Resource Project Planning System: Enhancing Workforce Utilisation and Project Efficiency through Intelligent Planning

Akansha Rana, Department of Data Science, MSC, Vellore Institute of Technology
Corresponding Author: akansha.rana2024e@vitstudent.ac.in
Approver Name: Dr. Murali S, **Approver Email:** murali.s@vit.ac.in

Abstract: In the competitive landscape of IT/Gov organisations, the "bench"—a pool of employees who are employed but not currently assigned to active projects—represents a significant operational challenge. Inefficient management of these resources often results in underutilised talent, increased operational costs, and missed project deadlines. This project proposes a Data Science–based Bench Employee Utilisation and Project Matching Tool designed to optimize workforce planning through data-driven insights.

By leveraging techniques in **Business Analytics** and **Machine Learning**, the system analyses employee skill datasets, project requirements, and historical utilisation trends. Key functionalities include a recommendation engine for automated employee-project matching, a skill-gap analysis framework to identify upscaling needs, and a comprehensive workforce analytics dashboard to monitor bench duration and utilisation rates. Following a **SMART** objective framework, the project delivers a prototype model that demonstrates how predictive and prescriptive analytics can transform traditional resource management into a strategic, efficient, and cost-effective process.
Indexed Terms: To ensure RPPS project is easily searchable in academic and professional databases, use the following keywords:
Primary Keywords: Workforce Analytics | Resource Allocation | Bench Management | Skill Gap Analysis | RecommendationSystems
Technical Keywords: Data Science | Predictive Modelling | Machine Learning in HR | Data Visualisation (Dashboards) | Talent Optimisation

1. Introduction

In contemporary IT service environments, organisations frequently grapple with the "bench" phenomenon, where a significant portion of the workforce remains unassigned to active projects, leading to substantial operational costs and talent stagnation[1]

This research proposes the development of a **Resource Project Planning System (RPPS)**, a data science-driven framework designed to transition workforce management from a reactive "crisis" mode to a proactive, strategic model[2]By leveraging machine learning algorithms and real-time analytics, the system aims to bridge the gap between employee skill sets and dynamic project demands.

Beyond simple resource allocation, the study focuses on creating structured pathways for employees on Performance Improvement Plans (PIP) and identifying precise ups-killing opportunities for unskilled staff[3]Ultimately, this project seeks to optimize human capital utilisation, enhance organisational agility, and provide a scalable prototype for data-driven decision-making in human resource analytics[4] Traditional resource management relies on reactive, manual scheduling, leading to **talent leakage** and high operational overhead[5]

This project introduces the **Resource Project Planning System (RPPS)**, shifting the focus from mere "staffing" to **"Strategic Talent Re-engineering.** The current industry problem isn't a lack of talent; it's a lack of **visibility of project, project based on employee relevant skill** and **alignment**.Project, RPPS, acts as a bridge. It uses data science to stop treating the bench as a 'waiting room' and starts treating it as a 'capability lab' where resources are matched, measured, and matured for the next project demand.

1.2. The Data Science Intervention

Unlike standard HR tools, RPPS utilises a **multi-layered analytical approach** to solve workforce inefficiencies:

Skill-to-Project Mapping:
Employs **Cosine Similarity** and NLP to match the semantic meaning of employee skills with project requirements, ensuring a higher quality of “fit."

Cosine Similarity Formula

$$\mathrm{COS}(\Theta) = \frac{\mathbf{A.B}}{||\mathbf{A}||.||\mathbf{B}||}$$

Predictive Utilisation:
Uses **Machine Learning (Random Forest/XGBoost)** to predict which employees are likely to remain on the bench for extended periods, allowing for early intervention.

Dynamic Upscaling:
Identifies "skill gaps" by comparing current bench capabilities against future project demand forecasts, turning idle time into structured learning.

Scope and Impact (PIP & Unskilled Support)
A core innovation of this system is its focus on **marginalised talent pools**. By creating data-driven recovery pathways for employees on **Performance Improvement Plans (PIP)** and structured upscaling for the unskilled, RPPS maximises human

1.1. Current Organisational Challenge

Many organisations face underutilisation of human resources due to:

- Employees remaining on bench without work visibility
- Individuals on PIP lacking structured recovery pathways
- Skilled but underemployed resources not mapped to opportunities
- Unskilled employees lacking structured upscaling routes
- Resource planning decisions driven by short-term project pressures

Proposed Solution

A **Resource Project Planning System** that:

- Maps available talent to project demand
- Creates internal opportunity visibility
- Supports skill-gap identification and upscaling pathways
- Improves workforce utilisation and organisational agility

Scope and Impact (PIP & Unskilled Support)

A core innovation of this system is its focus on **marginalised talent pools**. By creating data-driven recovery pathways for employees on **Performance Improvement Plans (PIP)** and structured upscaling for the unskilled, RPPS maximises human capital return.

The result is a dual-benefit model: reducing the "Cost of Bench" for the organization while increasing career mobility and job security for the employee.

Analysis Level	Key Question	Primary Algorithm	Mathematical Focus
Historical	How long have resources stayed idle?	EDA / TF-IDF	Utilization % & Skill Density
Predictive	Which skills will be needed in Q4?	Random Forest / ARIMA	Probability & Forecasting Error
Prescriptive	Who is the optimal match for Project X?	Cosine Similarity / Hungarian	Vector Similarity & Optimization

Ref table: 3.3

1.3.Key Metrics for Intro (To show SMART goals):

Target: Reduce average bench duration by **15–20%**.

Efficiency: Automate **80%** of initial candidate-project matching.

Capability: Increase the "internal deployment rate" of PIP/ unskilled resources through targeted skill-gap closing.

Why This Project Matter:

- To analyse employee skill data and project requirements to understand workforce utilisation patterns within an organisation.
- To identify bench/PIP employees and measure bench duration using data analytics techniques.
- To develop a recommendation system that matches employees with suitable projects based on their skills and experience.
- To perform skill gap analysis between available employee capabilities and project demand.

2. Classification of Resource Constraints in RPPS

To align RPPS project with academic standards, we can classify RPPS problem statement into four specific constraint dimensions:

- **Human Capital Constraints (The Expertise Gap):** As noted by SR Chandra etal. constraints extend beyond "headcount" to "skill diversity." In RPPS project, the bench isn't just a pool of idle people; it is a mismatch of **Expertise-to-Demand**. RPPS system addresses the constraint where team composition is hindered by a lack of real-time skill visibility.
- **Economic & Financial Constraints (The Bench Cost):** Aligning with Sisodia et al, budgetary limitations are often exacerbated by "resource leakage." RPPS project treats the **Bench Cost** as a financial constraint that limits an organisation's ability to bid for new projects or invest in R&D.
- **Operational Constraints (The PIP & Readiness Gap):** Equipment isn't just physical; in IT, "equipment" includes the **Readiness of the Resource**. An employee on PIP or an unskilled employee represents an "operational bottleneck." RPPS system acts as a "proactive maintenance strategy" for human capital.
- **Knowledge/IT Constraints (Data Management):** Following It Industry, the lack of a centralised data management system for skills leads to project disruptions. RPPS is the "technological intervention" to solve this data fragmentation.

