1	**Name of Course**	**Professional Diploma in Software Technology In Railway Sector**
2	**Max no.of Students**	30
3	**Duration**	1 Year
4	**Course Type**	Full Time
5	**No. of Days per week**	6 days
6	**No. of hours per day**	6 Hrs
7	**Space require**	66 m^2 classroom and 66 m^2 Laboratory
8	**Entry qualification**	Diploma Computer Science & Engineering / FE- Computer Science & Engineering, Computer Technology, Software Engineering, Information Technology, Computer Engineering, Bachelor of Computer Application, Bachelor of Computer Science
9	**Objective of syllabus**	To Learn Software Technologies that help Railway Industry to enhance their networks, strengthen security and Information System
10	**Employment opportunities**	Student will get jobs in Government as well as Private railway companies
11	**Teachers Qualification**	ME/ M.Tech/Ph.D
12	**Teaching Scheme :**	

Sr. No	Subject	Subject Code	Theory(Hr)	Credit	Practical(Hr)	Credit	Total
1	Railway IT Systems & Enterprise Software	RCSPCC-01	60	4	90	3	**7**
2	Cyber security for Railway Digital Infrastructure	RCSPCC-02	45	3	90	3	**6**
3	IoT, Embedded Systems & Predictive Maintenance	RCSMDM-03	45	3	90	3	**6**
4	Simulation, Digital Twin & Cloud Computing for Railways	RCSPP-04	45	3	90	3	**6**
5	Data Science, AI & Computer Vision for Railways	RCSSEC-05	45	3	90	3	**6**
6	Capstone Project (Industry-Oriented)	RCSCC-06	-	-	390	13	**13**
		Total	**240**	**16**	**840**	**28**	**44**

3 **Examination Scheme – Final Examination will be based on a syllabus of One year.**

Sr. No	Subject	Subject Code	Theory				Practical			Total	
			Duration (Hr.)	Max	Min	Int	Duration (Hr.)	Max	Min	Min	Max
1	Railway IT Systems & Enterprise Software	RCSPCC-01	3	80	32	20	-	-	-	40	100
2	Cyber security for Railway Digital Infrastructure	RCSPCC-02	3	80	32	20	-	-	-	40	100
3	IoT, Embedded Systems & Predictive Maintenance	RCSMDM-03	3	80	32	20	-	-	-	40	100
4	Simulation, Digital Twin & Cloud Computing for Railways	RCSPP-04	-	-	-		3	100	40	40	100
5	Data Science, AI & Computer Vision for Railways	RCSSEC-05	-	-	-		3	100	40	40	100
6	Capstone Project (Industry-Oriented)	RCSCC-06	-	-	-		-	100	40	40	100
Total											600

Note: For Paper I,II,III

Internal Examinations of Total Marks: 20

Pattern / Examination nature may be as follows (Any Two of Following): Written test/ Seminar/ PPT Presentation/ Open book examination / Field Work report / Project Report etc.

RCSPCC-01: Railway IT Systems & Enterprise Software

Duration: 60 hrs Theory + 90 hrs Practical

Course Objectives

By the end of this course, students will be able to:

1. Understand railway operations and IT system requirements for passenger, freight, and infrastructure management.
2. Analyze and design ticketing and reservation systems used in Indian Railways and global rail networks.
3. Apply ERP and asset management software concepts used in the railway industry.
4. Integrate multiple railway data sources into unified enterprise platforms.
5. Develop and test APIs and web services for real-time railway information sharing.

Course Outcomes

After completing this course, the learner will be able to:

CO1: Explain railway operational workflows in the context of IT systems.

CO2: Design and implement databases for railway ticketing and operations.

CO3: Develop REST-based services for railway data exchange.

CO4: Demonstrate ERP dashboards for railway asset and maintenance management.

CO5: Integrate enterprise-level applications for improved railway efficiency.

