M.TECH.
INFRASTRUCTURE ENGINEERING AND MANAGEMENT

Curriculum

NATIONAL INSTITUTE OF TECHNICAL TEACHERS TRAINING AND RESEARCH CHENNAI

Deemed to be University under Distinct Category – A Centrally Funded Technical Institute

CSIR Road, Taramani, Chennai

Regulations 2024

Logo Name

NATIONAL INSTITUTE OF TECHNICAL TEACHERS TRAINING AND RESEARCH CHENNAI

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M. Tech. INFRASTRUCTURE ENGINEERING AND MANAGEMENT REGULATIONS 2024

The M.Tech. in Infrastructure Engineering and Management is designed to equip students with advanced knowledge and skills in planning, designing, managing, and maintaining infrastructure systems. With the growing complexity of modern infrastructure projects, this program emphasizes both technical expertise and managerial competence, addressing the challenges of sustainable development, resource optimization, and project management.

The curriculum integrates engineering fundamentals with cutting-edge management principles, preparing graduates to tackle the interdisciplinary demands of infrastructure development in sectors such as structural, geotechnical, sustainability, transportation, urban development, energy, and water resources. Students will engage with real-world case studies, innovative technologies, and practical applications to enhance their analytical and problem-solving capabilities.

Program Education Objectives (PEOs)

Graduates will demonstrate ability to:

- **PEO 1:** Plan, design, construct, operate, and maintain sustainable infrastructure projects, contribute effectively to the development and management of infrastructure systems.
- **PEO 2:** Participate in public discussions and provide professional guidance on infrastructure issues in urban, suburban, and exurban settings, influencing policy and decision-making processes.
- **PEO 3:** Advancements in the field through continuing education, professional conferences, graduate studies, and self-learning experiences, and will demonstrate the capability to obtain and maintain professional licensing.
- **PEO 4:** Prepare for successful careers in local, state, and central government organizations, as well as in architectural and engineering firms, specializing in areas

such as infrastructure development, transportation, water resources, environmental engineering, structural engineering, geotechnical engineering, construction, and other related fields.

Program Outcomes (POs)

Our graduates by the time of graduation will be able to

- **PO 1:** Conduct thorough research and investigations into complex infrastructure issues using experimental methods, data analysis, and evidence-based approaches.
- **PO 2:** Identify, formulate, and analyse intricate engineering problems using research-based methodologies and advanced analytical techniques.
- **PO 3:** Exhibit a high level of mastery and expertise in infrastructure engineering and management through advanced problem-solving skills, innovative project design, and application of cutting-edge technologies, reflecting a deep understanding of the field's principles and practices.
- **PO 4:** Employ contemporary engineering tools, technologies, and software for effective modelling, simulation, and management of infrastructure projects.
- **PO 5:** Design and develop sustainable and innovative solutions for infrastructure projects, considering public health, safety, environmental impact, and economic factors.
- **PO 6:** Write clear, comprehensive, and technically sound reports on infrastructure projects, and ensuring the sustainable solutions and technical details in a professional manner.

Programme Credit Requirement

		PG Certificate	PG Diploma	PG Degree
PCC (Theory)	Credit	6	12	12
	Course	2	4	4
PCC (Lab)	Credit	4	8	8
	Course	2	4	4
PEC / OEC	Credit	9	9	18
	Course	3	3	6
FC	Credit		3	3
	Course		1	1
MC	Credit	3	3	3
	Course	1	1	1
	Credit	0	0	0

Audit Course	Course	2	2	2
IIC	Credit	0	0	4
	Course	0	0	1
IP	Credit	0	0	4
	Course	0	0	1
PD	Credit	0	5	28
	Course	0	1	2

Minimum Credit Requirement to obtain
PG Certificate – 20 Credits; PG Diploma – 40 Credits; PG Degree – 80 Credits

PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective
FC	Foundation Course
MC	Mandatory Course
AC	Audit Course
IIC	Industrial Integrated Courses
IP	Internship Programme
PD	Project Dissertation

Course Structure and Details

PROFESSIONAL CORE COURSES (Theory)			
S.No.	Course Code	Course Title	Credits
1	IM24P11	Project Management for Infrastructure	3
2	IM24P12	Substructure and Superstructure Engineering for Infrastructure	3
3	IM24P13	Infrastructure Planning and Management	3
4	IM24P14	Contract Management	3
PROFESSIONAL CORE COURSES (Laboratory)			
1	IM24P21	Building Information Modelling (BIM) Laboratory	2
2	IM24P22	GIS Laboratory	2
3	IM24P23	Infrastructure Material Testing Laboratory	2
4	IM24P24	Project Management Laboratory	2
FOUNDATION COURSE			
1	MA24M13	Statistical Methods for Engineers	3
MANDATORY COURSE			
1	RM24K11	Research Methodology and IPR	3

PROFESSIONAL ELECTIVE COURSE - PROJECT MANAGEMENT			
S.No	Course Code	Course Title	Credits
1	IM24A11	Procurement of Materials and Management	3
2	IM24A12	Project Cost and Risk Management	3
3	IM24A13	Lean Construction Management	3
PROFESSIONAL ELECTIVE COURSE – SMART MOBILITY			
1	IM24B11	Digital Twin for Infrastructure	3
2	IM24B31	Data Science for Smart Cities	3
3	IM24B12	Intelligent Transport System	3
PROFESSIONAL ELECTIVE COURSE – CONSTRUCTION TECHNOLOGY & NDT			
1	IM24C11	Repair and Rehabilitation of Structures	3
2	IM24C12	Non-destructive Testing and Sensing for Civil Infrastructures	3
3	IM24C13	Quality Control and Quality Assurance in Infrastructure Construction	3

PROFESSIONAL ELECTIVE COURSE – STRUCTURAL DESIGN AND MAINTENANCE			
1	IM24D11	Maintenance Engineering and Management	3
2	IM24D12	Earthquake Resistant Design of Buildings	3
3	IM24D13	Structural Health Monitoring	3
4	IM24D31	Analysis and Design of Structures Using Software	3
PROFESSIONAL ELECTIVE COURSE – SUSTAINABILITY MANAGEMENT			
1	IM24E11	Green Building Design and Implementation	3
2	IM24E12	Environmental and Energy Audit	3
3	IM24E13	Environmental Impact Assessment	3
4	IM24E14	Smart City Design and Implementation	3
PROFESSIONAL ELECTIVE COURSE – URBAN AND TRANSPORTATION PLANNING			
1	IM24F11	Urban Planning Fundamentals	3
2	IM24F12	Transportation Engineering and Planning	3
3	IM24F13	GATI sakthi Multi-Modal Connectivity (MOOC Course)	3
INDUSTRIAL INTEGRATED COURSES			
1	IM24G11	Applications of UAV in Civil Infrastructure	4
2	IM24G12	Advanced Concrete Technology	4
3	IM24G13	Pavement Maintenance and Management Systems	4
AUDIT COURSE			
1	AC24H11	English For Research Paper Writing	0
2	AC24H12	Indian Knowledge System	0
OPEN ELECTIVE			
1	OE24W11	Design Thinking for Educators	3
2	OE24W12	Blue Economy and Entrepreneurship	3
3	OE24W13	Swachhata Campus: Clean, Green and Sustainable Energy	3
4	OE24W14	Integration of AI in Educational Practices	3
5	OE24W15	Extended Reality Technologies	3

INDUSTRIAL TRAINING			
1	IM24G21	Internship Programme	4
PROJECT DISSERTATION			
1	IM24T21	Project Phase 1	12
2	IM24T22	Project Phase II	16

- ✓ **Theory: 1 Credit = 15 hours;**
- ✓ **Practical: 1 Credit = 30 hours;**
- ✓ **Experiential learning including relevant experience and proficiency/ professional levels acquired 1 Credit – 40 -45 hours**.

- **The guidelines for attendance and assessment as stipulated in the PG regulations.**

Detailed Syllabus

I. PROFESSIONAL CORE COURSES (Theory)

IM24P11	PROJECT MANAGEMENT FOR INFRASTRUCTURE	3 Credits

Course Description:

This course provides essential aspects of project management in infrastructure, from foundational concepts to advanced techniques and real-world applications. It covers key topics including project planning, scheduling, resource management, and cost estimation. The course also explores various project delivery methods and examines modern trends in project management. By integrating theoretical knowledge with practical case studies, it aims to equip learners with the skills needed to address project risks, manage resources efficiently, and ensure successful project outcomes in the dynamic field of infrastructure development.

Course Content:

Unit I Project Management - An Overview:

Introduction, Project Management process, Project Management techniques, Relationship to other management disciplines, Related endeavours, Concentric project management, Project formulation and development

Unit II Project Planning and Time Management:

Purpose, Project scheduling, activity definition, activity sequencing, activity duration estimating, schedule development, schedule control, project management using CPM\PERT-Network basics, Network development, PERT analysis, advantages. Computerized network analysis- features of PM software, capabilities of PM software, multi project analysis,

Unit III Resource Planning:

Introduction, Inputs, Tools, Outputs, Resource scheduling, Resource levelling, Resource restrained scheduling, strategies for shortening the schedule Assigning resources: Work, duration, resources, Effort driven scheduling, create a resource list, Exercise on resource planning using software, Level now command, levelling Gantt chart, assigning rate to resources, techniques of duration cost trade-off.

Unit IV Cost Estimation:

Costs Associated with Constructed Facilities - Approaches to Cost Estimation - Type of Construction Cost Estimates - Effects of Scale on Construction Cost - Unit Cost Method of

Estimation - Methods for Allocation of Joint Costs - Historical Cost Data - Cost Indices - Applications of Cost Indices to Estimating - Estimate Based on Engineer's List of Quantities - Estimation of Operating Costs.

Unit V Latest Trends & Case Studies:

Modern trends in Project Management - Different mode of projects – PPP, BOT, Turnkey Project, IPD, DBB - Effects of Project Risks – Reason for failure of projects - Case studies for failure and success of projects

Course Outcome:

CO1: Apply fundamental principles of project management in the context of infrastructure projects.
CO2: Develop and manage project schedules using techniques such as CPM and PERT, and leverage project management software.
CO3: Plan and allocate resources effectively, including scheduling, levelling, and managing resource constraints.
CO4: Estimate project costs accurately using various methods and understand the impact of cost on project outcomes.
CO5: Analyze and apply modern project management trends and delivery methods (e.g., PPP, BOT, Turnkey) to real-world scenarios.
CO6: Evaluate case studies to identify factors contributing to project success or failure, and apply lessons learned to future projects.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	1	3	2	3	1
CO3	1	1	2	3	3	1
CO4	3	3	2	3	1	1
CO5	1	2	3	1	2	3
CO6	1	3	1	3	2	3

References:

1. Harold Kerzner – Project Management – systems approach to planning, scheduling & controlling – 7th edition, John Wiley & sons, Canada.

2. Microsoft Project for Windows 2000 –Microsoft Press, USA 2000.
3. Tim Pyron – Microsoft Project 2000 in 24 hours – Sama Teach yourself series- Tech Media Published New Delhi.
4. Chit Kara, K.K. "Construction Project Management: Planning, Scheduling and Control", Tata McGraw-Hill Publishing Company, New Delhi, 1998.
5. Choudhury S, "Project Management", McGraw-Hill Publishing Company, New Delhi, 1988.
6. Chris Hendrickson and Tung Au, "Project Management for Construction – Fundamental Concepts for Owners, Engineers, Architects and Builders", Prentice Hall, Pittsburgh, 2000
7. Frederick E. Gould," Construction Project Management", Wentworth Institute of Technology, Vary E. Joyce, Massachusetts Institute of Technology, 2000.
8. George J. Ritz, "Total Construction Project Management" - McGraw-Hill Inc, 1994.

IM24P12	SUBSTRUCTURE AND SUPERSTRUCTURE ENGINEERING FOR INFRASTRUCTURE	3 Credits

Course Description:

This course provides an in-depth understanding of the principles and practices of substructure and super structure Engineering for infrastructure. It covers the detailed site investigation along with various substructure construction techniques. The course emphasizes the various application of materials and construction techniques used in superstructure. Students will gain skills in site investigation, soil testing, and the use of various techniques for construction of sub and superstructures.

Course Content:

Unit I: Soil Investigation

Field exploration – Direct, Semidirect, Indirect exploration – Insitu testing SPT, Plate bearing, Field Vane, Pressurement - Field Instrumentation – Surface movements – Subsurface Deformation - Soil Engineering Reports Interpretation

Unit II: Substructure Engineering

Construction of diaphragm walls - Shoring for deep cutting - Underpinning; Soil reinforcement – geotextiles- design criteria for geotextiles- Design step for erosion control and Geo-

composite drainage. Different types of facing elements, construction procedure, cost, design of Geosynthetics wrap around faced wall, - Trenchless Technology; Box jacking, Pipe Jacking. Tunneling Techniques; TBM - Piling Techniques-Driving Well and Caisson-Sinking Cofferdam - Cable Anchoring and Grouting.

Unit III: Precast and modular Construction

Prefabrication and modular construction - Precast concrete construction system - Prestressed concrete construction – 3D Volumetric concrete – Precast large concrete panel System – Precast Sandwich panel System - Steel Concrete composite structures.

Unit IV: Steel Structural System

Steel Structures: hot rolled and cold form steel sections - Connection detailing -Welding and bolting techniques - Fabrication processes (cutting, bending, welding) - **Erection Methods -** Lifting and hoisting equipment - Erection techniques (bottom-up, top-down)

Unit V: Materials & Techniques

Self-consolidating concrete (SCC) - Fiber-reinforced concrete (FRC) - High-performance concrete (HPC) - **Shotcrete - Geo-Exchange - Concrete 3D Printing – C & D waste products in construction – stamping concrete -** Tall structural systems - Static and dynamic loads on structures - Operation in tall buildings of various shapes and varying sections – launching techniques- suspended form work -erection techniques of tall structures, Large span structures – tunnel form technique - Slip-form construction – Aluminum formwork

Course Outcome:

CO1. Prepare a detailed geotechnical report by interpretation of geotechnical data obtained through site investigation

CO2: Implement appropriate techniques for substructure construction

CO3: Adopt precast construction techniques for superstructure

CO4: Execute in-situ steel structural systems

CO5: Select appropriate materials and techniques for construction of superstructure.

