CURRICULUM & SYLLABI

M.Tech. TRANSPORTATION ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship, and Technological services to society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial, and ethical future professionals fit for the globally competitive environment.
- Allowing stakeholders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth-creating center to serve societal needs.

Vision and Mission of the Department
CIVIL Engineering

VISION

To be a knowledge nerve centre in civil engineering education, research, entrepreneurship, and industry outreach services for creating sustainable infrastructure and enhancing the quality of life.

MISSION

- Generate a specialised cadre of civil engineers by imparting quality education and training.

- Attain international standards in teaching, research, and consultancy with global linkages.

Program: M.Tech. Transportation Engineering

Program Educational Objectives

The graduating students of the Transportation Engineering program will be able to:

PEO-1	Plan, design, construct, operate and maintain safe, cost-effective, and sustainable transportation systems in the context of environmental, economic, and social requirements.
PEO-2	Become competent professionals to fit into a broad range of career opportunities available in the transportation industry, research, government, and other fields.
PEO-3	Demonstrate good communication and management skills and leadership qualities to work effectively and lead interdisciplinary teams in rapidly changing and diverse workplaces.
PEO-4	Engage in lifelong learning by participating in technical events, conferences, workshops, seminars, events of professional societies, and allied activities for both personal development and career growth.
PEO-5	Execute complex transportation projects and evaluate their impact on society with an understanding of professional ethics and social responsibility.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
Generate a specialised cadre of civil engineers by imparting quality education and training.	3	3	2	2	3
Attain international standards in teaching, research, and consultancy with global linkages.	3	3	2	3	2

1-Slightly; 2-Moderately; 3-Substantially

Program: M.Tech. Transportation Engineering

Program Outcomes

At the end of the Transportation Engineering program, the graduating students will be able to:

PO-1	Engage in critical thinking and pursue research/investigations to evolve solutions for multi-faceted real-life problems.
PO-2	Communicate effectively on complex engineering activities with the engineering community and society and write and present technical reports.
PO-3	Demonstrate a higher level of professional skills to tackle multidisciplinary and complex problems related to Transportation Engineering.
PO-4	Plan, analyse, design, synthesise, execute, and sustainably manage complicated transportation infrastructure projects locally and globally.
PO-5	Provide cost-effective and technology-driven solutions for transportation-related societal problems, with good professional and ethical responsibility.
PO-6	Function as a member of a multi-disciplinary team and assume a leadership role in executing transportation infrastructure projects while updating skill sets required continuously throughout professional life

CURRICULUM
M.Tech. Transportation Engineering

1st Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE66001	Urban Transportation Planning	3-1-0	4
2	CE66003	Traffic Analysis and Design	3-0-0	3
3	CE66005	Pavement Analysis and Design	3-1-0	4
4	CE660XX	Professional Elective – I	3-0-0	3
5	CE660XX	Professional Elective – II	3-0-0	3
6	CE66007	Traffic Measurements Laboratory	0-1-2	2
7	CE66009	Transportation Analytics Laboratory	0-1-2	2
			Total Credits	**21**

Professional Elective Courses:

Professional Electives I, II		
S. No.	**Code**	**Course Title**
1	CE66021	Characterisation of Pavement Materials
2	CE66023	Highway Construction Practices
3	CE66025	Low-Volume Road Engineering
4	CE66027	Optimisation Methods in Transportation
5	CE66029	Pavement Drainage Systems
6	CE66031	Sustainable Transportation
7	CE66033	Traffic Control and Management
8	CE66035	Transport and Environment
9	CE66037	Transportation Data Analysis
10	CE66039	Transportation Demand and Systems Management

2nd Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE66002	Advanced Travel Demand Modelling	3-1-0	4
2	CE66004	Geometric Design of Transportation Facilities	3-1-0	4
3	CE660XX	Professional Elective - III	3-0-0	3
4	CE660XX	Professional Elective – IV	3-0-0	3
5	CE660XX	Professional Elective – V	3-0-0	3
6	CE66006	Pavement Materials and Evaluation Laboratory	0-1-2	2
7	CE66008	Transportation Software Laboratory	0-1-2	2
8	CE66096	Minor Project	0-0-0	2
			Total Credits	**23**

Professional Elective Courses:

Professional Electives III, IV, V		
S. No.	**Code**	**Course Title**
1	CE66022	Artificial Intelligence and Machine Learning in Transportation
2	CE66024	Airport Infrastructure Planning and Design
3	CE66026	Big Data Analytics in Transportation
4	CE66028	Freight Transportation
5	CE66030	Geoinformatics for Transportation
6	CE66032	Intelligent Transportation Systems
7	CE66034	Land Use and Regional Transportation Planning
8	CE66036	Pavement Evaluation and Rehabilitation
9	CE66038	Pavement Management System
10	CE66040	Public Transportation Systems
11	CE66042	Railway Infrastructure Planning and Design
12	CE66044	Road Safety Engineering
13	CE66046	Traffic Flow Modeling and Simulation
14	CE66048	Transport Economics and Project Appraisal
15	CE66050	Transportation Network Analysis

3rd Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE67089	Seminar and Technical Writing	0-0-0	2
2	CE67091	Summer Internship / Research Experience (SIRE)	0-0-0	2
3	CE67093	Comprehensive Viva- Voce	0-0-0	2
4	CE67097	Dissertation Part – A	0-0-0	8
		Total Credits		14