Module	Module Title & Topics	Hours
Module 1	**Introduction to Railway Systems & Digital Transformation** - Overview of passenger, freight, and infrastructure operations - Organizational structure of Indian Railways & global operators - Digital transformation in railways	**7**
Module 2	**Railway IT Infrastructure & System Requirements** - IT architecture in railway operations - Control centers, station IT systems, rolling stock IT systems - Safety, reliability, and scalability requirements	**7**
Module 3	**Ticketing & Reservation Systems – Fundamentals** - Components of ticketing systems (frontend, backend, databases) - Payment gateways and security - PNR generation logic	**8**

Module 4	**Advanced Ticketing Systems & Global Practices** - IRCTC system architecture - Global solutions: Amadeus Rail, Trainline APIs - High-availability and load-handling mechanisms	**7**
Module 5	**ERP Systems in Railway Operations** - Role of ERP in railways - SAP Railway and Transportation modules - Integration of finance, HR, operations	**7**
Module 6	**Railway Asset & Maintenance Management Systems** - Asset lifecycle management - IBM Maximo for rolling stock & infrastructure - Predictive and preventive maintenance	**8**
Module 7	**Railway Data Integration & Analytics** - Data from rolling stock, stations, and control centers - Middleware and interoperability - Data warehouses and analytics for decision-making	**8**
Module 8	**APIs & Real-Time Railway Information Systems** - REST & SOAP APIs - JSON/XML formats - Real-time train status systems - Security, authentication (OAuth, API keys) - Case study: NTES API	8

Practical List

1. **Study of Railway Operations Workflow**
   – Passenger, freight, and infrastructure operations using process diagrams.
2. **Case Study Analysis of Digital Initiatives in Indian Railways**
   – e-ticketing, NTES, freight operations information system (FOIS).
3. **Design of IT Architecture for a Railway Station**
   – Network layout, servers, databases, control systems.
4. **Requirement Analysis Document (RAD) for Railway IT System**
   – Functional and non-functional requirements (safety, reliability, scalability).
5. **Database Fundamentals for Railway Applications**
   – ER diagram and schema design.
6. **Create Relational Database for Ticketing System**
   – Tables for trains, schedules, coaches, passengers, bookings, payments.
7. **SQL Queries for Reservation Operations**

– Seat availability, fare calculation, PNR status queries.

8. **Study of IRCTC System Architecture**
   – Presentation on system layers, load balancing, security.
9. **Simulation of Ticket Booking Algorithm**
   – Seat allocation and wait-list logic.
10. **Comparative Study of Global Railway Ticketing APIs**
    – Amadeus Rail vs Trainline (features and data flow).
11. **Study of ERP Modules Used in Railways**
    – Finance, HR, Operations, Maintenance (SAP overview).
12. **Design ERP Data Flow Diagram for Railway Operations**
    – Integration between departments.
13. **ERP Transaction Simulation**
    – Asset procurement, work order creation, and approval flow.
14. **Asset Register Creation for Rolling Stock & Infrastructure**
    – Locomotives, coaches, tracks, signaling assets.
15. **Maintenance Scheduling Exercise**
    – Preventive and predictive maintenance planning.
16. **Mini Project on Asset Lifecycle Management**
    – Using IBM Maximo concepts or spreadsheet simulation.
17. **Data Integration Exercise**
    – Merge datasets from trains, stations, and control centers.
18. **Railway Operations Dashboard Development**
    – KPIs like punctuality, asset utilization, failures (Power BI / Tableau).
19. **Development of REST API for Train Status**
    – Using Python Flask / Node.js with JSON responses.
20. **Web Application for Real-Time Train Information**
    – Integrating train status API with authentication and basic UI.

Teaching & Learning Methodology

- Lectures with case studies of Indian Railways and global railway systems
- Live demonstrations of ticketing and ERP software
- Hands-on lab sessions for databases, APIs, and dashboards
- Group assignments and mini-projects on railway IT solutions

Reference Books & Resources

Books:

- *Enterprise Resource Planning* – Alexis Leon, McGraw Hill
- *Database System Concepts* – Silberschatz, Korth & Sudarshan, McGraw Hill
- *RESTful Web APIs* – Richardson, Amundsen, Ruby, O'Reilly
- *Railway Transportation Systems* – Christos N. Pyrgidis, CRC Press

Online Resources:

- IRCTC Official Documentation & Press Releases
- NTES API Documentation – Indian Railways

- SAP Transportation Management – SAP Learning Hub
- IBM Maximo Asset Management Documentation
- Amadeus Rail API – Developer Portal
- OpenRailwayMap & RailData.org

RCSPCC-02: Cyber security for Railway Digital Infrastructure

Duration: 45 hrs Theory + 90 hrs Practical

Course Objectives

By the end of this course, students will be able to:

1. Understand cybersecurity threats and vulnerabilities specific to railway IT and operational technology (OT) systems.
2. Implement security measures for SCADA, signaling, and control networks.
3. Apply encryption and authentication protocols for IoT-enabled railway devices.
4. Interpret and apply global cybersecurity standards in railway contexts (IEC 62443, NIST).
5. Develop and test incident response procedures for railway digital systems.