ARTICULATION MATRIX

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	2	2

CO2	3	1	2	2	1	2
CO3	2	1	3	1	1	1
CO4	2	2	3	2	1	2
CO5	1	1	3	2	1	3

REFERENCES:

1. Das, Braja M. Principles of Foundation Engineering. 8th ed. Cengage Learning, 2015.
2. Schroeder, W. L., Don C. Warrington, and S. E. Dickenson. Soils in Construction. 5th ed. Pearson Education, 2012.
3. Murthy, V. N. S. *Advanced Foundation Engineering*. New Delhi: CBS Publishers & Distributors, 2007.
4. Raj, P. Purushothama. *Ground Improvement Techniques*. New Delhi: Laxmi Publications (P) Ltd., 2007.
5. Ganapathy, C. “Modern Construction Materials”, EswarPress,2015.
6. Mamlouk, M.S. and Zaniewski, J.P., Materials for Civil and Construction Engineers, Prentice HallInc.,1999.
7. Santhakumar.A.R. “Concrete Technology”, Oxford University press, New Delhi.
8. IS 1892: 2021 Code of Practice for Subsurface Investigation for Foundations
9. IS 1888: 1982 Method of Load Test on Soils.
10. IS 2131: 1981 Method for Standard Penetration Test for Soils.
11. IS 2720: All parts: 1990 Methods of Test for Soils
12. IS 4434: 1978 Code of practice for in-situ vane shear test for soils.
13. IS 4453: 1980 Code of Practice for Subsurface Exploration by Pits, Trenches, Drifts and Shafts

IM24P13	INFRASTRUCTURE PLANNING AND MANAGEMENT	3 Credits

Course Description:

To understand and explain concepts of infrastructure, private involvement in infrastructure, challenges to successful infrastructure planning and implementation, strategies for successful infrastructure project implementation, sustainable development of infrastructure.

Unit I: An Overview of Basic Concepts Related to Infrastructure

Introduction to Infrastructure, an overview of the Power Sector in India., an Overview of the Water Supply and Sanitation Sector in India., an overview of the Road, Rail, Air and Port Transportation Sectors in India., an overview of the Telecommunications Sector in India, an overview of the Urban Infrastructure in India, an overview of the Rural Infrastructure in India, an Introduction to Special Economic Zones, Organizations and layers in the field of Infrastructure, The Stages of an Infrastructure Project Lifecycle., an overview of Infrastructure Project Finance.

Unit II: Private Involvement in Infrastructure

A Historical Overview of Infrastructure Privatization. The Benefits of Infrastructure Privatization, Problems with Infrastructure Privatization, Challenges in Privatization of Water Supply: A Case Study, Challenges in Privatization of Power: Case Study, Privatization of Infrastructure in India: Case Study, Privatization of Road Transportation Infrastructure in India.

Unit III: Challenges to Successful Infrastructure Planning and Implementation

Mapping and Facing the Landscape of Risks in Infrastructure Projects, Economic and Demand Risks: The Case study for Political Risks, Socio-Environmental Risks, Cultural Risks in International Infrastructure Projects, Legal and Contractual Issues in Infrastructure, Challenges in Construction and Maintenance of Infrastructure.

Unit IV: Sustainable Development of Infrastructure

Information Technology and Systems for Successful Infrastructure Management, - Innovative Design and Maintenance of Infrastructure Facilities, Infrastructure Modeling and Life Cycle Analysis Techniques, Capacity Building and Improving the Governments Role in Infrastructure Implementation, An Integrated Framework for Successful Infrastructure Planning and Management- Infrastructure Management Systems and Future Directions.

Unit V: Problem based Learning

-Micro Project- Term Paper based on Field Visit to Major Infrastructure Projects (for Example Chennai Metro Rail Project- Airports Authority of India

Course Outcome:

CO1: Explain the basic concepts related to infrastructure Projects

CO2: Discuss the role of private sector in infrastructure growth.

CO3: Describe the strategies for successful Infrastructure Project implementation.

CO4: Develop Infrastructure modeling and Life Cycle Analysis Techniques.

CO5: Explain Sustainable development of Infrastructure.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	3	2	1
CO2	2	3	3	2	1	1
CO3	2	3	3	1	1	2
CO4	1	1	3	2	1	3
CO5	1	1	3	1	1	3

References:

1. Grigg, Neil, Infrastructure engineering and management, Wiley, (1988).
2. Haas, Hudson, Zaniewski, Modern Pavement Management, Krieger, Malabar, (1994).
3. Hudson, Haas, Uddin, Infrastructure management: integrating design, construction, maintenance, rehabilitation, and renovation, McGraw Hill, (1997).
4. E. R. Yescombe, Public-Private Partnerships: Principles of Policy and Finance, Oxford: Butterworth-Heinemann (2007), Elsevier Science (2011)
5. Richard A. Fenner, Judith Sykes, Charles Ainger, Sustainable Infrastructure: Principles into Practice, Thomas Telford Ltd (2022)
6. Alvin S. Goodman and Makarand Hastak, Infrastructure Planning Handbook: Planning, Engineering, and Economics, McGraw-Hill Professional (2006)
7. Stefano Gatti, Project Finance in Theory and Practice: Designing, Structuring, and Financing Private and Public Projects, Academic Press (2008)
8. Barbara Weber and Hans Wilhelm Alfen, Infrastructure as an Asset Class: Investment Strategy, Sustainability, Project Finance, and PPP, Wiley (2010)
9. K. V. Sundaram, Urban Infrastructure: Finance and Management, Oxford University

Press (2000)
10. S. Bry Sarté, Sustainable Infrastructure: The Guide to Green Engineering and Design, Wiley (2010)
11. Martin Loosemore, John Raftery, Charles Reilly, and David Higgon, Risk Management in Projects, Taylor & Francis (2006)
12. Arnold Picot, Massimo Florio, Nico Grove, and Johann Kranz, The Economics of Infrastructure Provisioning: The Changing Role of the State, MIT Press (2015)
13. Jeffrey Delmon, Public-Private Partnership Projects in Infrastructure: An Essential Guide for Policy Makers, Cambridge University Press (2011)
14. David Simchi-Levi, Philip Kaminsky, and Edith Simchi-Levi, Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies, McGraw Hill (2003)
15. David T. Llewellyn and Tony W. Gunn, Infrastructure Investment: An Engineering Perspective, Routledge (2013).

IM24P14	CONTRACT MANAGEMENT	3 Credits

Course Description

This course provides the various types of construction contracts and their legal aspects and provisions. Similarly, the details of tenders, arbitration, legal requirements, and labour regulations are highlighted.

Course Content:

Unit-I: Construction Contracts

Infrastructure Projects-PPP in Infrastructure projects-Indian Contracts Act – Elements of Contracts – Types of Contracts – Features – Suitability – Design of Contract Documents – International Contract Document – Standard Contract Document – Law of Torts

Unit-II: Tenders

Objective of Tendering-Types of Tenders-Prequalification – Bidding – Accepting – Evaluation of Tender from Technical, Contractual and Commercial Points of View – Contract Formation and Interpretation – Potential Contractual Problems – World Bank Procedures and Guidelines-Case Studies

Unit-III: Arbitration

Comparison of Actions and Laws – Agreements – Subject Matter – Violations – Appointment of Arbitrators – Conditions of Arbitration – Powers and Duties of Arbitrator – Rules of Evidence – Enforcement of Award – Costs.

Unit-IV: Legal Requirements

Insurance and Bonding – Laws Governing Sale, Purchase and Use of Urban and Rural Land – Land Revenue Codes – Tax Laws – Income Tax, Sales Tax, Excise and Custom Duties and their Influence on Construction Costs – Legal Requirements for Planning – Property Law – Agency Law – Local Government Laws for Approval – Statutory Regulations.

Unit-V: Social Security

Welfare Legislation – Laws relating to Wages, Bonus and Industrial Disputes, Labour Administration – Insurance and Safety Regulations – Workmen's Compensation Act – Indian Factory Act – States Factory Act – Child Labour Act - Other Labour Laws.

Course Outcome

CO1: Able to explain different types of contracts in construction, arbitration and legal aspects and their provisions.

CO2: Analyze the tender and preparation of it by considering multiple factors

CO3: Describe the powers and duties of the Arbitrator

CO4: Examine the legal requirements of Purchase of Urban and Rural land

CO5: Discuss the laws relating to Wages, Bonuses and Industrial Disputes.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	1	1	2
CO2	1	1	3	2	1	3
CO3	1	1	2	1	1	1
CO4	1	2	2	1	1	2
CO5	1	1	2	1	1	1

References:

1. Gajaria G.T., Laws Relating to Building and Engineering Contracts in India,
2. Jimmie Hinze, Construction Contracts, McGraw Hill,2001.

3. Joseph T. Bockrath, Contracts and the Legal Environment for Engineers and Architects, McGraw Hill,2000.
4. Kwaku, A., Tenah, P.E. Jose M. Guevara, P.E., Fundamentals of Construction Management and Organisation, Printice Hall, 1985.M.M. Tripathi Private Ltd., Bombay,1982.
5. Patil. B.S, Civil Engineering Contracts and Estimates, Universities Press (India) Private Limited,2006.
6. Handbook on works contract management, https://rdso.indianrailways.gov.in/works/uploads/File/Handbook%20on%20Works%20Contract%20Management(1).pdf
7. Manual on procurement and contract management for PMGSY rural road projects https://pmgsy.nic.in/sites/default/files/circular/PMGSY_manual.pdf

II. PROFESSIONAL CORE COURSES (Laboratory)

IM24P21	BUILDING INFORMATION MODELLING Laboratory	2 Credits

Course Description

Building Information Modelling (BIM) is the use of intelligent 3D modelling software to help Architecture, Engineering and Construction (AEC) Professionals with project planning, design, construction management and ongoing building operations. By enabling a building to be represented by intelligent objects that carry detailed information about themselves and also understand their relationship with other objects in the building model, BIM facilitates multiple team members to collaborate on a design, checking a multidisciplinary model for conflicts prior to construction, and a enabling a distributed team to work simultaneously on a project in real time. This course provides the practical training of few tools used to achieve the concepts of model-based workflows in the construction industry.

Course Content

- Introduction to Building Information Modelling (BIM) - BIM tools and new workflows of construction planning & management.

- Creating intelligent 3D Modelling with Revit - Model-based quantity take-off and cost estimating.
- Planning and Scheduling with 4D BIM.
- Cloud-BIM for design/construction coordination & clash detection using Navis Work
- Point cloud data for as-built modelling.
- BIM for construction management.
- Case study

Course outcome

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

CO1. Apply the concept of BIM in integrating / coordinating various tasks performed by AEC Professionals

CO2. Create intelligent 3D modelling using the tool Autodesk Revit and Navis Work

CO3. Estimate the material requirement and the cost of the project.

CO4. Effectively manage the project by appropriate planning and scheduling

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1		3	3	
CO2		2		3	3	
CO3		3	2			2
CO4	2		3			3

References

1. BIM and Construction Management: Proven Tools, Methods, and Workflows", Brad Hardin, Dave McCool, John Wiley & Sons.
   - "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors", Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, Wiley.

IM24P22	GIS Laboratory	2 Credits

Course Description:

This lab course offers practical training in Geographic Information Systems, equipping learners with the skills to acquire, process, analyze, and present spatial data. It will help to learn to download and geo-reference spatial datasets, collect and explore attribute data using GPS, and perform onscreen digitization to create various map layers. This course guides to generate thematic maps and design professional-quality maps for real-world applications in spatial data management and analysis.

Course content

INTRODUCTION TO MAPS AND GIS

Maps – Definition – Evolution– Scale - Types of Maps – Elements of Map – Projection - purpose - types – Coordinate Systems: Geographic, Rectangular and Polar coordinates – Transformations - types and application – GIS: Introduction - History– Components of GIS – Applications of GIS – Types of satellite data – online resources - Popular GIS software – Open source GIS software - Database Management system – function – types – advantages - Entity Relationship Model - Normalization - GIS Data Model - Vector Data Structure - Raster Data structure – Network Data Structure - Comparison of Vector and Raster Data Structure – ODBC - Georeferencing- Digitization – Creating features - Topology – Topological Relationship - Raster Data Input – Errors in input – Data Editing – Linking Attribute Data – Raster File Formats – Vector File Formats – Meta Data- Bhuvan Platform Introduction to spatial analysis - Raster Data Spatial Analysis: Local, Neighbourhood, Zonal Operations - Vector Operations and Analysis: Topological and Non-topological operations - Network Analysis – DEM, DTM – Surface Analysis-Spatial and non-spatial data presentation - Map layout – Charts, graphs and multimedia output - Elements of spatial data quality - introduction to web GIS

Exercises:

1. Download spatial data like top sheets from Survey of India, satellite images from Bhuvan, Bhoonidhi, USGS
2. Geo-referencing the spatial data

3. Collect attribute data using GPS in the field and Explore in Google earth
4. Data Input – Onscreen Digitization – Creation of Point, Line and Polygon layers
5. Projection, Re-projection and Coordinate Transformation of Maps
6. Attribute data input and Measurement of Distance, Area
7. Linking External Database and Analysis attribute data using SQL commands
8. Performing spatial analysis
9. Generating Thematic maps for various data type
10. Map compilation and Design

Course Outcome:

CO1: Acquire, download, and geo-reference spatial data from various sources, ensuring accurate alignment with geographic coordinates.

CO2: Collect and explore field attribute data using GPS and Google Earth, enhancing practical skills in data acquisition and interpretation.

CO3: Perform onscreen digitization to create and manage spatial data layers, including point, line, and polygon features.