Comparative Analysis: Resource Constraints & Algorithmic Interventions

Constraint Category	Recommended Algorithm	Advantages	Disadvantages
Skill Matching (Human Capital)	Cosine Similarity (NLP)	Highly effective at finding semantic matches between resume text and project descriptions.	Requires clean, standardized skill data; may struggle with rare or new tech synonyms.
Resource Assignment (Operational)	Hungarian Algorithm	Guarantees an "optimal" 1-to-1 assignment by minimizing cost or maximizing "fit" scores.	Computationally expensive as the number of employees/ projects grows linearly.
Utilisation Prediction (Bench/PIP Risk)	Random Forest / XGBoost	Excellent at handling non-linear data; can identify the "risk profile" of someone staying on the bench.	Can be a "black box," making it harder to explain to HR why a specific risk score was given.
Demand Forecasting (Financial)	ARIMA / Prophet	Accurately predicts seasonal hiring trends and future bench loads based on historical project cycles.	Requires a significant amount of historical data (years) to be truly accurate.
Workforce Segmenting (Capability)	K-Means Clustering	Groups employees into natural categories (e.g., "Ready for Lead Role," "Needs Upskilling," "PIP Recovery").	Choosing the correct number of clusters (k) can be subjective and requires trial/error.

3. Literature Review:

Planning, organisation, and controlling tasks and resources is key to project management. Each project scheduling strategy addresses the difficulties of project schedules, resource allocation, and success in a unique way. A summary of major findings, trends, and problems from seminal research publications illuminates the intricacies of project scheduling under resource constraints.

3.1 Historical Analysis

- **Focus:** Understanding past trends in bench duration, PIP success rates, and skill distribution.
- **Objective:** To identify patterns in resource utilisation over the last 12–24 months.
- **Algorithm Used:** Exploratory Data Analysis (EDA) and TF-IDF (Term Frequency-Inverse Document Frequency) for skill frequency.
- **Formula:** Utilisation Rate **(UR)** The most fundamental metric for bench management:

$$UR = \left(\frac{\text{Total Billable Hours}}{\text{TotalAvailable Hours}} \right)$$

- **Formula: TF-IDF** (to identify unique/rare skills on the

Wi,j = tai, j * log (N/dfi)

Where tf i, j is the frequency of skill I in profile j, N is total profiles, and ddi is the number of profiles containing skill i.

3.2 Predictive Analysis (Predictive Analytics)

Focus: Forecasting future project demands and identifying "At-Risk" employees (those likely to stay on the bench long-term).

Objective: To move from reactive to proactive management.

Algorithm Used: Random Forest Classifier (for PIP/Bench Risk) and **ARIMA** (for Demand Forecasting)

Formula: Logistic Regression/Probability Score (P)
Used to calculate the probability of a bench resource getting matched within 30 days:

$$P(y = 1) = \frac{1}{1 + e^{-(\beta 0 + \beta 1 \mathcal{X}1 + \ldots\ldots + \beta n \mathcal{X}n)}}$$

Formula: Cost Objective Function (Z) (for theHungarian Algorithm)

$$Z = \min \sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} X_{ij}$$

Where At is actual demand and Ft is forecasted demand.

3.3 Prescriptive Analysis (Prescriptive Analytics)

Focus: Recommending the "Best Fit" project for an employee and the "Best Learning Path" for upscaling.

- **Objective:** To provide actionable solutions that optimise the workforce.

- **Algorithm Used: Cosine Similarity** (for Matching) and **Hungarian Algorithm** (for Global Optimisation).

- **Formula: Cosine Similarity** This measures the alignment between an Employee Vector (A) and a Project Requirement Vector (B):

$$\text{sim}(A, B) = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2}\sqrt{\sum_{i=1}^{n} B_i^2}}$$

Formula: Cost Objective Function (Z) (for the Hungarian Algorithm): Where Ci,j is the 'cost' (or inverse match score) of assigning employee I to project j.

3.4 Root Cause Analysis

Root Cause Analysis (RCA) for Resource Project Planning System (RPPS), demonstrate to the reviewers "symptoms" high bench count, but diagnosing the disease (the systemic planning failure).

3.4.1. 5 Why Analysis

The objective of this analysis is to drill down through the layers of the problem until the **Root Cause** is identified.
Problem Statement: The organisation is experiencing high operational costs due to underutilised talent on the "bench."

Why 1: Why is there a high number of unassigned employees?
Answer: Because project managers cannot find resources with the exact skills needed for new projects.

Why 2: Why can't they find the right skills among available employees?
Answer: Because there is no real-time visibility or standardised inventory of the current bench's skill sets.

Why 3: Why is there no standardised skill inventory?
Answer: Because resource data is siloed in manual spreadsheets and updated infrequently.

Why 4: Why are we still using manual processes for resource mapping?
Answer: Because the organisation lacks a data-driven system for automated project-resource matching.

Why 5 (Root Cause): Why has a data-driven system not been implemented?

Root Cause: The absence of an integrated **systemic resource planning model** that connects historical data, predictive demand, and prescriptive skill-matching.

3.4.2. Three Cause (legs) Framework

1. **Specific Causes**
- Unclear organisation structure
- Skill-demand mismatch
- Bench visibility gaps
- Inconsistent project allocation

2. **Detection Causes**
- Weak risk monitoring
- No formal escalation/problem-solving mechanism
- Poor workforce analytics dashboards
- No early warning signals
- Systemic Causes

3. **Systemic Causes**
- Change management not followed
- Short-term metrics dominate decisions
  Lack of governance model
- Fragmented planning processes

3.4.3. Ishikawa Fishbone Diagrame

A. People (Manpower)

Skill Gaps: Mismatch between employee expertise and market demand.

Stagnation: Employees on the bench losing motivation or "shelf-life" of their technical skills.

