VISVESVARAYA TECHNOLOGICAL UNIVERSITY BELAGAVI

Scheme & Syllabus of Teaching and Examinations (2026)
II Semester

M.Tech., in Civil Engineering

Specialization in Transportation Engineering (MCTE)

Choice-Based Credit System (CBCS) and Outcome-Based Education (OBE)

Specialization in – (Transportation Engineering)

II SEMESTER

Sl. No	Course	Course Code	Course Title	Teaching & Learning Scheme					Examination				Credits
				CI		LI	TW & SL	Total Hours	Duration in hours	CIE Marks	SEE Marks	Total Marks	
				L	T	P							
1	PCC/ IPCC	**1MCTE201/** 1MCTM201/ 1MCHT201	Traffic Flow Theory & Simulation (VISUM, VISSIM)	42	0	28	50	120	03	50	50	100	4
2	PCC	**1MCTE202/** 1MCTM202/ 1MCHT202	Sustainable Pavement Materials & Construction	42	0	0	48	90	03	50	50	100	3
3	PCC	**1MCTE203/** 1MCTM203/ 1MCHT203	Pavement Analysis and Mechanistic–Empirical Design	42	0	0	48	90	03	50	50	100	3
4	PCC	**1MCTE204/** 1MCTM204/ 1MCHT204	Transportation Planning, Public Transport & Sustainable Mobility	42	0	0	48	90	03	50	50	100	3
5	PEC	**1MCTE205X**	Professional Elective – III	42	0	0	48	90	03	50	50	100	3
6	PEC	**1MCTE206X**	Professional Elective – IV	42	0	0	48	90	03	50	50	100	3
7	PCC L	**1MCTEL207/** 1MCTML207/ 1MCHTL207	Pavement Materials and Evaluation Lab	0	0	28	02	30	03	50	50	100	1
8	PCC	**1MCTES208**	Minor Project/Skill Development Project	0	0	0	60	60	03	50	50	100	2
									Total	**400**	**400**	**800**	**22**

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Professional Elective Courses (PECs)					
PEC-III			**PEC-IV**		
Code	**Title of the Course**		**Code**	**Title of the Course**	
1MCTE205A/ 1MCHT205A/ 1MCTM205A	Geotechnical Investigations for Highway Development Projects		**1MCTE206A/** 1MCTM206A/ 1MCHT206A	Management Systems for Highway Construction and Maintenance	
1MCTE205B/ 1MCHT205B/ 1MCTM205B	Pavement Health Monitoring and Predictive Maintenance		**1MCTE206B/** 1MCTM206B	Electric Mobility & Charging Infrastructure	
1MCTE205C/ 1MCHT205C/ 1MCTM205C	Road Safety Planning and Implementation		**1MCTE206C/** 1MCTM206C	Sustainable Urban Transport & SDG-11	
1MCTE205D/ 1MCHT205D/ 1MCTM205D	Transport Economics & Contract Policy		**1MCTE206D/** 1MCHT206D/ 1MCTM206D	Pavement Asset Management System	
1MCTE205E/ 1MCTM205E	Urban Traffic Management & Analytics		**1MCTE206E/** 1MCHT206E/ 1MCTM206E	Innovative Practices in Road Construction	
1MCTE205F/ 1MCTM205F	Railway Engineering & Track Dynamics		**1MCTE206F/** 1MCHT206F/ 1MCTM206F	Detailed Project Report (DPR) preparation for Transportation Sector	
1MCTE205G/ 1MCHT205G/ 1MCTM205G	Urban Mass Transit Systems		**1MCTE206G/** 1MCHT206G/ 1MCTM206G	Big Data & AI in Transportation Systems	
1MCTE205H/ 1MCTM205H	Climate Resilient Transportation Infrastructure		**1MCTE206H/** 1MCTM206H	Airport Planning & Design	

TRAFFIC FLOW THEORY & SIMULATION (VISUM, VISSIM)			
Course Code	**1MCTE201**/1MCTM201/ 1MCHT201	Scheme	2026
Type of course	Integrated Professional Core Course (IPCC) – Theory + Laboratory	Semester	II
Teaching Hours/Week (L:T:P)	(2 : 0 : 2)	CIE Marks	50
Total Hours of Pedagogy (L:T:P:SL/TW)	70 (42: 0: 28: 0)	SEE Marks	50
Credits	04	Total Marks	100
Type of Examination	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	03

Course outcome (Course Skill Set)
At the end of the course, the student will be able to:

1. **CO1**: Analyze macroscopic and microscopic traffic-stream characteristics and evaluate fundamental traffic-flow models against field/simulated data.
2. **CO2:** Apply car-following, headway and psycho-physical (Wiedemann) models to explain microscopic driver behaviour used in simulation software.
3. **CO3**: Formulate and solve continuum-flow (shockwave/PDE) and queuing-theory problems for highway and urban traffic conditions.
4. **CO4**: Develop, code, calibrate and validate microscopic simulation models of intersections/corridors using PTV VISSIM.
5. **CO5:** Develop macroscopic travel-demand and network models and perform trip assignment/public-transport modelling using PTV VISUM.
6. **CO6**: Evaluate traffic-operations/design alternatives through simulation-based Measures of Effectiveness (MOEs) and validate outputs against field data.

Module-1

Introduction and Traffic Stream Parameters: Need for traffic flow theory in the era of simulation-based analysis. Macroscopic and microscopic traffic parameters – speed (time-mean speed, space-mean speed), density, flow; fundamental equation of traffic flow (q = k.v); relationships between traffic-flow parameters; time-space diagram and vehicular trajectories. Field methods for measuring traffic-stream parameters (spot-speed studies, moving-observer method, video/drone-based trajectory extraction) and their relevance as input/calibration data for simulation models.

Linked CO: CO1 **Number of Hours: 08**

Module-2

Macroscopic Traffic Flow Models: Empirical and theoretical macroscopic traffic-flow models – Greenshield's, Greenberg's, Underwood's and Northwestern models; single-regime and multi-regime models. Capacity and level-of-service concepts as per the Highway Capacity Manual (HCM); calibration of macroscopic models using field data and goodness-of-fit measures (R^2, RMSE); limitations of macroscopic models and the need for microscopic simulation.

Linked CO: CO1, CO6 **Number of Hours: 09**

Module-3

Microscopic Traffic Flow Models: Car-following theory – Pipes model, Forbes model, General Motors (GM) stimulus-response models; car-following simulation; vehicle-arrival (headway) models; optimal-velocity model; psycho-physical (Wiedemann) model and stability analysis; fluid-flow analogy models. Correspondence between car-following/lane-change logic and the driving-behaviour parameters (Wiedemann-74/99, CC-parameters) used in PTV VISSIM.

Linked CO: CO2, CO4 **Number of Hours: 09**

Module-4

Continuum Flow, Shockwave and Queuing Theory: Continuity equation and the Lighthill-Whitham-Richards (LWR) kinematic-wave theory; partial differential equations (PDE) of traffic flow - solving linear and non-linear PDEs; shockwave analysis and applications (bottlenecks, incidents, signal onset/offset). Deterministic and stochastic queuing systems, gap-acceptance models, random queuing systems, analysis of M/M/1 queues; incident analysis and probabilistic analysis of traffic flow.

Linked CO: CO3, CO6 **Number of Hours: 08**

Module-5

Fundamentals of Traffic Simulation and the VISUM-VISSIM Environment: Need for simulation in traffic and transportation engineering; classification of simulation models - macroscopic, mesoscopic and microscopic; the simulation-modelling process - conceptualization, network/input coding, calibration, verification, validation and output analysis. Overview of PTV VISUM - network objects, zone system, the four-step travel-demand model (trip generation, distribution, mode choice, assignment), static/dynamic assignment procedures, public-transport modelling. Overview of PTV VISSIM - network coding, traffic composition and desired-speed distributions, driving-behaviour (Wiedemann) parameters, signal control and VisVAP, Measures of Effectiveness (MOEs); calibration/validation protocol and the GEH statistic.

Linked CO: CO4, CO5, CO6 **Number of Hours:** 08

PRACTICAL COMPONENTS OF IPCC

LIST OF EXPERIMENTS (LI=28 Hrs)

1. Familiarisation with the PTV VISSIM interface; coding network geometry (links and connectors) for a simple road stretch.
2. Coding traffic composition, vehicle-input volumes and desired-speed distributions in PTV VISSIM.
3. Coding a signalised intersection with fixed-time signal control in PTV VISSIM and running the simulation.
4. Calibration of car-following (Wiedemann-99) and lane-change parameters in PTV VISSIM using field-observed headway/speed data.
5. Extraction and interpretation of Measures of Effectiveness (delay, queue length, LOS, throughput) from a PTV VISSIM simulation run.
6. Familiarisation with the PTV VISUM interface; creation of the zone system and base road network for a study area.
7. Coding travel-demand matrices and performing trip generation/distribution (four-step model) in PTV VISUM.
8. Route/traffic assignment (incremental and equilibrium assignment) for a road network using PTV VISUM.
9. Public-transport network coding and passenger assignment in PTV VISUM.
10. Comparative interpretation of macroscopic (VISUM) and microscopic (VISSIM) simulation outputs for the same corridor.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Drew, D.R., Traffic Flow Theory and Control, McGraw Hill Book Company, New York, 1st Edition, 1968
2. Daganzo, C.F., Fundamentals of Transportation and Traffic Operations, Pergamon (Elsevier Science), 1st Edition, 1997.

Reference books / manuals

1. Kerner, B.S., Introduction to Modern Traffic Flow Theory and Control: The Long Road to Three Phase Traffic Theory, Springer Verlag Berlin Heidelberg, 1st Edition, 2009.
2. Mannering, F.L. and Washburn, S.S., Principles of Highway Engineering and Traffic Analysis, John Wiley & Sons, Inc., 5th Edition, 2013.
3. Roess, R.P., Prassas, E.S. and McShane, W.R., Traffic Engineering, Pearson Education, Inc., Hoboken, NJ, 5th Edition, 2019.
4. Transportation Research Board, Highway Capacity Manual (HCM): A Guide for Multimodal Mobility Analysis, National Academies Press, Washington, D.C., 7th Edition (latest edition), 2022.
5. May, A.D., Traffic Flow Fundamentals, Prentice Hall, Englewood Cliffs, New Jersey, 1st Edition, 1990.
6. Gerlough, D.L. and Huber, M.J., Traffic Flow Theory: A Monograph, Transportation Research Board, National Research Council, Special Report 165, Washington, D.C., 1975.
7. PTV Group, PTV Vissim User Manual, PTV Planung Transport Verkehr GmbH, Karlsruhe, Germany, Latest Version.
8. PTV Group, PTV Visum User Manual, PTV Planung Transport Verkehr AG, Karlsruhe, Germany,

Web links and Video Lectures (e-Resources):

1. NPTEL courses on Traffic Engineering and Management / Transportation Systems Engineering - nptel.ac.in
2. PTV Group Training Portal (PTV VISUM / PTV VISSIM tutorials) - training.ptvgroup.com
3. Transportation Research Board (TRB) resources - trb.org

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped classroom for derivation-heavy topics (fundamental diagrams, PDEs) with in-class problem solving.
- Hands-on computer-laboratory sessions on PTV VISUM and PTV VISSIM aligned with every theory module.
- Case-based teaching using real intersections/corridors near the campus for network coding and calibration exercises.
- Use of NPTEL/MOOCs and PTV e-learning modules for self-paced learning of software features.
- Guest lecture/industry-expert session from a traffic-simulation or ITS consultancy.
- Field data-collection exercise (video-graphic/drone survey) to generate calibration datasets for models and simulation.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks**.

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

CIE Practical component:

The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks.

The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 10 marks. For laboratory test, the student is required to conduct one experiment each from both Part A and Part B.

Continuous Internal Evaluation (CIE)

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs 1.

(iii) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Table – ICs/IPCCs 1 Distribution of marks

Component	Description	Marks
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill in network coding/data preparation, adherence to lab protocol, and independent handling of PTV VISUM/VISSIM software during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of the simulation lab record (input files, screenshots, MOE outputs), accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		

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Laboratory Test / Experiment Performance	Ability to code a network/scenario, run the simulation/assignment, and obtain correct results in the test experiment (VISSIM or VISUM).	5 marks
Viva-Voce	Understanding of the underlying traffic-flow theory, model/behaviour parameters, and simulation procedure; ability to explain results.	5 marks
	Subtotal	**10**
	Total	**25**

Suggested rubrics for Practical continuous assessment:

Performance Indicators	Excellent	Very Good	Good	Satisfactory
Fundamental Knowledge (4) (PO1)	Student has in-depth knowledge of the traffic-flow theory and simulation concepts underlying the exercise. (4)	Student has good knowledge of most of the concepts underlying the exercise. (3)	Student can narrate the concept but cannot show in-depth understanding. (2)	Student has not understood the underlying concepts clearly. (1)
Network/Model Coding (5) (PO2 & PO3)	Student codes the VISSIM/VISUM network or model correctly and can justify all modelling choices made (geometry, demand, behaviour parameters). (5)	Student codes the network/model correctly for most elements but cannot justify a few choices. (4)	Student codes the network/model with some errors but with proper explanation. (3)	Student codes the network/model with significant errors and limited explanation. (1-2)
Simulation Execution, Calibration & Debugging (8) (PO3 & PO5)	Student runs the simulation/assignment successfully, calibrates parameters against field data and resolves errors independently, choosing the most suitable settings. (7-8)	Student runs the simulation successfully and calibrates parameters with minor guidance. (5-6)	Student runs the simulation with some errors, needing guidance to calibrate/debug. (3-4)	Student is able to run the simulation only with significant assistance. (1-2)
Result Extraction & Analysis (5) (PO4)	Student extracts the relevant MOEs (delay, queue length, LOS, flow, GEH etc.) for multiple scenarios and analyses them critically. (5)	Student extracts MOEs for all required scenarios and analyses them adequately. (4)	Student extracts MOEs for a few scenarios with limited analysis. (3)	Student extracts MOEs but is unable to analyse the output. (1-2)
Lab Record / Demonstration (8) (PO9)	The simulation lab record is well organised with clear sections (Objective, Network/Input Data, Coding Steps, Output/MOEs, Inference); screenshots and results are clearly labelled. (7-8)	The lab record is organised with clear sections, though a few sections are not well defined. (5-6)	The lab record lacks clear organisation; some sections are unclear or incomplete. (3-4)	The lab record is poorly organised, with missing or unclear sections. (1-2)

SUSTAINABLE PAVEMENT MATERIALS & CONSTRUCTION			
Course Code	**1MCTE202**/1MCTM202/ 1MCHT202	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L/T/P/SL&TW:	90 (42 : 0 : 0 : 48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course Outcomes (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Understand the principles of sustainability in pavement engineering and evaluate the environmental impact of conventional pavement materials. (RBT Level: L2)
2. CO2: Analyze the properties and performance characteristics of sustainable and recycled pavement materials including RAP, RCA, and industrial by-products. (RBT Level: L4)
3. CO3: Design sustainable pavement mix formulations using modified binders, green aggregates, and supplementary cementitious materials. (RBT Level: L5)
4. CO4: Evaluate sustainable pavement construction techniques including warm-mix asphalt, cold-mix technology, and green concrete pavements. (RBT Level: L5)
5. CO5: Apply life cycle assessment (LCA) and life cycle cost analysis (LCCA) frameworks to assess the sustainability of pavement systems. (RBT Level: L3)

Module-1

Sustainability Concepts in Pavement Engineering

Introduction to sustainable development — Brundtland definition, pillars of sustainability; Environmental challenges in road construction — carbon footprint, energy consumption, resource depletion; Green infrastructure and sustainable transport networks; Overview of sustainable pavement systems — permeable pavements, cool pavements, long-life pavements; Regulatory and policy framework: IRC guidelines, MoRTH circulars, ASTM/AASHTO sustainability standards

Linked CO: CO1 **Number of Hours: 08**

Module-2

Sustainable Binders and Modified Asphalt

Conventional bitumen — sources, grades (VG-10, VG-30, VG-40), limitations; Polymer-modified bitumen (PMB): SBS, SEBS, EVA — mechanisms and performance; Crumb rubber modified bitumen (CRMB) — wet and dry processes, IS:15462 specifications; Rejuvenators and bio-binders: vegetable oils, pyrolysis oil, tall oil; Warm-Mix Asphalt (WMA) technology — chemical additives (Sasobit, Evotherm), foaming processes (WAM-Foam, Double Barrel); Reduced mixing and compaction temperatures — energy and emission benefits; Performance grading (PG) system and MSCR testing of modified binders; Laboratory characterisation: DSR, BBR, RTFO, PAV — principles and interpretation.

Linked CO: CO2 **Number of Hours: 09**

Module-3

Recycled and Waste Materials in Pavements

Reclaimed Asphalt Pavement (RAP): extraction, characterisation, blending ratios; RAP mix design — Superpave approach, NCHRP 9-12 guidelines; Recycled Concrete Aggregate (RCA): properties, Los Angeles abrasion, alkali-silica reactivity; Industrial by-products as aggregates: Steel slag, copper slag, GGBS in granular layers; Use of fly ash (Class C and F) and silica fume in concrete pavements ; Bottom ash, municipal solid waste aggregate; Geosynthetics in pavement recycling — geogrid-reinforced RAP bases; Cold In-Place Recycling (CIR) and Full-Depth Reclamation (FDR) — field techniques and equipment; Quality control and acceptance testing for recycled material pavements.

Linked CO: CO2,CO3 **Number of Hours: 09**

Module-4

Green Concrete and Rigid Pavement Sustainability

Sustainable concrete pavements: JPCP, CRCP — material optimisation; Supplementary Cementitious Materials (SCMs): fly ash, GGBS, metakaolin, rice husk ash — replacement levels and properties; Ultra-High Performance Concrete (UHPC) and geopolymer concrete for rigid pavements; Pervious/permeable concrete pavements — design principles (ACI 522R), stormwater management benefits; Photocatalytic concrete (TiO_2) — air quality improvement; Self-healing concrete — microencapsulation and bacterial mechanisms; Roller Compacted Concrete (RCC) for heavy-duty pavements; Mix design for SCM-blended concrete — IS:10262, IS:456, IRC:44 considerations.

Linked CO: CO3, CO4 **Number of Hours: 08**

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Module-5

LCA, LCCA and Sustainable Construction Practices

Life Cycle Assessment (LCA): ISO 14040/14044 framework — goal & scope, inventory analysis, impact assessment, interpretation; System boundaries for pavement LCA — raw material extraction to end-of-life; Global Warming Potential (GWP), embodied energy, and resource depletion indicators; Life Cycle Cost Analysis (LCCA): FHWA Real Cost methodology, discount rate, agency and user costs; Pavement Management Systems (PMS) for sustainable maintenance; Sustainable construction practices: dust suppression, noise management, run-off control; Green procurement — BIS eco-mark, sustainable sourcing of aggregates; Carbon offsetting and carbon trading for road projects; Smart pavements — energy harvesting, solar roadways, piezoelectric pavement systems; Emerging trends: digital twin for pavement sustainability monitoring.

Linked CO: CO5 **Number of Hours: 08**

Suggested Learning Resources:

Text Books:

1. Kasthurirangan Gopalakrishnan, Sustainable Highways, Pavements and Materials: An Introduction, CreateSpace Independent Publishing Platform, 1st Edition, 2011.
2. Gina Ahlstrom et al., Sustainable Pavements and Materials, Federal Highway Administration (FHWA), Tech Brief / Guidelines Report, 1st Edition, 2014.
3. Imad L. Al-Qadi, Hasan Ozer, John Harvey (Eds.), Pavement Life-Cycle Assessment, Taylor & Francis Group, 1st Edition, 2017.
4. John Harvey, Imad L. Al-Qadi, Hasan Ozer, Gerardo W. Flintsch (Eds.), Pavement, Roadway, and Bridge Life Cycle Assessment 2020: Proceedings of the International Symposium on Pavement, Roadway, and Bridge Life Cycle Assessment 2020, CRC Press, 1st Edition, 2020.
5. Jorge de Brito, Luís Evangelista (Eds.), Eco-efficient Pavement Construction Materials, Woodhead Publishing (Elsevier), 1st Edition, 2020.
6. S.K. Khanna, C.E.G. Justo and Dr. Veeraraghavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference Books / Manuals / Codes:

1. Yue Xiao (Ed.), Sustainable Designed Pavement Materials, MDPI – Materials (Special Issue), 1st Edition, 2023 (Open Access).
2. Devi Kalla, Ahmed Faheem (Eds.), Sustainable Pavement Materials and Rheological Performance, Springer, 1st Edition, 2024.
3. Sherif El-Badawy, Ragaa Abd El-Hakim (Eds.), Recent Developments in Pavement Design, Modeling and Performance, Springer, Sustainable Civil Infrastructures Series, 1st Edition, 2019.
4. Stephen T. Muench, Adam J. Hand, Sustainable Asphalt Pavements: A Practical Guide – Sustainability Specifics (SIP 102), National Asphalt Pavement Association (NAPA), 1st Edition, 2019.
5. John Harvey, Imad L. Al-Qadi, Hasan Ozer, Gerardo W. Flintsch (Eds.), Green and Intelligent Technologies for Sustainable and Smart Asphalt Pavements, CRC Press / Routledge, 1st Edition, 2021IRC:37-2018 — Guidelines for the Design of Flexible Pavements, Indian Roads Congress, New Delhi.
6. IRC: SP:53-2010 — Guidelines on Use of Polymer and Rubber Modified Bitumen in Road Construction, IRC, New Delhi.
7. MoRTH Specifications for Road and Bridge Works, 5th Revision (2013), Ministry of Road Transport and Highways, India.
8. Chehovits, J. & Galehouse, L. (2010). Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements. Compendium of Papers, 1st International Conference on Pavement Preservation.
9. IS: 15462:2019 — Polymer and Rubber Modified Bitumen — Specification, Bureau of Indian Standards, New Delhi.
10. NCHRP Report 452 (2001). Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method. Transportation Research Board, Washington, D.C.