CO4: Conduct spatial analysis and apply SQL commands to manage and analyze attribute data within a GIS environment.

CO5: Generate thematic maps and design professional-quality maps, effectively presenting spatial data for various applications.

Reference:

1. Mastering QGIS by Kurt Menke, GISP, Dr. Richard Smith Jr., GISP, Dr. Luigi Pirelli, Dr. John Van Hoesen, GISP, PACKT Publish, 2016
2. Mastering ArcGIS by Maribeth Price, McGraw-Hill Education, 2019

IM24P23	INFRASTRUCTURE MATERIAL TESTING LABORATORY	2 Credits

Course Description:

This laboratory course provides hands-on experience in testing and analyzing the materials commonly used in infrastructure projects. Students will learn about various testing

methodologies for materials such as concrete, soil and water, gaining insights into their properties, performance, and suitability for construction applications. The course emphasizes the importance of quality control, standard testing procedures, and interpretation of test results in ensuring the safety, durability, and sustainability of infrastructure.

Unit I: Introduction to Material Testing & Quality Control

Importance of Material Testing in Infrastructure Projects - Overview of Testing Standards and Protocols (ASTM, IS Codes) - Safety Practices in the Laboratory - Principles of Quality Control in Material Testing - Role of Material Testing in Quality Assurance - Case Studies on Quality Failures and Lessons Learned

Unit II: Testing of Concrete

Workability Tests: Slump Test, Compaction Factor Test, Vee-Bee Consistometer Test - Compressive Strength Test of Concrete - Flexural Strength Test of Concrete - Split Tensile Strength Test - Testing of Rheology of concrete - Sulphate resistance / Rapid chloride penetration test / Sorptivity of concrete.

Unit III: Geotechnical and Environmental Testing

Grain Size Analysis (Sieve and Hydrometer) - Atterberg Limits (Liquid Limit, Plastic Limit, Shrinkage Limit) - Proctor Compaction Test - California Bearing Ratio (CBR) Test - Unconfined Compression Test for Soils - Triaxial shear test (Drained and Un-drained test) - Geotextile Testing; Water testing for construction as stated in IS 456

Unit IV: Pavement material Testing

Flakiness and Elongation Index test of aggregates-Aggregate crushing value test-Aggregate Impact test-Centrifuge extractor for asphalt mixture-Softening point test-Loss on a heating test of bitumen-Film stripped bitumen test-Flash and Fire point test-Dynamic cone penetrometer test-Skid resistance tester.

Unit V: Data Analysis, Interpretation and Report Preparation

Statistical Analysis of Test Data - Understanding Variability and Uncertainty in Material Properties - Use of Software Tools for Data Analysis (Excel, SPSS) - Guidelines for Preparing Laboratory Reports - Writing Clear and Concise Test Reports - Interpretation of Test Results in Reports - Presentation of Findings to Stakeholders

Course Outcome:

On completion of the course, the student is expected to be able to

CO1. Conduct standard tests on infrastructure materials, including concrete, soil and water, following established protocols and standards (IS codal provision).

CO2. Analyze the physical, mechanical, and chemical properties of construction materials and assess their performance under various conditions.

CO3. Interpret the results of material tests and evaluate the suitability of materials for different infrastructure applications.

CO4. Apply principles of quality control and assurance in the context of material testing and construction projects.

CO5. Prepare detailed reports documenting the testing process, results, and conclusions, ensuring clear communication with stakeholders.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. IS 2720: All parts: 1990 Methods of Test for Soils
2. IS 3025: Methods of sampling and testing of water
3. IS 456: (2000) – Plain and Reinforced Concrete – Code of practice.
4. IS 516 (1959): Methods of tests for strength of concrete.
5. IS 1199 (1959): Methods of sampling and analysis of concrete.

IM24P24	PROJECT MANAGEMENT LABORATORY	2 Credits

Course Description:

The Project Management Laboratory course provides hands-on experience in applying project management principles and tools. It provides various exercises to break down project components, define custom data items, and plan resources and to arrive costs effectively.

Through hands-on practice and a mini project, learners will gain the ability to plan, execute, and control projects, preparing them for real-world project management challenges.

Exercises:

- Breaking down project components.
- Defining custom data items.
- Planning resources and costs.
- Resource levelling.
- Tracking of Projects
- Quantity and Cost Estimation
- Hands on practice in MS Project and Primavera software packages
- Mini project

Course Outcome:

CO1: Acquire, download, and geo-reference spatial data from various sources, ensuring accurate alignment with geographic coordinates.

CO2: Collect and explore field attribute data using GPS and Google Earth, enhancing practical skills in data acquisition and interpretation.

CO3: Perform onscreen digitization to create and manage spatial data layers, including point, line, and polygon features.

CO4: Conduct spatial analysis and apply SQL commands to manage and analyze attribute data within a GIS environment.

CO5: Generate thematic maps and design professional-quality maps, effectively presenting spatial data for various applications.

References:

1. Project Planning and Scheduling Using Primavera Contractor Version 6. 1 by Harris P.E., Eastern Harris Publications, 2009.
2. Microsoft Project 2019 Step by Step By Cindy M. Lewis, Carl Chatfield, Timothy Johnson, Pearson Education, 2019.

III. **FOUNDATION COURSE**

MA24M13	STATISTICAL METHODS FOR ENGINEERS	3 Credits

Course Description:

This course is designed to provide the solid foundation on topics in various statistical methods which form the basis for many other areas in the mathematical sciences including statistics, modern optimization methods and risk modeling. It is framed to address the issues and the principles of Probability and random variables, estimation theory, testing of hypothesis, design of experiments and design of experiments.

Unit I: Probability and Random Variables

Probability – Axioms of probability – Conditional probability – Baye's theorem - Random variables – Probability function – Moments – Moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a random variable.

Unit II: Estimation Theory

Principle of least squares – Regression – Multiple and partial correlations – Estimation of parameters – Maximum likelihood estimates – Method of moments.

Unit III: Sampling

Concept of sampling – methods of Sampling- Sampling distributions and Standard error - Small and large samples -Tests based on Normal, t, F and Chi square distributions for testing of means, variance and proportions – Test of goodness of fit.

Unit IV: Design of Experiments

Basics principles of experimentation - Analysis of variance – One way and two way classifications – Completely randomized design – Randomized block design – Latin square design - 2 2 Factorial design.

Unit V: Multivariate Analysis

Random vectors and matrices – Mean vectors and covariance matrices – Multivariate normal density and its properties – Principal components: Population principal components – Principal components from standardized variables.

Course Outcome:

CO1: Apply basic probability axioms and rules and the moments of discrete and continuous random variables.

CO2: Least squares, correlation, regression, consistency, efficiency and unbiasedness of estimators, method of maximum likelihood estimation and Central Limit Theorem.

CO3: Use statistical tests in testing hypotheses on data.

CO4: List the guidelines for designing experiments and recognize the key historical figures in Design of Experiments.

CO5: Perform exploratory analysis of multivariate data, such as multivariate normal density, calculating descriptive statistics, testing for multivariate normality.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1	1	1	1
CO2	1	2	1	2	1	1
CO3	2	3	2	1	2	1
CO4	1	2	1	2	1	1
CO5	2	3	1	2	1	1

References:

1. Devore, J. L., “Probability and Statistics for Engineering and Sciences”, 9th Edition, Cengage Learning, 2016.
2. Gupta S.C. and Kapoor V.K., ” Fundamentals of Mathematical Statistics”, 12th Edition, Sultan and Sons, New Delhi, 2020.
3. Anderson, O.D, “Time Series Analysis: Theory and Practice”, North - Holland, Amsterdam, 1982
4. Johnson, R.A., Miller, I and Freund J., “Miller and Freund’s Probability and Statistics for Engineers, 9th Edition, Pearson Education, Asia, 2016.
5. Montgomery D.C and Johnson, L.A, “Forecasting and Time Series”, 6th Edition, McGraw Hill,1990

IV. MANDATORY COURSE

RM24K11	**Research Methodology and IPR**	**3 Credits**

Refer the syllabus of MOOC course

V. PROFESSIONAL ELECTIVE COURSES

Cluster A. PROJECT MANAGEMENT

IM24A11	**PROCUREMENT OF MATERIALS AND MANAGEMENT**	**3 Credits**

Course Description

This course provides a comprehensive understanding of the critical role of materials in the successful execution of civil engineering projects. Students will learn about the entire procurement process, from material identification and selection to contract management and inventory control. Emphasis is placed on efficient and cost-effective procurement strategies. The course covers a wide range of topics including material specification, tendering, contract administration, warehousing, and transportation. Students will develop skills in material management, enabling them to optimize resource utilization, minimize costs, and ensure project success.

Course Content

Unit I: Introduction to Material Management

Importance of materials in construction - Classification of construction materials - Material specifications and standards - Material testing and quality control - Material cost estimation

Unit II: Procurement Planning and Strategy

Procurement process overview - Material requirement planning - Vendor selection and evaluation - Supply chain management - Risk management in procurement

Unit III: Tendering and Contract Management

Tendering process and documentation - Contract types and their implications - Contract administration - Dispute resolution - Contract law and its implications

Unit IV: Inventory Control and Warehousing

Inventory management techniques - Economic order quantity - Inventory control systems - Warehouse management - Material handling and storage

Unit V: Material Transportation and Distribution

Modes of transportation - Transportation planning and optimization - Logistics and supply chain network - Material handling equipment - Construction site material management

Course Outcome

Upon successful completion of this course, students will be able to:

CO1: Identify, classify estimate requirement of construction materials for a project.

CO2: Develop effective procurement strategies and plans for civil engineering projects.

CO3: Manage the tendering process, contract negotiation, and contract administration efficiently.

CO4: Implement effective inventory control systems to optimize material utilization and reduce costs.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

- Purchasing and Supply Management by Monczka, Handfield, Giunipero, and Nixon
- Logistics and Supply Chain Management by Christopher, Bowersox, and Closs
- Operations and Supply Chain Management by Heizer and Render
- Construction Project Management by Cleland and Gareis
- Project Management: A Managerial Approach by Harold Kerzner
- Construction Contracts: Law and Management by Hudson
- Materials Management by A.K. Datta
- Construction Economics by Barrie Hudson

IM24A12	PROJECT COST AND RISK MANAGEMENT	3 Credits

Course Description:

This course provides an in-depth understanding of the principles and practices involved in managing project costs and risks. It covers the entire project lifecycle, from budgeting and cost estimation to risk identification, assessment, and mitigation. Students will learn to use various tools and techniques to manage financial resources effectively, anticipate potential risks, and develop strategies to minimize their impact on project success. The course emphasizes real-world application through case studies, simulations, and project-based learning.

Course Content:

Unit-I: Introduction to Project Cost Management & its techniques

Overview of Project Cost Management - Cost Management Processes (Planning, Estimation, Budgeting, Control) - Life-Cycle Costing - Types of Costs (Fixed, Variable, Direct, Indirect) - Overview of Cost Estimation Methods - Analogous Estimating - Parametric Estimating - Bottom-Up Estimating - Three-Point Estimating - Cost of Quality and Reserve Analysis

Unit-II: Budgeting and Cost Control

Developing a Cost Baseline - Budgeting Techniques - Cash Flow Analysis - Earned Value Management (EVM) - Variance Analysis and Forecasting - Cost Performance Index (CPI) and Schedule Performance Index (SPI)

Unit-III: Project Risk Management, Identification and Assessment

Overview of Risk Management - Risk Management Processes (Identification, Assessment, Response Planning, Monitoring) - Types of Risks (Technical, Financial, Legal, Environmental) - Risk Attitudes and Tolerance - Risk Identification Techniques (Brainstorming, Checklists, SWOT Analysis) - Risk Assessment Methods (Qualitative and Quantitative) - Probability and Impact Matrix - Risk Register Development -Sensitivity Analysis - Monte Carlo Simulation

Unit-IV: Risk Response Planning

Risk Avoidance, Mitigation, Transfer, and Acceptance - Contingency Planning and Reserves - Implementing Risk Responses - Risk Response Monitoring - Software Integration for Cost and Risk Management – Case Studies and Reflection.

Unit-V: Integrated Cost and Risk Management

Relationship between Cost Management and Risk Management - Cost Risk Analysis Strategies for Balancing Cost and Risk - Case Studies in Cost and Risk Management - Preparing Cost Reports - Risk Management Reporting - Communicating with Stakeholders - Using Dashboards and Visual Tools for Reporting

Course Outcome:

On completion of the course, the student is expected to be able to

CO1: Apply various cost estimation techniques to develop accurate detailed project budgets.

CO2: Identify potential project risks and assess their likelihood and impact using qualitative and quantitative methods.

CO3: Develop and implement risk mitigation plans to minimize the impact of risks on project objectives.

CO4: Use cost control techniques to monitor project expenses and ensure they align with the budget.

Prepare and present cost and risk management reports to stakeholders.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

1. Project Management Institute, A Guide to the Project Management Body of Knowledge (PMBOK Guide), 6th ed., PMI, 2017.

2. Chris Chapman, Stephen Ward, Project Risk Management: Processes, Techniques, and Insights, 2nd ed., John Wiley & Sons, 2011.

3. Joseph A. Sopko, Cost Engineering: Fundamentals and Applications, CRC Press, 2017.

4. Robert J. Chapman, The Rules of Project Risk Management: Implementation Guidelines for Major Projects, Gower Publishing, 2014.

5. Eric Verzuh, The Fast Forward MBA in Project Management, 6th ed., John Wiley & Sons, 2016.

IM24A13	LEAN CONSTRUCTION MANAGEMENT	3 Credits

Course Description

This course introduces the principles and practices of Lean Construction, a management philosophy aimed at maximizing customer value while minimizing waste in the construction industry. This course will help to apply Lean principles to improve project efficiency, quality, and delivery time. Eventually, it will emphasizes incorporating real-world case studies (India and Abroad).

