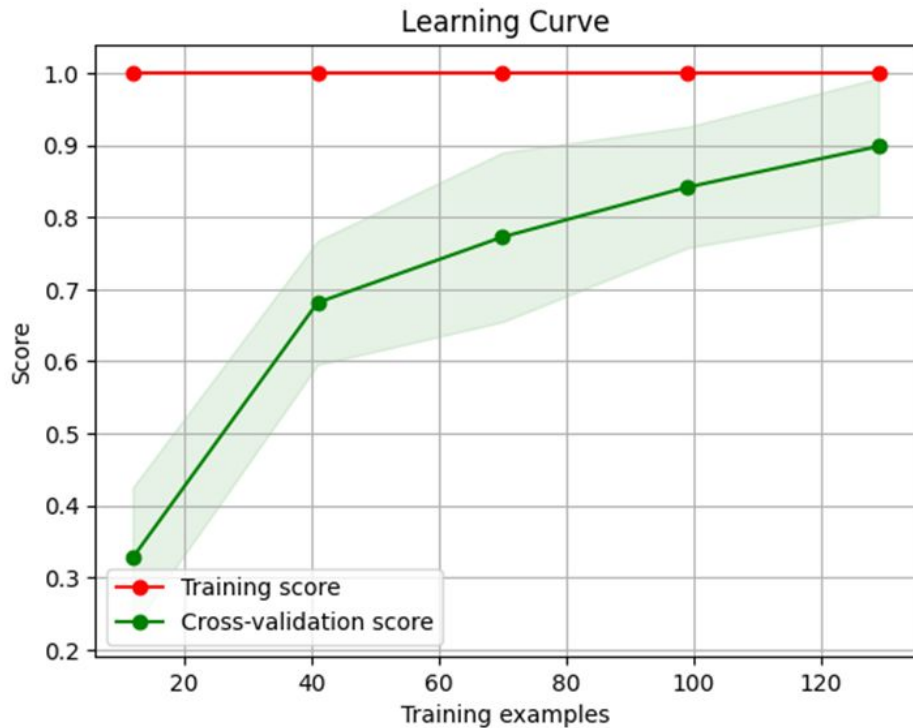
Learning curve of oversampled training and testing dataset on tuned **model 2**



Learning curve of oversampled training and testing dataset on tuned **model 3**



Learning curve of oversampled training and testing dataset on tuned **model 4**



Model 1 and Model 2 Performance Evaluation and Results Comparison

Tuned-Model Performance	TEST ACCURACY	TRAIN ACCURACY	F1 SCORE
Model 1 (Predicting Number of Departments)	91.66 %	97.91 %	0.91
Model 2 (Classifying departments to a new project)	92 %	100 %	0.99
Model 4 (Predicting department-wise staff count for new project)	99.5%	100 %	0.95

Model 3 and Model 4 Performance Evaluation and Results Comparison

Tuned-Model Performance	RMSE (Test)	Adjusted R-Squared (Test)	RMSE (Train)	Adjusted R-Squared (Train)
Model 3 (Predicting total staff/workforce required for new project)	0.23	1.00	0.48	0.99

Model Deployment with Streamlit

- Developed a resource planning tool for future projects with Streamlit for model deployment, enhancing user accessibility and interaction.
- Smooth **integration machine learning** models into intuitive interface.
- Empowers users to interact with predictive insights by inputting project details.
- Various **buttons trigger distinct functionalities** for forecasting department count, names, total employee figures, and more
- Easy Sharing of the tool Locally or on Cloud Platforms with Streamlit.



Dynamic Resource Planning Tool

Upcoming Project/Client Name

TEST-PROJECT

Order Intake (Cost in '000 EUR)

2000 - +

Duration (Project Hours)

6000 - +

Start Date (YYYY/MM/DD)

2022/04/11

End Date (YYYY/MM/DD)

2024/04/14

Predict Department Count

Predict Department Names

Predict Total Number of Employees for the new project

Predict Number of Employees in Each Department

Resource Planning Tool : Button Functionalities

1

Predict Department Count

Number of predicted departments for the project are 12

3

Predict Department Names

Predicted department names are:

1. ARCHITECTURAL
2. COMMERCIAL
3. CONSULTING
4. DESIGN MANAGEMENT
5. DOCUMENT CONTROL
6. ELECTRICAL
7. INDUSTRIAL MAINTENANCE
8. MANAGEMENT ACCOUNTS
9. MECHANICAL
10. OPERATIVE
11. PROJECT MANAGEMENT
12. QUALITY, SAFETY & ENVIRONMENT