Web Links and Video Lectures (e-Resources)

1. NPTEL — Pavement Design: https://nptel.ac.in/courses/105104098
2. NPTEL — Highway Engineering: https://nptel.ac.in/courses/105101091
3. FHWA Pavement Policy and Technology: https://www.fhwa.dot.gov/pavement/
4. Transportation Research Board (TRB) e-Library: https://www.trb.org
5. NCAT (National Center for Asphalt Technology): https://eng.auburn.edu/research/centers/ncat/
6. Asphalt Pavement Alliance — WMA Resources: https://www.asphaltroads.org
7. MIT Open Courseware — Environmental Engineering (LCA): https://ocw.mit.edu
8. European Asphalt Pavement Association (EAPA): https://www.eapa.org
9. Portland Cement Association — Sustainable Concrete Pavements: https://www.cement.org
10. IRC Publications e-portal: https://www.irc.org.in

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies are recommended to enhance effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

1. Flipped Classroom: Pre-recorded NPTEL / YouTube video lectures on sustainable materials assigned as pre-reading; in-class time used for problem-solving and discussion.
2. Problem-Based Learning (PBL): Students investigate a real highway project and propose a sustainable pavement solution with quantified environmental benefits.
3. Case-Based Teaching: Analysis of actual projects — NH-44 WMA overlay, Delhi-Meerut Expressway fly-ash embankment, IIT Madras permeable pavement campus trial.
4. Simulation and Virtual Labs: Use of PEMED software for LCA; PerRoad or KENPAVE for pavement distress simulation.
5. Industry Expert Sessions: Inviting professionals from NHAI, MoRTH, RITES, L&T Construction for guest lectures on field implementation of sustainable pavements.
6. Industrial Visits: Site visits to RAP processing plants, hot-mix asphalt plants with WMA capability, and concrete batching plants using SCMs.
7. ICT-Enabled Teaching: Use of Padlet, Kahoot, and Moodle platforms for interactive assessments and collaborative learning.
8. Role Play / Debate: Students assigned stakeholder roles (contractor, client, environmentalist, regulator) to debate sustainable pavement procurement decisions.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Sustainable pavement material study and mix design mini-project (flexible or rigid pavement). Students select 2–3 sustainable materials (e.g., RAP, recycled aggregates, SCMs, rubber, plastics), review literature, design a trial mix, and analyse expected	24
2	Pavement Life-Cycle Assessment (LCA) / Life-Cycle Cost Analysis (LCCA) case study. Students model two alternative pavement structures (conventional vs. sustainable) for a given traffic–climate scenario, using spreadsheets or available tools (e.g., simple LCA/LCCA calculators)	24

3	Design project: Sustainable pavement section for an urban or rural corridor. Students design a flexible or rigid pavement cross-section considering traffic, climate, subgrade, and sustainable materials/technologies (e.g., high RAP content, concrete overlays, fiber-reinforced or precast slabs).	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Completion of an online course on "Sustainable Pavements / Road and Pavement Engineering" (e.g., NPTEL/other MOOC covering sustainable materials and construction techniques)	24
2	Online tutorials and tool practice for pavement LCA/LCCA (e.g., generic LCA tools or spreadsheets demonstrated in publicly available tutorials). Students follow tutorials and then perform a small independent LCA/LCCA for a chosen pavement or material.	24
3	Video-based learning on sustainable asphalt and concrete pavement practices (construction, quality control, worker safety, AR/VR or BIM applications). Students watch curated videos and prepare a summary linking techniques to sustainability dimensions.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

09102026

PAVEMENT ANALYSIS AND MECHANISTIC–EMPIRICAL DESIGN			
Course Code	**1MCTE203**/1MCTM203/ 1MCHT203	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy/Semester L/T/P/SL&TW:	90 (42 : 0: 0 : 48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course Outcomes (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Understand the fundamental concepts of pavement mechanics, layered elastic theory, and stress-strain behaviour of pavement materials under dynamic loading. (RBT Level: L2)
2. CO2: Analyse the structural response of flexible and rigid pavement systems using analytical and numerical methods including finite element analysis. (RBT Level: L4)
3. CO3: Apply the AASHTO Mechanistic–Empirical Pavement Design Guide (MEPDG) and IRC:37 mechanistic framework to design flexible and rigid pavements. (RBT Level: L3)
4. CO4: Evaluate pavement performance models for fatigue cracking, rutting, thermal cracking, and faulting using transfer functions and calibrated distress models. (RBT Level: L5)
5. CO5: Critically assess the role of climate inputs, material characterisation (dynamic modulus, resilient modulus), and traffic loading spectra in ME pavement design. (RBT Level: L5)

Module-1

Fundamentals of Pavement Mechanics and Structural Response

Review of pavement types — flexible, rigid, composite, and semi-rigid; Wheel load and contact stress idealisation — circular and rectangular contact; Boussinesq's theory for homogeneous elastic half-space — vertical stress, settlement, and deflection; Burmister's two-layer and three-layer elastic theory — stress and deflection solutions; Multi-layer elastic theory (MLET) — assumptions, limitations, and extensions; Critical pavement response parameters — maximum tensile strain at bottom of bituminous layer (εt), maximum compressive strain at top of subgrade (εz), critical stress in PQC; Concept of equivalent single axle load (ESAL) and load equivalency factors (LEF); Axle load spectra and WIM (Weigh-in-Motion) data; Dynamic loading effects — pavement-vehicle interaction, impact factors; Thermal stress in rigid pavements — Westergaard's theory, temperature differentials.

Linked Cos:CO1 **Number of Hours: 08**

Module-2

Material Characterisation for Mechanistic Design

Subgrade characterisation: California Bearing Ratio (CBR) to resilient modulus (Mr) correlations (AASHTO, IRC:37); Resilient modulus testing — AASHTO T 307, stress-dependent models for cohesive and granular soils; Bituminous material characterisation: Dynamic (Complex) Modulus |E*| — AASHTO T 342, characterisation: flow number (FN), flow time (FT), triaxial repeated load permanent deformation; Concrete modulus of elasticity, Poisson's ratio, modulus of rupture (flexural strength), fatigue life of concrete — S-N curves; Granular layer stiffness — repeated load triaxial, Mr models.

Linked Cos: CO5 **Number of Hours: 09**

Module-3

Mechanistic–Empirical Pavement Design — Flexible Pavements

Philosophy of ME design — limitations of purely empirical AASHTO 1993 method; NCHRP Project 1-37A: MEPDG framework — three-level hierarchical input system; Traffic input: axle load spectra, vehicle classification, AADTT, directional and lane distribution factors; Climate inputs: IRC:37-2018 ME design framework — design procedure, reliability, pavement catalogue; Worked examples using KENPAVE / AASHTOW are Pavement ME Design software.

Application of IIT PAVE software, ANSYS, KENPAVE, KENLAYER, AASHTOWARE

Linked Cos:CO3, CO4 **Number of Hours: 09**

Module-4

Stress Analysis of Rigid Pavements

Introduction-Factors affecting design and performance of pavements-Important Definitions- Types of stresses and causes, factors influencing the stresses; general considerations in rigid pavement analysis, EWL, wheel load stresses, warping stresses, frictional stresses, combined stresses. Problems on above.

Linked Cos: CO2	**Number of Hours: 08**

Module-5

Rigid Pavement Design

Rigid pavement design factors, Determination of ESWL, EWL for dual and dual tandem wheel loads in Rigid pavements, General design principle, , design of cement concrete pavements (joints and slab thickness) as per IRC/PCA guidelines. Design features of CRCP, SFRC and ICBP, Problems. Application of Design Software.

Linked Cos:CO3 **Number of Hours: 08**

Suggested Learning Resources:

Text Books:

1. Huang, Y. H. (2004). Pavement Analysis and Design (2nd ed.). Pearson Prentice Hall, Upper Saddle River, NJ, USA.
2. Yoder, E. J. & Witczak, M. W. (1975). Principles of Pavement Design (2nd ed.). John Wiley & Sons, New York.
3. Ullidtz, P. (1987). Pavement Analysis. Elsevier Science Publishers, Amsterdam.
4. Mallick, R. B. & El-Corsi, T. (2013). Pavement Engineering: Principles and Practice (2nd ed.). CRC Press, Boca Raton, FL.
5. Croney, D. & Croney, P. (1997). Design and Performance of Road Pavements (3rd ed.). McGraw-Hill, New York.
6. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference Books / Codes / Manuals:

1. ARA Inc., ERES Consultants Division (2004). Guide for Mechanistic–Empirical Design of New and Rehabilitated Pavement Structures (NCHRP Project 1-37A Final Report). TRB, Washington, D.C.
2. IRC:37-2018 — Guidelines for the Design of Flexible Pavements (4th Revision). Indian Roads Congress, New Delhi.
3. IRC:58-2015 — Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (4th Revision). Indian Roads Congress, New Delhi.
4. AASHTO (2008). Mechanistic–Empirical Pavement Design Guide: A Manual of Practice. AASHTO, Washington, D.C.
5. MoRTH Specifications for Road and Bridge Works, 5th Revision (2013). Ministry of Road Transport and Highways, India.
6. NCHRP Report 696 (2012). Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High RAP Content. TRB, Washington, D.C.
7. Westergaard, H. M. (1926). Stresses in Concrete Pavements Computed by Theoretical Analysis. Public Roads, 7(2), 25–35.
8. FHWA-HRT-14-084 (2014). DARWin-ME / AASHTOWare Pavement ME Design — User Reference Guide. FHWA, Washington, D.C.

Web Links and Video Lectures (e-Resources)

1. NPTEL — Pavement Design (IIT Madras): https://nptel.ac.in/courses/105104098
2. NPTEL — Highway Engineering (IIT Kharagpur): https://nptel.ac.in/courses/105105052
3. AASHTOWare Pavement ME Design (DARWin-ME): https://www.aashtoware.org/pavement/
4. KENPAVE Software — University of Kentucky: https://www.civil.uky.edu/research/lpavement/
5. FHWA Pavement Design and Materials: https://www.fhwa.dot.gov/pavement/
6. Transportation Research Board — TRB e-Library: https://www.trb.org
7. NCAT — National Center for Asphalt Technology: https://eng.auburn.edu/research/centers/ncat/
8. PavementInteractive.org — Online Pavement Design Reference: https://www.pavementinteractive.org
9. MIT OpenCourseWare — Advanced Mechanics of Materials: https://ocw.mit.edu
10. IRC Publications e-portal: https://www.irc.org.in

Teaching-Learning Process (Innovative Delivery Methods)

The following strategies are recommended to enhance effectiveness of the teaching-learning process and facilitate achievement of course outcomes:

- Flipped Classroom: Pre-reading of MEPDG manual chapters and NPTEL lectures assigned before class; classroom time dedicated to problem-solving and software demonstrations.
- Problem-Based Learning (PBL): Students are given a real highway project data set (traffic, climate, subgrade) and design the pavement structure using both IRC:37-2018 and MEPDG, comparing results.
- Simulation and Virtual Labs: Hands-on sessions with KENPAVE for multi-layer elastic analysis, and AASHTOWare Pavement ME Design (or IITPAVE) for distress prediction.
- Case-Based Teaching: Analysis of pavement design reports from NHAI projects, CRRI research studies, and FHWA case studies on MEPDG implementation.
- Numerical Analysis Workshops: Tutorial sessions on FEM formulation for pavement problems; demonstration of 3D pavement model in ABAQUS or Plaxis with guided exercises.
- Industry Expert / Guest Lectures: Sessions by NHAI / CRRI / RITES professionals on real-world pavement design challenges, WIM data collection, and FWD testing.
- Industrial / Field Visits: Visit to a NHAI or State PWD project site for FWD testing demonstration, WIM station, and pavement coring.
- ICT-Enabled Teaching: Use of Moodle / Google Classroom for assignment submission, discussion forums, and weekly quizzes on transfer functions and distress models.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	1. Numerical assignment on Boussinesq, Burmister and multilayer elastic theory. 2. Comparative study of flexible, rigid, composite and semi-rigid pavements. 3. Problem-solving exercise on critical pavement responses, ESAL and load equivalency factors. 4. Short seminar on dynamic loading, WIM data and thermal stresses.	24
2	1. Laboratory/data-analysis assignment on resilient modulus and dynamic modulus. 2. Comparative report on CBR–M_r correlations recommended by AASHTO and IRC:37.	24
3	1.Guided design assignment using IRC:37 and the MEPDG framework. 2. Software-based exercise using KENPAVE, KENLAYER, IIT PAVE or AASHTOWare. 3. Case study on the effect of traffic spectra and climate inputs on flexible pavement design. 4. Performance-prediction assignment involving fatigue cracking, rutting and thermal cracking.	24

	5. Design review presentation comparing empirical and mechanistic–empirical methods.	
4	1.Numerical assignment on wheel-load, warping, frictional and combined stresses. 2. Analysis of rigid pavement response for single, dual and tandem axle configurations. 3. Spreadsheet or software-based parametric study of slab stress and deflection. 4. Case study comparing rigid and composite pavement structural behaviour. 5. Problem-based learning exercise on critical stress locations and failure mechanisms.	24
5	1. Complete design problems for ESWL/EWL under dual and dual-tandem wheel loads. 2. Design a cement concrete pavement as per IRC/PCA guidelines. 3. Prepare a slab-thickness and joint-detailing design sheet. 4. Comparative design study of CRCP, SFRC and ICBP. 5. Software-based rigid pavement design exercise and technical presentation.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Study an online lecture, video module or textbook section on Boussinesq theory, Burmister's layered theory and MLET.	24
2	Prepare a concept map showing the relationship between wheel load, contact stress, stress distribution, strain and deflection.	24
3	Review AASHTO T 307 and AASHTO T 342 test procedures using available digital resource	24
4	Complete a guided tutorial on KENPAVE, KENLAYER, IIT PAVE or AASHTOWare Pavement ME Design.	24
5	Compare the AASHTO 1993 and IRC:37 mechanistic–empirical design approaches.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

09102026

TRANSPORTATION PLANNING, PUBLIC TRANSPORT & SUSTAINABLE MOBILITY			
Course Code	**1MCTE204**/1MCTM204/ 1MCHT204	Scheme	2026
Type of Course	PCC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Explain the concepts, process and challenges of urban transportation planning within the framework of sustainability and policy.
2. CO2: Apply travel demand forecasting techniques (trip generation, trip distribution, modal split and traffic assignment) to analyse urban travel patterns.
3. CO3: Plan and evaluate public transportation systems, including capacity, performance measures and Transit-Oriented Development (TOD) strategies.
4. CO4: Design non-motorized transport facilities and formulate Travel Demand Management (TDM) and ITS-based strategies for sustainable mobility.
5. CO5: Appraise transport policies, financing mechanisms and investment strategies for sustainable and equitable transportation systems.

Module-1

Introduction to Transportation Planning and Urban Transport Systems

Urbanization and urban transportation; urban transportation problems and externalities – congestion, safety, emissions; overview of urban transport planning process – problem definition, generation and evaluation of alternatives, implementation; hierarchical levels of planning – conceptual plan, master plan, structure plan; systems approach to transportation planning; overview of the traditional four-stage travel demand forecasting process; need for sustainable and affordable mobility; overview of national and urban transport policy framework (NTDP, NUTP); role of the transportation engineer/planner in planning and policy-making.

Linked Cos: CO1 **Number of Hours: 08**

Module-2

Travel Demand Forecasting

Transport surveys – study area and zoning principles, types of movement, sample size computation, sampling techniques, Origin–Destination survey methods, questionnaire design and survey administration; Trip Generation – factors governing trip production and attraction, regression analysis, category/cross-classification analysis; Trip Distribution – growth factor methods (Fratar, Furness), Gravity Model and its calibration, doubly constrained models; Modal Split – aggregate and disaggregate mode-choice models, utility theory, binary and multinomial logit models; Traffic (Route) Assignment – network representation, shortest-path algorithms (Dijkstra, Moore), all-or-nothing, capacity-restrained, user-equilibrium and system-optimal assignment; illustrative examples using Trans CAD/Cube.

Linked Cos: CO2 **Number of Hours: 09**

Module-3

Public Transportation Planning, Operations and Transit-Oriented Development

Introduction to public transportation and its basic operating elements; bus transportation systems; rail transportation and Intermediate Public Transport (IPT); transit financing and marketing; measuring performance of transit systems; advanced operating concepts – bus and rail transit capacity, station capacity,

transit stop location; Transit-Oriented Development (TOD) – principles, planning and Indian case studies; multimodal transfer facilities and Park-and-Ride facility planning.

Linked Cos: CO3 **Number of Hours: 08**

Module-4

Non-Motorized Transport, Travel Demand Management and Intelligent Transportation Systems

Non-Motorized Transport (NMT) planning – assessment of existing NMT scenario, data collection and analysis, selection of interventions, economic and financial evaluation; pedestrian flow characteristics and Pedestrian Level of Service (PLOS) – flow-based and HCM methodologies; Bicycle Level of Service (BLOS) and Bicycle Compatibility Index (BCI); design principles for pedestrian and cycling infrastructure; Travel Demand Management (TDM) – push and pull measures, parking studies; introduction to Intelligent Transportation Systems (ITS) – components, applications, architecture; Electronic Toll Collection (ETC); Public Bicycle Sharing (PBS) systems integrated with ITS.

Linked Cos: CO4 **Number of Hours: 08**

Module-5

Sustainable Mobility, Transport Policy and Financing

Multimodal transportation environment and Multimodal Level of Service (MMLOS); pedestrian and cyclist road safety, risk factors, crash estimation and predictive methods; environmental concerns and sustainability strategies for urban transport; national and urban transport policy – National Transport Development Policy (NTDP), National Urban Transport Policy (NUTP); electric mobility policy landscape – eAMRIT, FAME and EMPS schemes, State EV policies; investment and pricing – cost-benefit analysis, congestion pricing, fare and subsidy policy, social costs of transportation; private-sector participation – PPP models (BOT, BOO), risk allocation; emerging trends – shared mobility, Mobility-as-a-Service (MaaS), smart and connected mobility.

Linked Cos: CO5 **Number of Hours: 09**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Khisty, C.J. and Lall, B.K., "Transportation Engineering – An Introduction", PHI, New Delhi, 3rd Indian Edition, 2006.
2. Kadiyali, L.R., "Traffic Engineering and Transportation Planning", Khanna Publishers, New Delhi, 2009.
3. Vuchic, V.R., "Urban Transit: Operations, Planning and Economics", John Wiley & Sons, 2005.

Reference books / Manuals:

1. Ortúzar, J.D. and Willumsen, L.G., "Modelling Transport", 4th Edition, John Wiley & Sons, 2011.
2. Papacostas, C.S. and Prevedouros, P.D., "Transportation Engineering and Planning", Prentice Hall, 2001.
3. Ceder, A., "Public Transit Planning and Operation: Modeling, Practice and Behavior", 2nd Ed., CRC Press, 2016.
4. Small, K.A. and Verhoef, E.T., "Urban Transportation Economics", 2nd Edition, Routledge, London, 2006.
5. Fruin, J.J., "Pedestrian Planning and Design", Elevator World Inc., 1987.
6. National Transport Development Policy Documents, Government of India, 2012; National Urban Transport Policy, MoUD, GoI, 2014.
7. IRC 103:2012 – Guidelines for Pedestrian Facilities; IRC 11:2015 – Design & Layout of Cycle Tracks, Indian Roads Congress.
8. TOD, NMT and PBS Guidance Documents, Ministry of Housing and Urban Affairs, Government of India.

Web links and Video Lectures (e-Resources):

1. NPTEL – "Urban Transportation Systems Planning", Prof. Bhargab Maitra, IIT Kharagpur (onlinecourses.nptel.ac.in).
2. NPTEL – Courses on Public Transportation Systems and Sustainable Urban Mobility, IIT Roorkee / IIT Madras.
3. Ministry of Housing and Urban Affairs (MoHUA) e-resources on TOD, NMT and Sustainable Mobility.

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Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped classroom for demand-modelling numerical topics (trip generation, distribution, mode choice, assignment).
- Case-based teaching using Indian city case studies on public transport, NMT and TOD interventions.
- Software demonstration (TransCAD/Cube) for travel demand modelling and traffic assignment.
- Partial delivery by industry/policy experts and field visit to a public transit facility or NMT corridor.

Assessment Structure (both CIE and SEE)
The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.
A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.
Continuous Internal Evaluation:
Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]
A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.
In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

09102026

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Identify urban transport problems through field observation; prepare problem tree and alternative-evaluation matrix.	24
2	Design an O–D survey; calculate trip generation, trip distribution, modal split and traffic assignment using Excel/QGIS/TransCAD/Cube.	24
3	Survey a bus route/station; analyse headway, capacity, load factor, speed, waiting time and service reliability.	24
4	Conduct PLOS/BLOS assessment; prepare an NMT corridor redesign and propose TDM/ITS measures.	24
5	Carry out cost-benefit analysis of a transport project and conduct a debate on congestion pricing, PPP or electric mobility.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Study NUTP/NTDP and prepare a policy brief for a selected city.	24
2	Develop a spreadsheet-based four-stage travel-demand model for a hypothetical urban area.	24
3	Prepare a TOD appraisal of a selected Indian transit corridor or station area.	24
4	Study pedestrian/cyclist safety and prepare an ITS-supported sustainable mobility strategy.	24
5	Prepare a mini-DPR for an integrated sustainable mobility project.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

09102026

PAVEMENT MATERIALS AND EVALUATION LABORATORY			
Course Code	**1MCTEL207**/1MCTML207/ 1MCHTL207	**Scheme**	2026
Type of Course	Laboratory Course (1 Credit)	**Semester**	II
Teaching Hours/Week (L:T:P)	28 (0 : 0 : 2)	**CIE Marks**	50
Total Hours of Pedagogy L:T:P:SL/TW	30 (0 : 0 : 28: 2)	**SEE Marks**	50
Credits	1	**Total Marks**	100
Examination type (SEE)	Practical	**Exam Hours**	3

Course Outcomes (Course Skill Set)

Course Outcomes

At the end of the course, the student will be able to:

1. CO1: Determine the physical, rheological, and mechanical properties of bituminous binders and aggregates as per relevant IS / ASTM / IRC standards, and interpret the results in the context of pavement material specifications. (RBT Level: L3)
2. CO2: Conduct mix design procedures for dense bituminous macadam (DBM) and bituminous concrete (BC) using Marshall and Superpave methods, and analyse the volumetric and mechanical parameters. (RBT Level: L4)
3. CO3: Evaluate the performance characteristics of pavement materials including fatigue life, rutting resistance, moisture susceptibility, and skid resistance using advanced laboratory equipment. (RBT Level: L5)
4. CO4: Perform field and laboratory evaluation of in-service pavement layers by conducting FWD deflection analysis, coring, GPR survey interpretation, and pavement condition assessment. (RBT Level: L4)
5. CO5: Design and execute open-ended experiments to investigate innovative pavement materials (modified binders, recycled aggregates, green materials) and correlate laboratory findings with field performance. (RBT Level: L5)

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6-8 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for 80 marks out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for 20 marks.