Course Content:

Unit I: Introduction

Introduction and overview of the construction project management -Review of Project Management& Productivity Measurement Systems – Productivity in Construction– Daily Progress Report-The state of the industry for its management practices –construction project phases - Essential features of contemporary construction management techniques - The problems with current construction management techniques– Current production planning.

Unit II: Lean Management

Introduction to lean management – Toyota's management principle-Evolution of lean in the construction industry - Production theories in construction –Lean construction value - Value in construction - Target value design – Lean project delivery system- Forms of waste in the construction industry – Waste Elimination

Unit III: Core Concepts in Lean

Concepts in lean thinking – Principles of lean construction – Variability and its impact – Traditional construction and lean construction – Traditional project delivery - Lean construction and workflow reliability – Work structuring – Production control.

Unit IV: Lean Construction Tools and Techniques

Value Stream Mapping – Work sampling – Last planner system – Flow and pull-based production – Last Planner System – Look ahead schedule – constraint analysis – weekly planning meeting- Daily Huddles – Root cause analysis – Continuous improvement – Just in time.

Unit V: Lean Construction Implementation

Lean construction implementation- Enabling lean through information technology – Lean in design - Design Structure Matrix Location Based Management System-BIM (Building Information Modelling) - IPD (Integrated Project Delivery) – Sustainability through lean construction approach-Case study.

Course Outcome:

CO1: Explains the contemporary management techniques and the issues in the present scenario.

CO2: Apply the basics of lean management principles and their evolution from the manufacturing industry to the construction industry.

CO3: Develops a better understanding of core concepts of lean construction tools and techniques and their importance in achieving better productivity.

CO4: Apply lean techniques to achieve sustainability in construction projects.

CO5: Apply lean construction techniques in design and modelling.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	1	1	2
CO2	3	2	3	2	2	2
CO3	2	3	3	1	3	2
CO4	3	2	3	2	3	2
CO5	1	1	3	2	3	2

References:

1. Corfe, C. and Clip, B., Implementing lean in construction: Lean and the sustainability agenda, CIRIA, 2013.

2. Shang Gao and Sui Pheng Low, Lean Construction Management: The Toyota Way, Springer, 2014.

3. Dave, B., Koskela, L., Kiviniemi, A., Owen, R., and Tzortzopoulos, P., Implementing lean in construction: Lean construction and BIM, CIRIA, 2013.

4. Ballard, G., Tommelein, I., Koskela, L. and Howell, G., Lean construction tools and techniques, 2002.

5. Salem, O., Solomon, J., Genaidy, A. and Luegring, M., Site Implementation and Assessment of Lean Construction Techniques, Lean Construction Journal, 2005.

6. Lincoln H. Forbes , Syed M. Ahmed, Lean Project Delivery and Integrated Practices in Modern Construction, Routledge Publishers, 2nd Edition, 2020.

Cluster B. SMART MOBILITY

IM24B11	DIGITAL TWIN FOR INFRASTRUCTURE	3 Credits

Course Description

The Digital Twin course provides a comprehensive understanding of the fundamentals, development approaches, data analytics, and practical applications of digital twins in modern industries. The course covers the historical evolution and significance of digital twins in digital transformation, exploring various frameworks, sensor technologies, IoT, and AI/ML integration. Students will learn about data types, analytics, real-time modeling, simulation, and visualization techniques, including 3D, AR, and VR. Through case studies, the course also addresses the challenges of implementing digital twins, focusing on scalability, security, and industry-specific applications, and offers strategies for successful digital transformation.

Course Content:

UNIT I: Fundamentals of Digital Twins

Overview of Digital Twins Historical context and evolution - Digital Twins maturity models - Significance in digital transformation and modern industries - Introduction to different Digital Twin framework – Sensor technologies - Internet of Things (IoT) - Cloud computing and edge computing - Machine learning and Artificial Intelligence

UNIT II: Digital Twin Development Approaches

Principles and applications - Examples - Data acquisition, preprocessing, and analytics - Integrating physical and data-driven elements - Advantages and challenges

UNIT III: Digital Twin Data Types and Analytics

Digital Twin Data Types and Management - Geometric, behavioral data; Historical, Synthetic, and real-time data; Data acquisition, storage, and processing - Data Analytics and Insights -

Descriptive analysis; Diagnostic analysis; Predictive analysis; Prescriptive analysis; Data-driven decision making

UNIT IV: Critical Functional and Non-functional Components

Realtime Modeling and Simulation - Dynamic modeling; Simulation techniques; Feedback loops and control systems - Visualization Techniques - 3D visualization; Augmented Reality (AR) and Virtual Reality (VR); User interfaces for Digital Twins

UNIT V: Case Studies

Preparing for Challenges - Anticipating challenges in digital twin implementation; Scalability, security, and integration with legacy systems; Metrics and performance measurement in the success of Digital Twins; Ethical considerations; Strategies for overcoming challenges - Industry-specific applications - Problem identification and digital transformation roadmap - Case studies

Course Outcome:

CO1: Apply the fundamentals of digital twins, including their historical context, evolution, and role in digital transformation, and explore various digital twin frameworks and enabling technologies like IoT, cloud computing, and AI.

CO2: Develop digital twin models by integrating physical systems with data-driven approaches, addressing the principles, applications, advantages, and challenges associated with digital twin development.

CO3: Manage and analyze diverse data types within digital twins, including geometric, behavioral, historical, synthetic, and real-time data, and apply descriptive, diagnostic, predictive, and prescriptive analytics for informed decision-making.

CO4: Implement real-time modeling, simulation techniques, and advanced visualization methods, such as 3D visualization, AR, and VR, to create dynamic and interactive digital twin environments.

CO5: Critically evaluate case studies to identify and address the challenges of digital twin implementation, including scalability, security, and integration with legacy systems, and develop strategies for successful digital transformation in various industries.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	1	3	1
CO2	2	3	2	2	3	1
CO3	2	3	1	3	3	1
CO4	2	2	3	2	3	1
CO5	1	2	2	2	2	3

References:

1. Digital Twin Technologies in Transportation Infrastructure Management by Wenjuan Wang, Qasim Zaheer, Shi Qiu, Weidong Wang, Chengbo Ai, Jin Wang, Sicheng Wang, Wenbo Hu.
2. Twin Systems: Digital Twins of the Built Environment by Dr. Erika Anneli Parn, Prof. Rafael Sacks, Prof. Ioannis Brilakis, Prof. Lucio Soibelman, Mark Enzer.
3. Digital Twin Technologies and Smart Cities by Maryam Farsi, Alireza Daneshkhah, Amin Hosseinian-Far, Hamid Jahankhani
4. The Digital Twin by Noel Crespi, Adam T. Drobot, Roberto Minerva

IM24B31	DATA SCIENCE FOR SMART CITIES	3 Credits

Course Description:

This course provides an interdisciplinary exploration of how data science techniques can be applied to the design, development, and operation of smart cities. Students will learn to harness the power of big data, machine learning, and artificial intelligence to solve urban challenges, optimize city functions, and enhance the quality of life for residents. Topics include data collection and management, predictive analytics, IoT, urban informatics, and the ethical considerations of data use in urban environments. The course emphasizes hands-on projects and case studies, preparing students to contribute to the development of smarter, more sustainable cities.

Course Content:

Unit I: Introduction to Smart Cities and Urban Informatics

Overview of Smart City Concepts - Key Components of Smart Cities (Infrastructure, IoT, Data Analytics) - Role of Data in Urban Planning and Management - Introduction to Urban

Informatics - Geographic Information Systems (GIS) and Spatial Data Analysis - Urban Mobility and Transportation Data Analytics - Case Studies of Existing Smart Cities.

Unit II: Data Science Techniques for Smart Cities

Machine Learning and AI in Urban Contexts - Predictive Analytics for Urban Planning - Data Mining and Pattern Recognition in Urban Data - Time Series Analysis and Forecasting for City Management - Sources of Urban Data (IoT Sensors, GIS, Social Media, Open Data) - Data Collection Techniques - Data Storage and Management (Big Data Technologies, Databases) - Challenges in Urban Data Management

Unit III: Internet of Things (IoT) in Smart Cities & Data Driven Decision Making

IoT Architecture and Components - IoT Applications in Smart Cities (Smart Grid, Smart Transportation, Smart Buildings) - Data Analytics for IoT-Enabled Urban Services Security and Privacy Issues in IoT - Data-Driven Infrastructure Management (Water, Energy, Waste) - Smart Transportation Systems and Traffic Management - Public Safety and Emergency Response Systems - Case Studies on Data-Driven Infrastructure Optimization**.**

Unit IV: Ethical and Legal Considerations in Smart Cities

Privacy, Security, and Data Protection in Smart Cities - Ethical Implications of Data Use in Urban Environments - Legal and Regulatory Frameworks - Social Impacts of Smart City Technologies.

Unit V: Smart City Project Development

Project Design and Proposal Writing - Collaboration in Multidisciplinary Teams - Implementation Strategies for Smart City Solutions - Presentation and Evaluation of Smart City Projects.

Course Outcome:

On completion of the course, the student is expected to be able to

CO1: Explain the key concepts and components of smart cities, including the role of data in urban planning and management.

CO2: Use data science techniques such as machine learning, data mining, and predictive analytics to address urban challenges.

CO3: Collect, manage, and analyze large-scale urban data from various sources, including IoT devices and social media.

CO4: Design data-driven solutions for optimizing urban infrastructure, transportation, energy use, and public services.

CO5: Critically evaluate the ethical, privacy, and security issues related to data use in smart cities.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. Anthony M. Townsend, Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia, W.W. Norton & Company, 2013.
2. Carlo Ratti, Matthew Claudel, The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life, Yale University Press, 2016.
3. Thakur, D. R., Data Science and Big Data Analytics in Smart Cities, Springer, 2020.
4. Albino, V., Berardi, U., Dangelico, R. M., Smart Cities: Definitions, Dimensions, and Performance, Taylor & Francis, 2015.
5. Zeiger, S., Building Smart Cities: Analytics, ICT, and Design Thinking, Routledge, 2019.

IM24B12	INTELLIGENT TRANSPORTATION SYSTEM	3 Credits

Course description

This course provides a comprehensive understanding of Intelligent Transportation Systems (ITS), exploring integrating information and communication technologies to enhance transportation efficiency, safety, and sustainability. Learner will delve into the fundamental

concepts, components, and applications of ITS, while developing a solid foundation in the underlying technologies and their impact on urban and regional transportation systems.

Course Content:

Unit I: Introduction

Introduction to Intelligent Transportation Systems (ITS) -Definition-Role of ITS -Challenges and opportunities in ITS- Advanced Traveller Information System – Fleet Oriented ITS Services – Electronic Toll Collection- Issues and challenges of ITS in India- ITS around the world.

Unit II: Detection and Data Collection Methods

Detection methods-Automatic pedestrian detection method-Red Light Violation Detection System-Automatic Number Plate Recognition Techniques-Data collection methods-Route Travel Time Estimation Models.

Unit III: Advanced Transportation Management System

Video Detection – Virtual Loop - Cameras - ANPR – IR Lighting – Integrated Traffic Management –Control Centre – Junction Management Strategies- ATMS – Advanced Traveler Information Systems(ATIS)- Route Guidance – Issues -– Historical – Current – Predictive Guidance – Data Collection –Analysis – Dynamic Traffic Assignment (DTA) – Components – Algorithm.

Unit IV: Intelligent Transport System Applications

ITS for traffic management system- Advanced traffic management system-Role of traffic management centre -ITS tools for safety- ITS for public transportation system -Fleet management and operations -Emergency vehicle management

Unit V: Phases for Implementation Of ITS

Phases I to V as per IRC: SP: 110 and case studies: application in bus transport-metro-railways and airways.

Course Outcome:

CO1: Identify various components of Intelligent transportation systems (ITS) and supporting technologies.

CO2: Analyse automated traffic data collected using sensors for varying roadway and traffic conditions

CO3: Potential uses of the transportation management system at critical spots

CO4: Apply ITS related strategies for varying roadway and traffic conditions using design and control parameters

CO5: Evaluate ITS related strategies for improving the sustainability, efficiency and safety of transportation system considering different case studies.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	3
CO2	2	2	3	1	2	3
CO3	2	2	3	2	2	2
CO4	2	2	3	1	2	1
CO5	2	2	3	2	3	2

References

1. Intelligent Transport Systems, Intelligent Transportation Primer, Washington, US, 2001.
2. Henry F.Korth, and Abraham Siberschatz, Data Base System Concepts, McGraw Hill, 1992.
3. Turban E.,"Decision Support and Export Systems Management Support Systems", Maxwell Macmillan, 1998.
4. Sitausu S. Mittra, "Decision Support Systems – Tools and Techniques", John Wiley, NewYork, 1986.
5. Cycle W.Halsapple and Andrew B.Winston, "Decision Support Systems – Theory and Application", Springer Verlog, New York, 1987
6. ITS Hand Book 2000: Recommendations for World Road Association (PIARC) by Kan Paul Chen, John Miles
7. Application of Intelligent Transportation System for urban roads. IRC:SP:110-2017, Publisher Indian Road Congress, New Delhi, India.
8. Srinivasa R Kumar. "Intelligent Transportation Systems" Orient blackswan Pvt LTD publisher,2021. ISBN-10 : 8195400922,ISBN-13 : 978-8195400928.
9. Bob Williams, Intelligent Transport Systems Standards, Artech House Publishers, 2008.

10. Sumit Ghosh and Tony Lee, Intelligent Transportation Systems, CRC Press, ISBN: 0849300673
11. Chris Drane and C. R. Drane, Positioning Systems in Intelligent Transportation Systems, Artech House Publishers, ISBN: 0890065365.
12. Judy Mc Queen and Bob Mc Queen, Intelligent Transportation System and Architecture, Artech House Publishers, ISBN: 089006525X
13. Asad J. Khattak , Intelligent Transportation Systems: Planning, Operations, and Evaluation,
CRC Press
14. Chowdhary M A and A Sadek. Fundamentals of Intelligent Transportation systems planning. Artech House Inc., US, 2003.
15. M.A. Chowdhury and A. Sadek, Fundamentals of Intelligent Transportation Systems Planning,Artech House, 2010.