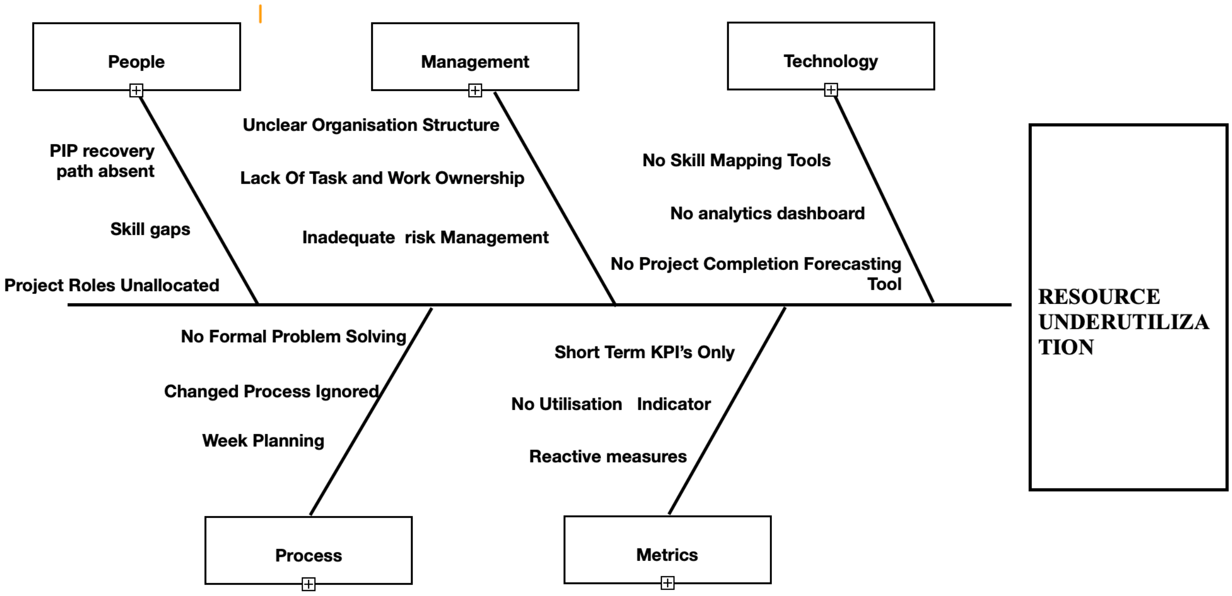
PIP Isolation: Lack of a recovery pathway for low-performers.

B. Process (Method)
Reactive Staffing: Hiring externally for new projects instead of checking the internal bench first.
Fragmented Planning: HR, Finance, and Project Managers working in silos without shared data.
Poor Forecasting: Failure to anticipate which skills will be needed 3 months in advance.

C. Technology (Machine)
Manual Tools: Reliance on Excel sheets that become outdated within days.
No Analytics: Absence of a recommendation engine to suggest "best-fit" candidates.
Data Silos: Resume data is not linked to project demand data.

D. Measurement (Metrics)
Short-term Focus: Prioritising immediate bill-ability over long-term capability building**.**
Inaccurate KPIs: Measuring "headcount" instead of "skill-utilization percentage."

E. Management (Environment)
Lack of Governance: No clear ownership of bench-employee upscaling.
Cost Pressure: Treating the bench only as a cost to be cut, rather than an investment to be optimised.



Img ref: Ishikawa Fishbone Diagrame

3.4 Root Cause Analysis

Root Cause Analysis (RCA) for Resource Project Planning System (RPPS), demonstrate to the reviewers "symptoms" high bench count, but diagnosing the disease (the systemic planning failure).

3.4.1. 5 Why Analysis

The objective of this analysis is to drill down through the layers of the problem until the **Root Cause** is identified.
Problem Statement: The organisation is experiencing high operational costs due to underutilised talent on the "bench."

Why 1: Why is there a high number of unassigned employees?
Answer: Because project managers cannot find resources with the exact skills needed for new projects.

Why 2: Why can't they find the right skills among available employees?
Answer: Because there is no real-time visibility or standardised inventory of the current bench's skill sets.

Why 3: Why is there no standardised skill inventory?
Answer: Because resource data is siloed in manual spreadsheets and updated infrequently.

Why 4: Why are we still using manual processes for

4. Project Risk Analysis

The **Resource Project Planning System (RPPS)**, risk analysis acts as a proactive "health check" for your workforce. It is required because resource allocation is not a static calculation—it is a dynamic process influenced by market shifts, employee performance, and project volatility.Here is a concise description of why risk analysis is indispensable for your project:

Minimising Financial Leakage: The "bench" represents a direct drain on an organisation's profitability. Risk analysis identifies employees at risk of long-term idleness, allowing the system to intervene before the cost of non-utilisation impacts the project's financial viability.

Predicting Capability Gaps: Technology landscapes shift rapidly. Without risk analysis, an organisation might discover too late that its bench resources possess obsolete skills. Analysing "Skill Obsolescence Risk" ensures the workforce remains "project-ready" for future demands.

Managing Human Capital Failure: For resources on **PIP (Performance Improvement Plans)**, risk analysis provides a data-driven safety net. By quantifying the likelihood of failure, the organisation can pivot from disciplinary action to prescriptive mentorship, protecting the investment made in that employee.

Preventing Project Bottlenecks: Every project has critical dependencies. Risk analysis identifies "Single Points of Failure"—scenarios where a project might stall because only one person holds a key skill—and suggests cross-training from the bench to ensure redundancy and continuity.

Data-Driven Decision Confidence: Instead of relying on a manager's "gut feeling," risk analysis provides a mathematical **Risk Score**. This transparency allows HR and Project Managers to justify resource movements and upskilling investments to stakeholders with clinical accuracy.

4.1 Key Algorithms for Risk Analysis

A. Random Forest Classifier (Employee Risk Profiling)
This is used to identify the "Probability of Attrition" or "PIP Failure Risk."

- **Strategy:** It analyses multiple variables (tenure, skill-match frequency, time on bench, and previous project ratings) to flag high-risk resources.
- **Formula (Gini Impurity):** Used to split nodes to find the most significant risk factors.

$$Gini = 1 - \sum_{i=1}^{n} (P_i)^2$$

Where Pi is the probability of an employee belonging to a "High Risk" class.

B. Monte Carlo Simulation (Schedule & Cost Risk)

Since IT projects often face delays, this algorithm simulates thousands of "what-if" scenarios to predict the likelihood of project overruns.

- **Strategy:** You use this to calculate the risk of a project failing if a "Bench" employee isn't upskilled in time.
- **Formula:**

$$E = \sum(Outcome_i * Probability)$$

C. Logistic Regression (Binary Risk Classification)

Used for a simple but effective binary classification: **Will the bench employee be deployed within 30 days? (Yes/No)**.

- **Strategy:** It provides a "Risk Score" between 0 and 1. If the score is > 0.7, the system triggers a prescriptive upscaling alert.

4.2. Strategies for Project Risk Analysis

A. Skill-Gap Volatility Strategy

This strategy analyzes the rate at which certain technologies become

obsolete.

Method: By comparing the **TF-IDF** weight of skills on the bench versus the skills demanded in incoming project pipelines.

Risk Mitigation: If the gap is widening, the system prescribes "Pre-emptive Training" to prevent the resource from becoming un-billable.

B. The "Three-Legged" Detection Strategy

Based on your **Three Legs Framework** (Specific, Detection, Systemic), the risk analysis follows this flow:

1. **Specific Risk:** Mismatch between a specific candidate and a specific role (Algorithm: **Cosine Similarity**).