For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from Part-B, along with other similar questions designed to enhance the students' skills.

LIST OF EXPERIMENTS

PART-A: FIXED EXPERIMENTS

1. **Experiment 1: Bituminous Binder Characterisation**
   Determine penetration, ductility, softening point, viscosity, flash and fire point, and specific gravity of bitumen as per relevant IS standards. Classify the binder and compare the results with VG-10, VG-30, and VG-40 specifications. CO Mapping: CO1
2. **Experiment 2: Aggregate Physical and Mechanical Properties**
   Determine Aggregate Impact Value, Los Angeles Abrasion Value, Aggregate Crushing Value, flakiness index, elongation index, water absorption, and specific gravity of aggregates. Evaluate their suitability according to MoRTH and IRC requirements. CO Mapping: CO1
3. **Experiment 3: Marshall Mix Design for Bituminous Concrete**
   Design a bituminous concrete mix using selected aggregate gradation and different binder contents. Determine Marshall Stability, Flow, density, air voids, VMA, VFA, and Optimum Binder Content, and compare the results with MoRTH and IRC:111 specifications. CO Mapping: CO2
4. **Experiment 4: Indirect Tensile Strength and Moisture Susceptibility**
   Determine the Indirect Tensile Strength of conditioned and unconditioned bituminous mix specimens. Calculate the Tensile Strength Ratio and evaluate moisture damage, stripping, and rutting susceptibility using the Hamburg Wheel Tracking Test, where available.CO Mapping: CO3
5. **Experiment 5: Pavement Core Analysis and Field Material Evaluation**

Extract pavement cores and determine layer thickness, in-situ density, bitumen content, recovered aggregate gradation, and pavement core condition. Identify cracking, ravelling, segregation, stripping, and delamination, and compare the results with as-built specifications. CO Mapping: CO3, CO4

6. **Experiment 6: Concrete Pavement Material Testing and Mix Design**
   Design an M40 pavement-quality concrete mix and determine slump, compaction factor, compressive strength, flexural strength, and modulus of elasticity. Evaluate the results with reference to IS:10262, IS:516, IRC:44, and IRC:58. CO Mapping: CO2, CO3.

PART-B: Open End Experiments

1. **Experiment 1: Modified Binder Evaluation**
   Investigate the effect of different concentrations of crumb rubber or SBS polymer on the penetration, ductility, softening point, viscosity, and performance of bitumen. Determine the optimum modifier content satisfying the applicable IRC specification. CO Mapping: CO1, CO5
2. **Experiment 2: Recycled Aggregate Pavement Mix**
   Prepare bituminous mixes containing different percentages of Reclaimed Asphalt Pavement material. Determine Marshall Stability, Flow, density, air voids, VMA, and VFA, and identify the maximum permissible RAP content. CO Mapping: CO2, CO3, CO5
3. **Experiment 3: Warm-Mix Asphalt Performance Study**
   Evaluate the effect of a warm-mix additive on mixing and compaction temperatures. Compare hot-mix and warm-mix specimens for stability, flow, density, air voids, and Indirect Tensile Strength, and estimate potential energy savings. CO Mapping: CO2, CO3, CO5
4. **Experiment 4: Pavement Condition Assessment and Structural Evaluation**
   Conduct a visual pavement condition survey over a selected road stretch. Record distress types, severity, and extent; measure pavement deflection using a Benkelman Beam or FWD simulator; and recommend suitable maintenance or strengthening measures. CO Mapping: CO3, CO4, CO5
5. **Experiment 5: Fly Ash or GGBS Modified Concrete Pavement Mix**
   Investigate the effect of partial replacement of cement with fly ash or GGBS in an M40 pavement-quality concrete mix. Determine workability, 7-day and 28-day compressive strength, flexural strength, modulus of elasticity, and water absorption. CO Mapping: CO2, CO3, CO5
6. **Experiment 6: Skid Resistance and Surface Texture Measurement**
   Determine the skid resistance and macro-texture of bituminous slabs prepared using different aggregate types and mix gradations. Conduct the British Pendulum Test and Sand Patch Test, and correlate the results with wet-weather pavement safety requirements. CO Mapping: CO3, CO5

Suggested Learning Resources

Text Books:

1. Khanna, S. K., Justo, C. E. G. and Veeraragavan, A., *Highway Engineering*, Nem Chand & Bros., Roorkee.
2. Huang, Y. H., *Pavement Analysis and Design*, Pearson Prentice Hall.
3. Mallick, R. B. and El-Korchi, T., *Pavement Engineering: Principles and Practice*, CRC Press.
4. Roberts, F. L. et al., *Hot Mix Asphalt Materials, Mixture Design and Construction*, NAPA Education Foundation.
5. Neville, A. M. and Brooks, J. J., *Concrete Technology*, Pearson Education.

Laboratory Manuals:

1. *Transportation Engineering Laboratory Manual*, Department of Civil Engineering, IIT (ISM) Dhanbad.
2. *Highway Engineering Laboratory Manual*, Department of Civil Engineering. Government Engineering College.
3. *Concrete and Highway Materials Laboratory Manual*, Department of Civil Engineering.
4. *Pavement Materials and Evaluation Laboratory Manual*, prepared with reference to the latest IS, IRC, ASTM, AASHTO, and MoRTH specifications.

Codes and Standards:

1. IS:73, IS:1201, IS:1202, IS:1203, IS:1205, IS:1206, IS:1208, IS:1209.
2. IS:2386 Parts I–VIII, IS:383, IS:5640, IS:6241, and IS:14798.
3. IS:10262, IS:1199, IS:3812, IS:456, and IS:516.
4. IS:15462, IS:17116, IS:17127, and IS:19008.
5. IRC:37, IRC:44, IRC:58, IRC:81, IRC:82, IRC:111, IRC:SP:16, IRC:SP:53, and IRC:115.
6. MoRTH *Specifications for Road and Bridge Works*, 5th Revision, 2013.
7. ASTM D6926, ASTM D6927, ASTM D2041, ASTM D5361, ASTM D6931, ASTM D2172, ASTM E303, ASTM E965, ASTM C78, and ASTM C469.
8. AASHTO T 283, T 312, and T 324.

Web Resources:

1. Bureau of Indian Standards, Know Your Standards Portal: BIS Standards Portal. The portal provides access to standard details, amendments, reaffirmation status, and related information.bis.gov
2. Indian Roads Congress, IRC Publications Portal: Indian Roads Congress.
3. Ministry of Road Transport and Highways, MoRTH Official Website: MoRTH.
4. NPTEL, Pavement Design: NPTEL Pavement Design.
5. NPTEL, Highway Engineering: NPTEL Highway Engineering.
6. Pavement Interactive, Online Pavement Reference: Pavement Interactive.
7. FHWA Pavement Technology Program: FHWA Pavement Technology.
8. National Center for Asphalt Technology: NCAT.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for a pass in the course.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject /course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation (CIE):

For the Professional Core Course Laboratory, the maximum marks prescribed are 100. Out of these, 50 marks are allotted for Continuous Internal Evaluation (CIE) and 100 marks for the Semester End Examination (SEE). The SEE marks obtained out of 100 shall be proportionately scaled down to 50 marks. The final result shall be declared based on the aggregate of the CIE marks (50) and the scaled-down SEE marks (50), totalling 100 marks."

Out of 50 marks, 40 marks shall be assigned for assessment of regular laboratory PART -A classwork, and 10 marks for Part – B. (Table 1)

Out of 40 marks, 25 marks shall be based on the regular classwork and allotment of marks shall be as per rubrics listed in Table 1.

The remaining 15 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for the practical test as indicated in the Table 1.

The open-ended question set for CIE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for 10 marks. The allotment of marks shall be as per rubrics listed in Table 2.

Table – 1 Distribution of marks corresponding to laboratory component

Component	Description	Marks
Allotment of marks for regular classwork		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	10 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	15 marks
	Subtotal	**25**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	10marks
	Subtotal	**15**
	Total	**40**

Table 2 Distribution of marks corresponding to PART -B of the laboratory component

Evaluation Rubrics for continuous internal evaluation CIE). Maximum marks:10

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Criteria and Guiding factors	Students' Level and Rubrics Excellent: E, Good: G, Fair: F Needs Improvements: NI			
	E	**G**	**F**	**NI**
(1) Problem Understanding **Criteria:** Is the problem understood correctly and framed appropriately? (i)Clarity in interpreting the given problem. (ii)Identification of relevant concepts and constraints. (iii) Ability to rephrase or model the problem logically.	2.0	1.5	1.0	0.5
(2) Conceptual Knowledge **Criteria**: Are the chosen methods or concepts valid for this type of problem? (i)Application of appropriate theories, principles, or laws. (ii)Integration of multiple concepts where necessary. (iii)Accuracy in stating relevant equations or models.	2.0	1.5	1.0	0.5
(3) Approach and Strategy **Criteria**: Is the approach well thought out and methodical? (i)Logical structure and progression. (ii)Use of diagrams, sketches, or flowcharts if applicable. (iii)Identification of assumptions and boundary conditions.	2.0	1.5	1.0	0.5
(4) Execution and Accuracy **Criteria**: Are the calculations correct? Is the final solution reasonable? (i) Correct application of formulas/methods. (ii)Accuracy of calculations or simulations (if any). (iii)Unit consistency and result verification.	2.0	1.5	1.0	0.5
(5) Innovation or Depth **Criteria**: Has the student shown original thinking or alternative methods? (i)Novel or efficient solutions. (ii)Consideration of alternate approaches. (iii)Interdisciplinary integration or practical extensions.	1	0.75	0.5	0.25
(6) Presentation and Clarity **Criteria**: Is the answer easy to follow and professionally written? (i)Organization and neatness. (ii)Clarity of explanation, labelling, and steps. (iii) Use of proper technical terminology.	1	0.75	0.5	0.25
Total	10	7.5	5.0	2.5

Note:
(i)The marks shown for Excellent, Good, Fair, Needs Improvement are indicative. The evaluator may also assign intermediate scores depending on the quality of work.
(ii)If the total score results in a fraction, it should be rounded off to the next higher integer.
(iii)The listed criteria are guidelines; evaluators may also consider other authentic dimensions (e.g., depth of insight, critical thinking, and practical awareness, recognition of limitations, or justified compromises.
(iv)To award the full10 marks in the excellent category, the student must demonstrate reasonably good performance across all six criteria; otherwise, proportionally lower marks may be given.

GEOTECHNICAL INVESTIGATIONS FOR HIGHWAY DEVELOPMENT PROJECTS			
Course Code	**1MCTE205A** /1MCTM205A/ 1MCHT205A	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3: 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42: 0 : 0 : 48)	SEE Marks	50
Credits	3	Total Marks	100
Examination Type	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1 L3- **:** Apply fundamental soil mechanics and advanced field testing to subgrade evaluation.
2. CO2 L4 - Analyze the mechanical and hydraulic behavior of unsaturated soils using state variables and suction control principles.
3. CO3 L4 - Evaluate the resilient modulus and permanent deformation characteristics of geomaterials under repetitive traffic loading.
4. CO4 L5 - Design climate-resilient infrastructure strategies for moisture-sensitive soils (expansive/frost-susceptible).
5. CO5 L6 - Formulate advanced stabilization and monitoring frameworks using GIS/Remote Sensing for infrastructure failure detection.

Module-1

Soil Mechanics Foundations & Advanced Field Exploration:

Recap of fundamental soil mechanics: Basic-properties and inter-relationships, index properties, and ISSCS classification. Permeability, compaction, and consolidation theory; shear strength and effective stress principles; stress distribution in soil and slope stability analysis. **Subsurface Exploration**: Planning for transportation projects; advancements and digital integration in California Bearing Ratio (CBR), Plate Load Test (PLT), and Dynamic Cone Penetrometer Test (DCPT) for subgrade characterization.

Linked COs: CO1 **Number of Hours (CI)=8 hrs**

Module-2

Transportation Geotechnics & Unsaturated Soil Principles:

Pavement and railroad track design philosophy; historical development and importance of substructure layers. Unsaturated Behavior: Introduction to the three-phase system in unsaturated states; fundamental principles of unsaturated soil mechanics. State Variables: Matric and osmotic suction; laboratory and field measurement/control of soil-water potential and moisture content.

Linked COs: CO2 **Number of Hours (CI) = 8 hrs**

Module-3

Hydraulic Characterization & Mechanistic-Empirical Design:

Moisture Retention: Measurement and estimation of Soil-Water Characteristic Curves (SWCC); practical evaluation for field engineers. Geotechnical testing methods for unsaturated hydraulic conductivity functions. Design Framework: Introduction to the Mechanistic-Empirical (M-E) design framework; laboratory characterization of geo-materials for pavements and railroads.

Linked COs: CO3 **Number of Hours (CI): 8 hrs**

Module-4

Deformation Mechanics under Repetitive Loading:

Stress-dependent behavior of geo-materials: Repeated load behavior of soils, aggregates, and railroad ballast. **Resilient Modulus**: Testing protocols and model development. **Deformation Analysis**: Permanent deformation testing and modeling; anisotropic behavior of unbound aggregates. Stress-deformation and volume change predictions for moisture-sensitive foundations.

Linked COs: CO4 **Number of Hours (CI): 10hrs**

Module-5

Climate Resilience, Stabilization & Failure Detection:

Environmental Sensitivity: Identification and behavior prediction of frost-susceptible and expansive soils; frost depth prediction and frost mechanisms. Hydraulic Flux: Ground surface flux; steady-state and transient flow through unsaturated subgrades. Stabilization: Mechanical and chemical subgrade stabilization techniques. Failure Detection: Case studies on pavement failures and landslides; application of Remote Sensing and GIS in infrastructure failure detection.

Linked COs: CO5 **Number of Hours (CI): 8 hrs**

Suggested Learning Resources:

Text Books:

1. "Basic and Applied soil Mechanics", Gopal Ranjan, ASR Rao, New Age International Publishers.
2. "Soil Mechanics & Foundation Engg", Dr.B.C. Punmia, Ashok Kumar Jain, Arun Kumar Jain, Laxmi Publications (P) Ltd, 16th edition.
3. S.K. Khanna, C.E.G Justo and A. Veeraragavan, "Highway Engineering"- Nem Chand and Bros., Roorkee. Revised 10th Edition.

Reference Books:

1. "Geotechnical aspects of pavement reference manual", US department of transportation, Publication no: FHWA NHI-05-037, Federal Highway Administration, May 2006, NHI course no:132040
2. "Soil Mechanics & Foundation Engg" – K.R. Arora Standard Publishers Distributors.
3. Soil Mechanics for road Engineers" – HMSO, London.
4. D. G. Fredlund, H. Rahardjo, M. D. Fredlund, "Unsaturated Soil Mechanics in Engineering Practice", John Wiley & Sons, Inc.
5. K R Arora, " Soil Mechanics and Foundation Engineering" Standard Publishers, New Delhi.
6. Relevant Indian Roads Congress (IRC) Code books, published by IRC New Delhi.
7. Rajib B. Mallick, Tahar El-Korchi, " Pavement Engineering: Principles and Practice", CRC Press- USA.
8. P. Purushothama Raj, " Ground Improvement Techniques" , Laxmi Publications, New Delhi.

Web links and Video Lectures (e-Resources):

1. SWAYAM course on "Ground Improvement" by Prof. Dilip Kumar Baidya (https://onlinecourses.nptel.ac.in/noc23_ce78/preview)
2. NPTEL course on "Unsaturated Soil Mechanics" by Dr. T V Bharat (https://onlinecourses.nptel.ac.in/noc25_ce61/preview)
3. NPTEL course on "Pavement Materials " by Dr. Nikhil Saboo (https://onlinecourses.nptel.ac.in/noc24_ce66/preview)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

Component	Key Methods/Activities	Support/Assessment
CI (42 hrs)	Interactive lectures on unsaturated soil mechanics; case studies on climate-resilient infrastructure; demonstrations of digital DCPT and PLT devices.	LMS for specialized geotechnical datasets; quizzes on M-E design concepts; participation rubrics.
TW (24 hrs)	Python/Matlab: SWCC estimation and hydraulic conductivity modeling (8h). Design: Resilient Modulus model development based on repeated load data (8h). Site Analysis: GIS-based landslide/failure detection mapping (8h).	Graded on mathematical precision (40%), innovation (30%), report clarity (20%), and timeliness (10%).
SL (24 hrs)	Self-paced study of IRC/AASHTO guidelines for subgrade exploration; review of research papers on partially saturated geomaterials; problem-solving in material stiffness.	LMS logs; reflection journals on environmental effects; technical portfolio linked to TW applications.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Solve numericals on index properties, ISSCS classification, stress distribution beneath highway loads; prepare a one-page summary of subgrade implications	24
2	Design a borehole and in-situ testing plan for a given highway alignment; prepare a TW report on selection of CBR, PLT and DCPT locations and data requirements.	24
3	Work out example problems involving matric suction, osmotic suction, and soil-water potential; prepare graphs and short interpretations for given soil profiles.	24
4	Given laboratory SWCC data for different subgrade soils, students interpret air-entry value, residual water content, and discuss implications for pavement performance.	24
5	solve repeat-load test data to back-calculate resilient modulus and permanent strain parameters; compare model fits and discuss suitability for different geomaterials.	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Work with sample CBR, PLT and DCPT datasets (from lab/field or open repositories); import into spreadsheet/software, compute design parameters, and generate subgrade evaluation report.	24
2	Observe or simulate suction measurement (tensiometer/pressure plate/filter paper); process given raw data to plot suction vs. water content and comment on field relevance.	24
3	Use given SWCC data to fit standard models (e.g., van Genuchten) in software; estimate unsaturated hydraulic conductivity functions and prepare a short engineering note for field application.	24
4	Analyse multi-stage cyclic test data for unbound aggregates; compute permanent strain accumulation and discuss anisotropic behaviour using plots and regression models.	24

Sample rubrics for TW activities:

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Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

PAVEMENT HEALTH MONITORING AND PREDICTIVE MAINTENANCE			
Course Code	**1MCTE205B /**1MCTM205B/ 1MCHT205B	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	3 : 0 : 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42 : 0 : 0 : 10 : 0	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3 Hours

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. **CO1:** Explain the mechanisms of pavement deterioration and the role of health monitoring in sustainable highway asset management. [RBL2]
2. **CO2:** Apply standard and advanced non-destructive evaluation (NDE) techniques to assess pavement surface and structural condition. [RBL3]
3. **CO3:** Utilise IoT, remote sensing, and smart sensor technologies for continuous and automated pavement monitoring. [RBL3]
4. **CO4:** Analyse pavement performance data using statistical and machine learning models to predict distress and remaining service life. [RBL4]
5. **CO5:** Evaluate and design predictive maintenance strategies using multi-criteria decision frameworks and pavement management systems. [RBL5]
6. **CO6:** Critically review international case studies and emerging research to propose innovative solutions for pavement health monitoring. [RBL6]

Module-1

Introduction to Pavement Health Monitoring: Importance of pavement health monitoring in highway infrastructure management; pavement deterioration mechanisms – fatigue cracking, rutting, ravelling, potholes, thermal cracking, and delamination; overview of pavement management systems (PMS); life-cycle cost analysis and economic justification for monitoring; international practices in pavement asset management (AASHTO, PIARC, World Bank HDM-4); regulatory frameworks and standards – IRC, MoRTH, AASHTO, EN 13036 series.

Linked COs: CO1 **Number of Hours: 8**

Module-2

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Pavement Condition Assessment: Methods and Technologies

Visual inspection and distress cataloguing – IRC:82, ASTM D6433; Pavement Condition Index (PCI) computation and interpretation; Present Serviceability Index (PSI) and Riding Quality Index (RQI); surface roughness measurement – IRI (International Roughness Index), MERLIN, Bump Integrator, road profilometers; skid resistance measurement – British Pendulum Tester, Grip Tester, SCRIM; rutting measurement – straight-edge, automated systems; crack detection – manual, semi-automated and fully automated methods; Falling Weight Deflectometer (FWD) for structural evaluation; Benkelman Beam Deflection (BBD); Ground Penetrating Radar (GPR) for subsurface investigation; pavement coring and laboratory testing.

Linked COs: CO2 **Number of Hours: 9**

Module-3

Remote Sensing, IoT, and Emerging Technologies in Pavement Monitoring

Unmanned Aerial Vehicles (UAVs/Drones) for aerial pavement assessment; photogrammetry and 3D point cloud generation for surface mapping; LiDAR-based pavement profiling; inertial measurement units (IMU) in pavement roughness estimation; smartphone-based pavement condition monitoring – accelerometer and GPS integration; Internet of Things (IoT) sensor networks embedded in pavement – strain gauges, MEMS sensors, fibre optic sensors; wireless sensor networks and data transmission protocols; cloud-based data management and real-time monitoring dashboards; smart highway infrastructure concepts; case studies from IIT research and international practices (MIT, TU Delft).

Linked COs: CO3 **Number of Hours: 8**

Module-4

Machine Learning and Data Analytics for Predictive Maintenance

Fundamentals of predictive maintenance vs. reactive and preventive maintenance; data pre-processing and feature extraction from pavement sensor data; regression models for pavement performance prediction – mechanistic-empirical approaches; machine learning techniques: Random Forests, Support Vector Machines, Artificial Neural Networks (ANN) for distress prediction; deep learning – Convolutional Neural Networks (CNN) for automated image-based crack detection and classification; pavement performance modelling using historical data; reliability and probabilistic approaches to maintenance decision-making; Pavement Management Systems (PMS) with predictive analytics – PAVER, dTIMS, ROMDAS; maintenance treatment selection: crack sealing, micro-surfacing, overlays, full-depth reclamation; multi-criteria decision analysis (MCDA) for maintenance prioritization.