4th Semester

S. No.	Code	Course Title	L-T-P	Credits
1	CE67098	Dissertation Part – B	0-0-0	12
		Total Credits		12

The Overall Credit Structure

S. No.	Courses	No. of Courses Offered					Credits
		I Year		II Year		Total	
		I Sem	II Sem	I Sem	II Sem		
A	Professional Core Courses (PCC) (24-33 credits)						
	1. Theory Courses	3	2	-	-	5	19
	2. Laboratory Courses	2	2	-	-	4	8
	Sub Total	**5**	**4**	**-**	**-**	**9**	**27**
B	Professional Elective courses (PEC) (12-18 credits)						
	Theory Courses	2	3	-	-	5	15
C	Minor Project	-	1	-	-	1	2
D	Summer Internship/ Research Experience (SIRE)	-	-	1	-	1	2
E	Seminar and Technical Writing	-	-	1	-	1	2
F	Comprehensive Viva-Voce (CVV)	-	-	1	-	1	2
G	Dissertation Work (DW)	-	-	A	B	2	20
	Grand Total	7	8	4	1	20	70

SYLLABI
M.Tech. Transportation Engineering

1st Semester

CE66001 **3-1-0 (4)**

Urban Transportation Planning

Pre-Requisites: NIL

Course Outcomes:

CO-1	Differentiate different urban forms and structures
CO-2	Identify urban transportation problems.
CO-3	Develop a database for the calibration of travel demand models.
CO-4	Estimate urban travel demand.
CO-5	Plan urban transport networks.
CO-6	Identify urban transport corridors and prepare urban transportation plans.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	2	2	3	-
CO-2	3	-	2	2	3	-
CO-3	3	-	2	3	3	-
CO-4	3	-	2	3	2	-
CO-5	3	-	2	2	2	-
CO-6	3	-	2	3	2	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Urban Forms and Structures: Urbanization and Migration, Findings of Commission on Urbanization, Urban forms: Garden City, Linear City, Radburn, Urban Neighborhood, Precinct, MARS, Le Corbusier, Collin Buchanan. Urban structures: Centripetal type, Grid type, linear type, and directional grid type; Evolution of spatial structure.

Urban Transportation Problems and Policy: Urban Transportation Issues, Travel Characteristics, Evolution of Planning Process, Supply and Demand – Systems approach; NUTP, Recommendations of 12th FYP and NTDP; Smart Cities, Service Level Benchmarks.

Travel Demand Approaches: Trends, Overall Planning Process, Long-term vs. Short-term Planning, Types of Plans, Master Plans, Demand Function, Independent Variables, Travel Attributes, Assumptions in Demand Estimation, Sequential and Simultaneous Approaches, Aggregate and Disaggregate Techniques, UTPS Approach.

Data Collection and Inventories: Collection of data – Organisation of surveys and Analysis, Study Area, Zoning, Types, and Sources of Data, Roadside Interviews, Home Interview Surveys, Commercial Vehicle Surveys, Sampling Techniques, Expansion Factors, Accuracy Checks, Use of Secondary Sources, Economic data: Income, Population, Employment, Vehicle Owner Ship.

Trip Generation: Trip Generation Analysis: Zonal Models, Category Analysis, Household Models, Trip Attraction Models, Commercial Trip Rates.

Trip Distribution: Trip Distribution: Growth Factor Methods, Gravity Models, Opportunity Models, Time Function Iteration Models.

Mode Split: Mode Choice Behavior, Competing Modes, Mode Split Curves, Models, and Probabilistic Approaches.

Traffic Assignment: Basic Elements of Transport Networks, Coding, Route Properties, Path Building Criteria, Skimming Tree, All-or-Nothing Assignment, Capacity Restraint Techniques, Reallocation of Assigned Volumes, Equilibrium Assignment, and Diversion Curves.

Corridor Identification - Plan Preparation and Evaluation: Selection of Corridor, Corridor Identification, Corridor deficiency Analysis; Multimodal Transportation Planning, TOD; Travel Forecasts to Evaluate Alternative Improvements, Impacts of New Development on Transportation Facilities; Pivot Point Analysis, Environmental and Energy Analysis.

Learning Resources:

Textbooks:

1. C. Jotin Khisty, B. Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. C.S. Papacostas, P.D. Prevedouros; Transportation Engineering and Planning; Pearson, 2015, Third Edition.

Reference Books:

1. B.G. Hutchinson; Principles of Urban Transportation System Planning, Hutchinson, Allen, Taylor & Francis, 1986.
2. David Johnson Victor, S. Ponnuswamy; Urban Transportation: Planning, Operation and Management, Tata McGraw-Hill Education Pvt. Ltd., 2012, First Edition.
3. ITE, Michael D. Meyer; Transportation Planning Handbook, Institute of Transportation Engineers, John Wiley & Sons, 2016, Fourth Edition.
4. Luis G. Willumsen, Juan de Dios Ortuzar; Modelling Transport, John Wiley & Sons, 2024, Fifth Edition.
5. Michael D. Mayer, Eric J. Miller; Urban Transportation Planning: A Decision-oriented Approach, McGraw Hill, 2001, Second Edition.
6. Michael J. Bruton; Introduction to Transportation Planning, Routledge Library Editions: Global Transport Planning, 2023.
7. S Raghava Chari, Urban Transportation Planning Lecture Notes, REC Warangal, 1990.

Online Resources:

1. http://www.nptelvideos.in/2012/11/urban-transportation-planning.html
2. https://nptel.ac.in/courses/105107067/
3. https://ocw.mit.edu/courses/civil-and-environmental-engineering/1-252j-urban-transportation-planning-fall-2016/
4. https://olc.worldbank.org/content/integrated-urban-transport-planning-self-paced

CE66003 **3-0-0 (3)**

Traffic Analysis and Design

Pre-Requisites: NIL

Course Outcomes:

CO-1	Estimate essential characteristics of the traffic stream.
CO-2	Explore various methods of traffic data collection.
CO-3	Model traffic stream behaviour at the micro and macro levels.
CO-4	Determine the capacity of highways.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	1	1	1
CO-2	3	3	3	3	3	2
CO-3	3	3	3	3	3	1
CO-4	3	3	3	3	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Components of Traffic System: Introduction to Traffic Engineering, Human-Vehicle-Road User-Environment system, Characteristics of road users, characteristics of vehicles, Characteristics of Pedestrians.