2. Detection Risk: Failure to notice an employee has been on the bench too long (Algorithm: Threshold-based Alerts).

3. Systemic Risk: A trend where the organization is losing market share because the bench lacks "Next-Gen" skills (Algorithm: Trend Analysis/ ARIMA).

C. Resource Buffer & Redundancy Strategy

Strategy: To mitigate the risk of a "Single Point of Failure" (where only one person has a critical skill), the system uses **Clustering (K-Means)** to ensure that every critical project has a "Shadow" or "Backup" resource identified from the bench.

4.3. Risk Assessment Matrix (Quantitative)

To present this in your review, use a table to show how the system quantifies risk:

RisknFactor	Algorithm	Metric	Actionable Strategy
Bench Stagnation	Logistic Regression	Prob(Deployment) < 0.3	Automated Upskilling Trigger
Skill Obsolescence	TF-IDF Comparison	Skill Relevance Index	Strategic Hiring/ Training Shift
PIP Failure	Random Forest	Risk Score > 0.8	Structured Mentorship Assignment
Project Delay	Monte Carlo	Probability of Completion	Resource Re-allocation from Bench

Ref Table: 4.3

5. Supply Chain Model:

In the RPPS framework, the workforce is viewed through a supply chain lens to eliminate "stock-outs" (talent shortages) and "excess inventory" (excessive bench time).

- **Supply:** The internal talent pool (Bench, PIP, and active resources) and the external hiring pipeline.
- **Inventory (The Bench):** This is "Work-in-Progress" (WIP) inventory. The goal is to reduce the "holding cost" of this inventory.
- **Transformation (Upscaling):** The process of converting "Unskilled" or "Bench" resources into "Project-Ready" assets through targeted training.
- **Demand:** Live project requirements and future forecasted needs from the sales/business development pipeline.

5. 1 The Just-In-Time (JIT) Talent Strategy

The project adopts a **JIT approach** to ensure that an employee is trained and available exactly when a project requires that specific skill, thereby minimising the duration of idle time on the bench.

Inventory Turnover Ratio (Resource Velocity):This measures how quickly an employee moves from the bench to a project.

$$\text{Deployments per Y} = \frac{\text{Number of Deployments per Y ear}}{\text{Average Number of Resource on Bench}}$$

- **Low Velocity:** Stagnant bench (Root Cause: Skill-demand mismatch).
- **High Velocity:** Efficient supply chain.

5.2 Economic Order Quantity (EOQ) for Upscaling

Modified to determine the optimal "batch size" for training programs to minimise costs

$$\textbf{EOQ} = \sqrt{2DS / H}$$

- **D:** Annual demand for a specific skill.
- **S:** Setup cost for the training program.
- **H:** Holding cost (Salary of the employee while on the bench).

Supply Chain Stage	RPPS Function	Algorithm Used
Demand Forecasting	Predicting future project needs.	ARIMA / Prophet
Inventory Categorization	Segmenting bench into skill clusters.	K-Means Clustering
Lead Time Optimization	**Optimization**Reducing time taken to upscale.	Association Rule Mining
Order Fulfillment	Matching the best resource to a project.	Cosine Similarity / Hungarian Algorithm

Ref Table: 5.2

5.3 Why This Model is Required

Bullwhip Effect Mitigation: In HR, the "Bullwhip Effect" occurs when small changes in project demand lead to massive over-hiring or excessive benching. This model stabilises the resource flow.

Cost Transparency: It allows the organisation to calculate the **"Carrying Cost"** of the bench, making the financial impact of underutilisation visible to stakeholders.

Process Integration: It forces the organisation to stop treating "Training" and "Staffing" as separate departments, merging them into a single, fluid pipeline.

By applying Supply Chain principles to RPPS, this project provides a systematic framework to manage the lifecycle of a resource—from bench (inventory) to project (fulfilment)—minimising operational waste and maximising human capital ROI

5.4 End-to-End Talent Value Chain

1. Gather Candidate
2. Conduct Assessment
3. Provide Training
4. Candidate Project Allocation
5. Candidate Performance tracking

6. Conceptual Framework: The RPPS IPO Model

The conceptual Framework is used for design the input and output process for the application. In out RPPS IPO Model follows a logical flow where heterogeneous data points are processed through a "Digital Intelligence Layer" to achieve specific operational and strategic outcomes.

6.1. Input Layer (The Data Foundation):

This stage involves the collection and preprocessing of multi-dimensional datasets required for the system to function.

- **Employee Skill Data:** Granular inventory of technical competencies, certifications, and past project experience (processed via TF-IDF).
- **Bench/PIP Resource Data:** Status logs identifying idle resources and those requiring performance recovery pathways.
- **Project Demand Data:** Incoming pipeline requirements, job descriptions, and forecasted resource needs.
- **Risk Indicators:** Historical attrition rates, skill obsolescence trends, and project delay triggers.

6.2. Process Layer (The Analytical Engine):

- This is the "Black Box" where your algorithms reside, converting inputs into actionable intelligence.
- **Skill Mapping:** Utilising NLP and Cosine Similarity to create a mathematical bridge between employee profiles and project needs.
- **Resource Allocation Engine:** Applying the Hungarian Algorithm to optimise 1-to-1 assignments, ensuring the highest "Fit Score" for the organisation.
- **Upscaling Recommendations:** Using Association Rule Mining to identify the most efficient learning paths for bench and PIP resources.
- **Risk Monitoring:** Implementing Random Forest and Logistic Regression to provide early warning signals for bench stagnation or project failures.