Cluster C. CONSTRUCTION TECHNOLOGY & NDT

IM24C11	REPAIR AND REHABILITATION OF STRUCTURES	3 Credits

Course Description

The field of repair and rehabilitation of structures is rapidly evolving, driven by the increasing age of infrastructure and the need for sustainable solutions. The service life of existing structures can be extended through effective maintenance and restoration strategies. **This course** is designed to provide students with a comprehensive understanding of the deterioration processes affecting civil engineering structures, assessment methodologies, and various repair and rehabilitation techniques. The course is relevant to civil engineers, structural engineers, and professionals involved in the maintenance and management of infrastructure.

Course Content:

Unit I

Causes of deterioration: Physical, chemical, and biological factors - Mechanisms of deterioration: Corrosion, cracking, spalling, alkali-aggregate reaction, etc. - Assessment of deterioration: Visual inspection, non-destructive testing (NDT) techniques and material testing

- Modeling of deterioration processes - Assessment procedure for evaluating damaged structure - Non-Destructive Testing of Concrete (Rebound Hammer, Ultrasonic Pulse Velocity)

Unit II

Repair materials: Concrete repair mortars, epoxy resins, polymers, fiber-reinforced composites, etc. - Protective coatings for concrete and steel - Repair techniques: Crack repair, concrete restoration, grouting, epoxy injection, waterproofing, etc. -– corrosion protection techniques – corrosion inhibitors, corrosion resistant steels, coating to reinforcement, cathodic protection - Design considerations for repair materials and techniques - Quality control and assurance in repair works.

Unit III

Strengthening techniques: Reinforced concrete jacketing, steel plate bonding, fiber-reinforced polymer (FRP) strengthening, etc. - Seismic retrofitting: Base isolation, energy dissipation devices, structural damping - Rehabilitation of masonry structures: Grouting, underpinning, strengthening, etc. - Rehabilitation of bridges and other infrastructure

Unit IV

Self-healing concrete - Smart materials - Fiber-reinforced polymers (FRPs) - 3D printing - Unmanned aerial vehicles (UAVs) for efficient and detailed inspection of structures

Unit V

Term Paper based on case study

Course Outcome:

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

CO1: Apply the knowledge and skills to assess the condition of existing structures,

CO2: Select appropriate repair materials and techniques

CO3: Apply appropriate retrofitting / strengthening techniques

CO4: Handle advanced materials and techniques for restoration of structures

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2

CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References

- Repair and Rehabilitation of Concrete Structures by John Newman
- Concrete Repair and Rehabilitation by RILEM
- Principles of Concrete Repair by R.D. Mehta
- Structural Rehabilitation by F.C. Robinson

IM24C12	NON-DESTRUCTIVE TESTING AND SENSING FOR CIVIL INFRASTRUCTURES	3 Credits

Course Description

This course provides a comprehensive understanding of non-destructive testing (NDT) and sensing techniques applied to civil infrastructure. It covers the fundamental principles, methods, and applications of NDT for assessing the condition, integrity, and performance of infrastructures. Similarly, it covers major NDT applications in civil engineering fields like structures, Geotechnical and Pavement engineering.

Course Content:

Unit-I: Introduction

Fundamentals of Civil Materials -Structure Integrity-Importance of quality control and quality assurance- Destructive methods-Semi destructive methods-non destructive methods-Relative merits and limitations-Various physical characteristics of materials and their applications-in NDT, visual inspection, and unaided and aided.

Unit-II: Non-Destructive Tests for Strength Estimation Of Concrete

NDT tests for strength estimation of concrete-Rebound hammer test (Schmidt hammer)-Ultrasonic pulse velocity tester- Combined use of rebound hammer and ultrasonic pulse velocity method- Pull off and pull-out test- the brake-off test- Core drilling method-Permeability test- Bond test.

Unit-III: Non-destructive Tests for Geotechnical Application

Site characterization and soil investigation- Seismic Refraction and reflection - Spectral Analysis of Surface Waves (SASW)- Electrical Resistivity Tomography (ERT)-Foundation and Calcium carbide method - Ground penetrating radar-Plate load test.

Unit-IV: Non-destructive Tests for Pavement Application

Structural and functional pavement evaluation- Roughness Measurement-Friction measurement- The ARRB Walking Profilometer-Nuclear density gauge- Lightweight deflectometer- Falling Weight Deflectometer- -Benkelman beam deflectometer-Dynamic Cone Penetrometer-Network Survey vehicle.

Unit-V: Drone technology in Civil engineering Application

Thermal images for water leakage test- UAV application in Civil engineering- Infrastructure inspection and monitoring with drones: Bridges, buildings, dams, and roads, Drones in water resources engineering: Flood modelling and hydrological monitoring, Drones in flood mapping, forest monitoring and post-disaster damage assessments, and Case studies.

Course Outcome:

CO1: Identify the essential need for NDT applications in Civil infrastructures

CO2: Selection of suitable concrete strength estimation using NDT devices.

CO3: Potential uses of NDT devices in Geotechnical engineering

CO4: Identifying suitable NDT devices for pavement maintenance and construction activities

CO5: Utilize advanced sensing technologies for monitoring and assessing the condition of bridges, buildings, and other civil structures using UAV.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	3	2
CO2	3	2	3	2	2	2
CO3	3	2	3	2	3	2
CO4	3	2	3	2	3	2
CO5	3	3	2	2	3	3

References:

1. Indian Standard codes related with non-destructive testing, Government Resolutions related to Structural Audits (BMC Act, etc.), Field manuals and reports by Expert Consultants.

2. Non Destructive testing of bridges, Indian railway institute of civil engineering https://iricen.gov.in/iricen/books_jquery/NDT-2022.pdf.

3. Thermal image guidebook for building and renewable energy applications. http://www.flirmedia.com/MMC/THG/Brochures/T820325/T820325_EN.pdf

4. Practical non-destructive testing: Baldev Raj, Tammana Jaya Kumar, M, Narosa Publishing house. https://www.lecollege.ac.in/uploads/subjectdata/3131904/3131904_E-book_NDT_By_Baldev_Raj_1252.pdf

5. Drone Technology in Architecture, Engineering, and Construction: A Strategic Guide to Unmanned Aerial Vehicle Operation and Implementation by Daniel Tal and Jon Altschuld, 2021.

6. Drones: Technology and Business Plan for Civil Engineering by Thiago Prudêncio and Gleydson Carlos Almeida, 2023.

IM24C13	QUALITY CONTROL AND QUALITY ASSURANCE IN INFRASTRUCTURE CONSTRUCTION	3 Credits

Course Description:

This course focuses on the principles and practices of quality control (QC) and quality assurance (QA) in the construction of infrastructure projects. Students will learn about the methodologies, standards, and tools used to ensure that construction processes and outcomes meet the required quality standards. Topics include quality management systems, construction materials testing, inspection techniques, and the implementation of QA/QC plans. The course combines theoretical knowledge with practical applications through case studies and hands-on projects.

Course Content:

Unit-I: Introduction to Quality in Construction

Overview of Quality Concepts in Construction - Importance of Quality in Infrastructure Projects - Concept of quality control, Quality assurance, Quality management - Quality Control vs.

Quality Assurance – TQM - Development and design Concept of TQM - International Standards and Guidelines (ISO 9001, ASQ)

Unit-II: Quality Management Systems (QMS)

Components of a Quality Management System - Developing a QMS for Construction Projects Role of QMS in Project Lifecycle - Certification and Accreditation Processes –Case Studies

Unit-III: Quality Assurance in Construction Processes

Developing and Implementing QA Plans - Monitoring Construction Processes for Quality - Documentation and Record Keeping in QA - Managing Non-Conformities and Deviations - Role of Third-Party Inspections in QA - Case Studies of Quality Control Failures and Successes - Lessons Learned from Major Infrastructure Projects - Role of Technology in Enhancing Construction Quality - Emerging Trends in Construction Quality- Future Directions in Construction Quality Assurance

Unit-IV: QC/QA Tools and Techniques

Statistical Quality Control (SQC) - Quality Measurement: Attributes and Variables - Statistical Process Control (SPC) Methods - Control Charts for Attributes - p-Charts - Proportion Defective - c-Charts - Number of Defects Per Unit - Control Charts for Variables - Other Types of Attribute-Sampling Plans- Acceptance Sampling - Use of Control Charts in Construction - Six Sigma and Lean Construction Techniques - Root Cause Analysis for Quality Issues

Unit-V: Legal and Ethical Considerations in QC/QA

Regulatory Requirements and Compliance - Ethical Issues in Quality Management - Role of Ethics in Ensuring Quality - Legal Implications of Quality Failures – Case Studies and Reflection.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Explain the fundamental principles of quality control and quality assurance in construction.

CO2: Perform standard tests and inspections on construction materials to ensure compliance with specifications.

CO3: Utilize various QC/QA techniques and tools to monitor and improve construction processes.

CO4: Prepare and maintain quality-related documentation, including QA/QC plans, inspection reports, and non-conformance reports.

CO5: Analyze real-world case studies to understand the challenges and solutions in implementing effective QC/QA in infrastructure construction.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	2	3	1	1	2	3

References:

1. David Arditi, Construction Quality Management, CRC Press, 2013.
2. Rk, Swamy. Quality Control Civil Work: Civil Engineering Guide India. N.p.: Independently Published, 2019.
3. Mireles, Alberto Munguia. Field Book for Quality Control in Earthwork Operations: Project Construction Management Book. United Kingdom: iUniverse, 2014.
4. Thorpe, Brian., Sumner, Peter. Quality Assurance in Construction. United Kingdom: Taylor & Francis, 2017.
5. O'Brien, James J.. Construction Inspection Handbook: Quality Assurance/Quality Control. Switzerland: Springer US, 2013.
6. Brian Thorpe, Peter Sumner, Quality Assurance in Construction, Gower Publishing, 1997.
7. M.L. Gambhir, Concrete Technology: Theory and Practice, McGraw-Hill Education, 2013.
8. IS/ISO 9001:2015, Quality Management Systems – Requirements, Bureau of Indian Standards.
9. Chung, H.W.. Understanding Quality Assurance in Construction: A Practical Guide to ISO 9000 for Contractors. United Kingdom: CRC Press, 2002.
10. American Society for Quality (ASQ), The ASQ Construction Quality Management Standards, ASQ, 2016.

Cluster D. STRUCTURAL DESIGN AND MAINTENANCE

IM24D11	MAINTENANCE ENGINEERING AND MANAGEMENT	3 Credits

Course Description:

This course provides a comprehensive understanding of the principles and practices involved in the maintenance, management, and preservation of civil infrastructure assets. It covers a wide range of topics, including condition assessment, maintenance planning, scheduling and cost control. Students will develop the skills to optimize the lifecycle performance of civil infrastructure systems through effective maintenance strategies. The course emphasizes the integration of engineering, management, and economic principles to ensure the long-term sustainability and reliability of civil infrastructure assets.

Course Content

Unit I: Introduction to Maintenance Engineering and Management

Definition and scope of maintenance engineering - Types of maintenance (corrective, preventive, predictive, condition-based) - Maintenance management systems (CMMS) - Reliability and maintainability concepts - Life cycle cost analysis

Unit II: Condition Assessment and Diagnosis

Inspection techniques (visual, non-destructive testing) - Condition assessment methodologies -Performance indicators and benchmarks - Failure analysis and root cause analysis - Predictive maintenance technologies

Unit III: Maintenance Planning and Scheduling

Maintenance planning process - Work order management - Maintenance scheduling techniques - Spare parts management - Maintenance resource planning - Safety and ergonomics in maintenance

Unit IV: Maintenance Cost Management

Maintenance cost estimation - Budget development and control - Cost-benefit analysis - Performance-based budgeting – Replacement analysis - Economic evaluation of maintenance options

Unit V: Case Study

Maintenance management in different infrastructure sectors (roads, bridges, buildings) - Maintenance challenges and best practices

Course Outcome

Upon successful completion of this course, students will be able to:

CO1: Apply various maintenance strategies to different types of civil infrastructure.

CO2: Conduct condition assessments using appropriate techniques and provide information to maintenance decisions.

CO3: Develop effective maintenance plans and schedules considering factors such as asset criticality, cost, and risk.

CO4: Estimate maintenance costs accurately and develop budgets for maintenance activities.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References

- Reliability and Maintenance Engineering by L.S. Srinath
- Plant Engineer's Handbook by Ralph L. Everett
- Total Productive Maintenance by Seiichi Nakajima
- Maintenance Management Handbook by Keith Mobley
- Infrastructure Management by A. Skitmore
- Asset Management for Engineers by David P. Jaiswal
- Infrastructure Planning and Management by David A. Okoye
- Civil Engineering Materials by Peter A. Claisse
- Industry-specific journals and publications: ASCE journals, Transportation Research Record, Journal of Infrastructure Systems, etc.
- Government reports and guidelines

IM24D12	EARTHQUAKE RESISTANT DESIGN OF BUILDINGS	3 Credits

Course Description

Earthquake resistant construction of a building or structure is able to withstand the sudden ground shaking thereby minimizing structural damage and human deaths and injuries. Suitable planning along with design and construction techniques are required to ensure good performance of buildings during earthquake. This introduces important concepts in the study of earthquakes related planning, analysis and design of structures to be made earthquake resistant. The performance evaluation of structures and strengthening techniques are discussed.

Course Content:

Unit I

Elements of Engineering Seismology - Causes of earthquakes – Elastic rebound theory - Seismic waves – Magnitude and intensity – Measuring instruments – Seismic zones - Performance of structures under past earthquakes.

Unit II

Introduction to theory of vibrations - Equations of Motion for SDOF and MDOF Systems - Undamped Free Vibration of SDOF and MDOF Systems - Mode Shapes and Frequencies of MDOF System - Rayleigh Damping Matrix - Flexibility of long and short period structures - Concept of response spectrum.