Traffic Data Collection Studies: traffic study components and types of data; volume studies; speed studies; travel time and delay studies; intersection studies; pedestrian studies; parking studies; vehicle detection methods; advanced methods: GPS, Instrumented Vehicles, Image Processing, Bluetooth, Infrared methods, Drone video analysis, Sample selection, and region traffic counts.

Characteristics of Traffic: Fundamental parameters of traffic and relationships; Time headways, temporal, spatial, and flow patterns; Growth factors; Interrupted and un-interrupted traffic; Microscopic and macroscopic speed characteristics; Vehicular speed trajectories; Speed characteristics-mathematical distributions; Speed and travel time variations.

Macroscopic Traffic Stream Models: Stream flow fundamentals; family of models; Hydrodynamic and Kinetic Analysis of Traffic; continuity equation; waves in traffic; Traffic fluid state considerations; Platoon diffusion.

Microscopic Traffic Stream Models: Car-following models; Stimulus-response models; distance-based models; psychophysical models; neuro-fuzzy models; gap acceptance models; mixed traffic flow behaviour: non-lane-based movement and challenges of modelling Indian mixed traffic; Heterogeneity in traffic.

Highway Capacity Analysis: Capacity and level of service concepts; Factors affecting capacity and LOS; Two-lane, Freeway, and multi-lane capacity analysis; Capacity of Urban arterials; Design and Capacity analysis of Signalized Intersections; US Highway Capacity Manual (HCM) and IRC standards, Indo-HCM standards.

Design of Signalised Intersections: Warrants for signalisation, design control variables, lost time estimation, saturation flow rate and capacity, dilemma zone analysis, signal timing design methods, pedestrian considerations, queue length and control delay, signal coordination for urban streets, adaptive traffic signals, design examples.

Learning Resources:

Textbooks:

1. Adolf Darlington May, Traffic Flow Fundamentals, Prentice Hall, 1990 (Digitized in 2011).
2. L.R. Kadiyali, Traffic Engineering and Transportation Planning, Khanna Publishers, 2024, Ninth Edition.
3. Partha Chakraborty, Animesh Das, Principles of Transportation Engineering, PHI Learning, 2017, Second Edition.

Reference Books:

1. C. Jotin Khisty, B. Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2020, 7th Edition.
3. IRC:93-1985, Guidelines on Design and Installation of Road Traffic Signals, Indian Roads Congress, New Delhi, 1985.
4. Louis J. Pignataro, Traffic Engineering: Theory and Practice; Prentice Hall, Inc., 1973 (Digitized in 2011).
5. Mike Slinn, Paul Matthews, Peter Guest; Traffic Engineering Design: Principles and Practice, Elsevier, 2005, Second Edition.
6. TRB, Highway Capacity Manual: A Guide for Multimodal Mobility Analysis, The National Academies Press, Washington, DC, 2022, Seventh Edition.
7. Nicholas J. Garber, Lester A. Hoel; Traffic and Highway Engineering, Cengage Learning India, 2024, Fifth Edition.
8. Roger P Roess, William R McShane, Elena S Prassas; Traffic Engineering, Pearson Education, 2020, Fifth Edition.
9. Satish Chandra, S. Gangopadhyay, S. Velmurugan, Kayitha Ravinder; Indian Highway Capacity Manual (Indo-HCM), CSIR-CRRI, India, 2017.

Online Resources:

1. https://nptel.ac.in/courses/105/101/105101008
2. https://nptel.ac.in/courses/105/104/105104098
3. https://www.classcentral.com/course/edx-intro-to-traffic-flow-modeling-and-intelligent-transport-systems-12728
4. https://www.crridom.gov.in/sites/default/files/Indo-HCM%20Snippets.pdf
5. https://www.monash.edu/engineering/its/publications/tem2017

CE66005 **3-1-0 (4)**

Pavement Analysis and Design

Pre-Requisites: NIL

Course Outcomes:

CO-1	Analyse stresses and strains in a flexible pavement using multi-layered elastic theory and KENLAYER.
CO-2	Compute stresses and strains in a rigid pavement using Westergaard's theory and KENSLABS.
CO-3	Design a flexible pavement using various methods.
CO-4	Design a rigid pavement using various methods.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	3	3	3	1
CO-2	2	1	3	3	3	1
CO-3	2	1	3	3	3	1
CO-4	2	1	3	3	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Pavement Types and Materials: Types and component parts of pavements; highway and airfield pavements; basic characteristics of materials used in pavements.

Stresses in Flexible Pavements: Layered system concepts; stress solution for one, two, and three-layered systems; fundamental design concepts; stress analysis in flexible pavements using KENLAYER.

Stresses in Rigid Pavements: Westergaard's theory and assumptions; joints in rigid pavements; stresses due to curling, stresses, and deflections due to loading, frictional stresses; stresses in dowel bars and tie bars, dowel group action; stress analysis in rigid pavements using KENSLABS.

Factors Affecting Pavement Design: Variables considered in pavement design; classification of axle types, standard and legal axle loads, tyre pressure, contact pressure, ESWL, EWLF, and EAL concepts; traffic analysis: ADT, AADT, truck factor, growth factor, lane distribution factor, directional distribution factor, and vehicle damage factor.

Design of Flexible Pavements: IRC method of flexible pavement design; Asphalt Institute's design methods with HMA and other base combinations; AASHTO method of flexible pavement design; design of flexible pavement shoulders; introduction to mechanistic-empirical pavement design guide.

Design of Rigid Pavements: IRC method of plain jointed, jointed reinforced, continuously reinforced rigid pavement design; design of conventional and thin white topping; AASHTO method of rigid pavement design; design of rigid pavement shoulders.