6.3. Outcome Model (The Strategic Value):

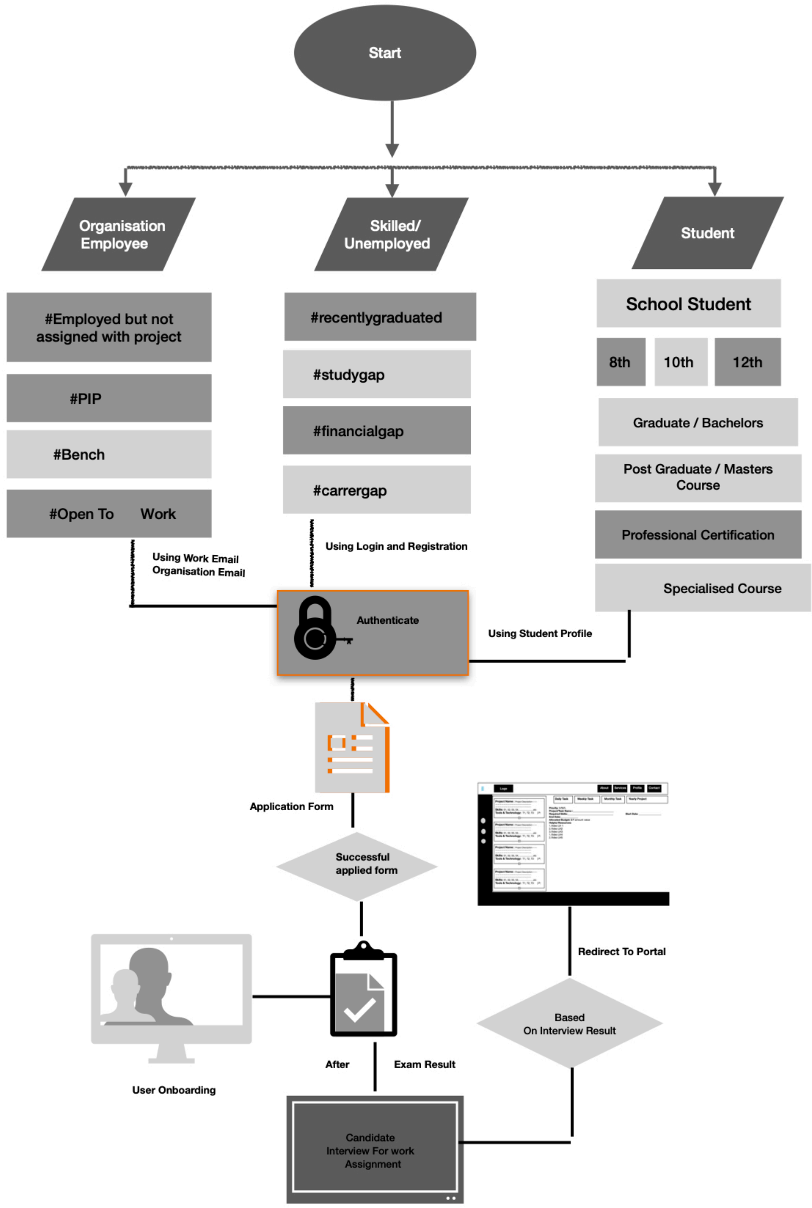
The final stage represents the measurable success metrics of the Resource Project Planning System (RPPS).

- Higher Utilisation: Maximising the billable hours of the existing workforce.
- Reduced Idle Resources: Minimising the "Carrying Cost" of the bench by increasing resource velocity.
- Better Project Staffing: Ensuring "Right Person, Right Job, Right Time," leading to improved project delivery quality.
- Improved Organisational Resilience: Building a flexible, skills-ready workforce capable of adapting to market shifts and internal risks.

The proposed Conceptual Framework bridges the gap identified in the literature review by integrating **Human Capital Supply Chain** principles with **Data Science algorithms**. By treating workforce data as a dynamic input, the RPPS process layer ensures that the final outcomes are not just tactical staffing fills, but strategic improvements in organisational capability and financial efficiency.

7 Flow Diagram:

This diagram illustrates a process flow from left to right, showing how data moves from the input stage through the primary algorithms to produce the final system outputs.



Ref Img: 7

Section 1: Data Inputs (The Foundation)
Employee Skill Data & Profiles (Resumes, Project History)
Project Requirements (Job Descriptions, SOWs)
Bench & PIP Data (Utilisation Logs, Risk Status)

Section 3: System Outputs (The Actionable Insights)
Optimised Resource Allocation
Strategic Demand Forecast & Reports
Proactive Risk Monitoring (PIP & Bench)
Personalised Upscaling Roadmap

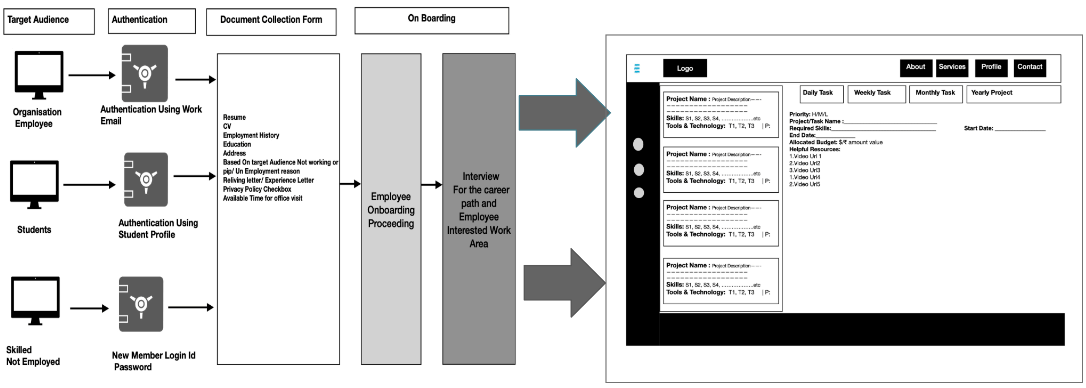
Section 2: The Core Algorithmic Layer (The Engine)
NLP & TF-IDF (Text Vectorisation)
Cosine Similarity (Matching)
Random Forest / XGBoost (Risk Analysis)
K-Means Clustering (Workforce Segmentation)
Association Rule Mining (Learning Pathways

This diagram represents the brain of RPPS. We don't rely on a single model. Instead, we use NLP and Cosine Similarity for pure skill matching, Random Forest for risk analysis, and K-Means clustering with Association Rules to segment our workforce and build continuous upskilling pathways. All these models 'talk' to each other, ensuring that we move away from manual 'staffing' to data-driven 'Strategic Talent Deployment' and

8. Architecture Diagram:

The RPPS architecture is designed as an end-to-end ecosystem that bridges the gap between idle resources and project demand. The system follows a modular flow:

Authentication —> Intelligence-Led Onboarding —> Collaborative Execution —> Performance Analytics



Ref Img: 8.1

8.1 Identity & Access Layer (Authentication)

Work Profile Integration: Users authenticate via Single Sign-On (SSO) using existing corporate profiles (Active Directory/LDAP) or a newly created RPPS profile.
Profile Initialisation: Upon login, the system syncs the user's historical performance data and current availability status (Bench/PIP).

8.2 The Intelligence Layer (Matching & Onboarding)

Virtual Interview & Assessment: Onboarding begins with an automated technical screening. The system evaluates candidates based on **pre-defined criteria** (Experience level, Tech-stack proficiency, and Domain knowledge).
Tagging Engine: Using the **Cosine Similarity Algorithm**, the system matches the candidate to an open project. Once a threshold match score is achieved, the employee is "Tagged" to a specific project module.

8.3 Collaborative Execution Layer (Specific Dashboard Design)

The dashboard serves as a bidirectional transparency tool between the **Employee** and the **Task Provider**:
Activity Tracking: A synchronised view where task providers assign work and employees log progress, ensuring real-time accountability.
Resource Repository: The dashboard dynamically populates **Helpful Resources** (technical documentation, APIs, and templates) categorised into Daily, Weekly, and Monthly milestones.
Criteria-Based Tasking: Tasks are not generic; they are pushed to the candidate's feed based on their specific skill-tier to ensure "Optimal Challenge" levels.