Course Outcomes (COs)

After completing this course, the learner will be able to:

CO1: Identify potential cyber threats to passenger ticketing systems, signaling, and control infrastructure.

CO2: Implement secure configurations for SCADA and railway signaling networks.

CO3: Apply encryption, authentication, and secure communication methods for IoT-based railway systems.

CO4: Evaluate and comply with railway-relevant cybersecurity standards.

CO5: Plan and execute a basic incident response process for cyber incidents in railways.

Module	Module Title & Topics	Hours
Module 1	**Railway Digital Infrastructure & Cyber Threat Landscape** • Railway IT & OT systems: ticketing, SCADA, signaling, IoT • Threat types: fraud, ransomware, APTs, GPS spoofing • Case studies of cyber incidents in global railways	**7**
Module 2	**Cyber Attacks & Vulnerability Assessment in Railways** • Attack vectors in railway networks • Vulnerability scanning and risk assessment • Threat modeling for railway systems	**7**

Module 3	**Securing SCADA & Signaling Networks** • SCADA architecture in railways • Network segmentation & secure protocols • IDS/IPS for control systems • Redundancy and failover	**8**
Module 4	**IoT Security, Encryption & Authentication** • PKI for railway IoT • Symmetric & asymmetric encryption • Device authentication methods • Secure firmware & patch management	**8**
Module 5	**Cybersecurity Standards & Compliance for Railways** • IEC 62443 for ICS • NIST Cybersecurity Framework • ISO/IEC 27001 • Indian Railways, RDSO & CERT-In guidelines	**7**
Module 6	**Incident Response, Forensics & Recovery in Railways** • Incident detection & classification • Response planning & containment • Digital forensics basics • Recovery, reporting & post-incident review	**8**

Practical List

1. **Study of Railway IT & OT Cyber Infrastructure**

– Study railway IT and OT system architecture and identify critical cyber assets.

2. **Identification of Cyber Threats in Railway Systems**

– Identify and classify cyber threats affecting railway IT and control systems.

3. **Case Study Analysis of Railway Cyber Incidents**

– Analyze real railway cyber incidents to understand attack vectors and impacts.

4. **Cyber Attack Simulation on Ticketing Systems (Conceptual)**

– Simulate common cyber-attacks on a mock railway ticketing system.

5. **Vulnerability Assessment of Railway Network Setup**

– Perform vulnerability assessment on a simulated railway network.

6. **Threat Modeling for Railway Digital Systems**

– Develop threat models for railway digital infrastructure and define mitigation strategies.

7. **SCADA Network Architecture Design for Railways**

– Design secure SCADA network architecture for railway signaling systems.

8. **Network Hardening for SCADA Systems (Firewall & Segmentation)**

– Implement firewall rules and network segmentation for SCADA security.

9. **Configuration of Secure Protocols for Control Networks**

– Configure secure communication protocols for railway control networks.

10. **IDS/IPS Configuration for Railway Control Systems**

– Configure IDS/IPS to monitor and protect railway control networks.

11. **Implementation of Encryption Techniques for Railway IoT**

– Implement encryption methods for secure railway IoT communication.

12. **Device Authentication & Secure Communication for IoT Devices**

– Implement device authentication and secure communication for railway IoT devices.

13. **Secure Firmware Update & Patch Management Simulation**

– Simulate secure firmware updates and patch management processes.

14. Study of IEC 62443 Compliance for Railway Systems

– Study and map IEC 62443 security requirements to railway systems.

15. ISO 27001 ISMS Documentation for Railway IT Systems

– Prepare ISO 27001–compliant ISMS documentation for railway IT systems.

16. **Cybersecurity Policy Drafting for Railway Infrastructure**

– Draft cybersecurity policies for railway IT and OT infrastructure.

17. **Incident Detection & Classification Exercise**

– Detect and classify cybersecurity incidents in railway systems.

18. Incident Response Simulation for Railway Cyber Attack

– Simulate incident response procedures for a railway cyber-attack.

19. Digital Forensics Basics for Railway Systems

– Perform basic digital forensic analysis on railway system data.