Learning Resources:

Textbooks:

1. E.J. Yoder, M.W. Witczak; Principles of Pavement Design, Wiley India Pvt. Ltd., New Delhi, India, 2011, Second Edition.
2. Yang Hsien Huang, Pavement Analysis and Design, Dorling Kindersley (India) Pvt. Ltd., New Delhi, India, 2008, Second Edition.

Reference Books:

1. AI MSI-1: Thickness Design – Asphalt Pavements for Highways and Streets, Manual Series No. 1, Asphalt Institute, Kentucky, USA, 1999, Ninth Edition.
2. IRC:37-2018, Guidelines for the Design of Flexible Pavements, Indian Roads Congress, New Delhi, India, 2018, Fourth Revision.
3. IRC:58-2015, Guidelines for the Design of Plain Jointed Rigid Pavements for Highways, Indian Roads Congress, New Delhi, India, 2015, Fourth Revision.
4. IRC:118-2015, Guidelines for Design and Construction of Continuously Reinforced Concrete Pavement, Indian Roads Congress, New Delhi, India, 2015.
5. IRC: SP76-2015, Guidelines for Conventional and Thin White topping, Indian Roads Congress, New Delhi, India, 2015, First Revision.

Online Resources:

1. http://onlinepubs.trb.org/onlinepubs/archive/mepdg/guide.htm
2. http://www.trb.org/Pavements/TRBPublications.aspx
3. https://link.springer.com/article/10.1007/BF03325749
4. https://pavementinteractive.org/

CE66007 **0-1-2 (2)**

Traffic Measurements Laboratory

Pre-Requisites: NIL

Course Outcomes:

CO-1	Conduct field studies to estimate traffic flow characteristics.
CO-2	Determine the capacity and level of service of a highway element.
CO-3	Estimate parking space requirements.
CO-4	Design traffic signal systems.
CO-5	Determine causative analysis of delays.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	3
CO-2	2	3	3	3	3	3
CO-3	3	3	3	3	3	3
CO-4	2	3	3	2	3	3
CO-5	2	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Volume Studies: Direction, Duration, and Classification of Traffic Volume at Mid-Block Sections and Intersections, Manual and Mechanical Methods, Vehicle Arrival Distributions, Pedestrian and Bicycle Volume Studies.

Speed Studies: Spot Speed Studies - Radar Speed Meters, Pedestrian and Bicycle Speed Studies.

Journey Time and Delay Studies: Travel Time and Delay Studies by Floating Car Method

Gap Acceptance Studies: Study of Gaps, Lags, Critical Gaps at Intersections

Intersection Delay Studies: Delay Measurement at Uncontrolled Intersections and Signalized Intersections.

Parking Surveys: Parking Inventory and Turnover Studies.

Measurement of Driver Characteristics: Reaction Testing, Action Judgement Testing, Driver Vision Testing, Discriminative Reaction Testing, Evaluation of Driver Knowledge – Traffic Rules – Road Signs & Markings – Traffic Signs and Motor Vehicle Act Relevant clauses.

Highway Capacity Estimation: Video graphics method, Dynamic PCU estimation.

Learning Resources:

Textbooks

1. L.R. Kadiyali, Traffic Engineering and Transportation Planning, Khanna Publishers, 2024, Ninth Edition.
2. Thomas R. Currin, Introduction to Traffic Engineering: A Manual for Data Collection and Analysis, CL Engineering, 2012, Second Edition.

Reference Books

1. C. Jotin Khisty, B Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2019, Seventh Edition.
3. IRC:108-2015, Guidelines for Traffic Forecast on Highways, Indian Roads Congress, New Delhi, 2015.
4. Louis J. Pignataro, Traffic Engineering: Theory and Practice; Prentice Hall, Inc., 1973 (Digitized in 2011).
5. NASEM, TRB, Highway Capacity Manual: A Guide for Multimodal Mobility Analysis, The National Academies Press, Washington, DC, 2022, Seventh Edition.
6. Roger P Roess, William R McShane, Elena S Prassas; Traffic Engineering, Pearson Education, 2020, Fifth Edition.
7. Satish Chandra, S. Gangopadhyay, S. Velmurugan, Kayitha Ravinder; Indian Highway Capacity Manual (Indo-HCM), CSIR-CRRI, India, 2017.

Online Resources:

1. https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/s13638-019-1628-5
2. https://medium.com/goodvision/the-development-of-traffic-data-collection-cd87cc65aaab
3. https://nptel.ac.in/content/storage2/courses/105101087/downloads/Lec-32.pdf
4. https://www.crridom.gov.in/sites/default/files/Indo-HCM%20Snippets.pdf
5. https://www.dot.state.mn.us/trafficeng/publ/tem/2009/Chapter-05.pdf

CE66009 **0-1-2 (2)**

Transportation Analytics Laboratory

Pre-Requisites: NIL

Course Outcomes:

CO-1	Identify data types and sampling methods.
CO-2	Perform data analysis and interpretation using programming tools and packages
CO-3	Apply statistical tests and interpret the results.
CO-4	Develop statistical and probabilistic models for transportation data.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	-	-	1	-
CO-2	3	2	-	1	1	1
CO-3	3	2	-	2	1	1
CO-4	2	3	3	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Data Presentation and Analysis: Speed data analysis and graphical representation, box plots and speed profiles, parameter estimation, and histograms using MS Office tools and other statistical packages, such as SPSS and R Studio.

Data Sampling and Description: Sampling exercises, data storing, handling, cleaning, and descriptive analysis exercises using MS Access, Excel, and statistical tools.

Data Analysis and Statistical Inference: Speed data, vehicle arrival data, headway data, distributions, analysis, correlation, results' interpretation and multiple linear regression analysis with speed and flow data, nonlinear regression model fits, before and after significance tests on speed data, Time series analysis using transportation data. Exercises with MS Excel, SPSS, and R- studio.

Basics of Data Analysis Programming:

R tools, programming packages for data analysis, and basic and advanced analysis with MATLAB and Python.