Unit III

Seismic design philosophy - Concept of Earthquake Resistant Design – Calculation of earthquake load on structures based on IS: 1893 – Equivalent Static method - Response spectrum method - Ductile detailing as per IS 13920

Unit IV

Building configuration (vertical and horizontal) for earthquake resistance – Irregularities - Building Systems – Moment Resisting Frames, Braced Frames, Shear Walls (concept only /no design) – Steel structural systems - Introduction to passive and active control systems - Energy dissipation devices - Adaptive systems – Base isolation

Unit V

Seismic performance evaluation - Push over Analysis – Damage assessment procedure and techniques – Earthquake effects on non-structural elements - retrofitting / strengthening of structural elements – Application of FRP in strengthening

Course Outcome:

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

CO1: Corelate the theory of vibrations with ground motions due to earthquake

CO2: Calculate lateral forces due to earthquake by ESM and Response spectrum method

CO3: Configure buildings for better earthquake resistant

CO4: Assess the performance of the buildings for earth and suggest appropriate strengthening Techniques

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

1. Earthquake Resistant Design of Structures by Shrikhande and Agarwal
2. Earthquake Resistant Design of Buildings by Muhammad Hadi and Mehmet Eren Uz:
3. Dynamics of Structures with Earthquake Engineering by Ashok K Jain:
4. Basics of Structural Dynamics and Aseismic Design by Kavitha and Damodarasamy:
5. Seismic Design Manuals and Codes: IS 1893 (Part 1), IS 13920, FEMA guidelines.

IM24D13	STRUCTURAL HEALTH MONITORING	3 Credits

Course Description:

A comprehensive understanding of Structural Health Monitoring (SHM) is essential for an Engineer to ensure the safety, reliability, and longevity of critical infrastructure. This course provides the concepts and applications of monitoring and assessing the condition of civil engineering structures. It also covers the principles, technologies, and methodologies involved in implementing effective SHM systems. This course is essential for civil engineering professionals seeking to advance their knowledge in structural engineering, asset management, and risk assessment.

Course Content:

Unit I

Definition and concept of SHM - Importance of SHM in civil engineering - Comparison of SHM with traditional inspection methods - Components of an SHM system (sensors, data acquisition, processing, and decision-making) - Objectives and operational evaluation of SHM

Unit II

Types of sensors (strain gauges, accelerometers, fiber optic sensors, etc.) - Sensor characteristics and selection criteria - Data acquisition systems and hardware - Signal conditioning and noise reduction techniques

Unit III

Fundamentals of structural dynamics - Modal analysis and vibration testing - Vibration-based damage detection methods - Time-frequency analysis techniques - Static and Vibration based SHM.

Unit IV

Damage mechanisms in structures - Damage detection methods (statistical, pattern recognition, model-based) - Damage localization and quantification - Damage prognosis and life prediction

Unit V

Self-sensing concrete - Data acquisition system (DAS) - IOT in SHM - AI in SHM, Energy harvesting technology in SHM - Real time SHM application for buildings, and other infrastructure - Case studies

Course Outcome:

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

CO1: Select appropriate sensors and instrumentation for SHM

CO2: Analyze structural vibration data for damage detection

CO3: Implement SHM systems for different types of structures

CO4: Evaluate the effectiveness of SHM systems.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

- Farrar, C. R., & Doebling, S. W. (Eds.). The Structural Health Monitoring of Aerospace Vehicles. Wiley.
- Sohn, H. Structural Health Monitoring: A Machine Learning Perspective. Academic Press.
- Rytter, A. Structural Health Monitoring of Civil Engineering Structures. Wiley.
- Structural Health Monitoring, Daniel Balageas, Claus_Peterr Fritzen, Alfredo Guemes, John Wiley and Sons.
- Health monitoring of Structural Materials and Components _ Methods with Applications, Douglas E Adams, John Wiley and Sons.
- Structural Health Monitoring and Intelligent Infrastructure, Vol 1, J.P.Ou, H. Li and Z.D.Duan, Taylor and Francis Group, London, UK,
- Structural Health Monitoring with Wafer Active Sensors, Victor Giurglutiu, Academic Press Inc,.

IM24D31	ANALYSIS AND DESIGN OF STRUCTURES USING SOFTWARE	3 Credits

Course Description

Structural analysis and design software is important due to its capacity to analyse and design complex structures and ensure precision, time efficiency, and compliance with codes. Structural engineers use these powerful tools to efficiently analyse and design structures, which improves the structure's overall efficiency and safety.

A comprehensive procedure for analysis and design of structures is explained in this course with software ETABS / STAAD Pro. Hands on training using these software are provided to model, analyse and design the structures as per relevant IS code provisions. Report preparation of the designed structures is demonstrated.

Course Content

- Introduction to analysis of structures using software
- overview of Finite Element Method
- Structural systems for lateral forces
- Calculation of lateral forces
- Modelling of structures
- Assigning loads including earthquake and wind loads
- Analysis of structures
- Designing structural elements
- Design of steel structures
- Generate output results and reports – Project work.

Course Outcome

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

CO1: Identify appropriate structural systems for vertical and lateral loads

CO2: Calculate the lateral forces due to earthquake and wind as per IS code provisions

CO3: Analyse and Design structural components as per IS code

CO4: Prepare analysis and design report for clients.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6

CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

Reference

1. ETABS / STAAD Pro Manuals
2. Relevant IS codes

Cluster E. SUSTAINABILITY MANAGEMENT

IM24E11	GREEN BUILDING DESIGN AND IMPLEMENTATION	3 Credits

Course Description:

This course provides a comprehensive overview of green building principles, design strategies, and implementation practices. Students will explore the concepts of sustainability in the built environment, focusing on energy efficiency, water conservation, sustainable materials, and indoor environmental quality. The course also covers green building certifications, such as GRIHA, LEED and BREEAM, and the processes involved in designing, constructing, and operating high-performance green buildings. Practical case studies and hands-on projects will enable students to apply theoretical knowledge to real-world scenarios

Course Content

Unit I: Introduction to Green Building Design

Definition and Principles of Green Building - Environmental, Economic, and Social Benefits of Green Buildings - Overview of Green Building Standards and Certifications (LEED, BREEAM, WELL, etc.) - Global Trends in Green Building

Unit II: Sustainable Site Design, Building Materials and Resources

Site Selection and Development - Sustainable Landscaping and Urban Heat Island Reduction - Transportation and Mobility Considerations in Green Building Design -Stormwater Management and Erosion Control - Criteria for Selecting Sustainable Materials -Life Cycle

Assessment (LCA) of Building Materials - Recycled, Renewable, and Low-Impact Materials - Indoor Environmental Quality (IEQ) and Material

Unit III: Energy Efficiency and Water Efficiency

Selection -Waste Management and Recycling in Construction

Principles of Energy-Efficient Design - Passive Design Strategies (Orientation, Shading, Natural Ventilation) - Building Envelope Design (Insulation, Windows, Thermal Mass) - Renewable Energy Systems (Solar, Wind, Geothermal) -HVAC Systems and Energy Management -Water-Efficient Building Design - Indoor Water Use Reduction (Low-Flow Fixtures, Greywater Systems) - Rainwater Harvesting and Reuse - Landscaping for Water Conservation (Xeriscaping, Drip Irrigation) - Water-Efficient Appliances and Technologies

Unit IV: Indoor Environmental Quality (IEQ)

Importance of IEQ in Green Buildings- Ventilation and Indoor Air Quality (IAQ) -Daylighting and Views - Acoustic Comfort - Use of Non-Toxic, Low-Emitting Materials - Case Studies of Innovative Green Buildings - Lessons Learned from Green Building Projects

Unit V: Green Building Certification Systems

Overview of Major Certification Systems (GRIHA, LEED, BREEAM, WELL) - Certification Processes and Requirements - Case Studies of Certified Green Buildings - Cost-Benefit Analysis of Green Building Certification - Module 8: Green Building Project Management - Integrating Sustainability into Project Management - Green Building Delivery Methods (Design-Bid-Build, Design-Build) - Managing Green Building Costs and Schedules - Construction Management Practices for Green Buildings - Post-Occupancy Evaluation and Performance Monitoring

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Explain the principles of green building design and the importance of sustainability in the built environment.

CO2: Implement sustainable design strategies that reduce the environmental impact of buildings and enhance occupant health and well-being.

CO3: Assess the sustainability of building materials and systems, considering factors such as energy use, resource efficiency, and lifecycle impacts.

CO4: Design energy-efficient and water-efficient buildings, using strategies such as passive design, renewable energy integration, and water-saving technologies.

CO5: Navigate the requirements and processes of green building certification systems, including GRIHA, LEED, BREEAM, and others.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	1	2	3	2	2
CO3	2	1	2	2	1	2
CO4	3	2	2	3	1	3
CO5	3	3	1	2	3	3

REFERENCES:

1. Kibert, Charles J. *Sustainable Construction: Green Building Design and Delivery*. 5th ed. Hoboken, NJ: Wiley, 2022.
2. Jerry Yudelson, Green Building A to Z: Understanding the Language of Green Building, New Society Publishers, 2007.
3. M. Jerry Weidner, Fundamentals of Green Building Design, Wiley, 2010.
4. Charles J. Kibert, Sustainable Construction: Green Building Design and Delivery, 4th ed., Wiley, 2016.
5. U.S. Green Building Council, LEED Reference Guide for Building Design and Construction, USGBC, latest edition.
6. GRIHA Version 2019: The Sustainable Habitat Handbook
7. Brian Edwards, Rough Guide to Sustainability, 4th ed., RIBA Publishing, 2014.
8. Sam Kubba, Handbook of Green Building Design and Construction: LEED, BREEAM, and Green Globes Butterworth-Heinemann; Latest edition

IM24E12	ENVIRONMENTAL AND ENERGY AUDIT	3 Credits

Course Description:

This course provides an in-depth understanding of environmental and energy auditing processes, focusing on techniques and tools used to assess the environmental impact and energy efficiency of various systems. Students will learn how to conduct audits in industrial, commercial, and residential settings, identify areas for improvement, and develop strategies to enhance sustainability and energy conservation. The course emphasizes practical applications, regulatory frameworks, and the role of audits in achieving compliance and sustainability goals.

Course Content

Unit I: Introduction to Environmental Audits and its process

Definition and Principles of Green Overview of Environmental and Energy Audits - Importance and Benefits of Audits - Types of Audits (Preliminary, Detailed, Compliance) - Role of Audits in Sustainability and Regulatory Compliance - Steps in Conducting an Environmental Audit Environmental Impact Assessment (EIA) - Waste Audits and Management - Water Use and Conservation Audits - Air Quality Audits - Environmental Risk Assessment

Unit II: Introduction to Energy Audits and its process

Introduction to Energy Audits - Importance and Benefits of Audits - Energy Audit Methodology (Walkthrough, Detailed) - Data Collection and Analysis Techniques - Energy Performance Indicators (EnPIs) -Energy Consumption Patterns and Benchmarking

Unit III: Energy Audits in Buildings and Industry

Building Envelope and Insulation Audits - HVAC Systems Efficiency Audits - Lighting Systems Audits - Renewable Energy Potential Assessment - Case Studies of Energy Audits in Buildings - Industrial Energy Systems and Processes - Auditing Boilers, Furnaces, and Steam Systems - Electrical Systems and Motor Efficiency Audits - Compressed Air Systems Audits - Energy Management Systems (EMS) and ISO 50001

Unit IV: Environmental and Energy Audit Tools and Techniques with Regulatory Framework

Use of Audit Instruments and Software - Data Logging and Monitoring Tools - Simulation and Modelling for Audits - Life Cycle Analysis (LCA) in Audits - Cost-Benefit Analysis of Audit

Recommendations - Environmental Regulations and Compliance - Energy Efficiency Regulations and Standards - International Standards for Auditing (ISO 14001, ISO 50001) - Legal Requirements and Ethical Considerations

Unit V: Developing and Implementing Audit Recommendations

Prioritizing Audit Findings - Developing Action Plans for Improvement - Project Management for Audit Implementation - Monitoring and Verification of Improvements - Continuous Improvement in Environmental and Energy Performance - Case Studies of Successful Environmental and Energy Audits - Lessons Learned from Audit Failures - Emerging Technologies in Environmental and Energy Auditing - Future Trends in Auditing for Sustainability.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Explain the fundamental principles of environmental and energy auditing, including the objectives, processes, and benefits.

CO2: Perform comprehensive environmental audits, assessing factors such as emissions, waste management, water use, and compliance with environmental regulations.

CO3: Conduct energy audits to evaluate the energy performance of buildings, industrial facilities, and other systems, identifying opportunities for energy efficiency improvements.

CO4: Prepare detailed audit reports that effectively communicate findings and recommendations to stakeholders.

CO5: Develop and manage projects to implement audit recommendations, ensuring continuous improvement in environmental and energy performance.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. Albert Thumann, Handbook of Energy Audits, 9th ed., Fairmont Press, 2013.
2. Lawrence B. Cahill, Environmental Audits, 2nd ed., Government Institutes, 2002.
3. Frank Kreith, Principles of Sustainable Energy Systems, 2nd ed., CRC Press, 2013.
4. Paul A. Erickson, Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, 2nd ed., CRC Press, 2018.

IM24E13	ENVIRONMENTAL IMPACT ASSESSMENT	3 Credits

Course Description:

This course provides an in-depth exploration of Environmental Impact Assessment (EIA) as it applies to infrastructure projects. Students will learn about the methodologies, legal frameworks, and practical applications of EIA in assessing the potential environmental impacts of infrastructure development. The course covers the entire EIA process, from screening and scoping to public participation, impact prediction, and the development of mitigation strategies. Real-world case studies will be used to illustrate the complexities and challenges of conducting EIAs in various infrastructure sectors.