20. **Recovery, Reporting & Post-Incident Review Exercise**

– Prepare recovery actions and post-incident reports for railway cyber incidents.

Teaching & Learning Methodology

- Lectures with real-world railway cyber incident case studies.
- Lab-based security implementation and testing.
- Simulation-based exercises for SCADA and web app security.
- Assignments focusing on standard compliance and policy drafting.

Reference Books & Resources

Books:

1. *Industrial Network Security* – Eric D. Knapp, Joel Thomas Langill, Elsevier
2. *Cybersecurity for Industrial Control Systems* – Tyson Macaulay, Bryan L. Singer, CRC Press
3. *Applied Cyber Security and the Smart Grid* – Eric D. Knapp, Raj Samani, Elsevier
4. *Practical IoT Hacking* – Fotios Chantzis, Elsevier

Standards & Guidelines:

- IEC 62443 – Security for Industrial Automation and Control Systems
- NIST Cyber security Framework
- ISO/IEC 27001 – Information Security Management
- CERT-In Guidelines for Critical Infrastructure Protection

Online Resources:

- UIC Railway Cyber security Guidelines
- RDSO Indian Railways IT Security Documents
- MITRE ATT&CK for ICS

RCSMDM-03: IoT, Embedded Systems & Predictive Maintenance

Duration: 45 hrs Theory + 90 hrs Practical

Course Objectives

By the end of this course, students will be able to:

1. Understand the architecture and components of IoT systems for railway applications.
2. Implement embedded controllers for signaling and onboard monitoring.
3. Acquire and process data from railway sensors (vibration, temperature, GPS).
4. Apply AI-driven predictive maintenance strategies for rolling stock and track assets.
5. Follow global railway safety-critical embedded software standards (EN 5012

Course Outcomes (COs)

After completing this course, students will be able to:

CO1: Explain IoT system architecture for railway monitoring and control.
CO2: Program embedded controllers for railway signaling and onboard applications.
CO3: Collect, transmit, and analyze railway sensor data.
CO4: Implement basic predictive maintenance algorithms using AI analytics.
CO5: Apply EN 50128 safety principles in embedded railway systems.

Module	Module Title & Topics	Hours
Module 1	**IoT Ecosystem & Architecture for Railways** • Railway IoT ecosystem overview • Sensors, gateways, cloud platforms, analytics • Railway communication protocols	**7**
Module 2	**Railway Communication Protocols & Networks** • MQTT, CoAP, LoRaWAN, GSM-R • Edge vs cloud computing • Data reliability & latency requirements	**7**
Module 3	**Embedded Controllers for Railway Applications** • Microcontrollers, microprocessors, PLCs • Signaling and onboard embedded systems • Hardware interfacing	**8**

Module 4	**Sensor Data Acquisition & Train Health Monitoring** • Vibration, temperature, GPS, strain sensors • Data logging and wireless sensor networks • Train tracking systems	**8**
Module 5	**Predictive Maintenance Using IoT & AI** • Maintenance strategies • IoT data analytics • ML models for failure prediction • Global railway case studies	**7**
Module 6	**Safety-Critical Embedded Systems & Standards** • EN 50128 compliance • IEC 61508 fundamentals • Testing, validation, and documentation	**8**

Practical List

1. **Identification of IoT Use Cases in Railway Systems** – Identify practical IoT applications in railway operations and asset monitoring.
2. **Configuration of IoT Communication Protocols (MQTT/CoAP)** – Configure MQTT/CoAP protocols for railway sensor data transmission.
3. **Data Transmission Using LoRaWAN / GSM-R (Simulation)** – Simulate long-range railway data communication using LoRaWAN or GSM-R.
4. **Introduction to Embedded Controllers (Arduino/ARM)** – Study architecture and programming basics of embedded controllers for railways.
5. **Embedded Programming for Railway Signaling Application** – Develop embedded code for basic railway signaling control logic.
6. **Interfacing Sensors with Embedded Controllers** – Interface railway sensors with embedded controllers for real-time data acquisition.
7. **PLC Programming Basics for Railway Signaling Systems** – Implement basic PLC logic for railway signaling and control systems.
8. **Data Acquisition from Vibration & Temperature Sensors** – Acquire and monitor vibration and temperature data from railway assets.
9. **GPS-Based Train Location Tracking System** – Develop a GPS-based system for real-time train location tracking.
10. **Wireless Sensor Network Setup for Track Monitoring** – Configure wireless sensor networks for railway track health monitoring.
11. **Cloud Data Upload & Visualization Using IoT Platform** – Upload railway sensor data to cloud platform and visualize dashboards.