Linked COs: CO4 **Number of Hours: 9**

Module-5

Case Studies, Standards, and Emerging Research Frontiers

Case studies from NHAI, PWD, and state highway agencies on pavement health monitoring projects; World Bank and ADB funded highway projects with integrated monitoring; emerging research: self-healing pavements, bio-inspired materials, energy-harvesting pavements; digital twin frameworks for pavement infrastructure; integration of BIM with pavement asset management; carbon footprint and sustainability considerations in maintenance planning; lifecycle assessment (LCA) of pavement maintenance strategies; ASTM, IRC, and AASHTO standards relevant to pavement monitoring and evaluation; future directions: autonomous monitoring vehicles, AI-powered maintenance scheduling, block-chain for asset data integrity. Seminar presentations and term project on a selected monitoring/predictive maintenance problem.

Linked COs: CO5,CO6 **Number of Hours: 8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text Books:

1. Papagiannakis, A. T. & Masad, E. A. (2008). Pavement Design and Materials. John Wiley & Sons.
2. Yoder, E. J. & Witczak, M. W. (1975). Principles of Pavement Design (2nd ed.). Wiley-Interscience.
3. Haas, R., Hudson, W. R. & Zaniewski, J. (1994). Modern Pavement Management. Krieger Publishing.
4. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference Books / Manuals:

1. ASTM International – Annual Book of Standards, Vol. 04.03 (Road and Paving Materials, Vehicle Pavement Systems).
2. IRC:37-2018 – Guidelines for the Design of Flexible Pavements (4th Revision). Indian Roads Congress, New Delhi.

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3. IRC:82-2015 – Code of Practice for Maintenance of Bituminous Surfaces of Highways. Indian Roads Congress.
4. MoRTH – Manual for Construction and Supervision of Bituminous Works (2001). Ministry of Road Transport and Highways, Govt. of India.
5. FHWA – Long-Term Pavement Performance (LTPP) Data Analysis Report. Federal Highway Administration, US DOT.
6. Flintsch, G. W. et al. (Eds.) (2012). Transportation Research Circular E-C162: Pavement Surface Condition/Performance Assessment. TRB

Web links and Video Lectures (e-Resources):

1. NPTEL – Highway Engineering & Pavement Design (IIT Kharagpur): https://nptel.ac.in
2. FHWA Pavement Design & Analysis: https://www.fhwa.dot.gov/pavement/
3. Long-Term Pavement Performance (LTPP) Database: https://infopave.fhwa.dot.gov
4. MIT OpenCourseWare – 1.564J Infrastructure Systems (Transportation): https://ocw.mit.edu
5. TU Delft – Pavement Engineering MOOCs (edX): https://www.edx.org/school/delftx
6. CSIR-CRRI Publications & Reports: https://crri.res.in
7. AASHTO Pavement ME Design Software & Documentation: https://www.aashtoware.org
8. YouTube – IIT Bombay/Madras/Roorkee Civil Engineering lecture playlists on highway engineering.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- **Flipped Classroom:** Students study NPTEL/online resources on NDT methods and PMS tools prior to class; classroom time used for problem-solving and data analysis exercises.
- **Problem-Based Learning (PBL):** Small groups analyse real pavement condition datasets (PCI surveys, FWD deflection data) and formulate maintenance recommendations.
- **Case-Based Teaching:** Discussion of NHAI highway project reports, World Bank-funded corridor rehabilitation case studies, and published IIT/NIT research papers.
- **Simulation and Virtual Labs:** Use of PAVER software, open-source Python libraries (scikit-learn, TensorFlow) for ML-based distress prediction exercises.
- **ICT-Enabled Teaching:** Guest lectures by industry experts from CSIR-CRRI, NHAI, L&T, or Stantec/AECOM; virtual site visits via 360° pavement inspection videos.
- **Partial Delivery by Industry Expert / Industrial Visit:** One module or lab session co-delivered by a pavement management practitioner; optional field visit to a highway testing laboratory.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Identify and classify pavement distresses from photographs or field observations	24
2	Prepare a pavement deterioration cause–effect matrix for fatigue cracking, rutting, ravelling, potholes, and thermal cracking	24
3	Solve a basic life-cycle cost comparison for two pavement maintenance alternatives	24
4	Compute Pavement Condition Index using sample distress data based on ASTM D6433 principles	24
5	Select suitable NDE methods for different pavement problems such as loss of layer strength, hidden voids, rutting, and cracking	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Develop a conceptual workflow for pavement distress prediction using Random Forest, SVM, ANN, or CNN	24
2	Rank maintenance treatments using a simple weighted multi-criteria decision matrix	24
3	Compare UAV, LiDAR, smartphone, and GPR-based monitoring for a selected highway application	24
4	Design a basic IoT-based pavement monitoring system	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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ROAD SAFETY PLANNING AND IMPLEMENTATION			
Course Code	**1MCTE205C /1**MCTM205C/1MCHT205C	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester (L /T/P/SL&TW)	90 (42 : 0 : 0 : 48)	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3 Hours

Course Outcomes:

1. **CO1:** Describe the global and national burden of road traffic crashes, the Safe System philosophy, and the multi-disciplinary regulatory framework governing road safety. [RBL2]
2. **CO2:** Apply statistical and GIS-based methods to analyse crash data, identify black spots, and compute safety performance indicators. [RBL3]
3. **CO3:** Conduct road safety audits and recommend engineering countermeasures for network safety improvement in accordance with IRC and international guidelines. [RBL3]
4. **CO4:** Formulate evidence-based road safety action plans integrating engineering, enforcement, education and emergency response strategies with investment appraisal. [RBL4]
5. **CO5:** Evaluate the effectiveness of road safety programmes using cost-benefit analysis, before-after studies, and safety performance functions. [RBL5]
6. **CO6:** Critically analyse emerging technologies and international case studies to propose innovative, locally adaptable road safety interventions. [RBL6]

Module-1

Road Safety – Concepts, Frameworks and the Global Burden:

Introduction to safety: Road accidents, Trends, causes, Collision and Condition diagrams, Highway safety, human factors, Vehicle factors Road Safety Management System: Multi-causal dynamic systems approach to safety, crash vs accident, road safety improvement. Magnitude of road traffic crashes (RTCs) – global, national (India) and state-level statistics; WHO Global Status Report on Road Safety; socio-economic costs of road crashes – NASEM, MoRTH estimates; safe system approach and vision zero philosophy; Highway Safety in India: traffic crashes on

Indian highways, traffic on national highways and state highways, safety on national highways. strategies, elements of a road safety plan, Safety Data Needs.

Linked COs: CO1 **Number of Hours: 8**

Module-2

Road Safety Data: Collection, Analysis and Crash Investigation:

Types of road safety data – crash reports (Form 16/MV Act), hospital injury data, traffic volume, road inventory; limitations of police-reported crash data and under-reporting; crash data management systems – iRASTE, CRISP, Integrated Road Accident Database (iRAD).

Statistical Interpretation and Analysis of Crash Data: Before-after methods in crash analysis, Advanced statistical methods, Black Spot Identification & Investigations, Case Studies. Urban Safety and Mobility, Traffic Calming

Linked COs: CO2 **Number of Hours: 9**

Module-3

Road Safety Engineering – Design, Audit and Countermeasures:

Geometric design principles for safety – horizontal and vertical alignment, stopping sight distance (IRC:66), cross-section elements; road safety audit (RSA) – purpose, stages, process and checklists as per IRC:SP:88 guidelines; road safety inspection (RSI); forgiving roadsides – clear zone concept, roadside hazard management, crash barriers (IRC:119); intersection safety – at-grade and grade-separated, conflict points, roundabout design for safety; pedestrian and cyclist safety – footpaths, pedestrian crossings, cycle tracks, school zone treatments; speed management – design speed, operating speed, 85th percentile speed, speed calming measures (humps, tables, chicanes, raised intersections); road marking and signage effectiveness (IRC:35, IRC:67); rumble strips, edge lines, retro reflectivity; tunnel and work-zone safety; network safety screening using iRAP ViDA / SRMS tools.

Road Safety Audits: Key elements of a road safety audit, Road Safety Audits & Investigations, Crash investigation and analysis.

Linked COs: CO3 **Number of Hours: 9**

Module-4

Crash Reconstruction:

Describe the basic information that can be obtained from the roadway surface, understand basic physics related to crash reconstruction, speed for various skid, friction, drag, and acceleration scenarios, variables involved in jump and flip crashes, variables involved in pedestrian crashes, Case Studies. Road Safety Impact Assessment (RSIA); prioritisation of interventions using cost-effectiveness analysis; NITI Aayog / MoRTH road safety targets; public–private partnership models in road safety; institutional arrangements – lead agency concept, inter-agency coordination; enforcement programmes – speed cameras, drunk-driving checkpoints, automated traffic enforcement (ATE); road user behaviour modification – theories of behaviour change, seat-belt and helmet campaigns, THINK! and SafeRoads campaigns; trauma care and emergency response – golden hour, designation of Level-I/II trauma centres along National Highways.

Linked COs: CO4 **Number of Hours:8**

Module-5

Emerging Technologies, Case Studies and Research Frontiers

Advanced Driver Assistance Systems (ADAS) and their safety benefits – FCW, AEB, LKA, ESC; connected and autonomous vehicles (CAV) – implications for road safety planning; V2X communication and intelligent transport systems (ITS) for safety; AI and computer vision for real-time crash detection and prediction; big data analytics for predictive road safety management; digital twin of road networks for safety simulation; drone-based traffic surveillance and crash reconstruction;

Mitigation Measures: Accident prevention by better planning, Accident prevention by better design of roads, Crash Countermeasures, Highway operation and accident control measures, Highway Safety Measures during construction, Highway geometry and safety.

Road safety management, road safety policy-making, stakeholders involved, developing the road safety management system, capacity building.

Linked COs: CO5, CO6 **Number of Hours:8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text Books:

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1. V.F. Babkov “Road Conditions and Traffic Safety”, Mir Publishers.
2. Pignataro , “ Traffic Engineering”, John wiley & sons.
3. Nicholas J Garber, Lester A Hoel, “Traffic & Highway Engineering”- Third edition, Thompson Learning
4. Ogden, K.W. Safer Roads: A Guide to Road Safety Engineering. Avebury Technical, 1996.
5. Martin Belcher, Steve Proctor and Phil Cook, Practical Road Safety Auditing, Third edition, ICE Publications, 2015
6. Gitam Tiwari, Dinesh Mohan, “Transport Planning and Traffic Safety-making cities, roads & vehicles safer”, Published by CRC Press, ISBN-9781498751452
7. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference Books / Manuals / Guidelines:

1. RC:SP:88-2019 – Manual on Road Safety Audit. Indian Roads Congress, New Delhi.
2. IRC:SP:55-2014 – Guidelines for Traffic Safety Barriers. Indian Roads Congress, New Delhi.
3. IRC:66-1976 – Recommended Practice for Sight Distances on Rural Highways. IRC, New Delhi.
4. MoRTH – Road Accidents in India (Annual Report, latest year). Ministry of Road Transport & Highways, Govt. of India.
5. WHO (2023). Global Status Report on Road Safety. World Health Organization, Geneva.
6. AUSTROADS (2020). Guide to Road Safety. Austroads, Sydney (Parts 1–9).
7. FHWA (2019). Road Safety Fundamentals: Concepts, Strategies, and Practices that Reduce Fatalities and Injuries on the Road. US DOT/FHWA.
8. iRAP (2019). Star Rating Roads for Safety (SR4S) Manual. International Road Assessment Programme.
9. National Academies of Sciences, Engineering, and Medicine (NASEM) – Highway Safety Manual (1st ed., 2010). Transportation Research Board, Washington D.C.

Web links and Video Lectures (e-Resources):

1. NPTEL – Road Safety (IIT Madras): https://nptel.ac.in/courses/105106151
2. WHO Road Safety Data Portal: https://www.who.int/data/gho/data/themes/road-safety
3. iRAP Road Assessment Programme: https://www.irap.org
4. MoRTH Road Accident Data & iRAD Portal: https://irad.nic.in
5. FHWA Road Safety Resources: https://safety.fhwa.dot.gov
6. Highway Safety Manual (TRB): https://www.highwaysafetymanual.org
7. SWOV Institute for Road Safety Research (Netherlands): https://www.swov.nl/en
8. TRL Road Safety Publications: https://trl.co.uk
9. UN Road Safety Collaboration / Decade of Action 2021–2030: https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/decade-of-action-for-road-safety-2021-2030
10. Vision Zero Network (US & International): https://visionzeronetwork.org

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Problem-Based Learning (PBL):** Students work in groups on real crash datasets to identify black spots, quantify safety deficiencies, and recommend countermeasures — simulating a professional road safety audit process.
2. **Case-Based Teaching:** Structured discussion of documented road safety successes (Sweden's Vision Zero, New Zealand Safe System) and failures; analysis of NHAI NH black-spot remediation reports.
3. **Flipped Classroom:** Selected NPTEL and WHO e-learning modules assigned as pre-class reading; classroom sessions devoted to debate, data exercises, and design critiques.
4. **Simulation / GIS Lab:** Hands-on sessions using GIS (QGIS/ArcGIS) for crash mapping, hot-spot analysis, and iRAP ViDA for network-level star-rating exercises.
5. **ICT-Enabled Delivery / Expert Lectures:** Guest sessions by road safety officers from NHAI, NHIDCL, State Road Safety Councils, or international practitioners (WHO/iRAP); use of dash-cam footage and drone video for hazard analysis.

6. **Partial Delivery by Industry Expert / Field Visit:** Co-delivery of Module 3 (RSA) by a certified road safety auditor; optional visit to a state traffic management centre (TMC) or CSIR-CRRI road safety division.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Term Work (TW) and Self Learning (SL) components:

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Black-spot identification exercise: Using a provided/collected crash dataset of a selected urban or rural road stretch, identify top-five crash black spots using at least two methods (frequency, EPDO), prepare GIS maps and a structured technical report with recommended countermeasures.	24
2.	Road Safety Audit (RSA) field exercise: Conduct a stage-III or stage-IV RSA of a selected road section following IRC:SP:88 checklist; prepare a formal audit report with photographic evidence, findings, and recommendations.	24
3.	Seminar: Critical review of a research paper published in Accident Analysis & Prevention / Transportation Research Record on a road safety topic; 10-minute presentation with Q&A.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL MOOC: 'Road Safety' (IIT Madras / MORTH-NHAI Collaboration) or WHO/iRAP e-learning module on Safe System Approach – complete at least 4 modules; submit completion certificate.	24
2.	Self-study of IRC:SP:88-2019 (Road Safety Audit), IRC:SP:55 (Urban Road Safety), MoRTH Road Accident Data Report (latest year), and WHO Global Status Report on Road Safety (2023).	24
3.	Exploration of iRAP ViDA / ArcGIS Online for network safety screening; prepare a one-page summary of the tool's workflow, data requirements, and sample output interpretation.	24

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Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

cc

TRANSPORT ECONOMICS & CONTRACT POLICY			
Course Code	**1MCTE205D/** 1MCTM205D/1MCHT205D	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L/T/P/SL&TW	90 (42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1. Explain the fundamental principles of transport economics, including demand-supply behaviour, cost structures and market structures relevant to transport systems.
2. CO2. Apply investment appraisal and economic evaluation techniques (cost-benefit analysis, NPV, IRR, multi-criteria analysis) to transport project decisions.
3. CO3. Analyse pricing, taxation, subsidy and social-cost issues, including congestion pricing and value-capture financing, in transportation systems.
4. CO4. Evaluate transport financing mechanisms and contract/procurement models (BOT, BOO, BOOT, HAM, EPC, PPP) used for transport infrastructure delivery.
5. CO5. Assess national and state-level transport policies, institutional and regulatory frameworks, and risk allocation practices in transport contracts.

Module-1

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Fundamentals of Transport Economics

- Nature and scope of transport economics; transport as a derived demand; distinctive features of transport markets.
- Demand for transport: demand functions, price/income/cross elasticity of demand, factors influencing passenger and freight demand.
- Supply of transport and cost structure: fixed and variable costs, short-run and long-run cost curves, economies of scale and scope, marginal cost pricing.
- Market structures in transport – perfect competition, monopoly, oligopoly; rationale for regulation and deregulation

Linked COs: CO1 **Number of Hours: 8**

Module-2

Investment Appraisal and Project Economics

- Time value of money and discounting techniques; Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR).
- Cost-Benefit Analysis (CBA) of transport projects: identification and valuation of costs and benefits – value of time (VOT), vehicle operating cost (VOC), accident cost, environmental cost.
- Multi-Criteria Decision Analysis (MCDA) for transport project selection; sensitivity and risk analysis in project appraisal.
- Economic analysis vs. financial analysis; shadow pricing; social discount rate; appraisal frameworks used by MoRTH/NHAI and multilateral agencies.

Linked COs: CO2 **Number of Hours: 8**

Module-3

Pricing, Taxation and Transport Financing

- Transportation taxes and user charges; theory and practice of road pricing and congestion pricing.
- Toll financing, fare policy and subsidy issues; value-capture financing – land value capture, tax increment financing (TIF).
- Social costs of transportation – externalities of congestion, pollution and accidents; approaches to internalising externalities.
- Sources of transport infrastructure financing – public funds, private capital, blended finance; municipal and green bonds for transport.

Linked COs: CO3 **Number of Hours: 8**

Module-4

Contract Policy and Public-Private Partnerships (PPP) in Transport

- Rationale, advantages and limitations of private sector participation in transport infrastructure; contracts for services vs. procurement of assets.
- PPP models – BOT, BOO, BOOT, DBFOT, Annuity, Hybrid Annuity Model (HAM), Engineering-Procurement-Construction (EPC) contracts.
- Contract structuring: concession agreements, payment mechanisms, whole-life approach to design-build-operate, identification and allocation of risk between government and private parties.
- Procurement processes – transparent and competitive bidding, clear legal and institutional framework, contract management and dispute-resolution mechanisms.

Linked COs: CO4 **Number of Hours: 8**

Module-5

Transport Policy Framework in India

- National Transport Development Policy (NTDP) – background, objectives, growth projections, institutional framework for planning and coordination.
- National Urban Transport Policy (NUTP) – equitable allocation of road space, integrated land-use and transport planning, Unified Metropolitan Transport Authority (UMTA).
- Sector-specific policies – roads (Bharatmala, IRC guidelines), railways, ports and airways; Electric Vehicle policies – FAME, PM E-DRIVE, eAmrit; National Logistics Policy.

- Case studies of transport PPP/contract practice in India – NHAI toll/HAM concessions, metro-rail PPPs; emerging trends and lessons learnt.

Linked COs: CO5 **Number of Hours: 8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Kenneth A. Button, Transport Economics, 3rd Edition, Edward Elgar Publishing, Cheltenham, UK, 2010.
2. Kenneth A. Small and Erik T. Verhoef, The Economics of Urban Transportation, 2nd Edition, Routledge, London, 2007.
3. Herbert Mohring, Transportation Economics, Ballinger Publishing Company, Cambridge, MA, 1976.

Reference books / Manuals:

1. Dai Nakagawa and Ryoji Matsunaka, Transport Policy and Funding, Elsevier, Oxford, UK, 2006.
2. E. M. Gramlich, A Guide to Benefit-Cost Analysis, 2nd Edition, Waveland Press, 1990.
3. Institute of Civil Engineers, Highway Investment in Developing Countries, Thomas Telford Ltd., London, 1983.
4. National Transport Development Policy Committee, Government of India, New Delhi, 2014.
5. National Urban Transport Policy, Ministry of Urban Development, Government of India, New Delhi, 2014.
6. David Banister and Joseph Berechman, Transport Investment and Economic Development, UCL Press, London, 2000.
7. Model Concession Agreements and Guidance Manuals, NHAI / MoRTH, Government of India.

Web links and Video Lectures (e-Resources):

1. NPTEL/SWAYAM courses on Transportation Economics and Transportation Planning – https://swayam.gov.in
2. Ministry of Road Transport & Highways (MoRTH) – https://morth.nic.in
3. National Highways Authority of India (NHAI) – https://nhai.gov.in
4. World Bank PPP Knowledge Lab – https://ppp.worldbank.org

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Case-study based discussion of PPP contracts, toll and HAM concessions.
2. Numerical problem-solving sessions on CBA, NPV, IRR and elasticity estimation.
3. Guest lectures / interaction with practitioners from NHAI, state PWDs or transport consultants.
4. Use of NPTEL/MOOC video resources for select topics.
5. Group project/assignment on the economic evaluation of a real or hypothetical transport project.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Term Work (TW) and Self Learning (SL) components

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE.

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The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	Group project / seminar on economic evaluation of a real or hypothetical transport project (elasticity, CBA, NPV, IRR)	24
2	Case study presentation on PPP/contract models (BOT, BOOT, HAM, EPC) and industrial visit / interaction with NHAI, state PWD or transport consultants	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	NPTEL/SWAYAM MOOC on Transportation Economics and Transportation Planning	24
2	Self-study and review of MoRTH/NHAI Model Concession Agreements, guidance manuals and toll/HAM case studies	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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URBAN TRAFFIC MANAGEMENT AND ANALYTICS			
Course Code	**1MCTE205E** /1MCTM205E	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L/T/P/SL&TW	90 (42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: L3 - Characterize urban transport planning morphology and statutory frameworks for hierarchical city development.
2. CO2: L4 - Analyze travel demand using advanced data collection and automated tracking techniques.
3. CO3: L4 - Calibrate and validate mathematical models for Trip Generation and Distribution (Gravity/Growth models).
4. CO4: L5 - Evaluate Modal Split through disaggregate logit/probit modeling and optimize Traffic Assignment using network algorithms.
5. CO5: L6 - Formulate integrated Land-Use Transportation Interaction (LUTI) models and Big Data analytics solutions for urban mobility (SDG 11).

Module-1

Urban Transport Planning Morphology & Data Needs:

Impacts of urbanization: Behavioural changes, congestion, and externalities. Transport planning morphology: Solution analysis and evaluation. Hierarchical levels: Master plans, statutory plans, and detailed development plans. Information needs: Study area and zoning. Advanced Data Collection: Innovative commercial vehicle tracking, registration-number surveys, and automated License Plate Recognition (LPR) techniques.

Linked COs: CO1 **Number of Hours (CI) = 8 hrs**

Module-2

Advanced Travel Demand Modeling:

Trip Generation: Basic considerations: Character of urban activity and special generators. Mathematical Methods: Multiple Linear Regression (MLR)—zonal vs. household-based considerations. Category analysis: Specifying trip production/attraction structures. Model stability: Temporal and geographical stability analysis.