Learning Resources:

Textbooks:

1. L.R. Kadiyali, Traffic Engineering and Transportation Planning, Khanna Publishers, 2024, Ninth Edition.
2. Simon Washington, Matthew G. Karlaftis, Fred Mannering, Panagiotis Anastasopoulos; Statistical and Econometric Methods for Transportation Data Analysis, Routledge, 2020, Third Edition.
3. Thomas R. Currin, Introduction to Traffic Engineering: A Manual for Data Collection and Analysis, CL Engineering, 2012, Second Edition.

Reference Books:

1. C. Jotin Khisty, B Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2019, Seventh Edition.

3. Louis J. Pignataro, Traffic Engineering: Theory and Practice; Prentice Hall, Inc., 1973 (Digitized in 2011).
4. NASEM, TRB, Highway Capacity Manual: A Guide for Multimodal Mobility Analysis, The National Academies Press, Washington, DC, 2022, Seventh Edition.
5. Roger P Roess, William R McShane, Elena S Prassas; Traffic Engineering, Pearson Education, 2020, Fifth Edition.
6. IRC:108-2015, Guidelines for Traffic Forecast on Highways, Indian Roads Congress, New Delhi, 2015.

Online Resources

1. https://jwcn-eurasipjournals.springeropen.com/articles/10.1186/s13638-019-1628-5
2. https://medium.com/goodvision/the-development-of-traffic-data-collection-cd87cc65aaab
3. https://nptel.ac.in/content/storage2/courses/105101087/downloads/Lec-32.pdf
4. https://www.crridom.gov.in/sites/default/files/Indo-HCM%20Snippets.pdf
5. https://www.dot.state.mn.us/trafficeng/publ/tem/2009/Chapter-05.pdf

Professional Electives – 1, 2

CE66021 **3-0-0 (3)**

Characterisation of Pavement Materials

Pre-Requisites: NIL

Course Outcomes:

CO-1	Appreciate the need for pavement material characterisation.
CO-2	Identify appropriate test conditions that are to be simulated while characterising pavement materials.
CO-3	Recognise the rationale of material inputs that are incorporated into pavement design.
CO-4	Appreciate the development of performance tests and material specifications.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	1	1	2
CO-2	3	3	2	1	1	2
CO-3	3	3	2	1	1	2
CO-4	3	3	2	1	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus

Introduction to pavement Materials: Pavement structure; Introduction to materials used in different layers; Factors affecting pavement performance, Need for material characterisation, performance data collection, specification development

Subgrade Soil and Stabilisation: Characterization of subgrade soil for pavement design – Index properties, compaction characteristics; Hydraulic conductivity; Frost susceptibility; Stiffness and Strength of soil, Resilient Modulus; Subgrade soil strength for rigid pavements; Deformation characteristics of subgrade soil; Soil Stabilisation concepts: mechanical and chemical; Geosynthetic application in pavements

Aggregates: Origin, physical and mechanical characterisation of aggregates; requirement of aggregate property in different pavement layers – aggregate gradations; aggregate packing characteristics; Factors affecting the performance of unbound aggregate layers- Selection of candidate test – Screening tests, Compaction, Shear strength, Stiffness – static and triaxial load tests, frost susceptibility, toughness and abrasion, durability; Modelling of Material stiffness in pavement design: E-CBR relationship; Mr-θ relationship; Permanent deformation behaviour of unbound aggregate layers; Recycled aggregates and Marginal aggregates in pavement construction – Physical, strength and durability requirements

Bituminous Binders: Types; Manufacture and Storage of paving grade bitumen, Constitution and structure of bitumen, Requirements of paving grade binder, Unmodified and modified bitumen, physical characterisation, Ageing phenomena – Simulative tests, Rheology of bitumen – the concept of linear visuo-elasticity, rheological characterisation of binders, Grading of Binders – Penetration, Viscosity, and Performance Grading; Performance tests to assess rutting, cracking, healing and ageing susceptibility, Review of binder performance specifications, Rheological modelling of performance tests. Chemical characterisation of bitumen – FTIR, SARA Analysis; bituminous emulsion- manufacturing process, Storage and handling, Breaking phenomenon, Modification of bitumen emulsion properties, Classification of bitumen emulsions, Grading as per BIS

Bituminous Mix Design and Performance tests: Objectives of bituminous mix design, Material selection and Aggregate batching, Selection of mixing and compaction temperatures, Volumetrics of compacted bituminous mixes, Marshall mix design, Superpave mix design, Balanced Mix design

concept; Mixture performance tests – Resilient and Dynamic Modulus, Permanent Deformation, Fatigue cracking, Non-load associated cracking, Moisture Induced Damage; Specification development; RAP Mix design; Cold mix design

Cement and Cement Concrete: Cement-chemical composition, physical properties, admixtures, Physical properties of cement concrete related to pavement application, Design of cement concrete for pavements, Special types of cement concrete: polymer concrete composites, Sulphur concrete composites, Fiber reinforced concrete, ferrocement, roller compacted concrete, and high strength concrete.

Learning Resources

Textbooks:

1. AI MS-2, Asphalt Mix Design Methods, Manual Series No. 2 (MS-2), Asphalt Institute, Kentucky, USA, 2014, Seventh Edition.
2. NCAT, Hot Mix Asphalt Materials, Mixture Design and Construction, National Center for Asphalt Technology, 2023, Third Edition.
3. Robert N. Hunter, Andy Self and John Read, The Shell Bitumen Handbook, ICE Publishing, 2015, Sixth Edition.

Reference Books:

1. P.T. Sherwood, Alternative materials in road construction, Thomas Telford, New York, USA, 2001, Second Edition.
2. Prithvi Singh Kandhal, A. Veeraragavan, Rajan Choudhary; Bituminous Road Construction in India, PHI Learning Pvt. Ltd., New Delhi, India, 2023, Second Edition.
3. Ministry of Road Transport and Highways, Specifications for Road and Bridge Works, Indian Roads Congress, New Delhi, India, 2013, Fifth Revision.
4. IRC:44-2017, Guidelines for Cement Concrete Mix Design for Pavements, The Indian Roads Congress, New Delhi, India, 2017.