12. **Analysis of Railway Sensor Data for Fault Detection** – Analyze IoT sensor data to detect faults in railway assets.
13. **Implementation of Predictive Maintenance Logic** – Implement basic predictive maintenance logic using railway sensor data.
14. **Machine Learning Model for Railway Failure Prediction** – Develop a simple ML model for predicting railway component failures.
15. **Case Study Implementation of Predictive Maintenance** – Implement predictive maintenance strategy based on real railway case study.
16. **Study of EN 50128 Safety-Critical Software Lifecycle** – Study EN 50128 lifecycle for railway safety-critical embedded software.
17. **Safety Requirement Analysis for Embedded Railway System** – Perform safety requirement analysis for embedded railway applications.
18. **Testing & Validation of Embedded Railway Application** – Test and validate embedded railway system as per safety standards.
19. **Documentation & Compliance Report as per EN 50128** – Prepare documentation and compliance report as per EN 50128 standard.

Teaching & Learning Methodology

Classroom lectures with case studies from Indian Railways & global operators.

20. Hardware demonstrations of IoT-enabled railway systems.
21. Lab-based experiments for embedded programming & IoT data analysis.
22. Mini-projects integrating sensors and cloud platforms.

Reference Books & Resources

Books:

1. *Internet of Things: Principles and Paradigms* – Rajkumar Buyya, Elsevier
2. *Embedded Systems: Introduction to ARM Cortex-M Microcontrollers* – Jonathan W. Valvano
3. *Predictive Maintenance in Smart Factories* – Jan Holler, Elsevier
4. *Railway Safety, Reliability, and Security: Technologies and Systems Engineering* – Xing Liu, CRC Press

Standards & Technical References:

- EN 50128 – Railway Applications: Software for Railway Control and Protection Systems
- IEC 61508 – Functional Safety of Electrical/Electronic/Programmable Systems
- IRIS Certification (ISO/TS 22163) for rail industry quality management

Online Resources:

- MQTT.org – Messaging Protocol Documentation
- Arduino.cc – Official Arduino Tutorials
- ThingSpeak IoT Platform (for cloud dashboards)
- Indian Railways RDSO IoT initiatives reports

RCSPP-04: Simulation, Digital Twin & Cloud Computing for Railways

Duration: 45 hrs Theory + 90 hrs Practical

Course Objectives

By the end of this course, students will be able to:

1. Understand railway-specific simulation tools for scheduling, capacity analysis, and performance optimization.
2. Apply digital twin technology to model and monitor stations, rolling stock, and infrastructure.
3. Use cloud computing platforms to deploy real-time railway applications.
4. Integrate GIS mapping into railway planning and route optimization.
5. Analyze global industry case studies for practical implementation strategies.

Course Outcomes (COs)

After completing this course, the learner will be able to:

CO1: Operate railway simulation software for scheduling and capacity optimization.
CO2: Develop simple digital twin models for stations or rolling stock.
CO3: Deploy railway monitoring applications on cloud platforms.
CO4: Apply GIS tools for railway route mapping and optimization.
CO5: Evaluate global best practices for simulation and digital twin use in railways.

Module	Module Title & Topics	Hours
Module 1	**Introduction to Railway Simulation Systems** • Role of simulation in railway planning • Types of railway simulations • Key performance indicators	**7**
Module 2	**Railway Scheduling, Capacity & Performance Simulation** • Train scheduling & timetable optimization • Capacity planning & delay analysis • OpenTrack, RailSys, AnyLogic overview	**8**
Module 3	**Digital Twin Concepts & Data Integration** • Digital twin lifecycle • Data sources: IoT, SCADA, ERP • Real-time vs simulation-based twins	**7**

Module 4	**Digital Twins for Stations & Rolling Stock** • Station digital twin: crowd flow & assets • Rolling stock digital twin • Energy & maintenance optimization	**8**
Module 5	**Cloud & Edge Computing for Railways** • Cloud service models • Railway application deployment • Edge computing for low latency	**7**
Module 6	**GIS Integration & Global Railway Case Studies** • GIS for route planning • Integration with simulation & twins • Global best practices	**8**