Linked COs: CO2 **Number of Hours (CI) = 8 hrs**

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Module-3

Synthetic Modeling:

Trip Distribution & Modal Split: Trip Distribution: Growth factor methods (Fratar, Furness); Synthetic methods: Gravity model calibration using the BPR approach. Intervening and Competing opportunities models. Modal Split: Influencing factors; Disaggregate modeling—Utility theory and Probabilistic choice theory. Binary and Multinomial Logit models; Nested logit structures.

Linked COs: CO3 **Number of Hours (CI) = 10-hrs**

Module-4

Network Analysis & Traffic Assignment Algorithms:

Network properties: Link cost functions, connectivity, and diurnal patterns. Network Algorithms: Implementation of Kruskal, Prims, Dijkstra, and Floyd for shortest path determination. Route Choice Behavior: User Equilibrium (UE) vs. System Equilibrium (SE). Deterministic and Stochastic assignment techniques; Overview of Dynamic Traffic Assignment (DTA).

Linked COs: CO4 **Number of Hours (CI) = 10 hrs**

Module-5

Urban Logistics, Land-Use & Emerging Analytics: Land Use and Transportation Interaction (LUTI): Accessibility and mobility modeling. Urban Goods Movement: Classification, modeling approaches, and facility planning for city logistics. Emerging Trends: Activity-based modeling, Spatial Data Infrastructure (SDI), and Big Data analytics for resilient urban governance (Industry 5.0).

Linked COs: CO5 **Number of Hours (CI) = 6 hrs**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Hutchinson, B.G., Principles of Urban Transport Systems Planning, McGraw Hill, London, 1974.
2. Khisty, C. Jotin and Lall, B. Kent., Transportation Engineering and Planning, 3rd Edition, Pearson India, 2001.

Reference books / Manuals:

1. Papacostas, C. S., and Prevedouros, P. D., Transportation Engineering and Planning, 3rd Edition, Prentice-Hall of India Pvt. Ltd., 2002.
2. Garber N.J., and Hoel L.A., Traffic and Highway Engineering, 4th Edition, Cengage Learning, 2009.
3. Kadiyali, L.R., Traffic Engineering and Transport Planning, Khanna Publishers, New Delhi, 2013.

Web links and Video Lectures (e-Resources):

1. NPTEL: Urban Transportation Systems Planning (Video Course)
2. NPTEL: Urban Transportation Planning (Web Course)

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem-Based Learning (PBL) using real city travel-demand and network datasets for trip generation/distribution exercises.
2. ICT-enabled teaching using transportation planning/GIS software (e.g., QGIS, TransCAD/EMME) for network and assignment demonstrations.
3. Case-based teaching through case studies of urban transport plans of Indian cities.
4. Partial delivery through invited talks / industrial visits by transport planning practitioners.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Students' activities for TW/SL under NCrF: Samples only As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	Trip Generation & Distribution modeling assignment using field/secondary data (Modules 2 & 3)	24
2	Case study report on urban transport planning morphology of a selected city (Module 1)	24
3	Seminar/ presentation on network analysis and traffic assignment algorithms (Module 4)	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Self-study of NPTEL course(s) on Urban Transportation Systems Planning	24
2	Literature review on Land-Use Transportation Interaction (LUTI) and Big Data analytics for urban mobility (Module 5)	24
3	Self-exploration of a transport planning/GIS software tool (e.g., QGIS, TransCAD/EMME) for network coding and assignment	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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RAILWAY ENGINEERING & TRACK DYNAMICS			
Course Code	**1MCTE205F** /1MCTM205F	Scheme	2026
Type of Course	Theory	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L/T/P/SL&TW	90 (42 : 0 : 0)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	PEC	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1 (L3): Analyze the fundamental mechanics and material failures of permanent way components.
2. CO2 (L4): Evaluate track stresses and deformation using the Zimmermann method and determine track modulus for varying substructures.
3. CO3 (L4): Design advanced geometric alignments and turnouts for high-speed regimes, optimizing for cant and transition curves.
4. CO4 (L5): Formulate stability criteria for Long Welded Rails (LWR) and Continuous Welded Rails (CWR) und thermal and longitudinal loads.
5. CO5 (L6): Design modern intelligent signaling, interlocking systems, and resilient maintenance frameworks (Industry 5.0).

Module-1

Fundamentals of Permanent Way & Material Mechanics

Introduction to railway systems: Gauges, wheels, axles, and traction resistances. Structural performance of Rails: Sections, length, tests, and failures. Sleeper Technology: Spacing, density, and design of prestressed concrete sleepers. Ballast & Formation: Material properties, drainage requirements, and the role of geosynthetics in track stability.

Linked COs: CO1 **Number of Hours: 8**

Module-2

Track Geometry & High-Regime Kinematics

Alignment selection factors and requirements. Curve Mechanics: Equilibrium speed, safe speed, and permissible speed. Design of transition curves (Cubic Parabola, Clothoid) and vertical curves. Management of cant deficiency and cant excess. Switch Design: Types and design parameters for turnouts and crossings for high-speed transitions.

Linked COs: CO2 **Number of Hours:** 9

Module-3

Track Dynamics & Stress Analysis

Mechanics of track-structure interaction: Zimmermann's Analysis of track as a beam on elastic foundation. Calculation of track modulus (u) and relief of stress. Distribution of vertical, lateral, and longitudinal stresses in rails, sleepers, and formation. Impact of dynamic augments and wheel flats on track degradation.

Linked COs: CO3 **Number of Hours:** 8

Module-4

Thermal Stability & Elastic Fastenings

Rail joints: Types, requirements, and insulation. Welding technologies: Alumino-Thermit and Flash-Butt welding. Stability of LWR/CWR: Analysis of buckling and thermal stresses. Creep in Rails: Causes, measurement, and remedial measures. Fastening systems: Rail-to-rail and rail-to-sleeper elastic clips and damping characteristics.

Linked COs: CO4 **Number of Hours:** 9

Module-5

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Intelligent Control, Operations & Future Rails

Signals: Classification, placement, and functions. Interlocking Principles: Transition from mechanical/electrical to Electronic Interlocking (EI). Train Control Systems: Block vs. Non-block systems; implementation of Kavach (TCAS). Track Maintenance: Criteria, equipment, and predictive analytics. High-Speed Rails (HSR): Technologies, aerodynamic considerations, and global best practices.

Linked COs: CO5 **Number of Hours:** 8

Suggested Learning Resources: (Text Book / Reference Book / Manuals):

Text books:

1. Saxena, S.C. and Arora, S. P. "A Text Book of Railway Engineering", 7th ed. Dhanpat Rai & Sons, New Delhi, 20
2. Chandra, S. & Agarwal, M. M., Railway Engineering. Oxford University Press, New Delhi, 2013.

Reference books / Manuals:

1. Basics of Railway Signal Engineering by G V Rao, ITD-2, Indian Railways Institute of Signal Engineering and Telecommunication, IRISET, Secunderabad.
2. Basics of Track Structure and Components, Indian Railways Centre for Advanced Maintenance Technologies, IRCAMT, Maharajpur, Gwalior, 2023.
3. Indian Railway Maintenance Manual (Works).
4. Indian Railway Tracks by M M Agarwal.
5. Relevant Indian Railway Standard (IRS) Code books, issued by Research Designs and Standards Organisation Lucknow, Uttar Pradesh.

Web links and Video Lectures (e-Resources):

1. NPTEL: Railway Engineering by Prof. Rajat Rastogi – https://onlinecourses.nptel.ac.in/noc24_ce81/preview
2. NPTEL: Introduction to Railway Engineering – https://nptel.ac.in/courses/105107123

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Interactive lectures on track mechanics supported by mathematical demonstrations of Zimmermann's beam-on-elastic-foundation theory.
- Case studies on High-Speed Rail (HSR) corridors and comparative analysis of global best practices (Shinkansen, TGV).
- Use of LMS-hosted datasets and quizzes for stress-analysis and track-modulus problem solving; flipped-classroom numerical sessions.
- ndustry/RDSO-linked exposure: review of IRPWM updates, IRS codes, and signalling/interlocking standards.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

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Term Work (TW) and Self Learning (SL) components		
Students' activities for TW/SL under NCrF: Samples only As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	Number of Hours / Semester
1	Track Modulus Calculation – Determine track modulus (u) and rail deflection using Zimmermann's theory for varying sleeper densities (Module 3; CO2)	24
2	Geometric Design – Detailed layout of a transition curve (Clothoid) for a 200 kmph HSR corridor (Module 2; CO3)	24
3	Wear Analysis – Numerical estimation of rail-head wear and permissible limits for heavy-haul tracks (Module 1; CO1)	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	Number of Hours / Semester
1	NPTEL/MOOC advanced certification in Railway Engineering / Track Mechanics	24
2	RDSO/IR Standards – Review of the Indian Railways Permanent Way Manual (IRPWM) updates	24
3	HSR Global Study – Analysis of Shinkansen or TGV track-structure interaction	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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URBAN MASS TRANSIT SYSTEMS			
Course Code	**1MCTE205G** /1MCTM205G/1MCHT205G	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1. Explain the need, evolution, and planning process for urban mass transit systems, and relate them to the principles of sustainable and inclusive urban mobility.
2. CO2. Analyse urban travel demand and apply appropriate techniques for ridership forecasting and mode-choice estimation for various mass transit modes.
3. CO3. Design and evaluate key technical and operational parameters of mass transit systems, including alignment, station spacing, capacity, fleet size, and scheduling.
4. CO4. Apply the principles of Transit-Oriented Development (TOD), multimodal integration, fare policy, and financing models to sustainable mass transit planning.
5. CO5. Evaluate the role of Intelligent Transportation Systems (ITS), performance benchmarking, safety, and emerging technologies in improving urban mass transit systems.

Module-1

Introduction to Urban Mass Transit Systems

- Urbanization trends and growth of travel demand; need, role and objectives of mass transit in sustainable urban mobility; urban transport problems and externalities (congestion, safety, emissions, energy).
- Classification and characteristics of mass transit modes: conventional bus, Bus Rapid Transit (BRT), Light Rail Transit (LRT)/tram, Metro Rail, Monorail, Suburban/Regional rail; transit hierarchy and modal suitability by corridor demand and city size.
- Urban transport policy framework in India: National Urban Transport Policy (NUTP), Metro Rail Policy, role of Unified Metropolitan Transport Authority (UMTA); overview of the mass transit planning process and stakeholders.

Linked COs: CO1 **Number of Hours: 8**

Module-2

Travel Demand Estimation and Ridership Forecasting

- Four-stage urban transportation planning process applied to transit corridors: study area delineation, zoning (TAZ), and data needs (O-D surveys, household travel surveys, cordon and screen-line counts).
- Trip generation and trip distribution for transit demand estimation; deterrence/impedance functions and gravity models.
- Mode choice modelling: aggregate and disaggregate approaches, binary and multinomial logit models, elasticity of transit demand, catchment area and access-mode analysis.
- Transit ridership forecasting techniques and traffic/passenger assignment concepts on transit networks; introduction to travel-demand modelling software tools (e.g., EMME, VISUM, CUBE) used in practice.

Linked COs: CO2 **Number of Hours: 9**

Module-3

Planning, Design and Operations of Mass Transit Systems

- Corridor identification and alignment alternatives; horizontal and vertical alignment considerations; station location, spacing and typology (at-grade, elevated, underground).
- Capacity analysis: line capacity, vehicle/train capacity, headway, dwell time, and level-of-service for mass transit.

- Operations planning: fleet sizing, frequency setting, scheduling and timetabling basics; rolling stock characteristics for bus/BRT, LRT and Metro systems; depot and yard planning fundamentals.
- Performance metrics for transit operations: load factor, operating ratio, passengers per unit distance/time (PUDO), reliability and punctuality.

Linked COs: CO3 **Number of Hours: 9**

Module-4

Transit-Oriented Development, Integration and Financing

- Transit-Oriented Development (TOD): principles, density and land-use mix around transit corridors/stations; TOD Policy of Ministry of Housing and Urban Affairs (MoHUA); case studies of TOD implementation in Indian cities.
- Multimodal integration and last-mile connectivity: feeder services, Intermediate Public Transport (IPT) integration, pedestrian and Non-Motorized Transport (NMT) linkages, park-and-ride facilities.
- Fare structure, fare collection systems (Automatic Fare Collection/Common Mobility Card), farebox recovery and subsidy concepts.
- Financing and institutional arrangements for mass transit: Public-Private Partnership (PPP) models, Viability Gap Funding, land value capture, and the role of transit authorities.

Linked COs: CO4 **Number of Hours: 8**

Module-5

Intelligent Transportation Systems, Sustainability and Emerging Trends

- Application of Intelligent Transportation Systems (ITS) in mass transit: GPS/Automatic Vehicle Location (AVL), Passenger Information Systems (PIS), Integrated Traffic/Transit Control Centres.
- Accessibility and universal design in mass transit facilities; safety and security considerations for passengers and operations.
- Environmental and sustainability assessment of mass transit systems: emissions, energy consumption and life-cycle considerations; benchmarking against national and international performance indicators.
- Case studies of Indian metro rail and BRT systems; emerging trends — Personal Rapid Transit, Mobility-as-a-Service (MaaS), autonomous and electric transit vehicles, Common Mobility Card ecosystems.

Linked COs: CO5 **Number of Hours: 8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Vukan R. Vuchic, "Urban Transit Systems and Technology", John Wiley & Sons, 2007.
2. Vukan R. Vuchic, "Urban Transit: Operations, Planning and Economics", John Wiley & Sons, 2005.
3. C. S. Papacostas and P. D. Prevedouros, "Transportation Engineering and Planning", Prentice Hall / PHI Learning.

Reference books / Manuals:

1. L. R. Kadiyali, "Traffic Engineering and Transport Planning", Khanna Publishers, New Delhi.
2. Jean-Paul Rodrigue, Claude Comtois and Brian Slack, "The Geography of Transport Systems", Routledge.
3. Ministry of Housing and Urban Affairs (MoHUA), Government of India — "Transit Oriented Development (TOD) Policy" and "Metro Rail Policy, 2017".
4. Institute of Urban Transport (India) — publications and toolkits on Comprehensive Mobility Plans (CMP) and Service Level Benchmarks.
5. Relevant IRC codes/guidelines, e.g., IRC:SP:41 (Guidelines for design of at-grade intersections) and other applicable IRC publications on urban roads and bus facilities.

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Web links and Video Lectures (e-Resources):

1. NPTEL/SWAYAM: "Urban Transportation Systems Planning" — Prof. Bhargab Maitra, IIT Kharagpur (nptel.ac.in).
2. NPTEL/SWAYAM: "Introduction to Multimodal Urban Transportation Systems" — IIT Kharagpur (nptel.ac.in).
3. NPTEL: "Urban Transportation Planning" — Prof. V. Thamizh Arasan, IIT Madras (nptel.ac.in).
4. Ministry of Housing and Urban Affairs (MoHUA) — Urban Transport division resources: mohua.gov.in.
5. Institute for Transportation & Development Policy (ITDP) India — BRT and TOD resources: itdp.in.

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped-classroom delivery for travel-demand modelling concepts, supported by NPTEL video resources, followed by in-class problem solving.
2. Case-based teaching using Indian metro/BRT/LRT project case studies; guest lecture by a transit authority/consultant; field visit to a local mass transit facility.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Term Work (TW) and Self Learning (SL) components

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Site visit to a local Metro/BRT/bus depot and preparation of an observation report	24
2.	Group assignment on transit ridership/demand estimation for a chosen corridor	24
3.	Seminar on an emerging mass transit technology or a recent Indian metro/BRT project	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL/SWAYAM lectures on Urban Transportation Planning / Multimodal Urban Transportation Systems	24
2.	Self-study of the MoHUA Transit-Oriented Development (TOD) Policy and Metro Rail Policy documents	24
3.	Review of a recent Comprehensive Mobility Plan (CMP) of an Indian city	24

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Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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CLIMATE RESILIENT TRANSPORTATION INFRASTRUCTURE			
Course Code	**1MCTE205H** /1MCTM205H	Scheme	2026
Type of Course	**PEC**	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	**03**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Explain the science of climate change, extreme weather trends, and their impact on transportation infrastructure.
2. CO2: Assess the vulnerability and risk of highway, pavement, bridge, and drainage assets to climate hazards using GIS/remote-sensing based tools.
3. CO3: Apply resilience engineering principles to design climate-adaptive pavements, drainage, and cross-drainage structures.
4. CO4: Evaluate sustainable, low-carbon materials and nature-based solutions for resilient road infrastructure.
5. CO5: Develop climate adaptation, disaster risk management, and asset management plans for transportation networks.
6. CO6: Apply ITS, IoT and digital-twin based monitoring tools for real-time resilience assessment of transportation systems.

Module-1

Introduction to Climate Change and Transportation Infrastructure:

Climate change science - greenhouse gas emissions, global warming, IPCC scenarios (RCP/SSP); extreme weather events - floods, cyclones, heat waves, sea-level rise, freeze-thaw cycles, and their impacts on roads, pavements, bridges, and culverts; concepts of vulnerability, exposure, resilience, adaptation, and mitigation; overview of national and international policy frameworks - Paris Agreement, IPCC AR6, NAPCC, IRC guidelines on climate resilient roads; case studies of transportation infrastructure failures due to climate extremes.

Linked COs: CO1 **Number of Hours: 08**

Module-2

Vulnerability and Risk Assessment of Transportation Infrastructure:

Climate risk and vulnerability assessment framework; hazard identification - flooding, landslides, extreme heat, permafrost thaw, coastal/riverine erosion; asset inventory, criticality and exposure analysis; climate projections and downscaling techniques; GIS and remote sensing-based vulnerability and hazard mapping; probabilistic risk assessment and risk matrices; case studies of climate risk assessment for highway corridors, bridges, and culverts.

Linked COs: CO2 **Number of Hours: 08**

Module-3

Resilient Design of Pavements and Drainage Systems:

Effect of rising temperature and rainfall intensity on pavement performance - rutting, thermal and moisture-induced cracking; resilient modulus and performance grading of binders under climate stress; design of climate-adaptive flexible and rigid pavements; hydraulic design of culverts, bridges and cross-drainage structures for increased rainfall intensity; Sustainable Urban Drainage Systems (SUDS) and permeable pavements; urban heat-island mitigation using cool and reflective pavements.

Linked COs: CO3 **Number of Hours: 09**

Module-4

Resilient Materials and Sustainable Construction Practices:

Low-carbon and sustainable materials - Reclaimed Asphalt Pavement (RAP), fly ash, GGBS, geopolymers, warm mix asphalt; use of geosynthetics for slope stabilization, erosion control and reinforcement; nature-based and bioengineering solutions for embankment and slope protection; life cycle assessment (LCA) and carbon footprint of pavement materials and construction; circular economy principles in road construction and maintenance.

Linked COs: CO4 **Number of Hours: 08**

Module-5

Adaptation Planning, Disaster Risk Management and Emerging Technologies:

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Climate adaptation planning framework for transportation networks; disaster risk reduction (Sendai Framework), emergency response planning and network redundancy; resilience metrics and indices for infrastructure systems; Intelligent Transportation Systems (ITS) for early warning and real-time monitoring; smart sensors, IoT and digital-twin based infrastructure health monitoring; institutional, policy and financing mechanisms for climate resilient infrastructure in India (Bharatmala, PMGSY); global best practices and case studies.

Linked COs: CO5 **Number of Hours: 07**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Ryan, J. and Faust, K., "Climate Adaptation Engineering: Risk Management for Transportation and Infrastructure", Elsevier, 1st Edition, 2022.
2. Huang, Y. H., "Pavement Analysis and Design", Pearson Education, 2nd Edition, 2004.
3. Sinha, K. C. and Labi, S., "Transportation Decision Making: Principles of Project Evaluation and Programming", John Wiley & Sons, 2007.

Reference books / Manuals:

1. IRC: SP:42, "Guidelines on Road Drainage", Indian Roads Congress, New Delhi.
2. Ministry of Road Transport and Highways (MoRTH), "Guidelines for Climate Resilient Design and Construction of Roads", Government of India.
3. IPCC, "Climate Change 2022: Impacts, Adaptation and Vulnerability", Cambridge University Press.

Web links and Video Lectures (e-Resources):

1. NPTEL Course on Sustainable and Resilient Transportation Infrastructure - https://nptel.ac.in
2. World Bank Climate Resilient Transport Toolkit - https://www.worldbank.org
3. FHWA Climate Resilience Resources - https://www.fhwa.dot.gov/environment/sustainability/resilience/
4. The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
5. Use of documented case studies of climate-related transportation infrastructure failures to build analytical and problem-solving skills.
6. Hands-on exercises using GIS/remote-sensing tools for climate vulnerability mapping; guest lectures by industry/climate experts; group discussions and literature review on emerging adaptation strategies.

Teaching-Learning Process (Innovative Delivery Methods):

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

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In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Term Work (TW) and Self Learning (SL) components		
Students' activities for TW/SL under NCrF: Samples only As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Assignment / seminar on climate vulnerability assessment techniques for transportation infrastructure	24
2.	Field/industrial visit to a climate-affected road/bridge site or flood-resilience project, with a technical report	24
3.	Micro-project: preliminary climate-resilient design proposal for a selected pavement or drainage stretch	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
4.	NPTEL course module on Sustainable and Resilient Transportation Infrastructure	24
5.	Self-study of IRC/MoRTH guidelines on climate resilient road design and drainage	24
6.	Review of recent journal articles / IPCC reports on climate adaptation in transportation systems	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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MANAGEMENT SYSTEMS FOR HIGHWAY CONSTRUCTION AND MAINTENANCE			
Course Code	**1MCTE206A** /1MCTM206A/ 1MCHT206A	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course Outcomes:

At the end of the course, the student will be able to:

1. **CO1:** Explain the concepts, objectives, and evolution of Pavement Management Systems (PMS) from project-level to network-level asset management, and describe the institutional framework and PMS platforms used in India (PAVER, dTIMS, HDM-4, eMAST) and internationally.
2. **CO2:** Collect, process, and evaluate pavement condition data — distress surveys, PCI, IRI, skid resistance, and FWD/BBD-based structural evaluation — and assess data quality against IRC/ASTM protocols for use in a PMS database.
3. **CO3:** Apply empirical and mechanistic-empirical pavement performance/deterioration models to predict fatigue cracking, rutting, and roughness progression at the network level.
4. **CO4:** Design and optimise maintenance and rehabilitation treatment programmes using intervention matrices, cost-effectiveness analysis, and life-cycle cost analysis (LCCA), including multi-year works programming under budget constraints.
5. **CO5:** Evaluate network-level PMS outputs generated using software tools such as HDM-4 and PAVER, including works-programme optimisation and economic (NPV-based) budget-scenario comparisons.
6. **CO6:** Appraise emerging PMS technologies — GIS/BIM/digital-twin integration, machine learning-based distress prediction, IoT, and UAV-based data collection — and propose their application to next-generation network-level pavement asset management.