Course Content

Unit I: Introduction to Environmental Impact Assessment

Definition and Purpose of EIA - History and Evolution of EIA - Principles and Objectives of EIA - Sustainable Development challenges and need- Key approaches for Impact Assessment - Assessing Environmental Impacts - Legal and Regulatory aspects in India - - Types of EIAs: Strategic, Regional, and Project-Specific and Objectives

Unit II: EIA Process with Legal and Regulatory Frameworks

Stages of the EIA Process: Screening, Scoping, Impact Analysis, Mitigation, and Reporting Screening - Determining the Need for an EIA - Scoping - Identifying Key Issues and Impacts -Developing Terms of Reference (ToR) for EIA - Overview of EIA Legislation (National and International) - Key Regulatory Bodies and Their Roles - EIA Guidelines and Standards (e.g., World Bank, IFC, UNEP) - Legal Requirements for Infrastructure Projects

Unit III: Impact Identification, Prediction and Mitigation

Methods for Identifying Environmental Impacts (Checklists, Matrices, Networks) - Predictive Techniques (Modelling, Simulation, Trend Analysis) - Assessing Cumulative and Synergistic Impacts - Risk Assessment in EIA - Designing Mitigation Measures to Address Adverse Impacts - Overview and Scope of Social Impact Assessment, S I A model and the planning process, Land acquisition -Legal aspects, Resettlement & Rehabilitation and Development

Unit IV: Public Participation and Environmental Management Plan

Importance of Public Participation - Techniques for Engaging Stakeholders (Public Meetings, Surveys, Workshops) - Addressing Public Concerns and Feedback - Environmental Management Plans (EMP) - Monitoring and Compliance in EIA - Adaptive Management and Follow-Up - Environmental Risk Assessment (ERA) - Cost-Benefit Analysis (CBA) in EIA - Multi-Criteria Decision Analysis (MCDA The Analytic Hierarchy process based approach to project appraisal - Emerging Dimensions and future Directions-Strategic Environmental Assessment - Technological Assessment and Risk Assessment.

Unit V: Case studies

EIA for Transportation Projects (Roads, Railways, Airports) - EIA for Energy Projects (Hydropower, Wind Farms, Solar Projects) - EIA for Water Resources Projects (Dams, Irrigation, Water Supply) - EIA for Urban Development and Housing Projects - Case Studies of Successful and Challenging EIA Projects - Lessons Learned from EIA in Large-Scale Infrastructure - Emerging Trends in EIA (Climate Change Considerations, Biodiversity Offsetting) - The Future of EIA: Towards Sustainable Infrastructure Development

Course Outcome:

On completion of the course, the student is expected to be able to

CO1: Explain the fundamental principles and objectives of Environmental Impact Assessment, particularly in the context of infrastructure projects.

CO2: Apply the different stages of the EIA process, including screening, scoping, impact analysis, and reporting.

CO3: Perform detailed environmental impact analyses using various tools and methodologies, including risk assessment and cost-benefit analysis.

CO4: Design and propose mitigation measures to minimize the adverse environmental impacts of infrastructure projects.

CO5: Navigate the legal and regulatory frameworks governing EIA, including national and international standards.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

REFERENCES:

1. Larry W. Canter, Environmental Impact Assessment, 2nd ed., McGraw-Hill, 1996.
2. Peter Morris, Riki Therivel, Methods of Environmental Impact Assessment, 3rd ed., Routledge, 2009.
3. John Glasson, Riki Therivel, Andrew Chadwick, Introduction to Environmental Impact Assessment, 4th ed., Routledge, 2012.
4. Christopher Wood, Environmental Impact Assessment: A Comparative Review, 2nd ed., Prentice Hall, 2003.
5. World Bank, Environmental Impact Assessment Sourcebook, World Bank Publications, latest edition.
6. Canter, L.W.," Environmental Impact Assessment", McGraw Hill, NewYork,1996.
7. Anjaneyulu, Yerramilli, and Valli Manickam, "Environmental impact assessment methodologies", Hyderabad: BS Publications,2007.
8. Lawrence, D.P., "Environmental Impact Assessment- Practical Solution store current problems", Wiley-Interscience, NewJersey,2003.
9. Petts, J., "Handbook of Environmental Impact Assessment', Vol., I and II, Blackwell science, London,1999.

IM24E14	SMART CITY DESIGN AND IMPLEMENTATION	3 Credits

Course Description:

This course provides a comprehensive overview of the design and implementation of smart cities, focusing on integrating technology, data, and urban planning to create sustainable, efficient, and livable urban environments. Students will explore key components of smart city infrastructure, including smart transportation, energy management, water systems, and governance. The course covers the use of IoT, big data, and AI in urban planning, the challenges of implementing smart city projects, and the role of public participation and governance in creating successful smart cities

Course Content

Unit I: Introduction to Smart Cities and Urban Infrastructure

Definition and Key Concepts of Smart Cities - The Evolution of Urban Planning to Smart Cities - Components of a Smart City: Infrastructure, Technology, Governance - Global Trends and Smart City Initiatives - Smart Transportation Systems (Intelligent Traffic Management, Autonomous Vehicles) - Smart Energy Grids and Renewable Energy Integration - Smart Water Management Systems - Waste Management and Recycling in Smart Cities

Unit II: Technology and Data in Smart Cities

ICT to integrate Urban service - ICT system for Smart Cities – Data Storage and Netowrk Infrastructure – ICT Emerging Technologies - Internet of Things (IoT) in Urban Infrastructure - Big Data Analytics for Urban Planning and Management - Artificial Intelligence and Machine Learning in Smart City Applications – Fifth Generation Network Services - Cybersecurity and Data Privacy in Smart Cities

Unit III: Smart City Planning, Design and Mobility

Principles of Smart Urban Design - Sustainable and Resilient Infrastructure Design - Integration of Green Spaces and Environmental Considerations - Urban Mobility and Accessibility Planning – Transit Oriented Development – Real-time Traffic Information System (RTIS) - Real-time Traffic Monitoring System (RTMS) – Automated Vehicle Location (AVL) system – Public Mobility – Infrastructure and Policies.

Unit IV: Governance and Policy in Smart Cities

Smart Governance Models and Frameworks - Public-Private Partnerships in Smart City Projects - Regulatory Challenges and Policy Development - Ethical Considerations in Smart City Design - Importance of Citizen Engagement in Smart Cities - Tools and Techniques for Public Participation - Smart Citizen Services and E-Government -Building Inclusive and Accessible Smart Cities

Unit V: Implementation Challenges and Strategies

Technical Challenges in Smart City Implementation - Managing Complexity and Interoperability in Smart Systems - Financing Smart City Projects - Risk Management and Resilience Planning - Analysis of Leading Smart Cities (e.g., Singapore, Barcelona, Dubai) - Lessons Learned from Smart City Initiatives - Success Factors and Common Pitfalls in Smart City Projects - Future Trends in Smart City Development

Course Outcome:

On completion of the course, the student is expected to be able to

CO1: Explain the fundamental principles and components of smart cities, including technology integration, sustainability, and urban resilience.

CO2: Develop comprehensive smart city plans that incorporate smart infrastructure, services, and governance models.

CO3: Apply technologies such as IoT, big data analytics, and AI in the design and operation of smart city systems.

CO4: Plan and manage the implementation of smart city projects, addressing technical, social, and regulatory challenges with the involvement of stakeholders.

CO5: Critically analyze case studies of existing smart cities to identify best practices and lessons learned.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

CO5	3	3	2	2	3	3

REFERENCES:

1. Carlo Ratti and Matthew Claudel, The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life, Yale University Press, 2016.
2. Vito Albino, Umberto Berardi, and Rosa Maria Dangelico, Smart Cities: Definitions, Dimensions, and Performance, Taylor & Francis, 2015.
3. Anthony M. Townsend, Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia, W.W. Norton & Company, 2013.
4. Lara Schrijver, Understanding Smart Cities: A Tool for Smart Government or an Industrial Complex? Birkhäuser, 2019.

   Thakur, D. R., Smart Cities and Digital India: An Integrated Approach, Springer, 2020

Cluster F. URBAN AND TRANSPORTATION PLANNING

IM24F11	URBAN PLANNING FUNDAMENTALS	3 Credits

Course Description

This course provides a foundational understanding of the principles, theories, and practices of urban planning. It explores the historical evolution of cities, the challenges faced by urban areas, and the role of planners in shaping sustainable and equitable communities. This course will develop a comprehensive knowledge of urban systems, including land use, transportation, housing, economic development, and environmental planning.

Course Content:

Unit I: Evolution of Town Planning

Evolution in planning and physical form- Concept of urban human settlement- Differentiation between rural and urban settlement- concept of town- Evolved and Created Town Characteristics- Features of urban planning process- Role of urban planner- Genesis of urban form; Social, Geographical and Cultural impacts- Contemporary developments in planning-Impacts of Industrial revolution on town and regional planning.

Unit II: Urbanization

Demography and Census Statistics- Significance of Census and Demographics- Planning policies framed based on Census-Use of Census Data in Urban Planning Rural and urban Migration, impacts of urbanisation, socio – economic impacts of growth of population, Social and Economic Environmental Administrator, Levels of Urbanisation, Indian scenario - Issues and Policies, Global scenario, Future trends of urbanization - Impact of Government Policies on Urbanization.

Unit III: Urban Land Use Planning: Objectives and Principles of Urban planning- Different Land use planning norms- Environmental aspects of land use planning- Role of URDPFI guidelines in Town planning-Land use Structures- demand and supply of land relationship- Government policies of urban development- Role of Professional bodies.

Unit IV: Planning surveys

Objectives, types, significance, methodology, analysis, and applications- Researches through planning surveys- Use of planning surveys in Urban Modelling like Multiple Linear Regression Analysis- Planning parameters, aims, objectives, principles, methodology and systems approach, and environmental parameters.

Unit V: Case Studies

Reforms in urban planning capacity in India- Chandigarh city planning case study-Sustainable planning techniques. Filed visit to Chennai Metropolitan Development Authority/Local authorized agencies.

Course Outcome:

CO1: Aware of urban planning concepts and theories

CO2: Identify the factors influencing urbanization

CO3: Various policies and guidelines in urban land use planning

CO4: Identify the suitable planning surveys required for urban planning

CO5: Assess the suitable urban development planning considering various case studies.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	3	2
CO2	2	2	3	1	2	2

CO3	2	2	3	2	2	1
CO4	3	2	3	2	2	1
CO5	3	3	2	2	2	1

References

1. A.B. Gillion and Simon Eisner, “The Urban Pattern”, CBS Publishers and Distributors, Delhi.
2. Rishma A., “Town Planning in Hot Cities”, Mir Publishers, Moscow.
3. Ward S (2002), “Planning the 20th Century City” John Wiler & Sons.
4. R. Ramachandran, “Urbanisation and Urban Systems in India”, Oxford Publications.
5. K. C. Shivrama Krishnan, “Revisioning Indian Cities”, Sage Publications
6. Reforms in urban planning capacity in India, Final report, September 2021. NITI Aayog.
7. MARGARET ROBERTS, “Town Planning Techniques”, Hutchinson Educational Publication.
8. N.V. MODAK AND V.N. AMBDEKAR, “Town and Country Planning and Housing”, Orient Longman Limited.
9. R.G. GUPTA, “Planning and Development of Towns”, New Delhi.
10. K.S. RAMEGAUDA, “Urban and Regional Planning, Mysore University Publication.
11. Pratap Rao, “Urban Planning Theory and Practices”, 2014, CBS Publishers.

IM24F12	TRANSPORTATION ENGINEERING AND PLANNING	3 Credits

Course Description

Transportation Engineering and Planning is a course that typically covers the fundamental principles and practices of Traffic engineering and transportation planning systems. This course is interdisciplinary, integrating elements of Infrastructure engineering and transportation planning components.

Course Content:

Unit I: Elements of Traffic Engineering

Road user, vehicle and roadway- Vehicle characteristics -IRC standards - Design speed, volume. Highway capacity and levels of service - capacity of urban and rural roads - PCU

concept and its limitations - Road user facilities – Parking facilities - Cycle tracks and cycleways - Pedestrian facilities. Traffic volume studies, origin destination studies, speed studies, travel time and delay studies-Parking studies, Traffic analysis and Accident studies.

Unit II: Trip Generation and Trip Distribution

Trip production process- household characteristics-classification based on trip purpose trips for work, education, shopping, social and recreational purposes; influencing variables of trips made for different purposes- modelling trip production- Trip attraction process; attraction of trips for different purposes, factors influencing trip attraction for different trip purposes; modelling trip attraction. Presentation of trip distribution data OD matrix, PA matrix to depict trip distribution among zones; factors influencing trip distribution; variable formulation, modelling trip distribution; Gravity model of trip distribution; calibration of Gravity models.

Unit III: Mode Choice Analysis

Mode choice for different trip purposes- Influencing factors socioeconomic characteristics of travelers and characteristics of the different modes of transport; influence of trip purpose on mode choice- modelling mode choice of travellers - trip-end and trip-interchange modelling; Disaggregate mode-choice models- utility concept- Logit model of mode choice- model calibration; model validation.

Unit IV: Route assignment

Route assignment description of transport network for route assignment; influencing variables and assignment algorithms; all-or-nothing assignment; multipath traffic assignment; capacity restrained traffic assignment. Case studies.

Unit V: Field studies

Conducting transportation surveys- the study of traffic speed & delay, traffic volume, O & D, parking and accidents in the field. Data collection, analysis and presentation.

Course Outcome:

CO1: Aware of traffic engineering elements and its applications

CO2: Able to prepare detailed four staged modelling for a city based on problem identification

CO3: Systematic preparation of data collection, data analysis on field studies.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6

CO1	3	2	3	2	2	2
CO2	2	3	3	2	2	2
CO3	2	2	3	2	2	2

References

1.Bowmen,J. and M.ben Akiva, Activity based travel Forecasting; in Activity based travel forecasting. Washington, DC:U.S.DepartmentofTransportation,Report DOT-97-17.