Practical List

1. **Study of Railway Simulation Software Tools** – Study features and applications of OpenTrack, RailSys, and AnyLogic.
2. **Railway Timetable Simulation Basics** – Simulate a basic railway timetable and analyze train movement.
3. **Train Scheduling Optimization Exercise** – Optimize train schedules to reduce conflicts and delays.
4. **Capacity Analysis of Railway Line** – Perform capacity analysis for a railway corridor using simulation tools.
5. **Delay Analysis & Performance Evaluation** – Analyze delays and evaluate railway performance indicators.
6. **Introduction to Digital Twin Modeling** – Study digital twin concepts and modeling workflow for railways.
7. **Station Digital Twin – Basic Layout Modeling** – Create a basic digital twin model of a railway station layout.
8. **Passenger Flow Simulation in Station Digital Twin** – Simulate passenger movement and crowd behavior in station model.
9. **Asset Monitoring Using Digital Twin Concept** – Model asset condition monitoring using digital twin approach.
10. **Rolling Stock Digital Twin Simulation** – Create a simple digital twin of rolling stock for condition tracking.
11. **Integration of IoT Data into Digital Twin (Simulation)** – Integrate simulated IoT sensor data into a digital twin model.
12. **Study of Cloud Platforms for Railway Applications** – Study AWS, Azure, and GCP

services used in railway systems.

13. **Deployment of Railway Application on Cloud** – Deploy a basic railway monitoring application on cloud platform.
14. **Real-Time Train Tracking Application** – Develop and deploy a real-time train tracking web application.
15. **Edge Computing Use Case for Railways** – Simulate edge computing for low-latency railway applications.
16. **Introduction to GIS Tools for Railways** – Study GIS tools and spatial data used in railway planning.
17. **Railway Route Mapping Using GIS** – Create railway route maps using QGIS with spatial layers.
18. **GIS-Based Route Optimization Analysis** – Perform route optimization using distance and elevation data.
19. **Integration of GIS with Simulation Model** – Integrate GIS data with railway simulation or digital twin model.
20. **Case Study Implementation of Digital Twin & Simulation** – Implement a mini case study combining simulation, cloud, and GIS.

Teaching & Learning Methodology

- **Lectures:** Theoretical foundation with tool demonstrations.
- **Labs:** Hands-on use of simulation software, cloud platforms, and GIS tools.
- **Case Study Analysis:** Evaluation of real-world railway digital twin deployments.
- **Mini Projects:** Application of simulation and cloud tools to railway problems.

Reference Books & Resources

Books:

1. *Railway Timetable & Traffic Simulation* – Ulrich Weidmann, Andreas Nash, ETH Zurich Lecture Notes
2. *Digital Twin Driven Smart Manufacturing* – Fei Tao, Ang Liu, Springer
3. *Cloud Computing: Concepts, Technology & Architecture* – Thomas Erl, Prentice Hall
4. *GIS for Transportation* – Harvey J. Miller, Shih-Lung Shaw

Software & Tools:

- OpenTrack (railway simulation)
- AnyLogic (multi-method simulation)
- QGIS (open-source GIS mapping)
- AWS, Microsoft Azure, Google Cloud Platform

Online Resources:

- Siemens Mobility Railigent case studies
- Network Rail Digital Twin project reports
- Indian Railways GIS & digital initiatives (RDSO publications)

RCSSEC-004: Data Science, AI & Computer Vision for Railways

Duration: 45 hrs Theory + 90 hrs Practical

Course Objectives

By the end of this course, students will be able to:

1. To introduce the fundamentals of Data Science, Artificial Intelligence, and Computer Vision in the context of railway systems.
2. To develop the ability to analyze, preprocess, and visualize railway operational and passenger data using Python-based tools.
3. To provide knowledge of time-series forecasting and machine learning techniques for passenger demand estimation and train delay prediction.
4. To expose students to AI-based optimization approaches for railway scheduling and energy-efficient operations.
5. To familiarize learners with computer vision and deep learning methods for railway infrastructure inspection and safety monitoring.

Course Outcomes

After successful completion of the course, students will be able to:

1. Understand and explain the role of data science, AI, and computer vision in improving railway operations and decision-making.
2. Process and analyze railway datasets using data preprocessing, exploratory data analysis, and visualization techniques.
3. Apply forecasting and machine learning models to predict passenger demand and train delays effectively.
4. Utilize AI-based optimization concepts for railway scheduling and energy consumption analysis.
5. Implement computer vision and basic deep learning models for railway defect detection, crowd monitoring, and safety analytics.