Module-1

Foundations of Pavement Management Systems

Concepts and objectives of pavement management; historical evolution from project-level to network-level management; PMS as a component of infrastructure asset management – ISO 55000 series; institutional framework for PMS in India – MoRTH, NRRDA (PMGSY), NHAI, state PWDs; PMS architecture – data collection, condition assessment, performance modelling, decision support, and programme optimization; integration with Geographic Information Systems (GIS) and national road asset databases; overview of established PMS platforms: PAVER, dTIMS CT, HDM-4, ROMDAS, eMAST (CSIR-CRRI), PMGSY-MIS; life-cycle cost analysis (LCCA) philosophy. Components & principals of pavement management systems, pavement maintenance measures, planning investment, research management. Pavement Management Data Needs, Inventory Data Needs, Project level and network level data needs

Linked Cos:CO1 **Number of Hours: 09**

Module-2

Pavement Condition Data: Collection, Indicators and Quality

Pavement distress types and their significance in management decisions – fatigue cracking, rutting, ravelling, patching, edge failures, thermal cracking; condition indices: Pavement Condition Index (PCI – ASTM D6433), Present Serviceability Index (PSI), Structural Number (SN); surface functional parameters: International Roughness Index (IRI), skid resistance, texture depth; structural evaluation: Falling Weight Deflectometer (FWD), Benkelman Beam Deflection (BBD), back-calculation of layer moduli (ELMOD, BAKFAA); automated data collection technologies – High-Speed Road Survey Vehicle (HSRSV), Ground Penetrating Radar (GPR), laser profilometers, video logging; manual visual condition surveys per IRC:82 and ASTM E2840; data quality management – sampling strategies, repeatability, reproducibility, QA/QC protocols; road inventory data requirements; integration of condition data into PMS databases; data update cycles and cost considerations; case studies from NHAI NH condition surveys and PMGSY rural road surveys.

Linked Cos:CO2 **Number of Hours: 09**

Module-3

Pavement Performance Modelling and Deterioration Prediction

Principles of pavement performance modelling; primary distress modes and performance indicators; empirical deterioration models: polynomial, exponential, sigmoidal, Markov chain models; mechanistic-empirical (M-E) performance mo

Linked Cos:CO3 **Number of Hours: 06**

Module-4

Maintenance Treatment Design, Optimisation and Programme Development

Classification of maintenance treatments: routine, periodic, rehabilitation, reconstruction; treatment selection criteria – trigger values (IRI, PCI, rut depth), condition thresholds, structural adequacy; maintenance intervention matrix (MIM) and decision trees; cost-effectiveness analysis of treatment alternatives; optimisation models for maintenance programming: network-level optimisation, integer programming, genetic algorithms; budget allocation and prioritisation under constrained budgets; multi-year maintenance programme development; pavement life-cycle cost analysis (LCCA) – agency costs vs. user costs (vehicle operating costs, travel time costs, accident costs); HDM-4 economic analysis module; Works Programme in HDM-4 and dTIMS; maintenance contracts: performance-based contracts (PBC), output- and outcome-based road contracts (OPRC); long-term performance contracts: DBFOT, OMT on NHAI corridors; monitoring and evaluation of maintenance programme outcomes; benchmarking maintenance productivity and cost norms.

Linked Cos:CO4, CO5 **Number of Hours: 09**

Module-5

Advanced PMS Applications, Digital Tools and Emerging Practices

Network-level PMS implementation: case studies – NHAI's IAAS (Infrastructure Asset Administration System), Karnataka PWD PMS, PMGSY eMAST; PMS for urban roads – differences in data, modelling, and decision support; integration of PMS with BIM and Digital Twins for highway infrastructure; machine learning applications in PMS: random forests, neural networks for distress prediction and treatment selection; big data and IoT for real-time PMS updating; drone/UAV-based pavement data collection for large network surveys; cloud-based PMS platforms; climate resilience in PMS – accounting for extreme weather and climate change in deterioration modelling. **Expert systems and Pavement Management**: Role of computers in pavement management, applications of expert systems for managing pavements, expert system for pavement evaluation and rehabilitation, knowledge – based expert systems, case studies. Implementation of Pavement Management Systems. **Use of software : HDM-4/dTIMS**

Linked Cos:CO5, CO6 **Number of Hours: 09**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Haas, R., Hudson, W. R. & Zaniewski, J. (1994). Modern Pavement Management. Krieger Publishing Co., Malabar, Florida.
2. Papagiannakis, A. T. & Masad, E. A. (2008). Pavement Design and Materials. John Wiley & Sons, New Jersey
3. Huang, Y. H. (2004). Pavement Analysis and Design (2nd ed.). Pearson Prentice Hall, New Jersey.
4. Yoder, E. J. & Witczak, M. W. (1975). Principles of Pavement Design (2nd ed.). Wiley-Interscience, New York.
5. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference books / Manuals:

1. World Bank (2000). HDM-4 Highway Development and Management, Volume 1–4. PIARC / World Bank, Washington D.C.
2. AASHTO (2011). A Policy on Geometric Design of Highways and Streets (Green Book). AASHTO, Washington D.C.
3. AASHTO (2013). AASHTO Transportation Asset Management Guide: A Focus on Implementation. AASHTO, Washington D.C.
4. IRC:115-2014 – Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique. Indian Roads Congress, New Delhi.
5. IRC:82-2015 – Code of Practice for Maintenance of Bituminous Surfaces of Highways. Indian Roads Congress, New Delhi.

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6. IRC:37-2018 – Guidelines for Design of Flexible Pavements (4th Revision). Indian Roads Congress, New Delhi.
7. MoRTH – Specifications for Road and Bridge Works (5th Revision, 2013). Ministry of Road Transport & Highways, Govt. of India.
8. CSIR-CRRI (2013). Manual for Survey, Investigation and Preparation of Road Projects (Volume I & II). CSIR-Central Road Research Institute, New Delhi.
9. FHWA (2013). Life-Cycle Cost Analysis in Pavement Design – In Search of Better Investment Decisions. FHWA-SA-98-079. US DOT/FHWA, Washington D.C.
10. AUSTROADS (2021). Guide to Asset Management, Part 5B: Pavement Performance. Austroads, Sydney.

Web links and Video Lectures (e-Resources):

1. NPTEL – Pavement Design and Performance (IIT Kharagpur): https://nptel.ac.in/courses/105105160
2. HDM-4 Software and Documentation (ISOHDM / World Bank): https://www.hdm4.piarc.org
3. PAVER Software (USACE / APWA): https://www.paver.com
4. LTPP InfoPave Database (FHWA): https://infopave.fhwa.dot.gov
5. FHWA Pavement Asset Management: https://www.fhwa.dot.gov/asset/pavement.cfm
6. PMGSY Online Monitoring & Management System (OMMAS): https://omms.nic.in
7. CSIR-CRRI Publications and Technical Reports: https://crri.res.in
8. AASHTOWARE Pavement ME Design: https://www.aashtoware.org/products/pavement/
9. TRL Software – DTIMS / HDMGlobal: https://www.trl.co.uk
10. ARRB – Australian Road Research Board, Pavement Asset Management resources: https://www.arrb.com.au
11. Transportation Research Board (TRB) – Pavement Management Committee resources: https://www.trb.org

Teaching-Learning Process (Innovative Delivery Methods):

The following strategies are recommended to achieve the course outcomes and foster higher-order thinking:

1. **Problem-Based Learning (PBL):** Students analyse a real or synthetic pavement network dataset – progressing from condition assessment through performance modelling to works programme optimisation – mirroring a professional PMS consultancy workflow.
2. **Simulation / Software Lab:** Structured hands-on sessions in HDM-4 (deterioration runs, economic analysis, works programme) and PAVER (section definition, condition data entry, budget scenarios); QGIS used for condition mapping and spatial prioritisation.
3. **Flipped Classroom:** NPTEL video lectures and HDM-4 documentation chapters assigned as pre-class preparation; classroom time devoted to model calibration exercises, critical discussion of model assumptions, and peer review of works programmes.
4. **Case-Based Teaching:** Analysis of NHAI NH condition and maintenance reports, PMGSY third-party quality monitoring outcomes, and international PMS implementation case studies (UKPMS, NZTA ONRC, Sri Lanka Road Development Authority PMS).
5. **ICT-Enabled Delivery / Expert Lectures:** Guest sessions by practitioners from NHAI, state PWDs, CSIR-CRRI, or international consultants (WB, ARRB, TRL) experienced in HDM-4 and network-level PMS implementation.
6. 6. **Partial Delivery by Industry Expert / Field Visit:** Co-delivery of Module 2 (condition data collection) by an HSRSV operator or FWD testing agency; optional visit to a NHAI project office or pavement testing laboratory to observe live data collection.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

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A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.
In addition, Continuous Comprehensive Assessment (CCA) shall be conducted for a total of 25 marks

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Pavement Network Condition Assessment Exercise: Collect or use a provided pavement condition dataset (minimum 5 km network, including IRI, PCI, rut depth); compute weighted Pavement Condition Index, prepare GIS-based condition maps, identify candidate sections for maintenance, and submit a structured technical report with maintenance recommendations referenced to IRC/ASTM standards.	24
2.	HDM-4 / PAVER Software Exercise: Set up a representative road network (minimum 10 sections) in HDM-4 or PAVER; run deterioration analysis, generate a three-year maintenance works programme under two budget scenarios (unconstrained and 70% budget); compare NPV of alternatives; submit a lab report with outputs and critical commentary.	24
3.	Seminar Presentation: Critical review of a published case study or research article on PMS implementation (Indian or international) from Transportation Research Record, IJPE, or equivalent; 10-minute presentation with Q&A and a one-page abstract.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL MOOC: 'Pavement Design and Performance' (IIT Kharagpur) or World Bank-iRAP e-course on 'Infrastructure Asset Management' – complete at least 4 modules; submit completion certificate.	24
2.	Self-study of HDM-4 Volume 2 (Analytical Framework and Model Descriptions) – Chapters 1–4 on deterioration modelling; IRC:115-2014 (Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements); MoRTH Annual Reports on NH condition.	24
3.	Exploration of PAVER 7 (free educational version) or PMGSY eMAST portal / documentation: understand data dictionary, section definition, condition data entry, work history, and budget analysis modules; prepare a one-page reflection note.	24

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Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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ELECTRIC MOBILITY & CHARGING INFRASTRUCTURE			
Course Code	**1MCTE206B /**1MCTM206B	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90 (42 : 0:0:48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1. Explain the fundamentals of electric mobility, EV technology, battery systems and the national/global policy landscape for e-mobility.
2. CO2. Analyse the performance characteristics of electric vehicles and compare them with conventional and hybrid vehicles for urban transport applications.
3. CO3. Design and size charging infrastructure (AC/DC, slow/fast/battery-swapping) for public, private, fleet and highway corridor applications.
4. CO4. Evaluate the impact of EV charging loads on the power grid and apply smart-charging, V2G and renewable-integration concepts.
5. CO5. Plan city-level and highway-corridor electric mobility and charging infrastructure networks, and assess their techno-economic and environmental viability.

Module-1

Introduction to Electric Mobility

- Evolution of electric mobility; need for e-mobility in the context of urban air quality, energy security and climate change (SDG-7, SDG-11, SDG-13).
- Types of electric vehicles: BEV, HEV, PHEV, FCEV; vehicle architecture and drivetrain configurations.
- Overview of electric two-wheelers, three-wheelers, cars, buses and freight vehicles in the Indian context.
- National and state EV policies: FAME-I/II, PM E-DRIVE, State EV policies, PLI scheme for advanced chemistry cells.

Linked Cos:CO1 **Number of Hours: 8**

Module-2

Technology and Performance Characteristics

- Electric motors and controllers: BLDC, PMSM, induction motors - basic principles and selection criteria.
- Battery technologies: Li-ion chemistries, battery management systems (BMS), energy/power density, cycle life, degradation and thermal management.
- Vehicle performance: range estimation, energy consumption modelling, regenerative braking, driving-cycle based analysis.
- Comparative life-cycle cost and emissions analysis of EVs versus IC-engine and hybrid vehicles.

Linked Cos:CO2, CO3 **Number of Hours: 8**

Module-3

Charging Technologies and Infrastructure Design

- Charging types and standards: AC slow/normal charging, DC fast charging, ultra-fast charging, battery swapping; connector standards (Bharat AC-001/DC-001, CCS, CHAdeMO, Type-2).
- Charger sizing and site design for residential, commercial, public on-street, fleet-depot and highway/expressway charging stations.
- Charging infrastructure guidelines: MoP/BEE/BIS standards, Ministry of Housing and Urban Affairs (MoHUA) charging-station guidelines.
- Siting and spacing criteria for charging stations along highway corridors; range-anxiety mitigation.

Linked Cos:CO3 **Number of Hours: 9**

Module-4

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Grid Integration and Smart Charging

- Impact of EV charging loads on distribution networks: load forecasting, peak-load management, transformer and feeder loading.
- Smart charging strategies: managed/unmanaged charging, time-of-day tariffs, demand-side management.
- Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) concepts; integration with renewable energy sources (solar-powered charging stations).
- Metering, billing and interoperability of charging networks; charge point management systems

Linked Cos:CO4 **Number of Hours: 9**

Module-5

Planning, Economics and Policy for Electric Mobility:

- Planning electric mobility for cities: electrification of public transport fleets (e-buses), last-mile e-mobility, e-mobility zones.
- Highway corridor electrification: charging infrastructure planning for national highways and expressways; case of Indian expressway EV corridors.
- Techno-economic analysis: capital and operating costs, total cost of ownership (TCO), viability gap funding, PPP models for charging infrastructure.
- Environmental and social considerations: battery end-of-life management/recycling, just transition for informal transport workers; international best practices (Norway, China, California).

Linked Cos:CO3, CO4, CO5 **Number of Hours: 8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Mi, C., Masrur, M. A. and Gao, D. W., "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives", John Wiley & Sons.
2. Husain, I., "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press.
3. Larminie, J. and Lowry, J., "Electric Vehicle Technology Explained", John Wiley & Sons.

Reference books / Manuals:

1. NITI Aayog, "India's Electric Mobility Transformation" and "Handbook of EV Charging Infrastructure Implementation", Government of India.
2. Bureau of Energy Efficiency (BEE) / Ministry of Power, "Charging Infrastructure for Electric Vehicles - Guidelines and Standards".
3. Ministry of Housing and Urban Affairs (MoHUA), "Handbook for Electric Vehicle Charging Infrastructure Implementation".
4. International Energy Agency (IEA), "Global EV Outlook" (latest edition).

Web links and Video Lectures (e-Resources):

1. NPTEL course on Electric Vehicles / Hybrid Electric Vehicles, IIT Madras/IIT Delhi/IIT Bombay - https://nptel.ac.in
2. NITI Aayog e-AMRIT portal on electric mobility - https://eamrit.niti.gov.in
3. Bureau of Energy Efficiency, EV charging infrastructure resources - https://beeindia.gov.in
4. International Energy Agency, Global EV Outlook - https://www.iea.org/reports/global-ev-outlook
5. Ministry of Heavy Industries, FAME India Scheme portal - https://fame2.heavyindustries.gov.in

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Flipped classroom sessions using NPTEL/MOOC videos on EV technology followed by in-class discussion.
- Case-based teaching using Indian EV policy and charging-infrastructure case studies.
- ICT-enabled teaching with demonstration of EV simulation/sizing software and charging-load modelling tools.
- Guest lectures/webinars by EV OEM engineers, charging-infrastructure developers and DISCOM/utility representatives.
- 5. Field/industrial visit to an EV manufacturing facility, charging station or fleet depot for observational learning.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

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A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of two Internal Assessment Tests (IA) shall be conducted. Each test shall be conducted for a maximum of 25 marks. The average of the two test marks shall be the marks secured by a student in IA.

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
	Survey/compilation of EV models, battery specifications and charging standards available in the Indian market	24
	Sizing exercise for a charging station (residential/public/fleet-depot) for a given EV load	24
	Field/industrial visit and observational report on an EV charging station or fleet depot	24
	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
	NPTEL/MOOC self-paced module on Electric Vehicles/Electric Mobility	24
	Case-study reading on EV charging infrastructure rollout in Indian cities/highway corridors	24
	Online reading of IEA Global EV Outlook / NITI Aayog e-mobility reports	24
	(Add rows if required)	

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.

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Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

SUSTAINABLE URBAN TRANSPORT & SDG-11			
Course Code	**1MCTE206C**/ 1MCTM206C	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42 (3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90 (42 : 0 : 0: 48)	SEE Marks	50
Credits	3	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1. Explain the concept of sustainable urban transport, the targets/indicators of SDG-11, and the challenges of urbanization and motorization in Indian and global cities.
2. CO2. Analyse urban travel demand and evaluate the sustainability performance of transport systems using indicators, indices and carbon-emission accounting methods.
3. CO3. Design and evaluate Non-Motorized Transport (NMT) infrastructure, Transit-Oriented Development (TOD) and multimodal integration strategies for Indian cities.
4. CO4. Apply Travel Demand Management (TDM) strategies and low-carbon mobility solutions (electric and shared mobility) and assess their environmental and social impacts.
5. CO5. Formulate sustainable urban transport plans and policies aligned with SDG-11, National Urban Transport Policy (NUTP) and international best practices.

Module-1

Introduction to Sustainable Urban Transport and SDG-11

- Urbanization trends, motorization and urban mobility challenges in Indian and global cities; the sustainability paradigm shift from 'predict and provide' to 'sustainable mobility'.
- SDG-11 (Sustainable Cities and Communities): targets and indicators (11.2, 11.6, 11.a, 11.b) and their linkage with other SDGs (climate action, health, gender).
- Three pillars of sustainable transport - environmental, economic and social; concept of accessibility vs. mobility.
- Policy frameworks: National Urban Transport Policy (NUTP), Smart Cities Mission, AMRUT, Sustainable Development Goals - India VNR reporting.

Linked Cos:CO1 **Number of Hours: 8**

Module-2

Sustainability Assessment and Performance Indicators

- Sustainable transportation indicators and composite indices; multimodal Level of Service (LOS) and Ease of Moving Index.
- Greenhouse gas (GHG) emission accounting in urban transport: emission factors, GHG Protocol, Measurement-Reporting-Verification (MRV) basics.
- Introduction to life-cycle assessment (LCA) concepts for transport infrastructure and vehicles.
- Benchmarking and rating tools: Sustainable Mobility Index, Ease of Living Index (transport component); case studies of Indian cities.

Linked Cos:CO2 **Number of Hours: 8**

Module-3

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Non-Motorized Transport, Transit-Oriented Development and Multimodal Integration

- NMT planning and design: pedestrian and cycling infrastructure, footpath and cycle-track design standards, complete streets concept.
- Transit-Oriented Development (TOD): principles, density and mixed land-use, station-area planning, walkability.
- Multimodal integration and first/last-mile connectivity; Mobility-as-a-Service (MaaS) concepts.
- Parking management and pricing strategies as a demand-side tool.

Linked Cos:CO3 **Number of Hours: 9**

Module-4

Travel Demand Management and Low-Carbon Mobility

- Travel Demand Management (TDM): congestion pricing, carpooling, staggered/flexible work hours, parking restraint measures.
- Electric mobility: EV policy landscape (FAME, State EV policies), charging-infrastructure planning for cities.
- Shared and micro-mobility: bike-share, e-scooters, ride-hailing and their role in reducing private vehicle dependence.
- Public transport as the backbone of sustainable mobility: bus, BRT and metro rail - planning and operational considerations.

Linked Cos:CO4 **Number of Hours: 9**

Module-5

Sustainable Urban Transport Planning, Policy and Governance

- Comprehensive Mobility Plan (CMP): preparation process, integrating SDG-11 targets into urban transport planning.
- Institutional frameworks for transport governance: Unified Metropolitan Transport Authority (UMTA), coordination among agencies.
- Financing sustainable transport: Public-Private Partnership (PPP) models, value capture financing, green bonds.
- International best practices (Curitiba, Copenhagen, Singapore) and Indian case studies; monitoring and reporting of SDG-11 indicators.

Linked Cos:CO5 **Number of Hours: 8**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Vuchic, V. R., "Urban Transit: Operations, Planning and Economics", John Wiley & Sons.
2. Kadiyali, L. R., "Traffic Engineering and Transport Planning", Khanna Publishers, New Delhi.
3. Banister, D., "Unsustainable Transport: City Transport in the New Century", Routledge.

Reference books / Manuals:

1. Litman, T., "Sustainable Transportation and TDM: Planning That Balances Economic, Social and Ecological Objectives", Victoria Transport Policy Institute (VTPI).
2. Cervero, R., "The Transit Metropolis: A Global Inquiry", Island Press.
3. UN-Habitat, "World Cities Report - Urbanization and Sustainable Transport", United Nations Human Settlements Programme.
4. Ministry of Housing and Urban Affairs (MoHUA), "National Urban Transport Policy" and "Comprehensive Mobility Plan Toolkit", Government of India.

Web links and Video Lectures (e-Resources):

1. NPTEL course on Urban Transportation Planning, IIT Bombay/IIT Roorkee - https://nptel.ac.in
2. United Nations SDG-11 portal - https://sdgs.un.org/goals/goal11
3. Institute for Transportation and Development Policy (ITDP) India - https://itdp.in
4. Smart Cities Mission portal, MoHUA - https://smartcities.gov.in
5. 5. UN-Habitat resources on sustainable urban mobility - https://unhabitat.org

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped classroom sessions using NPTEL/MOOC videos followed by in-class discussion.
2. Case-based teaching using Indian and global city case studies on sustainable mobility.
3. ICT-enabled teaching with demonstration of GIS/transport planning software for accessibility and network analysis.
4. Guest lectures/webinars by urban transport practitioners and policy makers.
5. 5. Field visit to a BRT corridor, metro station or city bus depot for observational learning.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Literature review and compilation of SDG-11 urban-mobility indicators for a selected Indian city	24
2	GIS-based mapping/spatial analysis of NMT and public-transport network for a selected study area	24
3	Field visit and observational report on a BRT corridor / metro station / city bus facility	24
4.	(Add rows if required)	

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
7.	NPTEL/MOOC self-paced module on Sustainable Urban Transport Systems	24
8.	Case-study reading on Transit-Oriented Development practices in Indian metros (Delhi, Pune, Ahmedabad)	24
9.	Online reading of UN-Habitat World Cities Report / India SDG-11 progress reports	24
10	(Add rows if required)	

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.