Online References:

1. https://www.eng.auburn.edu/research/centers/ncat/research/other-publications.html
2. https://www.pavementinteractive.org/

CE66023 **3-0-0 (3)**

Highway Construction Practices

Pre-Requisites: NIL

Course Outcomes:

CO-1	Develop construction procedures for subgrade, unbound, and bound granular layers.
CO-2	Formulate strategies to produce optimal bituminous mixes.
CO-3	Propose appropriate construction procedures for bituminous and concrete layers.
CO-4	Choose appropriate pavement quality-control tests and quantify construction variability.
CO-5	Demonstrate the knowledge and skills for effective construction and quality control of concrete pavements.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	2	2
CO-2	3	3	2	3	2	1
CO-3	3	2	3	2	3	2
CO-4	2	2	1	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Highway Construction and Management: Phases of highway construction projects; Pre-construction activities; construction supervision; field inspection and quality assurance.

Construction of Unbound and Bound Granular Layers: Gradation and material quality requirement for granular subbase and base layers; blending and proportioning; compaction requirements; field quality control; stabilised subbase and base layers: mix design, placing, laying, and compaction requirements; crack relief and SAMI layer; geosynthetic application reinforced granular layers; construction of subsurface drainage for highways and airfield pavements.

Asphalt Plant Operations, Transport, and Delivery: Asphalt plant functions, batch, drum, and continuous mix plants, emission controls, mix storage, and asphalt mix transport: planning, haul trucks, dressing segregation; material transfer vehicle; visual inspection of the mix, and troubleshooting.

Asphalt Paving Operation: Preparing for paving: new construction/overlay, prime coat, tack coats: recommended, applications, distribution, verifying the application rates; asphalt pavers and compaction; screed operations and control; joints; compaction mechanics; cold weather paving; roller types; sequence of rolling: breakdown, intermediate, and finishing; tender mixes and component troubleshooting; quality assurance: sampling methods for asphalt mixtures, laboratory design versus field production; quality control tests; volumetric adjustments, density specifications.

Construction of Concrete Pavements: Concrete production; preparation of subgrade and base; reinforcement presetting for JPCP and CRCP; establishing string line; PCC slab constructions: slip form paving, fixed form paving; curing process; quantification of curing effectiveness; quality control tests; rehabilitation of concrete pavements.

Learning Resources:

Textbooks:

1. Prithvi Singh Kandhal, A. Veeraragavan, Rajan Choudhary; Bituminous Road Construction in India, PHI Learning Pvt. Ltd., New Delhi, India, 2023, Second Edition.
2. Ministry of Road Transport and Highways, Specifications for Road and Bridge Works, Indian Roads Congress, New Delhi, India, 2013, Fifth Edition.
3. Ministry of Rural Development, Specifications for Road and Bridge Works, Indian Roads Congress, New Delhi, India, 2014, Fifth Revision.
4. Alberto Munguia Mireles, Highway Construction and Inspection Field book: Project Construction Management Book, iUniverse, 2014, First Edition.

Reference books:

1. Norbert J. Delatte, Concrete Pavement Design, Construction and Performance, CRC Press, 2014, Second Edition.
2. MS-22, Construction of Quality Asphalt Pavements, Asphalt Institute, 2020, Third Edition.
3. Sanford E. B., Concrete in Highway Construction: A Textbook for Highway Engineers and Supervisors, Thompson, 2022.

Online Resources

1. https://pavementinteractive.org/reference-desk/construction/site-preparation/subgradepreparation-for-new-pavements/
2. https://www.virginiadot.org/vtrc/main/online_reports/pdf/15-r6.pdf

CE66025 **3-0-0 (3)**

Low-Volume Road Engineering

Pre-Requisites: NIL

Course Outcomes:

CO-1	Plan low-volume road network.
CO-2	Design low-volume road geometrics.
CO-3	Identify appropriate materials and cost-effective technologies for LVRs.
CO-4	Analyse and design flexible and rigid pavements for LVRs.
CO-5	Select an appropriate pavement construction technique and quality control tests.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	2	3	2
CO-2	3	2	2	3	3	2
CO-3	2	2	2	2	3	2
CO-4	3	1	2	3	3	2
CO-5	3	2	2	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Low Volume Road Network Planning: significance, definitions, characteristics of LVRs; PMGSY; development of LVRs in India; Rural roads vision 2025; international scenario of LVRs developments; Master plan and core network concepts; network planning of LVRs and models; detailed project report preparation; environmental issues; and GIS-based rural road network planning.

Geometric Design of LVRs: topography and physical features; traffic; geometric design standards for LVRs concerning PMGSY; Hill Roads: design concepts and criteria, cross-section elements, CD works, horizontal alignment, vertical alignment, and traffic engineering requirements; international recommendations, experience, and various country standards on LVR geometric designs and discussion on case studies.

Marginal and New Materials: This section provides an overview of conventional materials, waste materials, sources of marginal materials, guidelines, subgrade stabilisation, dealing with poor subgrades, a framework for appropriate use of marginal materials, new technologies and their design aspects, Geosynthetic applications, functions, and design methods.

Pavement Design of LVRs: LVR design principles, vehicle classifications, traffic volumes, ESALs per vehicle class, design traffic classes, pavement design methods for LVRs: empirical approaches, AUSTROADS pavement, AASHTO, US MEPDG, flexible and rigid pavement using IRC methods, and gravel road design.

Construction and Specifications of LVRs: conventional construction methods, specifications, new technologies and construction aspects, benefits, case studies, low-cost construction techniques, quality control and assurance mechanism, and MoRD specifications.