Module	Module Title & Topics	Hours
Module 1	**Introduction to Data Science for Railway Systems** • Role of data science in railways • Railway data sources and data types • Data preprocessing and visualization	**7**
Module 2	**Railway Data Analysis & Visualization** • Exploratory data analysis (EDA) • Passenger flow and operational data analysis • Visualization for decision-making	**7**

Module 3	**Passenger Demand Forecasting Techniques** • Time series analysis (ARIMA, Prophet) • Seasonal trend analysis • Capacity planning using forecasts	**8**
Module 4	**Machine Learning for Train Delay Prediction** • Regression and classification models • Feature engineering • Model evaluation metrics	**8**
Module 5	**AI for Railway Scheduling & Energy Optimization** • AI-based timetable optimization • Energy-efficient train operation • Simulation-based optimization	**7**
Module 6	**Computer Vision Applications in Railways** • Image preprocessing techniques • Track defect detection using CV & CNNs • Crowd monitoring and safety analytics	**8**

Practical List

1. **Introduction to Python for Railway Data Analysis** – Set up Python environment using Jupyter Notebook/Colab for railway data analysis.
2. **Loading and Exploring Railway Datasets** – Load railway datasets and explore data structure using Pandas.
3. **Data Cleaning and Preprocessing for Railway Data** – Perform missing value handling, normalization, and data cleaning.
4. **Visualization of Passenger and Train Operation Data** – Visualize railway data using Matplotlib and Seaborn.
5. **Exploratory Data Analysis (EDA) for Railway Operations** – Perform EDA to identify trends and anomalies in railway data.
6. **Passenger Flow Analysis Using Historical Data** – Analyze passenger flow patterns for peak and off-peak periods.
7. **Time Series Analysis for Passenger Demand Forecasting** – Apply time series techniques for passenger demand prediction.
8. **Forecasting Passenger Demand Using ARIMA/Prophet** – Build forecasting models using ARIMA or Prophet libraries.
9. **Feature Engineering for Train Delay Prediction** – Create relevant features from railway datasets for ML models.

10. **Train Delay Prediction Using Regression Models** – Develop regression models to predict train delays.
11. **Train Delay Classification Using Machine Learning** – Implement classification models to identify delayed vs on-time trains.
12. **Evaluation of Machine Learning Models** – Evaluate ML models using MAE, RMSE, accuracy, and confusion matrix.
13. **AI-Based Train Scheduling Optimization (Conceptual)** – Apply AI concepts to optimize train scheduling scenarios.
14. **Energy Consumption Analysis of Train Operations** – Analyze train energy consumption data for optimization insights.
15. **Simulation-Based Energy Optimization Exercise** – Simulate energy-efficient train operation strategies.
16. **Image Preprocessing for Railway Infrastructure Inspection** – Perform image preprocessing for railway track images using OpenCV.
17. **Track Crack Detection Using Computer Vision** – Detect cracks in track images using edge detection and contours.
18. **Basic CNN Model for Railway Defect Detection** – Develop a basic CNN model for defect detection using TensorFlow/Keras.
19. **Crowd Detection and Monitoring Using Video Analytics** – Implement crowd detection using computer vision techniques.
20. **Case Study Implementation of AI in Railways** – Implement a mini case study applying data science or AI to railway operations.

Teaching & Learning Methodology

- Case study–driven lectures
- Python-based lab work on real and synthetic datasets
- Use of railway datasets (public/open data or anonymized industry data)
- Mini-projects and assignments applying AI to operational problems

Reference Books & Resources

Books:

1. *Python for Data Analysis* – Wes McKinney, O'Reilly
2. *Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow* – Aurélien Géron, O'Reilly
3. *Learning OpenCV* – Gary Bradski & Adrian Kaehler, O'Reilly
4. *Artificial Intelligence for the Internet of Everything* – William Lawless et al., Elsevier

Case Study References:

- SNCF Digital Transformation Reports – SNCF Group
- Deutsche Bahn AI Projects – DB Digital Ventures

- JR East Predictive Maintenance Publications

Online Resources:

- Kaggle datasets on railway operations & delays
- OpenRailwayMap.org (for spatial data)
- Scikit-learn.org (ML library documentation)
- OpenCV.org (Computer Vision library documentation)

RCSCC-06 Capstone Project (Industry-Oriented)

Duration: 390 hrs Practical

Course Objective

1. To enable students to apply theoretical knowledge and practical skills gained from earlier subjects to develop an end-to-end solution for a real-world railway domain problem.
2. To cultivate project management, teamwork, and industry-relevant software/hardware development competencies.
3. To produce a functional prototype demonstrating understanding of railway IT systems, IoT, AI, cybersecurity, cloud computing, and digital twins.