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Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

PAVEMENT ASSET MANAGEMENT SYSTEM			
Course Code	**1MCTE206D**/1MCTM206D/1MCHT 206D	Scheme	2026
Type of Course	**PEC**	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	**03**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Explain the concepts of pavement asset management systems, their components, and the policy framework governing road asset maintenance in India.
2. CO2: Apply various pavement condition assessment methods and interpret field data for distress identification, roughness, and structural evaluation.
3. CO3: Select appropriate pavement condition indices and maintenance/rehabilitation treatment options based on distress severity and functional requirements.
4. CO4: Analyze life cycle costs of pavement maintenance strategies and evaluate trade-offs using economic principles including NPV, BCR, and IRR.
5. CO5: Develop network-level maintenance programs using optimization techniques and budget-constrained multi-year planning approaches.

Module-1

Introduction to Pavement Asset Management:

Concepts, definitions and need for PAMS; asset management lifecycle; ISO 55000 framework and its adaptation for road assets. Pavement Management System (PMS): Historical development, objectives and scope; PAMS components - inventory, condition data, performance models, and work programs.

Road Network Inventory: Classification of road network; data requirements; GIS-based inventory systems; IRC and MoRTH guidelines for road asset data management.

Policy and Institutional Framework: National and state-level policies for road asset management; World Bank and ADB guidelines; roles of NHAI, MoRTH, State PWDs and ULBs.

Overview of pavement types: Flexible, rigid and composite pavements; structural components and behavior under traffic loading; pavement design life concepts.

Linked Cos:CO1 **Number of Hours: 08**

Module-2:

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Pavement Condition Assessment and Data Collection:

Pavement Distress Identification: Types of distresses in flexible pavements (cracking, rutting, bleeding, raveling, potholes) and rigid pavements (faulting, joint deterioration, corner breaks); IRC:SP:11 visual survey guidelines.

Pavement Surface Condition: International Roughness Index (IRI) - measurement using MERLIN, roughometer, and laser profilometer; Present Serviceability Index (PSI) and its correlation with IRI.

Pavement Structural Evaluation: Falling Weight Deflectometer (FWD), Benkelman Beam Deflection (BBD) method as per IRC:81; back calculation of layer moduli; structural adequacy number.

Skid Resistance and Texture Measurement: Sand patch method, Circular Texture

Data Management and Pavement Management Database: Automated Road analyzer (ARAN), Meter (CTM), SCRIM, Grip Tester; friction standards and safety implications as per IRC:SP:91.video logging; database design; quality control and validation of condition data; integration with GIS.

Linked Cos:CO2, CO3 **Number of Hours: 09**

Module-3

Pavement Condition Indices and Treatment Selection:

Pavement Condition Index (PCI): Methodology as per ASTM D6433; deduct value curves; calculation procedure for flexible and rigid pavements; PCI rating scale and maintenance thresholds.

Combined Condition Index (CCI) and Ride Quality Index (RQI): IRC guidelines; composite indices for overall pavement health assessment; condition transition matrix.

Maintenance and Rehabilitation (M&R) Treatment Options: Preventive maintenance (crack sealing, micro-surfacing, fog seal, slurry seal); corrective maintenance (patching, overlay); rehabilitation (milling and resurfacing, reconstruction); IRC:SP:16, IRC:SP:72.

Treatment Selection Logic and Decision Trees: Condition-based trigger levels; benefit-cost considerations; compatibility of treatments with distress types; treatment effectiveness and service life extension.

Pavement Design Standards in Asset Management Context: IRC:37 and IRC:58 provisions; overlay design using BBD/FWD deflection data; strengthening of weak pavements.

Linked Cos:CO3 **Number of Hours: 09**

Module-4

Life Cycle Cost Analysis and Maintenance Strategies:

Life Cycle Cost Analysis (LCCA): Concepts of LCCA in pavement management; agency costs, user costs and social costs; discount rate and analysis period selection; FHWA LCCA guidelines.

Economic Evaluation Methods: Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), Equivalent Uniform Annual Cost (EUAC); sensitivity analysis and uncertainty in cost estimates.

Pavement Performance Modeling: Deterministic vs. probabilistic models; regression-based deterioration models; Markov chain transition probability models; HDM-4 road deterioration models.

Maintenance Strategy Optimization: Do-nothing, minimum maintenance, and optimal maintenance strategies; optimal intervention timing; cost-effectiveness analysis using effectiveness curves.

Risk and Uncertainty in Asset Management: Risk identification in pavement deterioration; Monte Carlo simulation; climate change impacts on pavements; risk-based maintenance prioritization.

Linked Cos:CO4, CO5 **Number of Hours: 08**

Module-5

Network-Level Analysis, Prioritization and Programming:

Network-Level Pavement Management: Project-level vs. network-level analysis; condition distribution analysis; network health index (NHI); performance gap analysis.

Prioritization Methods: Ranking methods (condition-based, criticality-based); Analytical Hierarchy Process (AHP); Multi-Criteria Decision Analysis (MCDA); stakeholder involvement in prioritization.

Budget Optimization and Multi-Year Programming: Budget-constrained optimization; linear programming; greedy algorithms; genetic algorithms; multi-year maintenance programming and rolling work program.

HDM-4 Application: Road deterioration and works effects models; vehicle operating cost models; HDM-4 for project, programme, and strategic analysis; case studies from Indian national and state highways.

GIS-based DSS and Emerging Technologies: Integration of GIS with PAMS; Decision Support Systems (DSS); AI/ML applications in automated pavement condition monitoring; deep learning for distress detection; BIM for road assets.

Linked Cos:CO4, CO5 **Number of Hours: 08**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Hudson, W.R., Haas, R., and Uddin, W. (1997). Infrastructure Management: Integrating Design, Construction, Maintenance, Rehabilitation, and Renovation. McGraw-Hill, New York.
2. Haas, R., Hudson, W.R., and Zaniewski, J. (1994). Modern Pavement Management. Krieger Publishing Company, Malabar, Florida.
3. Mannering, F.L. and Washburn, S.S. (2019). Principles of Highway Engineering and Traffic Analysis. 7th Ed., Wiley.
4. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference books / Manuals:

1. IRC:SP:11 (2013). Handbook of Quality Control for Construction of Roads and Runways. IRC, New Delhi.
2. IRC:SP:16 (2004). Guidelines for Surface Evenness of Highway Pavements. IRC, New Delhi.
3. IRC:SP:72 (2015). Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads. IRC, New Delhi.
4. MoRTH (2019). Manual for Construction and Supervision of Bituminous Works. Ministry of Road Transport and Highways, New Delhi.
5. FHWA (2002). Life-Cycle Cost Analysis Primer. U.S. Department of Transportation, Federal Highway Administration.
6. World Bank (1994). World Development Report: Infrastructure for Development. World Bank, Washington D.C

Web links and Video Lectures (e-Resources):

1. NPTEL Course on Pavement Engineering: https://nptel.ac.in/courses/105104098
2. HDM-4 World Road Association: https://www.piarc.org/en/activities/Road-Management-Pavement/Road-Management/HDM-4
3. FHWA Pavement Design: https://www.fhwa.dot.gov/pavement/
4. IRC Publications: https://www.irc.org.in/
5. MoRTH Road Statistics: https://morth.nic.in/
6. World Road Association (PIARC): https://www.piarc.org/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped classroom sessions using NPTEL/MOOC videos followed by in-class discussion.
2. Case-based teaching using Indian and global city case studies on sustainable mobility.
3. ICT-enabled teaching with demonstration of GIS/transport planning software for accessibility and network analysis.
4. Guest lectures/webinars by urban transport practitioners and policy makers.
5. Field visit to a BRT corridor, metro station or city bus depot for observational learning.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete

minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Pavement condition distress survey and PCI/CCI computation for an assigned pavement section (field + report write-up)	24
2.	Life Cycle Cost Analysis (LCCA) case study preparation — NPV/BCR/IRR computation, deterioration modelling, sensitivity analysis	24
3.	Network-level prioritization exercise using AHP/MCDA for an assigned road network of 10 segments (includes work programme)	24
4.	HDM-4 / PAVER software exploration — input data, run deterioration model, compare M&R scenarios and report (individual)	24
5.	Literature review on an assigned emerging PAMS technology (AI/ML for distress detection, digital twins, or self-healing pavements)	24
6.	Seminar / class presentation on a PAMS-related case study or research paper (15 min. + Q&A)	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	NPTEL Online Course: Pavement Engineering (IIT Kharagpur / IIT Madras) — select and complete relevant modules	24
2.	Study of IRC:SP:11, IRC:SP:16, IRC:SP:72, and IRC:81 — self-reading and note preparation with examples	24
3.	Exploration of FHWA Life-Cycle Cost Analysis Primer and HDM-4 user documentation	24
4.	Study of ASTM D6433 (PCI methodology) — worked example for a hypothetical pavement section	24
5.	Online resource: PIARC HDM-4 modules and World Bank pavement management resources	24
6.	Review of published DPR/asset management reports from NHAI, NRRDA, or State PWD for Indian context understanding	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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INNOVATIVE PRACTICES IN ROAD CONSTRUCTION			
Course Code	**1MCTE206E** /1MCTM206E/1MCHT206E/	Scheme	2026
Type of Course	**PEC**	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42: 0 : 0 : 48)	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Analyze special geotechnical, drainage, foundation and environmental problems encountered during road construction, and select appropriate innovative solutions.
2. CO2: Apply innovative materials, pavement technologies and construction methods for flexible and sustainable road infrastructure.
3. CO3 Evaluate and select advanced materials and technologies for the construction, rehabilitation, maintenance and life-cycle management of bituminous and concrete pavements.
4. CO4: Design or recommend suitable applications of geosynthetics, reinforced soil systems, erosion-control measures and slope-stabilization techniques for roads and hill-road infrastructure.
5. CO5: Explain and assess the application of smart materials, intelligent construction equipment, AI/ML, IoT, non-destructive testing and digital twins in road asset management, quality assurance and road safety.

Module-1

Introduction - Overview of traditional vs. innovative practices in road construction and their relative merits, Problems in construction of roads in marshy areas and weak / expansive soils and water- logged areas. Control of capillary rise and seepage flow in road construction. Design and construction of filter drains and capillary cut-off. Flood Disaster Mitigation, Methods of strengthening weak soil foundation for pavement construction, acceleration of consolidation and settlement of compressible embankment foundation, vertical sand drains, design and construction as per MoRTH/ Indian Roads Congress and International best practices.

Linked Cos:CO1 **Number of Hours:08**

Module-2

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Innovative Materials and Technologies in Bituminous Pavements: Characterization of Polymer Modified binders, Rubberized binders, HiMA binders, polymer modified emulsions, warm mix asphalt, porous asphalt, high-performance bituminous mixes with modifiers and construction steps, Construction of Stone Matrix Asphalt, Cold Mix Technologies, Sustainable Road Construction practices viz., use of recycled pavement materials – hot and cold recycling, central plant and in-place recycling, choice of types of recycling, use of industrial by-products and wastes in construction. Cement treated bases and sub-bases, full depth reclamation, Construction and Quality Control as per Indian Roads Congress specifications, Perpetual pavements, sustainable pavement construction; reduction in Carbon footprints; green highways.

Linked Cos:CO2 **Number of Hours:09**

Module-3

Innovative Materials and Technologies in Concrete Pavements: Construction and Quality Control of Jointed Concrete Pavements, Continuously reinforced concrete pavements with elastic joints (CRCP), Short Slab concrete pavements, Fibre-reinforced concrete pavements, Pre-cast Concrete pavements, Interlocking Concrete Block pavements (ICBP), Roller compacted concrete (RCCP) pavements, White topping, Cell filled concrete (CFC) pavements; innovative practices for rehabilitation of concrete pavements as per IRC/MoRTH Specifications

Linked Cos:CO3 **Number of Hours:09**

Module-4

Geosynthetics in Road Construction: Types of geosynthetics and their applications, Benefits of using geosynthetics in road construction, Problems in construction of high embankments, stability of foundation and embankment slopes, Construction & maintenance of hill roads, Stability of hill slopes, control of erosion, Gabion structures, Retrofitting measures for protection of road system, Use of special materials such as geo-synthetics reinforced pavements, coir geotextiles, Reinforced soil walls, Use of reinforced earth retaining walls, soil nailing technology. Case studies and best practices.

Linked Cos:CO4 **Number of Hours:08**

Module-5

Smart Materials and Road Construction Technologies: Smart pavement materials (self-healing, solar roads), Application of AI/ML and IoT in asset management, road evaluation and condition of pavements, road safety, Safe System approach, Automated Intelligent Machine Controlled Construction, Intelligent Compaction, Application of dielectric profile systems for real time quality control, paver mounted thermal profile systems, quality assurance through non-destruction technologies, Use of Digital twins in highway construction, Case studies

Linked Cos:CO5 **Number of Hours:08**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Prithivi Singh Kandhal, Veeraragavan. A and Rajan Choudhary, Bituminous Road Construction in India, Second Edition, PHI, 2023
2. Koerner, R.M., Designing with Geosynthetics"- 4th Edition Prentice Hall, New Jerssey, 1997.
3. FHWA, Geotechnical Aspects of Pavements Reference Manual, FHWA NHI-05- May 2006.
4. Shivakumar Babu, G.L, Prithvi S Kandhal, Nivedya Mandankara Kottayi, Rajib Mallick, A.Veeraragavan, Pavement Drainage- Theory and Practice", , CRC Press
5. FHWA, Automation in Highway Construction, FHWA Publication No.: FHWA-HRT-16-032
6. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference books / Manuals:

1. IRC:SP:11 (2013). Handbook of Quality Control for Construction of Roads and Runways. IRC, New Delhi.
2. IRC:SP:42 (2014). Guidelines on Road Drainage. IRC, New Delhi.
3. IRC:75 (2015). Guidelines for the Design of High Embankments. IRC, New Delhi.
4. IRC:SP:59 (2019). Guidelines for Use of Geotextiles in Road Pavements and Associated Works. IRC, New Delhi.
5. IRC:SP:63 (2018). Guidelines for the Use of Interlocking Concrete Block Pavement. IRC, New Delhi.
6. IRC:SP:79 (2008). Tentative Specifications for Stone Matrix Asphalt. IRC, New Delhi.
7. IRC:SP:100 (2014). Use of Cold Mix Technology in Construction and Maintenance of Roads. IRC, New Delhi.
8. MoRTH (2013). Specifications for Road and Bridge Works. 5th Revision. Ministry of Road Transport and Highways.
9. FHWA (2006). Geotechnical Aspects of Pavements Reference Manual. Publication No. FHWA NHI-05-037.

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10. Leonards, G.A. (1962). Foundation Engineering. McGraw-Hill, New York.

Web links and Video Lectures (e-Resources):

1. NPTEL Course - Pavement Engineering: https://nptel.ac.in/courses/105104098
2. FHWA Pavement Technology: https://www.fhwa.dot.gov/pavement/
3. IRC Publications and Codes: https://www.irc.org.in/
4. MoRTH Technical Circulars and Specifications: https://morth.nic.in/
5. World Road Association (PIARC) - Innovative Road Technologies: https://www.piarc.org/
6. NRRDA - PMGSY Technical Manuals: https://pmgsy.nic.in/
7. NHAI - Knowledge Repository: https://nhai.gov.in/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Lecture-cum-demonstration sessions using multimedia, field photographs, and video case studies from Indian highway and rural road projects (NHDP, PMGSY, state highways).
1. 2. Problem-Based Learning: Group case study assignments on selection of innovative techniques for given site conditions (e.g., choice of WMA vs. cold mix for a rural PMGSY project; geosynthetic selection for an embankment over soft soil).

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Term Work (TW) and Self Learning (SL) components

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes.

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Literature review / report on any one innovative bituminous pavement technology (e.g., Warm Mix Asphalt, SMA, or Cold Mix)	24
2.	Detailed study and report on geosynthetics application in road construction with case study	24
3.	Assignment on design and construction of filter drains / capillary cut-off as per MoRTH/IRC guidelines	24
4.	Mini project: Comparative analysis of traditional vs. innovative practices in road construction (Unit-1 focus)	24
5.	Site visit / industrial visit to an ongoing road construction project and submission of a technical visit report	24
6.	Assignment on IRC code provisions for any one topic (Geosynthetics / Recycling / Concrete Pavements)	24
7.	Seminar presentation on Smart Materials and Technologies (self-healing pavements / solar roads / IoT in asset management)	24

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8.	Problem-solving exercises on construction of high embankments, vertical sand drains, and foundation strengthening	24
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	MOOC / Online course on Pavement Engineering or Highway Materials (NPTEL / Coursera)	24
2.	Online spoken tutorials / video lectures on Geosynthetics in Road Construction	24
3.	Self-study of relevant IRC codes: IRC:SP:59, IRC:SP:53, IRC:SP:79, IRC:SP:101, IRC:58, IRC:101, IRC:SP:140	24
4.	Reading and review of FHWA publications on Geotechnical Aspects of Pavements and Automation in Highway Construction	24
5.	Study of research papers / journal articles on AI/ML and IoT applications in pavement asset management	24
6.	Self-learning on Digital Twins in highway construction (online resources / YouTube / industry reports)	24
7.	Exploration of software tools used in road project management (Primavera / MS Project overview)	24
8.	MOOC / Online course on Pavement Engineering or Highway Materials (NPTEL / Coursera)	24
9.	Online spoken tutorials / video lectures on Geosynthetics in Road Construction	24
10.	Self-study of relevant IRC codes: IRC:SP:59, IRC:SP:53, IRC:SP:79, IRC:SP:101, IRC:58, IRC:101, IRC:SP:140	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

09102026

DETAILED PROJECT REPORT (DPR) PREPARATION FOR TRANSPORTATION SECTOR			
Course Code	**1MCTE206F** /1MCTM206F/1MCHT206F	Scheme	2026
Type of Course	**PEC**	Semester	II
Teaching Hours/Week (L:T:P)	42(3: 0: 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42: 0: 0: 48)	SEE Marks	50
Credits	**03**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CLO1: Appreciate the structure and components of a comprehensive DPR for transportation infrastructure projects, referring to IRC, MoRTH, and IS standards.
2. CLO2: Conduct topographic, geotechnical, hydrological, and traffic investigations required for DPR preparation in the transportation sector.
3. CLO3: Assess environmental, social, and land acquisition impacts as per national legislations and EIA guidelines applicable to road and transport projects.
4. CLO4: Carry out geometric design, pavement design, and drainage design computations as integral components of a transportation DPR.
5. CLO5: Prepare cost estimates, BOQ, rate analysis, and financial viability reports including economic analysis, PPP frameworks, and funding mechanisms.
6. CLO6: Compile a complete DPR document with drawings, tender documents, quality control plans, and monitoring frameworks for transportation projects.

Module-1

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Introduction to Detailed Project Reports and Transportation Infrastructure Planning:

Concept and significance of Detailed Project Report (DPR) in transportation sector; Types of transportation infrastructure projects: new construction, upgradation, rehabilitation, maintenance.

Stages of project preparation: Project Identification, Pre-Feasibility Study, Feasibility Study, DPR, Bid Process Management.

Organisational and HR structure for DPR preparation and implementation; Typical TOR for DPR consultants.

Key Acts and regulations governing transportation projects: National Highways Act, Land Acquisition Act (RFCTLARR Act 2013), Motor Vehicles Act, NHAI Act; Role of MoRTH, NHAI, NHIDCL, State PWDs.

Salient features of flagship infrastructure schemes: Bharatmala Pariyojana, PMGSY, Smart Cities Mission; Case studies of DPRs for National Highways, Urban Expressways, and Rural Roads.

IRC standards, MoRTH specifications, and IS codes relevant to road project DPR preparation.

Linked Cos:CO1 **Number of Hours: 08**

Module-2

Engineering Surveys, Traffic Studies, and Site Investigations for DPR:

Topographic surveys: Reconnaissance, preliminary and detailed surveys; Total station, DGPS, and drone-based surveys; Corridor of Impact (COI) delineation.

Traffic Studies: Traffic volume counts, classified volume count, Origin-Destination (OD) surveys, Speed-Delay studies, PCU equivalents; Traffic growth rate estimation; Design period and design traffic (CVPD) as per IRC:37 and IRC:9.

Geotechnical and Pavement Investigations: Sub-surface explorations, soil classification, CBR testing; Benkelman Beam Deflection (BBD) tests for existing pavements; material surveys for pavement construction.

Hydrological Investigations: Catchment area delineation, peak discharge estimation by Rational Method and Dicken's formula; Cross-drainage structure sizing.

Utility surveys, ROW acquisition data, tree enumeration; Pavement condition surveys, bridge condition inspection.

Use of GIS and Remote Sensing in DPR preparation; Satellite imagery interpretation; Digital Elevation Models (DEM); Open-source tools (QGIS, Google Earth Pro).

Linked Cos: CO2 **Number of Hours:09**

Module-3

Environmental and Social Impact Assessment for Transportation Projects:

Environmental Impact Assessment (EIA): Objectives, methodology, stages (screening, scoping, impact identification, mitigation); EIA for linear infrastructure projects.

Applicable legislations and clearances: Environmental Clearance (EC) under EIA Notification 2006 (and 2020 amendment), Forest Clearance under Forest Conservation Act 1980, CRZ clearance, Wildlife Board clearance; Air and noise quality standards.

Social Impact Assessment (SIA) and Resettlement Action Plan (RAP): Land acquisition under RFCTLARR Act 2013; Vulnerable group identification; Livelihood restoration measures.

Environmental Management Plan (EMP): Construction stage EMP, operation stage EMP; Tree plantation, landscaping, soil erosion control, dust suppression.