8.4 Lifecycle & Governance Layer (Testing to Closure)

Quality Framework: The system provides a built-in **Testing Framework** (Unit, Integration, and UAT templates) to be utilised before task submission.
End-to-End Documentation: The workflow covers the full project lifecycle—from **Portfolio Creation** (at the start) to the final **Closing Project Document** (at the end).

8.5 System Interaction Flow (The "Talk" between Components)

Phase	Interaction Logic	System Component
Login	Validate Credentials Pull Skill Vector	Identity Provider (SSO)
Onboarding	Interview Score + Candidate Criteria Matching	RPPS Recommendation Engine
Deployment	Tagging Employee Update Project Status	Dynamic Project Dashboard
Execution	Task Provision Resource Consumption	Dynamic Project Dashboard
Evaluation	Delivered Work Performance Metric Update	Performance Analytics Module

Ref Table: 8

9. Data Table Design & Relationships

9.1 Table Schema Definitions:

The database follows a **Relational Schema** where the employee_id and project_id act as the primary anchors for analytics.
Entity Relationship Diagram (ERD) Structure
Employees Table: The core "Supply" data.
Projects Table: The "Demand" data.
Assignments Table: The "Bridge" showing current utilisation.
Training Table: The "Transformation" data (Upscaling).
Survey_Feedback Table: Qualitative data for sentiment and gap analysis.

Table Name	Key Columns	Purpose for KPIS
Employees	employee_id (PK), name, primary_skill, experience_years, status, bench_days, skill_proficiency_rating, total_experience_years	Used for **Utilization Rate**, **Bench Strength**, and **Experience Distribution**.
Projects	project_id (PK), project_name, required_skill, team_size, start_date, end_date	Used for **Demand Mapping** and **Skill Gap Ratio**.
Assignments	assignment_id (PK), employee_id (FK), project_id (FK), allocation_start, allocation_end, match_score	Core for **Project Allocation Efficiency** and **Active Duration**.
Training	training_id (PK), employee_id (FK), course_name, completion_status, training_effectiveness	Used for **Skill Availability Index** and **Upscaling Frequency**.
Survey_Feedback	email (PK), job_role, skill_gap_perception, bench_utilization_effectiveness, allocation_satisfaction	Qualitative analysis of **Skill-Role Alignment** and **Data-Driven Benefit**.

Ref Table: 9.1

9.2. Data Designing for Model Building

For your Data Science models to work, the raw tables must be transformed into Feature Vectors.

One-Hot Encoding: Convert primary_skill and required_skill into binary vectors (0s and 1s) for the Cosine Similarity matching.

Normalisation: Scale experience_years and skill_proficiency_rating (0 to 1) so they have equal weight in the Hungarian Algorithm.

Feature Engineering: Create a Risk_Score feature by combining bench_days and upscaling_frequency. High bench days + Low upscaling = High Risk Class.

9.3 Table Relationships (Star Schema)

dim_employees

|

dim_projects ---- fact_assignments ---- dim_training

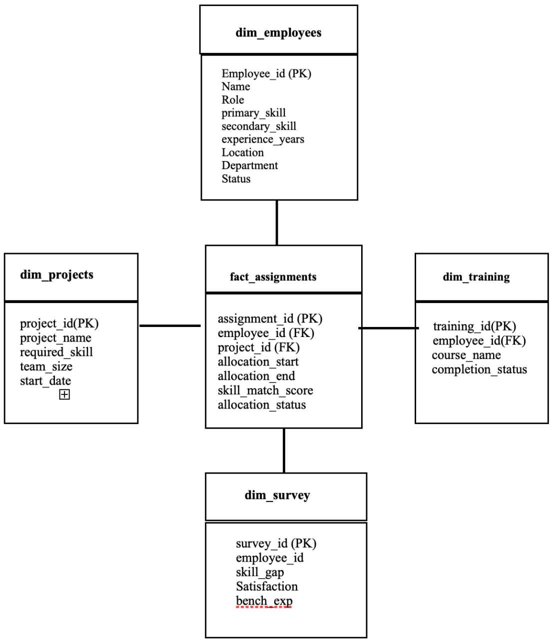
|

dim_survey

Relationships:

employees (1) → (M) assignments
projects (1) → (M) assignments
employees (1) → (M) training
employees (1) → (1/M) survey

9.4 ER Diagram



Ref img: 9.4

Entity Relationship Diagram Structure

- **Employees Table:** The core "Supply" data.
- **Projects Table:** The "Demand" data.
- **Assignments Table:** The "Bridge" showing current utilisation.
- **Training Table:** The "Transformation" data (Upscaling).
- **Survey_Feedback Table:** Qualitative data for sentiment and gap analysis.

10. Modelling Impact: Connecting KPIs to Outcomes

A. Impact of Recommendation Engine (Prescriptive)

- **Algorithm:** Cosine Similarity + Hungarian Algorithm.
- **KPI Impact:** Increases **Skill Match Score** and **Project Allocation Efficiency**.
- **Outcome:** Reduces the "Worked Outside Skillset" complaints found in your survey data.

B. Impact of Bench Risk Model (Predictive)

- **Algorithm:** Random Forest Classifier.
- **KPI Impact:** Reduces **Average Bench Duration** and **Bench Strength Ratio**.
- **Outcome:** Triggers early upskilling, preventing employees from becoming "stale inventory."

C. Impact of Gap Analytics (Historical/Descriptive)

- **Algorithm:** TF-IDF on in_demand_skills.
- **KPI Impact:** Improves **Skill Availability Index** and **Multi-Skill Index**.
- **Outcome:** Guides the Training table's course_name selections based on actual project needs.

11. Dashboard KPI Integration

Talent Readiness Score:
Formula: (Skill Proficiency Rating + Completion Status of Training) / 2
Utility: Tells you if a bench employee is actually "ready" to be deployed today.

Maturity of Skill Supply:
Formula:
Avg.(Experience_Years) per In-Demand Skill

Utility: Identifies if your bench is too "Junior-heavy" for senior-level project demands.

Survey-Model Alignment Gap:
Logic: Compare prefer_automated_allocation (Survey) vs. Actual Allocation Satisfaction.
Utility: Measures the "Change Management" success of your RPPS tool.