Learning Resources:

Textbooks:

1. AASHTO, Guidelines for Geometric Design of Low Volume Roads, American Association of State Highway and Transport Officials, Washington, DC, 2019, Second Edition.
2. Gordon Keller, James Sherar; Low-Volume Roads Engineering: Best Management Practices Field Guide, USDA Forest Service / USAID, 2003.
3. Robert A. Douglas, Low Volume Road Engineering: Design, Construction and Maintenance, CRC Press, 2018.

Reference Books:

1. E.J. Yoder, M.W. Witczak; Principles of Pavement Design, Wiley India Pvt. Ltd., New Delhi, India, 2011, Second Edition.
2. Ethiopian Roads Authority, Manual for Low Volume Roads: Ethiopia, Parts A-G, Federal Democratic Republic of Ethiopia, 2016.
3. Michael J. Bruton, An Introduction to Transportation Planning, Routledge Library Editions: Global Transport Planning, 2021.
4. Ministry of Rural Development, Specifications for Rural Roads, Indian Road Congress, New Delhi, 2014, First revision.
5. IRC:52-2019, Guidelines for the Alignment Survey and Geometric Design of Hill Roads, Indian Road Congress, New Delhi, 2019, Third Revision.
6. IRC: SP103-2014, Guidelines on Tree Plantation along Rural Roads, Indian Road Congress, New Delhi, 2014.
7. IRC: SP126-2019, Guidelines for the Design and Construction of Low Volume Rural Roads Using Jute Geotextiles Indian Road Congress, New Delhi, 2019.
8. IRC: SP20-2002, Rural Road manual, Indian Roads Congress, New Delhi, 2002.
9. IRC: SP62-2014, Guidelines for Design and Construction of Cement Concrete Pavements for Low Volume Roads, Indian Road Congress, New Delhi, 2014, First Revision.
10. IRC: SP72-2015, Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads, Indian Road Congress, New Delhi, 2015, First Revision.
11. IRC: SP89(P-II)-2018, Guidelines for the Design of Stabilized Pavement, Indian Road Congress, New Delhi, 2018.

Online Resources:

1. http://omms.nic.in/ReferenceDocs/PMGSY_Guidelines.pdf
2. http://www.trb.org/LowVolumeRoadsConference/LVR10Literature.aspx
   https://pdf.usaid.gov/pdf_docs/PNADB595.pdf
3. https://pmgsy.nic.in/publications
4. https://www.fs.fed.us/t-d/programs/forest_mgmt/projects/lowvolroads/

CE66027 **3-0-0 (3)**

Optimisation Methods in Transportation

Pre-Requisites: **NIL**

Course Outcomes:

CO-1	Differentiate various optimisation techniques for the transport network.
CO-2	Analyse the characteristics of the transport network.
CO-3	Formulate an LP model for the transportation problem.
CO-4	Analyse multicriteria optimisation for optimality.
CO-5	Apply different inventory methods to optimise logistics distribution.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	-	-	-
CO-2	3	2	2	2	-	-
CO-3	3	3	2	2	-	1
CO-4	3	2	2	2	-	-
CO-5	3	3	3	3	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Basics of Optimisation: General methods for operation research models; Objective function, Constraints and Constraint surface; Formulation of design problems as mathematical programming problems, Classification of optimisation problems, Optimisation techniques classical and advanced techniques; introduction to linear and non-linear programming formulation of different models

Network Analysis: Network definition and network diagram representation, network attributes, minimum spanning tree, maximum flow, and minimum cost network flow problems.

Linear Programming (LP) in Transportation: Introduction to LP and formulation of linear programming problems, Canonical form of LP problem; Assumptions in LP Models; Elementary operations; graphical solution method, alternative or multiple optimal solutions, unbounded solutions, infeasible solutions, maximisation – simplex algorithms.

Duality Theory: Primal vs. dual formulations, duality theory, complementary slackness, and sensitivity analysis.

Mathematical Optimisation: Optimality Criteria for the Unconstrained Problems, Optimality Criteria for the Constrained Problems, Optimality Criteria for General Optimisation Problems, Post optimality Analysis; Multicriteria Optimisation, Optimisation on Fuzzy Sets.

Inventory Models and Transportation Problem: Introduction to inventory control, deterministic inventory model, EOQ model with a quantity discount, initial basic feasible solutions of balanced and unbalanced transportation/assignment problems, optimal solutions.

Learning Resources:

Textbooks:

1. Didem Cinar, Konstantinos Gakis., Panos M. Pardalos (Eds), Sustainable Logistics and Transportation: Optimization Models and Algorithms, Springer, 2017, First Edition.
2. Singiresu S. Rao, Engineering Optimisation: Theory and Practice, Wiley Publisher, 2019, Fifth Edition.

Reference Books:

1. Ennio Cascetta, Transportation Systems Analysis: Models and Applications, Springer, 2012, Second Edition
2. Jasbir Singh Arora, Introduction to Optimum Design, Academic Press Inc, 2016, Fourth Edition
3. Matti Pursula, Jarkko Niittymäki (Eds); Mathematical Methods on Optimization in Transportation Systems, Springer; 2001, First Edition.

Online resources

1. https://nptel.ac.in/courses/112106134
2. https://sboyles.github.io/teaching/ce367R

CE66029 **3-0-0 (3)**

Pavement Drainage Systems

Pre-Requisites: **NIL**

Course Outcomes:

CO-1	Assess the impact of water on pavement performance.
CO-2	Judge requirement of different cross drainage structures.
CO-3	Design surface drainage system.
CO-4	Evaluate the performance of pavement concerning sub-surface drainage methods.
CO-5	Plan sustainable drainage systems.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	1	2	3	2
CO-2	3	2	2	3	2	2
CO-3	3	2	2	3	3	2
CO-4	2	2	2	3	3	1
CO-5	3	2	2	3	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Pavement Drainage Structures: Pavement types, relevant pavement materials, source and role of water, factors affecting the flow of water, hydraulic conductivity, estimation of surface runoff, typical drainage in pavements, detention and retention ponds, estimation of discharge of detention and retention of ponds, and impact of water on pavement distresses.