Course Outcomes (COs)

Upon completion, students will be able to:

CO1: Define and analyze a complex railway sector problem statement aligned with industry needs.

CO2: Design and implement a working prototype integrating software, hardware, and data analytics components.

CO3: Use software development lifecycle practices including requirement gathering, design, implementation, testing, and documentation.

CO4: Demonstrate interdisciplinary skills combining IoT, AI, cybersecurity, cloud computing, and simulation/digital twin concepts.

CO5: Present project results effectively to technical and non-technical stakeholders.

Project Work Components (Suggested Breakdown)

Sr. No.	Project Component	Description	Hours
1	**Problem Identification & Requirement Analysis**	Identification of a relevant railway problem, literature review, feasibility study, scope definition, stakeholder analysis, and preparation of functional & non-functional requirements (safety, reliability, scalability, security).	**50**
2	**Tool Familiarization & Skill Readiness**	Hands-on training on selected tools and technologies such as Python, SQL, IoT platforms, AI/ML libraries, cloud services, dashboards, version control, and development environments. Includes mini exercises and proof-of-concepts.	**40**

3	**System Design & Architecture**	Design of system architecture, block diagrams, data flow diagrams, database schema, selection of technologies (IoT, AI, cloud, cybersecurity), and design validation reviews.	**70**
4	**Development & Implementation**	Coding and implementation of software modules, development of IoT/embedded prototypes, AI/ML model building, cloud integration, API development, and full system integration.	**150**
5	**Testing & Validation**	Unit testing, integration testing, system testing, performance validation, debugging, optimization, and verification against defined requirements.	**45**
6	**Industry Practices, Safety & Professional Skills**	Application of industry best practices, safety and risk assessment, cybersecurity and data ethics awareness, basic project management, teamwork, communication, and professional conduct.	**20**
7	**Documentation & Presentation**	Preparation of final project report, technical documentation, user manuals, test reports, presentation slides, demo preparation, and viva voce readiness.	**15**
	Total		**390 Hours**

Example Project Ideas

- **AI-powered Train Delay Prediction & Passenger Notification App:** Use ML models to predict delays and notify passengers in real-time via mobile/web app.
- **IoT-enabled Smart Coach Health Monitoring System:** Sensor-based real-time condition monitoring of coaches with predictive alerts.
- **Cloud-based Freight Tracking & Delivery Confirmation Platform:** End-to-end digital solution using GPS, cloud, and mobile alerts for freight logistics.
- **Blockchain-based Railway Ticketing and Anti-Fraud System:** Implement tamper-proof ticket ledger with smart contracts.
- **Computer Vision Platform for Automatic Track Defect Detection:** Use cameras and ML/CV models to identify track cracks and anomalies automatically.

Teaching & Learning Methodology

- Guided project mentorship by faculty and industry experts.
- Collaborative teamwork with defined roles (developer, tester, documentation, presentation).

- Agile/scrum style iterative development encouraged.
- Regular reviews and feedback sessions.

Assessment Scheme

Assessment Component	Weightage
Problem Definition & Requirement Analysis	10%
System Design & Architecture	15%
Implementation & Integration	40%
Testing & Validation	15%
Documentation & Presentation	20%

Reference Books & Resources

- *Software Engineering: A Practitioner's Approach* – Roger S. Pressman, McGraw Hill
- *Design Patterns: Elements of Reusable Object-Oriented Software* – Erich Gamma et al., Addison-Wesley
- *Internet of Things: Architecture and Applications* – Rajkumar Buyya et al., Wiley
- *Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow* – Aurélien Géron, O'Reilly
- *Blockchain Basics* – Daniel Drescher, Apress
- Open-source tools & platforms: Arduino, Raspberry Pi, TensorFlow, AWS/Azure/GCP, Hyperledger Fabric, OpenCV, AnyLogic