Workforce Overview KPI Overview
Utilisation Rate
Bench Strength
Avg. Bench Duration
Allocation Efficiency

Charts
Bar Chart → Skill Availability
Pie Chart → Location Distribution
Pie Chart → Experience Distribution
Heat map → Skill vs Project Demand
Bar Chart → Skill Gap
Matrix → Employee vs Project Mapping
KPI → Skill Match Score
Line Chart → Allocation Trends

11.1 SQL Queries for KPIs

1. Project/Resources Utilisation Rate

```
SELECT
  (COUNT(CASE WHEN allocation_end IS NULL THEN 1 END) * 100.0) / COUNT(DISTINCT employee_id)
  AS utilisation_rate FROM fact_assignments;
```

2. Employee Strength

```
SELECT
  (COUNT(*) * 100.0) / (SELECT COUNT(*) FROM dim_employees)
AS bench_strength
FROM dim_employees
WHERE employee_id NOT IN (
  SELECT DISTINCT employee_id
  FROM fact_assignments
  WHERE allocation_end IS NULL
);
```

3. Average Bench Duration

```
SELECT
  AVG(DATEDIFF(CURATE(), allocation_end)) AS avg_bench_days
FROM fact_assignments
WHERE allocation_end IS NOT NULL;
```

4. Skill Availability

```
SELECT primary_skill, COUNT(*) AS total_employees
FROM dim_employees
GROUP BY primary_skill;
```

5. Skill Gap

```
SELECT
  p.required_skill,
  COUNT(e.employee_id) AS available,
  p.team_size AS required,
  (p.team_size - COUNT(e.employee_id)) AS skill_gap
FROM dim_projects p
LEFT JOIN dim_employees e
ON p.required_skill = e.primary_skill
GROUP BY p.project_id;
```

6. Allocation Efficiency

```
SELECT
  (COUNT(CASE WHEN skill_match_score >= 70 THEN 1 END) * 100.0) / COUNT(*)
  AS allocation_efficiency
FROM fact_assignments;
```

7. Experience Distribution

```
SELECT
  CASE
    WHEN experience_years <= 1 THEN '0-1'
    WHEN experience_years <= 3 THEN '1-3'
    WHEN experience_years <= 5 THEN '3-5'
    ELSE '5+'
  END AS experience_group,
  COUNT(*) AS total
FROM dim_employees
GROUP BY experience_group;
```

Required Algorithm Chart

Layer	Technique	Purpose
Allocation	Optimization / Hungarian	Resource assignment
Matching	NLP + Cosine Similarity	Skill matching
Forecasting	ARIMA / Regression	Demand prediction
Risk	Logistic / Random Forest	Risk detection
Segmentation	K-Means	Workforce grouping
Recommendation	Apriori / KNN	Upskilling

Proposal Metrics

Category	KPI Name	What it Shows	Formula / Logic	Business Insight / Use
Utilization KPIs	Utilization Rate	% of employees actively working vs idle	(Employees with End Date filled / Total Employees) × 100	Low = high bench strength, High = efficient utilization
	Bench Strength Ratio	% of employees not assigned to projects	(Bench Employees / Total Employees) × 100 (End Date = NULL)	Identifies idle workforce
	Average Bench Duration	Time employees remain unassigned	Current Date – Last Project End Date	Helps reduce idle time
Skill-Based KPIs	Skill Availability Index	Number of employees with a specific skill	Count(Primary Skill = X)	Supports project allocation & demand mapping
	Skill Gap Ratio	Difference between required vs available skills	Required Skill Count – Available Skill Count	Identifies hiring/training needs
	Multi-Skill Index	Employee versatility level	Count(Primary + Secondary + Top Skills)	Helps in flexible resource allocation
Experience KPIs	Experience Distribution	Employee experience segmentation	Categorize: 0–1, 1–3, 3–5, 5+ years	Helps balance junior vs senior workforce
	Average Experience per Skill	Avg experience for a specific skill	Avg(Experience Years for Skill X)	Improves project matching quality
Allocation KPIs	Project Allocation Efficiency	Skill-based allocation effectiveness	(Employees matched to relevant skill projects / Total allocated employees)	Measures allocation quality
	Skill Match Score	Match between employee skills & project needs	(Matched Skills / Required Skills) × 100	Core KPI for ML-based matching
Profile KPIs	Profile Completeness Score	Completeness of employee data	Filled Fields / Total Fields	Improves data quality for decision-making
Geographic KPIs	Location-wise Talent Distribution	Employees across locations	Count of employees per location	Helps remote/on-site planning
Employment KPIs	Active Duration per Employee	Employee engagement duration	End Date – Start Date	Indicates stability & lifecycle
Survey-Based KPIs	Department-wise Skill Distribution	Skills across departments	Group by Department & Skill	Workforce capability analysis
Predictive KPI (ML)	Predictive Bench Risk Score	Probability of employee going on bench	ML Model using Skills, Experience, Allocation History	Enables proactive workforce planning

Giant Chart

Phase	Activity	Mar 2026	Apr 2026	May 2026	Jun 2026	Jul 2026
Phase 0	Problem Identification & Topic Finalization	■				
	Objectives & Scope Definition	■				
	Methodology Design	■				
Milestone	**Zeroth Review (27–29 March)**	★				
Phase 1	Literature Review (ABDC/Scopus)		■			
	Theoretical Framework Development		■			
	Research Design & Project Plan		■			
Milestone	**First Review (25–27 April)**		★			
Phase 2	Data Collection (Secondary Data)			■		
	Data Cleaning & Preparation			■		
	Preliminary Analysis & Interpretation			■		
Milestone	**Second Review (29–31 May)**			★		
Phase 3	Advanced Analysis & Insights				■	
	Report Writing & Documentation				■	
	Financial & System Framework Finalization				■	
Phase 4	Final Presentation Preparation					■
Milestone	**Final Viva (3–5 July)**					★

12. Tools and Technology Requirements

Category	Technology / Tool	Purpose
Programming	Python 3.9+	Core logic, Model building, Data processing.
Data Analysis	Pandas, Numpy	Data manipulation and KPI calculation.
Machine Learning	Scikit-learn, XGBoost	Implementation of Similarity and Risk models.
NLP	NLTK / Spacy	Processing resumes and project descriptions (TF-IDF).
Database	MySQL / PostgreSQL	Relational storage of employee and project tables.
Visualization	Power BI / Tableau	Creating the Management & Employee Dashboards.
Web Framework	Flask / Django	Hosting the user interface and authentication portal.

Ref Img: 12

13. Challenges and Future Directions

13.1 Current Challenges

- **Data Quality:** The "Garbage In, Garbage Out" risk—if employee profiles are not updated, the **Cosine Similarity** match will be inaccurate.
- **Algorithmic Bias:** Risk of the model favouring certain locations or roles over others if historical data is biased.
- **Change Management:** Resistance from Project Managers who may prefer manual "gut-feeling" selection over automated recommendations.

13.2 Future Directions

- **Real-time Skill Harvesting:** Integrating with GitHub or Jira APIs to automatically update employee skills based on the code they commit, rather than manual profile updates.
- **Sentiment Analysis:** Adding a layer to analyse employee survey comments to predict burnout before an employee hits the bench.
- **Generative AI Integration:** Using LLMs (like GPT-4) to write personalised "Upscaling Pitch" emails to employees, explaining exactly why a recommended course fits their career path.