2

Predict Total Number of Employees for the new project

Total number of predicted employees for the new project are 23

4

Predict Number of Employees in Each Department

Predicted number of employees in each department of the New Project:

1. ARCHITECTURAL: 1
2. COMMISSIONING: 2
3. DATA & SECURITY: 2
4. DEVELOPMENT: 1
5. DOCUMENT CONTROL: 3
6. ESTIMATING: 1
7. MANAGEMENT: 1
8. MANAGEMENT & ADMIN: 1
9. MANAGEMENT ACCOUNTS: 5
10. MECHANICAL: 3
11. PROCUREMENT: 3
12. PROJECT MANAGEMENT: 1

Resource Planning Tool : Project Plan Summary

Resource Planning Summary for TEST-PROJECT

Project Name: TEST-PROJECT

Number of predicted departments: 12

Predicted department names:

1. ARCHITECTURAL
2. COMMERCIAL
3. CONSULTING
4. DESIGN MANAGEMENT
5. DOCUMENT CONTROL
6. ELECTRICAL
7. INDUSTRIAL MAINTENANCE
8. MANAGEMENT ACCOUNTS
9. MECHANICAL
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12. QUALITY, SAFETY & ENVIRONMENT

Total number of predicted employees: 23

Predicted number of employees in each department:

1. ARCHITECTURAL: 1
2. COMMISSIONING: 2
3. DATA & SECURITY: 2
4. DEVELOPMENT: 1
5. DOCUMENT CONTROL: 3
6. ESTIMATING: 1
7. MANAGEMENT: 1
8. MANAGEMENT & ADMIN: 1
9. MANAGEMENT ACCOUNTS: 5
10. MECHANICAL: 3
11. PROCUREMENT: 3
12. PROJECT MANAGEMENT: 1

Challenges & Limitations

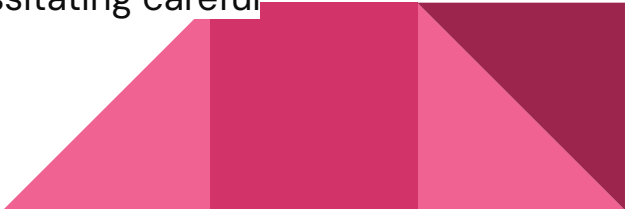
1. **Scarcity of Data:**

- Limited access to only 42 unique projects from employee timesheet data spanning 2021 to 2023. Minimal training data hindered the model's ability to generalize effectively.

1. **Limited Data Features:**

- Absence of essential attributes like project location, onsite/offsite staff indicators, and subcontractor information.

2. **Data Imbalance and Overfitting Risk:**

- Handling data imbalance through oversampling methods increased the likelihood of overfitting. Small dataset size posed challenges during model training, necessitating careful hyperparameter tuning.
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Future Work/Recommendations

1. Enhancing Model Generalization:

- Acknowledge the model's potential limitations in generalizing predictions due to limited data. Augment the dataset with diverse values to improve predictive accuracy.

2. Expansion into Predicting Job Titles and Departments:

- Extend the model's capabilities to predict job titles and department allocations, providing stakeholders with comprehensive project insights.

3. Incorporation of Employee Allocation System:

- Integrate an employee allocation system to optimize resource allocation and streamline project execution based on schedules and availability.



Conclusion – Achievements

1. **Comprehensive Resource Planning Framework:**

Developed a sophisticated framework that integrates predictive models with user-friendly interfaces.

2. **Predictive Model Optimization:**


Enhanced predictive accuracy by fine-tuning random forest models and addressing data challenges with techniques like RandomOverSampler.

3. **User-Friendly Interface:**

Created an intuitive UI for the Resource Planning Tool that effectively translates data insights into actionable strategies.



Conclusion – Impacts

1. **Cost Optimization:**
Improved resource allocation through predictive models, leading to significant cost savings and financial performance enhancement.
 2. **Improved Project Timelines:**
Streamlined staff allocation strategies to reduce project delays and improve schedule adherence.
 3. **Enhanced Efficiency:**
Automated resource planning tasks, reducing manual workloads and improving operational efficiency and productivity.
 4. **Strategic Insights:**
Provided stakeholders with actionable insights that maximize data utility and relevance, fostering informed decision-making.
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Feedback and Q/A