Road Safety Audit (RSA): Principles, stages, and checklists as per IRC:SP:88; Black spot identification and rectification.

Linked Cos:CO3 **Number of Hours:09**

Module-4

Geometric and Pavement Design, Cost Estimation, and Project Financing:

Geometric Design: Design speed, sight distances, horizontal and vertical alignment, cross-section elements as per IRC:73, IRC:SP:84 (rural roads) and IRC:86 (urban roads).

Pavement Design: Flexible pavement design as per IRC:37-2018; Rigid pavement design as per IRC:58-2015; Design of overlays as per IRC:81; Bituminous mix design.

Cost Estimation Methods: Rough cost estimates, detailed estimates, plinth area method; Preparation of Abstract Estimate and Detailed Estimate; Schedule of Rates (SOR).

Rate Analysis: Prerequisites and factors; overhead expenses; labour and material requirements; rate analysis for earthwork, granular sub-base, bituminous layers, concrete works, and drainage structures as per MoRTH and MORTH SOR.

Bill of Quantities (BOQ): Preparation of BOQ for road works, bridges, culverts, and ancillary structures.

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Economic and Financial Analysis: Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit-Cost Ratio; Vehicle Operating Cost (VOC) savings; Time savings; Financial Internal Rate of Return (FIRR); Toll feasibility and traffic projection.

Project Financing: Government budgetary allocation, IEBR, EAP (World Bank, ADB); PPP models: BOT-Toll, BOT-Annuity, HAM (Hybrid Annuity Model); VGF mechanism; Risk allocation in PPP.

Linked Cos:CO4 **Number of Hours:08**

Module-5

DPR Documentation, Tendering, Contract Management, and Construction:

Structure of a complete DPR: Cover page, executive summary, project description, traffic study report, survey and investigation report, design report, environmental and social reports, cost estimates and BOQ, drawings, appendices.

Drawing requirements: Key plan, strip plan, typical cross-sections, longitudinal section, drainage details, structure drawings; Use of AutoCAD and Civil 3D in DPR preparation.

Tender Documents: Components of tender documents as per FIDIC and MoRTH/NHAI standard bidding documents; NIT, Instructions to Bidders, Conditions of Contract (General and Special), Technical Specifications, Drawings, BOQ.

Tender Evaluation: Two-envelope system; Technical evaluation criteria (RFQ, RFP); Financial bid analysis; L1 selection; Negotiation and award.

Contract Management: Types of contracts (EPC, Item Rate, Lump Sum); Milestone-based payment; Price escalation clauses; DLP and retention money.

Construction Monitoring and QA/QC: Quality control plan; Material testing frequencies as per MoRTH 5th Revision; Independent Engineer role; Third-party quality audits; Monitoring formats and progress reports.

Project Management Information Systems (PMIS): Use of Primavera P6, MS Project; Earned Value Management (EVM); Monthly progress reporting to client/funding agencies.

Linked Cos:CO5, CO6 **Number of Hours:08**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. L.R. Kadiyali and N.B. Lal, Principles and Practices of Highway Engineering, Khanna Publishers, New Delhi.
2. S.K. Khanna and C.E.G. Justo, Highway Engineering, Nem Chand & Bros, Roorkee.
3. Rangwala and Rangwala, Project Planning and Management, Charotar Publishing House.
4. Peter Morris and R. Keith Therivel (Eds.), Methods of Environmental Impact Assessment, 3rd Ed., Routledge.
5. Clarkson H. Oglesby and R. Gary Hicks, Highway Engineering, 4th Ed., John Wiley & Sons.
6. S.K. Khanna, C.E.G. Justo and Dr. A.Veeraragavan, Highway Engineering, Nem Chand & Bros, Roorkee.

Reference Books / Codes / Manuals:

1. IRC:SP:19-2020 – Manual for Survey, Investigation and Preparation of Road Projects.
2. IRC:SP:30-2009 – Manual on Economic Evaluation of Highway Projects in India.
3. IRC:37-2018 – Guidelines for the Design of Flexible Pavements.
4. IRC:58-2015 – Guidelines for the Design of Plain Jointed Rigid Pavements for Highways.
5. IRC:SP:84-2014 – Manual for Specifications and Standards for Four-Laning of Highways.
6. IRC:SP:88-2018 – Manual on Road Safety Audits.
7. MoRTH Specifications for Road and Bridge Works, 5th Revision, 2013.
8. IS 15883 (Part 1):2009 – Guidelines for Preparing DPRs for Infrastructure Projects.
9. NHAI Standard Bidding Documents for EPC / BOT-Toll / HAM Contracts.
10. World Bank / ADB Project Appraisal Document Guidelines.

Web links and Video Lectures (e-Resources):

- NPTEL – Highway Engineering (IIT Kharagpur, IIT Bombay): https://nptel.ac.in
- PMGSY OMMAS Portal – Rural Road DPR resources: https://omms.nic.in
- MoRTH publications and IRC codes: https://morth.nic.in | https://irc.nic.in
- NHAI e-Learning resources: https://nhai.gov.in
- QGIS tutorials for GIS-based DPR preparation: https://qgis.org
- YouTube – IIT lectures on Transportation Planning and Highway Engineering: https://www.youtube.com/c/IITKharagpurJuly2018onNPTEL

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Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1	Mini DPR preparation (group project) – includes surveys, design, estimation, and report writing.	06
2	Field visit to an ongoing highway/urban road project and preparation of a visit report.	02
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1	Study of one published IRC code (assigned per student) and submission of a 2-page summary with applications.	03
2	Online NPTEL module on Highway Engineering or Project Management (min. 4 hours); submission of completion certificate.	03
3	Study of a complete DPR available from PMGSY / NHAI portal; prepare a structured synopsis.	02

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes**.**

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Mini DPR preparation (group project) – includes surveys, design, estimation, and report writing.	24
2.	Field visit to an ongoing highway/urban road project and preparation of a visit report.	24

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SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Study of one published IRC code (assigned per student) and submission of a 2-page summary with applications.	24
2.	Online NPTEL module on Highway Engineering or Project Management (min. 4 hours); submission of completion certificate.	24
3.	Study of a complete DPR available from PMGSY / NHAI portal; prepare a structured synopsis.	24

Sample rubrics for TW activities:

Criteria	**4 - Excellent**	**3 - Good**	**2 - Satisfactory**	**1 - Needs Improvement**
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

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BIG DATA & AI IN TRANSPORTATION SYSTEMS			
Course Code	**1MCTE206G** /1MCTM206G/ 1MCHT206G	**Scheme**	2026
Type of Course	PEC	**Semester**	II
Teaching Hours/Week (L:T:P)	42(3: 0 : 0)	**CIE Marks**	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42: 0 : 0 : 48)	**SEE Marks**	50
Credits	03	**Total Marks**	100
Examination type (SEE)	Theory	**Exam Hours**	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. Explain the fundamental characteristics of Big Data and identify the diverse sources of transportation data, including GPS/GNSS probe data, connected-vehicle streams, smart-card, ANPR/CCTV and crowdsourced data. (RBL2)
2. Apply machine learning and deep learning techniques to transportation datasets for prediction, classification and clustering tasks such as traffic-flow forecasting and mode-choice modelling. (RBL3)
3. Analyze Big Data analytics techniques for traffic operations, travel-time/O-D estimation and pavement performance evaluation using AI-assisted methods. (RBL4)
4. Evaluate AI-enabled Intelligent Transportation System (ITS) applications for adaptive signal control, public-transit optimization and road-safety/crash analytics. (RBL5)
5. Design a Big Data/AI based analytical framework or prototype to address a real-world transportation engineering problem using appropriate platforms and tools. (RBL6)

Module-1

Introduction to Big Data and Transportation Data Ecosystems

- Big Data: definition and the 5 V's (Volume, Velocity, Variety, Veracity, Value); overview of the Big Data ecosystem (Hadoop, Spark, NoSQL databases).
- Sources of transportation data: GPS/GNSS probe and fleet-tracking data, connected and autonomous vehicle (CAV) data streams, smartphone and app-based sensing, automatic fare collection (AFC)/smart-card data, loop detectors and other roadside sensors, CCTV/ANPR video data, crowdsourced and social-media data (e.g., Waze, Google/HERE traffic feeds).
- Data quality, cleaning, integration and fusion issues specific to transportation datasets; missing-data and noise handling in probe/GPS trajectories.
- Data governance, privacy, security and ethical considerations in Intelligent Transportation Systems (ITS).
- Case studies: Big Data applications in urban transportation planning, freight and logistics, and public transit agencies.

Linked COs: CO1 **Number of Hours: 8**

Module-2

Machine Learning and AI Foundations for Transportation Engineers

- Overview of AI/ML paradigms: supervised, unsupervised and reinforcement learning; typical transportation use-cases for each.
- Regression and classification algorithms (linear/logistic regression, decision trees, random forests, support vector machines) applied to traffic and travel-behaviour data.
- Clustering techniques (k-means, DBSCAN, hierarchical clustering) for trip pattern and driver-behaviour segmentation.
- Introduction to neural networks and deep learning: ANN, CNN and RNN/LSTM architectures for time-series traffic forecasting and image-based applications.
- Model development workflow: feature engineering with spatio-temporal transportation data, train/validation/test splitting, hyperparameter tuning.

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- Model evaluation metrics: RMSE, MAE, MAPE, accuracy, precision–recall, confusion matrix; overfitting/underfitting and regularization.

Linked COs: CO2 **Number of Hours:08**

Module-3

Big Data Analytics for Traffic Operations and Pavement Engineering

- Short-term and long-term traffic-flow/speed prediction using statistical and ML/DL models (ARIMA, LSTM, Graph Neural Networks).
- Travel-time estimation and Origin–Destination (O-D) matrix estimation from probe/GPS and AFC data.
- Traffic incident detection and anomaly/outlier detection using Big Data streams.
- AI in pavement engineering: automated pavement distress detection using image processing/CNNs, prediction of IRI and pavement performance indices, integration of ML with HDM-4 based pavement management for Indian conditions.
- Connected and Autonomous Vehicle (CAV) data analytics: trajectory data mining and driving-behaviour analysis.

Linked COs: CO3 **Number of Hours:09**

Module-4

AI-enabled Intelligent Transportation Systems (ITS)

- Smart/adaptive traffic-signal control: SCOOT/SCATS concepts, reinforcement-learning based signal timing optimization.
- AI applications in public transit: demand and ridership prediction, bus-bunching detection and mitigation, dynamic route/schedule optimization.
- Analytics for app-based ride-hailing and shared-mobility services (dynamic pricing, dispatch optimization).
- Computer-vision applications: ANPR, automatic vehicle classification and counting, video-based surveillance and incident detection.
- AI-based road-safety analytics: crash-severity prediction, black-spot/hotspot identification and real-time risk assessment using ML.

Linked COs: CO3 **Number of Hours:08**

Module-5

Big Data Platforms, Visualization and Emerging Trends

- Big Data processing frameworks: Hadoop/MapReduce, Apache Spark, stream processing with Kafka; cloud and IoT platforms (AWS, Microsoft Azure, Google Cloud IoT) for transportation data pipelines.
- Data visualization and dashboards for transportation analytics: GIS integration, Power BI/Tableau, real-time traffic-management dashboards.
- Digital twins for transportation infrastructure and network-level decision support.
- Explainable AI (XAI), bias and fairness considerations in AI-based transportation decision-making.
- Policy and regulatory perspectives: MoRTH's National ITS Policy, National Urban Transport Policy; emerging trends — autonomous vehicles, Mobility-as-a-Service (MaaS) and smart-city transportation systems.

Linked COs: CO4 **Number of Hours:09**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Antoniou, C., Dimitriou, L. and Pereira, F. (Eds.), "Mobility Patterns, Big Data and Transport Analytics: Tools and Applications for Modeling", Elsevier, 2018.
2. Geron, A., "Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow", 3rd Edition, O'Reilly Media, 2022.

Reference books / Manuals:

1. Provost, F. and Fawcett, T., "Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking", O'Reilly Media, 2013.
2. Zheng, Y., "Trajectory Data Mining: An Overview", ACM Transactions on Intelligent Systems and Technology, 2015.
3. Vlahogianni, E.I., Karlaftis, M.G. and Golias, J.C., "Short-term Traffic Forecasting: Overview of Objectives and Methods", Transport Reviews (journal compendium used as reference material).

4. HDM-4 (Highway Development and Management Model) Technical Reference Manuals, World Road Association (PIARC).
5. IRC:SP:112 and related IRC guidelines on Intelligent Transportation Systems and data-driven pavement management, Indian Roads Congress.

Web links and Video Lectures (e-Resources):

- NPTEL: "Data Analytics for Transportation Systems" / "Machine Learning" / "Intelligent Transportation Systems" — https://nptel.ac.in
- MoRTH National ITS Policy and Guidelines — https://morth.nic.in
- swayam.gov.in courses on Big Data Analytics and AI applications
- Selected open-access datasets: NGSIM, PeMS (Caltrans Performance Measurement System), Uber Movement, OpenStreetMap-based mobility datasets

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Flipped-classroom sessions using NPTEL/MOOC video content on ML/Big Data fundamentals, followed by in-class problem solving on transportation datasets.
2. Hands-on laboratory-style demonstrations using Python/R (Pandas, Scikit-learn, TensorFlow/Keras) on open transportation datasets (PeMS, NGSIM, Uber Movement).
3. Case-based teaching using real-world case studies of AI/Big Data deployment by transport agencies and industry partners.
4. Guest lectures/industry expert sessions on ITS, connected-vehicle data and pavement AI applications.
5. Use of simulation and visualization tools (GIS, traffic simulation software) to illustrate AI-based traffic management concepts.

Assessment Structure (both CIE and SEE)

The weightage assigned to Continuous Internal Evaluation (CIE) and Semester End Examination (SEE) shall be 50% each. A student shall secure a minimum of 50% of the maximum marks prescribed for CIE and a minimum of 40% of the maximum marks prescribed for SEE to be eligible for passing.

A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Term Work (TW) and Self Learning (SL) components

Students' activities for TW/SL under NCrF: Samples only

As per National credit formwork (NCrF) students must spend 90 hours of study for 3 credit courses, which include Course instructions (CI-42 hour) and Teamwork/ Self learning (TW/Sl-48 hours). Hence, students must complete minimum of two actives as part of NCrF. These learning activities shall be considered as CCA components of CIE. The evaluation activities will be done using set of rubrics developed for each activity. The following sample activities are listed below. The sample activities are given below. The course coordinator can also give their own TW/SL activities as per the course outcomes

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Seminar / case-study report on a real-world Big Data or AI application in transportation (e.g., adaptive signal control, pavement distress detection, crash prediction) presented to the class.	24

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2	Group mini-project: development and report of a Python-based ML/DL model for a transportation prediction task using an open dataset (PeMS/NGSIM/Uber Movement).	24
3	Field/industrial visit to a Traffic Management Centre (TMC), ITS control room, or a transport-data analytics unit, with a submitted visit report.	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	Self-paced NPTEL/MOOC module on "Python for Data Science" or "Machine Learning" fundamentals, with a completion/summary note.	24
2	Self-study and written summary of a recent research paper/case study on AI or Big Data applications in transportation engineering.	24
3	Independent exploration of an open transportation dataset (PeMS/NGSIM/Uber Movement/OpenStreetMap-based) with a short exploratory data analysis (EDA) note.	24

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
Analysis	Robust interpretation and valid results.	Generally, sound with minor errors.	Partial analysis with gaps.	Weak or incorrect analysis.
Recommendations	Strong, feasible, and context-specific.	Relevant with minor limitations.	Generic recommendations.	Incomplete or unrealistic.
Presentation	Well organized and professional.	Good organization with minor issues.	Acceptable but uneven.	Poorly presented.

AIRPORT PLANNING & DESIGN			
Course Code	**1MCTE206H** /1MCTM206H	Scheme	2026
Type of Course	PEC	Semester	II
Teaching Hours/Week (L:T:P)	42(3 : 0 : 0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90(42 : 0 : 0 : 48)	SEE Marks	50
Credits	03	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

At the end of the course, the student will be able to:

1. CO1: Explain the air transportation system, airport planning process and the factors governing selection of an airport site. (L2)
2. CO2: Determine the orientation and geometric design elements of runway and taxiway based on wind analysis and aircraft characteristics. (L3)
3. CO3: Design flexible and rigid airport pavements for given aircraft loading conditions. (L3, L4)
4. CO4: Plan airport drainage, lighting, marking and terminal/apron facilities as per ICAO/DGCA standards. (L3)
5. CO5: Analyse airport capacity, delay and prepare an airport master plan. (L4)
6. CO6: Assess the environmental impact of airports and apply sustainable/green airport concepts. (L5)

Module-1

Introduction to Air Transportation and Airport Planning:

Air transport system – structure and organization; growth trends and challenges; forecasting air travel demand – trend and analytical methods; air freight demand.

Characteristics of aircraft as they affect airport planning – wing span, undercarriage configuration, Aircraft Reference Field Length (ARFL), ICAO aerodrome reference code.

Airport planning requirements: airport master planning process as per ICAO guidelines; site selection criteria; airport classification (ICAO Annex 14, AAI/DGCA norms).

Airport zoning regulations, obstruction limitation surfaces; environmental and regulatory considerations in airport planning; financial planning of airports.

Linked COs: CO1 **Number of Hours: 08**

Module-2

Runway and Taxiway Planning and Geometric Design:

Wind analysis and wind rose diagram; determination of runway orientation.

Basic runway length and corrections for elevation, temperature, gradient and wind – computation of corrected runway length.

Geometric design elements of runway – width, longitudinal and transverse gradients, sight distance, safety area, runway–taxiway separation.

Taxiway design – exit taxiway location and design, holding apron, taxiway geometric standards.

Airport capacity and delay – factors affecting runway capacity, FAA and ICAO capacity/delay estimation methods.

Linked COs: CO2 **Number of Hours: 08**

Module-3

Airport Pavement Design:

Difference between highway and airport pavement design; aircraft wheel loading, gear configuration, Equivalent Single Wheel Load (ESWL).

Flexible pavement design – FAA method, Load Classification Number (LCN)/Pavement Classification Number (PCN) concept, CBR method.

Rigid pavement design – Westergaard's theory, FAA method for rigid pavement thickness design.

Overview of computer-aided pavement design (e.g., FAARFIELD); pavement evaluation using non-destructive testing (NDT); overlay design principles.

Linked COs: CO3 **Number of Hours: 09**

Module-4

Airport Drainage, Lighting, Marking and Terminal Facilities: Airport surface and sub-surface drainage system design.
Airfield lighting system – runway and taxiway lighting, approach lighting systems, visual aids for air traffic control.
Airport marking and signage as per ICAO Annex 14; air traffic control and communication facilities.
Terminal area planning – concepts of passenger and cargo terminal buildings, apron layout and aircraft parking configurations.
Landside facilities – access roads, curb design, multi-level/surface car parking.

Linked COs: CO4 **Number of Hours: 08**

Module-5

Airport Capacity, Environmental Impact and Sustainable Airports:
Heliports – planning and design considerations.
Airport level of service and capacity analysis; environmental impact of airports – aircraft noise, air quality, land-use compatibility.
Green/sustainable airport concepts – energy efficiency, water harvesting, renewable energy at airports.
Airport economics and financing – PPP models for airport development; case studies of Indian greenfield and brownfield airports.
Emerging trends – smart airports, digital technologies, UAV/drone integration in airport operations.

Linked COs:CO5 **Number of Hours: 09**

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Horonjeff, R., McKelvey, F.X., Sproule, W.J., Young, S.B., "Planning and Design of Airports," McGraw-Hill Education, 5th Edition.
1. Ashford, N.J., Mumayiz, S., Wright, P.H., "Airport Engineering: Planning, Design and Development of 21st Century Airports," John Wiley & Sons, 4th Edition.
2. Khanna, S.K., Arora, M.G., Jain, S.S., "Airport Engineering," Nem Chand & Bros., Roorkee.

Reference books / Manuals:

1. de Neufville, R., Odoni, A.R., "Airport Systems: Planning, Design, and Management," McGraw-Hill Education, 2nd Edition.
2. ICAO Annex 14 to the Convention on International Civil Aviation – Aerodromes, Volume I: Aerodrome Design and Operations.
3. Federal Aviation Administration (FAA), Advisory Circulars – AC 150/5300 series (Airport Design, Pavement Design).
4. Rangwala, S.C., "Airport Engineering," Charotar Publishing House.

Web links and Video Lectures (e-Resources):

1. NPTEL course on Airport Engineering / Airport Planning and Design – https://nptel.ac.in
2. International Civil Aviation Organization (ICAO) – https://www.icao.int
3. Airports Authority of India (AAI) – https://www.aai.aero
4. Federal Aviation Administration (FAA), Advisory Circulars – https://www.faa.gov

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

- Chalk-and-talk lectures supplemented with PPT presentations and video demonstrations of airport facilities.
- Discussion of case studies of Indian and international airport master plans.
- Numerical problem-solving sessions on runway length correction, wind rose analysis and pavement thickness design.
- Use of software/GIS tools for airport site evaluation and layout planning.
- Guest lectures / interaction with industry and Airports Authority of India (AAI) experts.
- 6. Group discussions, seminars and quizzes on emerging airport technologies and sustainable airport concepts.

Assessment Structure (both CIE and SEE)

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A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to a subject/course only if he/she secures not less than 50% of the aggregate marks obtained in CIE and SEE taken together.

Continuous Internal Evaluation:

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1	Study of ICAO Annex 14 provisions and preparation of a compliance checklist for an existing airport	24
2	Site / virtual study visit report of an airport terminal, apron and airside facilities	24
3	Numerical exercises on runway length correction, wind rose analysis and airport pavement thickness design	24

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1	NPTEL / MOOC course on Airport Engineering / Airport Planning and Design	08
2	Review of FAA Advisory Circulars on airfield pavement design and preparation of a summary note	04
3	Case study report on planning features of a Greenfield airport project in India	06
11	(Add rows if required)	

Sample rubrics for TW activities:

Criteria	4 - Excellent	3 - Good	2 - Satisfactory	1 - Needs Improvement
Problem understanding	Clear problem framing with strong justification.	Mostly clear with minor gaps.	Basic attempt with limited clarity.	Poorly defined problem.
Data and method	Appropriate data and sound methodology.	Mostly appropriate with minor issues.	Limited data or partial method.	Inadequate or incorrect method.
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