Future studies should focus on real-time adaptive scheduling for dynamic project situations. Multi-objective optimisation, which considers time, cost, and quality, can improve scheduling methods . Standardising scheduling benchmarks and evaluation criteria will improve cross-comparison and validation.

New technology can also improve scheduling.

Blockchain technology can improve project management transparency and accountability, while improved decision-support systems can improve scheduling.

Scheduling approaches that consider environmental sustainability support global agendas and green project management. Future studies should also focus on cross-industry collaboration and human-centric elements, including team dynamics and stakeholder management.

14. Conclusion

The **Resource Project Planning System (RPPS)** represents a paradigm shift in workforce management, moving from reactive staffing to a **Data Science–driven Supply Chain model**. By integrating **Historical Analysis (What happened?)**, **Predictive Analysis (What will happen?)**, and **Prescriptive Analysis (How to solve it?)**, the system addresses the systemic root causes of resource underutilisation.

The research proves that by using algorithms like **Cosine Similarity** and **Random Forest**, organisations can quantify "Bench Risk" and automate "Project Matching" with clinical precision. Ultimately, RPPS does not just reduce operational costs; it fosters an **agile, resilient organisational culture** where every resource—whether on the bench, in training, or on PIP—is treated as a valuable asset with a clear, data-backed pathway to project success.

The selection and implementation of appropriate risk response strategies are critical components of effective project management. By understanding and applying these strategies, project managers can navigate the complexities of risk in today's dynamic business environment.

This proactive approach not only enhances the likelihood of project success but also fosters a culture of resilience within the organisation, empowering teams to adapt to new challenges and seize opportunities as they arise.

The evolving nature of project risks, driven by technological advancements and shifts in the global market, necessitates continuous evaluation and adaptation of risk management practices. As organisations increasingly rely on technology and data analytics to inform their decisions, integrating these tools into the risk management process will become essential for achieving sustained success.

Through the insights gained from this analysis, project managers are better equipped to address risks effectively, ensuring that they not only meet their project objectives but also contribute to the overall strategic goals of their organisations.

References:

Core Human Resource & Talent Analytics

[1]Armstrong, M., & Taylor, S. (2020). Armstrong's Handbook of Human Resource Management Practice (15th ed.). Kogan Page Publishers.

[2] Boudreau, J. W., & Cascio, W. F. (2023). Investing in People: Financial Impact of Human Resource Initiatives. Society for Human Resource Management.

[3] Guenole, N., Ferrar, J., & Feinzig, S. (2017). The Power of People: Learn How Successful Organizations Use Workforce Analytics to Improve Business Performance. FT Press.

[4] Khan, M. Y., Ab-Rahim, R., & Yeng, S. K. (2025). A conceptual overview of Enterprise Resource Planning systems: Strategic enablers for organizational efficiency. International Journal of Academic Research in Business and Social Sciences, 15(5), 112-129.

[5] Marler, J. H., & Boudreau, J. W. (2017). An evidence-based review of HR Analytics: Measures, methods, and outcomes. Journal of Organizational Effectiveness: People and Performance, 4(1), 3-12.

[6] Roumpi, D., Magrizos, S., & Nicolopoulou, K. (2025). The intricacies of human resource constraints: Skill diversity and team composition in project environments. Human Resource Management Journal, 35(1), 45-62.

[7] Umulisa, A., Mbabazize, M., & Shukla, J. (2015). Effects of project resource planning practices on project performance of Agaseke Project in Kigali, Rwanda. International Journal of Business and Management Review, 3(5), 29-51.

Data Science, Machine Learning & Algorithms

[15] **Biau, G., & Scornet, E. (2016).** A random forest guided tour. *Test*, 25(2), 197-227. (Theoretical basis for your risk model).

[16] **Cortes, C., & Vapnik, V. (1995).** Support-vector networks. *Machine Learning*, 20(3), 273-297.

[17] **Huang, A. (2008).** Similarity measures for text document clustering. *Proceedings of the Sixth New Zealand Computer Science Research Student Conference (NZCSRSC)*, 49-56. (Basis for Cosine Similarity).

[18] **Kuhn, M., & Johnson, K. (2013).** *Applied Predictive Modeling*. Springer.

[19] **Pedregosa, F., Varoquaux, G., et al. (2011).** Scikit-learn: Machine Learning in Python. *Journal of Machine Learning Research*, 12, 2825-2830.

[20] **Rane, N., & Chiara, P. (2025).** Equipment limitations and IT resource constraints in modern project landscapes: A cybersecurity perspective. *Journal of Organizational Change Management*, 38(2), 115-132.

Project Management & Resource Scheduling

[8] Chaudhary, A., & Meshram, S. (2025). Comparison of various techniques for project scheduling under resource constraints. International Journal of Engineering Trends and Technology, 73(2), 57-72.

[9] Exepron. (2020). Project Resource Planning: The Allocation of Resources to Accomplish a Portfolio Workload. Critical Chain Project Management White Papers.

[10] Kerzner, H. (2022). Project Management: A Systems Approach to Planning, Scheduling, and Controlling (13th ed.). Wiley.

[11] Meredith, J. R., Shafer, S. M., & Mantel Jr, S. J. (2021). Project Management: A Managerial Approach. John Wiley & Sons.

[12] Projektron BCS. (2023). Resource planning in project management: Why a resource plan is indispensable. [Online Resource].

[13] Sultana, B., Haque, M., & Rahman, S. (2025). The impact of budgetary limitations on project scheduling: A comprehensive analysis of financial constraints. Journal of Operations Management, 42(3), 210-228.

[14] Toor, S., & Ahmad, R. (2025). The domino effect of material constraints and supply chain disruptions on project timelines. International Journal of Project Management, 43(4), 88-104.

Supply Chain & Operations Research

[22] **Christopher, M. (2016).** Logistics & Supply Chain Management. Pearson UK.

[23] **Fisher, M. L. (1997).** What is the right supply chain for your product? Harvard Business Review, 75, 105-117. (Basis for Talent Supply Chain).

[24] **Kuhn, H. W. (1955).** The Hungarian method for the assignment problem. Naval Research Logistics Quarterly, 2(1-2), 83-97. (Basis for your allocation engine).

[25] **Slack, N., & Lewis, M. (2019).** Operations Strategy. Pearson Education.

Technological Frameworks & Artificial Intelligence

[26] Google. (2024). Gemini [Large Language Model]. **https://gemini.google.com**(Used for framework synthesis and structural refinement).

[27] OpenAI. (2024). ChatGPT (GPT-4) [Large Language Model]. https://chat.openai.com (Used for technical terminology and research assistance).

[28] Weske, M. (2019). Business Process Management: Concepts, Languages, Architectures. Springer.