2. ChakrobortyP.,DasN.,Principles of Transportation Engineering (2nd edition),PHI,NewDelhi,2017

3. DickeyJ.W.,MetropolitanTransportationPlanning,TataMc-Graw Hill1980

4. KhistyCJ.,LallB.Kent,TransportationEngineering–AnIntroduction(3rd Edition),Pearson Education,2017

5. Ortuzar,J.D.,Willumsen,L.G.,ModelingTransport(4th edition),JohnWiley&Sons,2011

6. PapacostasC.S.andPrevedouros,P.D.,TransportationEngineering&Planning (3rd edition) ,PHI,NewDelhi,2001

7. P.K. Sarkar, Vinay Maity, G.J.Joshi., Transportation Planning: Principles, Practices and Policies (2nd edition),PHI, New Delhi, 2017

8. Geetam Tiwari, “Urban Transport for Growing Cities”, Macmillan India Ltd., 1st Edition, 2002.

9. B.G. Hutchinson, “Principles of Urban Transport Systems Planning”, McGraw-Hill Book Company, 10th Reprint, 2010

Jason C.yu, “Transportation Engineering: Introduction to Planning, Design and Operations”, Elsevier,1992.

IM24F13	GATI SHAKTI MULTI-MODAL CONNECTIVITY	3 Credits

(MOOC COURSE)

Course Description

This course provides a comprehensive understanding of the recent initiative of Gati Shakti aimed at enhancing multi-modal connectivity infrastructure in India. The course will delve into planning, developing, and managing integrated transportation networks that connect different

modes of transport, such as roadways, railways, waterways, and airways. It will emphasize the importance of seamless connectivity for economic growth, regional development, and sustainable urbanization in the Indian context.

Course Content:

Unit I: Introduction

Introduction and Concepts- Gati Shakti Objective and Problem Statement- Objectives of NMP and six engines of infrastructure- Six pillars of Gati Shakti- Benefits and roles- Importance of Infrastructure development- Road sector and Bharatmala Pariyojana-Railway sector-Ports-Sagarmala and airways-case study.

Unit II: Transportation Economics And Logistics Management

Transportation Economics- National Logistic Policy- Implementation of National Logistic Policy- Logistics and Warehouse Management- Objectives of Logistic Management- Role of technology in logistic management- Warehouse Management- Design Criteria of warehouse-LEADS Part-I- LEADS Part-II- LEADS Questionnaire Part-I- LEADS Questionnaire Part-2.

Unit III: Dynamic Mapping Using GIS

Role of BISAG-N in Gati Shakti- Application of Geospatial Technology for Good Governance: Institutionalization- Spatial thinking- Functional Capabilities of GIS

Unit IV: Sustainable Development

Definition of Sustainability- Three Pillars of Sustainability- Dimensions of Sustainability-Sustainable Transportation- Sustainable Development Goals Integration- Funds for Sustainable Development- Sustainable Linked Loans for Sustainable Development

Unit V: Field Study

The field study aims to give students hands-on experience with multi-modal transportation systems, logistics hubs, and infrastructure projects under the Gati Shakti initiative. Students need to observe and analyze the integration of different transportation modes, understand the challenges and solutions in implementation, and interact with professionals in the field.

Course Outcome:

CO1: Grasp the fundamental principles of multi-modal connectivity and its significance for economic growth in the Indian context.

CO2: Aware of GIS-based dynamic mapping concerning Infrastructure development

CO3: Analyze the policy and regulatory framework governing multi-modal transportation in India.

CO4: Understand the principles of sustainable development and incorporate environmental, social, and economic considerations into infrastructure planning and implementation.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2

References:

1. IBEF (2018), 'About Indian Economy Growth Rate & Statistics', Available https://www.ibef.org/economy/indian-economy-overview. Last accessed on June 30, 2018

2. Hindustan Times (2017), 'India's economy to become 3rd largest, surpass Japan, Germany by 2030'. https://www.hindustantimes.com/business-news/india-s-economy-will-become-third-largest-in-the-world-surpass-japan-germany-by-2030-us-agency/story-wBY2QOQ8YsYcrIK12A4HuK.html. Last accessed on June 30, 2018

3. Niti ayog. Goods on the move, Efficiency and sustainability in Indian Logistics, September 2018.

4. Potential of Multimodal connectivity in India, chrome extension://mhnlakgilnojmhinhkckjpncpbhabphi/pages/pdf/web/viewer.html?file=https%3A%2F%2Fcuts-citee.org%2Fpdf%2Findia-potential-of-multimodal-connectivity.pdf

5. Towards NayaBharat, A study of infrastructure, Community and development. National Institute of Industrial education, National Book trust India publisher, Sep 2023.

VI. **INDUSTRIAL INTEGRATED COURSES**

IM24G31	APPLICATION OF UAV IN CIVIL INFRASTRUCTURE	4 Credits

Course Description

This course provides a comprehensive overview of Unmanned Aerial Vehicles (UAVs) or drones and their applications in the civil infrastructure sector. Students will gain a solid understanding of UAV technology, flight operations, data acquisition, processing, and analysis. The course emphasizes practical applications in surveying, mapping, structural engineering and transportation engineering. Additionally, the course covers legal and ethical considerations related to UAV operations.

Course Content:

Unit I: Introduction to UAVs

Basic principles of flight - UAV components (airframe, propulsion, payload, flight control) - types of UAVs (fixed wing, rotary wing, hybrid) - UAV platforms and sensors (cameras, LiDAR, thermal, multispectral) - UAV legal regulations and ethical considerations in airspace management

Unit II: UAV Flight Planning and Operations

Flight planning software - Mission planning and design - UAV ground control stations - Safety regulations and procedures - UAV flight operations and data acquisition

Unit III: Image Processing and Analysis

Digital image processing fundamentals - Photogrammetry and structure from motion (SfM) - Point cloud generation and processing - 3D model creation and visualization - Image analysis techniques for object detection and classification

Unit IV: Applications

Topographic mapping and terrain analysis - Volumetric calculations - Construction progress monitoring - Bridge inspection and assessment - Building facade inspection - Structural health monitoring - Damage detection and assessment - Traffic monitoring - Road condition assessment

Unit V

Term Paper based on case study

Course Outcome

Upon successful completion of this course, students will be able to:

CO1: Demonstrate a comprehensive understanding of UAV technology, components, and flight principles.

CO2: Plan and execute UAV flight operations safely and efficiently, adhering to relevant regulations.

CO3: Acquire high-quality spatial data using UAV-mounted sensors (cameras, LiDAR, etc.).

CO4: Utilize UAVs for tasks such as topographic mapping, structural inspection and traffic monitoring

CO5: Effectively integrate UAV technology into civil engineering projects.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. Remote Sensing and Image Interpretation: These books cover the fundamental principles of image processing and analysis, which are essential for UAV data processing.

2. Photogrammetry and Geospatial Information Science: These books delve into the techniques used to extract spatial information from images, crucial for creating maps and models from UAV data.

3. Civil Engineering and Construction Management: These textbooks can provide context for the application of UAVs in different civil engineering fields.

4. ASCE Journals: The American Society of Civil Engineers (ASCE) publishes numerous journals related to civil engineering, including those focusing on infrastructure, construction, and geotechnical engineering. These journals often feature articles on UAV applications.

5. ISPRS Journal of Photogrammetry and Remote Sensing

6. Conference Proceedings

IM24G32	ADVANCED CONCRETE TECHNOLOGY	4 Credits

Course Description

This course on Concrete Technology provides a comprehensive understanding of the properties, behavior, and testing of fresh and hardened concrete. It covers essential topics including workability, strength, and durability of concrete, with an in-depth analysis of factors affecting creep, shrinkage, and the long-term performance of concrete structures. The course also delves into statistical quality control methods for concrete, ensuring reliability and consistency in construction. Additionally, students will explore special types of concrete, such as self-compacting, fiber-reinforced, and geopolymer concrete, along with specialized concreting processes for different environmental conditions.

Course Content

Unit I: Properties of Fresh and Hardened Concrete

Workability-Factors affecting workability- tests to measure workability, Compressive strength, spilt tensile strength, flexural strength, modulus of elasticity-Test procedures- effect of w/c ratio.

Unit II: Creep and Shrinkage of Concrete

Factors affecting creep – effects of concrete, Factors affecting shrinkage – Plastic shrinkage, drying shrinkage, autogenous shrinkage, carbonation shrinkage –effects

Unit III: Durability of Concrete

Permeability-Correction-Carbonation-Chloride Penetration-Sulphate attack–acid attack–Fire resistance – Frost damage – alkali silica reaction – Penetration test – Rebound hammer test – Ultra pulse velocity method, Pull out test.

Unit IV: Statistical Quality Control of Concrete

Mean strength-standard deviation- coefficient of variation- Sampling-testing-acceptance criteria

Unit V: Special Topic in Concrete Technology

Special concrete: Self Compaction concrete-Fibre reinforced concrete-Ready mix concrete-Geo polymer concrete-Green concrete-lightweight concrete. Special Process: Under water concreting-cold weather concrete-hot weather concreting-mass concrete.

Course Outcomes

CO1: Analyze the workability and strength properties of fresh and hardened concrete, including the effects of factors like water-cement ratio and environmental conditions.

CO2: Evaluate the impact of creep and shrinkage on concrete structures, and understand the underlying factors that influence these behaviors over time.

CO3: Assess the durability of concrete through an understanding of various deterioration mechanisms, such as permeability, carbonation, chemical attacks, and apply non-destructive testing methods for evaluating concrete integrity.

CO4: Apply statistical quality control methods to concrete production, including the calculation and interpretation of mean strength, standard deviation, and coefficient of variation, ensuring the acceptance criteria are met in construction projects.

CO5: Demonstrate knowledge of special concretes and concreting techniques, including self-compacting concrete, fiber-reinforced concrete, and specific processes for challenging environments like underwater or extreme temperatures.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	1	1
CO2	1	2	3	3	1	2
CO3	2	1	1	3	3	1
CO4	3	3	2	1	3	3
CO5	2	1	2	1	1	3

References:

1. Santhakumar A.R., Concrete Technology, Oxford Publication, 2006.

2. Gambhir.M.L. Concrete Technology, Fifth Edition, McGraw Hill Education, 2017.

3. Gupta.B.L.,Amit Gupta, “Concrete Technology, Jain Book Agency, 2010.

4. Neville, A.M., Properties of Concrete, Prentice Hall, London, 2012.

5. Shetty M.S., Concrete Technology, Revised Edition, S.Chand and Company Ltd. Delhi, 2018.

6. Job Thomas., Concrete Technology, Cencage learning India Private Ltd, New Delhi, 2015

IM24G33	PAVEMENT MAINTENANCE AND MANAGEMENT SYSTEMS	4 Credits

Course Description

This course provides a comprehensive understanding of pavement maintenance and management systems (PMS). It focuses on the principles, methodologies, and technologies employed in preserving and extending the life of pavement infrastructure. It will explore various aspects of pavement performance evaluation, distress identification, maintenance strategies, and the utilization of PMS software for optimal decision-making.

Course Content:

Unit I: Introduction

Purpose – Classification of Pavement Evaluation Methods- Performance Evaluation of Pavements-Functional Evaluation -Structural Evaluation – Economic Evaluation of Pavements- Pavement Maintenance Management System- Concept of Pavement Evaluation and Maintenance Management.

Unit II: Distress Types for Asphalt Concrete Pavement and Rigid Pavement

General Introduction to Distress Surveys-Distress Definition in General -The Significance of Distress Measurement-Categorisation of Distresses in Asphalt Pavement-Identification, Causes and Measurement of Distresses- Distress Surveys and Maintenance Alternatives for Portland Cement Concrete Pavement.

Unit-III: Pavement Performance

Structural and functional Condition – Pavement roughness (IRI)- Non-destructive Measurement and Analysis – Deflection Measurements, KGPBACK and IIT Pave software-Structural Capacity Index Concepts – Network versus Project Level- Applications of Structural Capacity Evaluation.

Unit-IV: Rehabilitation and Maintenance Alternatives

Identification of Alternatives – Pavement Preservation – Types of maintenance-Decision Process and Expert Systems Approach to Identifying Feasible Alternative – Deterioration Modelling- Priority Programming: Basic Approaches – Program Period -Functions – Methods – Budget Level Evaluation – Final Program Selection.

Unit-V: Pavement network management

Economic evaluation of Highway Projects-Net present value method-Benefit cost ratio method-IRR method- HDM-4: Functions – Structure – Program Analysis – Project Analysis-Case studies.

Course Outcome:

CO1: Classification of pavement evaluation concepts

CO2: Identify the pavement distress and severity

CO3: Able to analyse the pavement performances

CO4: Identify the rehabilitation and maintenance strategies

CO5: Identify the pavement evaluation cost for the project and network level

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	2	2	3	3	2	2
CO3	3	2	3	3	2	2
CO4	3	2	3	2	2	2
CO5	3	3	2	2	3	3

References

1. Ralph Hass, W.Ronald Hudson with Lyne Cowe Falls., “Pavement Asset Management”-Scrivner Publisher, copyright 2015

2. Ralph Hass, W. Ronald Hudson. W. R., Zaniewisti .J. “Modern Pavement Management” – Krieger Publishing Company, Florida, 1994.

3. R.Srinivas Kumar. Pavement Evaluation and Maintenance Management System, university press India Pvt ltd. 2020.

4. Relevant Indian code books, ASTM etc

5. Modern Pavement Management, Haas, Hudson and Zaniewski, Krieger Publishing Company.

6. Pavement Management System, Haas and Hudson, McGraw- Hill Book Company.

VII. **AUDIT COURSE :** (0 credit)

Refer Swayam – MOOC Syllabus

VIII. **OPEN ELECTIVE:** (3 credits)

Refer SWAYAM – MOOC Syllabus.

IX. **INTERNSHIP PROGRAMME:** (4 credits)

Refer PG Regulations 2024.

X. **Project DISSERTATION:**

i. Project Phase I (12 credits)

ii. Project Phase II (16 credits)

Refer PG Regulations 2024.

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