Cross Drainage Works: The necessity of culverts, planning of culverts and effective drainage, types and size of culverts, ditches, side drains design considerations, common culverts problems and solutions, disposal of drainage water and maintenance of drainage system, stormwater harvesting methods, and benefits of groundwater recharge.

Surface Drainage: General, the effect of standing water on pavement performance, factors affecting the surface drainage, geometric features of pavement, maintenance of side drains, medians, culverts, the hydrological requirement of roadside drains, factors affecting runoff, and design methodologies.

Subsurface Drainage: Permeable bases stabilised and unstabilised bases, aggregate layers, geotextiles separate layers, longitudinal drains, filter design, geocomposite design, and capillary barrier drain, determination of pavement permeability, and framework for drainage systems under new concrete pavements.

Sustainable Drainage: Porous asphalt pavement design, construction, and maintenance; design of porous concrete; design of permeable interlocking concrete pavements, construction, and maintenance; sustainable urban drainage systems; and applicability of specific SUDS structures.

Learning Resources:

Textbooks:

1. E.J. Yoder, M.W. Witczak; Principles of Pavement Design, Wiley India Pvt. Ltd., New Delhi, India, 2011, Second Edition.
2. Phil Pitman, External Works, Roads, and Drainage: A Practical Guide, CRC Press, 2017, First Edition.
3. Sivakumar Babu G.L., Prithvi S. Kandhal; Pavement Drainage: Theory and Practice, CRC Press, New Delhi, India, 2019.

Reference Books:

1. Caleb N. Arika, Dario J. Canelon, John L. Nieber, Subsurface Drainage Manual for Pavements in Minnesota, LRRB, Minnesota Department of Transportation, 2009.
2. J. Paul Guyer, An Introduction to the Principles of Pavement Drainage, Independently Published, 2013.
3. S.N. Sachdeva, Design of Road Drainage System: A Design Reference Book, Create Space Independent Publishing Platform, 2018.
4. W Hudson, Ralph Haas, Waheed Uddin; Infrastructure Management: Integrating Design, Construction, Maintenance, Rehabilitation, and Renovation, McGraw Hill Education, 1997.
5. AASHTO Drainage Manual, American Association of State Highway Officials, 2014.
6. AASHTO Highway Drainage Guide, American Association of State Highway and Transportation Officials, Washington DC, 2007, Fourth Edition.
7. IRC: SP20-2013, Guidelines on Urban Drainage, Indian Roads Congress, New Delhi, 2013.

Online Resources:

1. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4986
2. https://freevideolectures.com/course/3352/geosynthetics-engineering-in-theory-and practice/21
3. https://www.youtube.com/watch?v=YQDR6fro8mM

CE66031 **3-0-0 (3)**

Sustainable Transportation

Pre-Requisites: **CE6601**

Course Outcomes:

CO-1	Identify a sustainable transportation system.
CO-2	Consider sustainability in providing mode choices for the public.
CO-3	Develop and plan pedestrian facilities for sustainable transportation.
CO-4	Plan for bicycle facilities.
CO-5	Suggest policies that improve the sustainability of transportation.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	3	2	3	-
CO-2	2	2	3	2	3	-
CO-3	2	2	3	2	3	-
CO-4	2	3	3	1	3	-
CO-5	1	2	3	2	3	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Problem of Sustainability in Transport: Energy use in the transport sector; Transport and climate change; Greenhouse gas emissions, urban air quality, Congestion, and sustainability, Sustainable Development Goals; Sustainable transport concepts – society, environment and economy, indicators based approach Policy initiatives and programs on sustainable transport - global perspectives (SUMP, KYOTO Protocol); national policies (NUTP, CMP and NAPCC) and local initiatives; Transport system effectiveness and efficiency – service level benchmarks

Planning for Sustainability: Urban form, Indicator based planning, Land-use plans, zoning schemes and provisions, Integrated land use and transport planning and neighbourhood designs, Compact City, Public Transit, TOD, NMT, First and Last Mile Connectivity; Integrated multi-modal transport networks, Regulations and Enforcements (Parking policy, Congestion pricing).

Evaluation of Non-Motorized Transportation: Surveys, Demand Estimation, and Analysis; Crash Data, Barrier Effect; Cycling Condition Evaluation Techniques; Pedestrian Condition Evaluation Techniques; Prioritizing Improvements and Selecting Preferred Options.

Planning for Pedestrians: Types of pedestrians and Characteristics; Pedestrian facilities and planning; Pedestrian standards and improvements; Pedestrian Facility Design, LOS; Pedestrian safety programs.

Planning for Bicyclists: Types of cyclists and Bikeways; Integrating cycling into roadway planning; Bicycle network planning; Accommodating cyclists on rural roads; Design of Bicycle boulevards/bike paths; Bicycle Parking/storage Facilities; Roadway maintenance for cyclists.

Sustainable Policies: Continuum of Policies, speed and speed limit policies, national policies, sustainable travel demand management, public awareness, pricing transportation, total cost of transportation, pricing, and taxation.

Sustainable Technology: Telecommuting, Information and Communication Technologies, E-commerce, Alternative Cleaner Fuels, vehicle technologies, fuel cells, and Intelligent Transport Systems.

Learning Resources:

Textbooks:

1. Henrik Gudmundsson, Ralph P. Hall, Greg Marsden, Josias Zietsman, Sustainable Transportation: Indicators, Framework, and Performance Management, Springer, 2016.
2. Preston L. Schiller, Jeffrey R. Kenworthy, An Introduction to Sustainable Transportation: Policy, Planning and Implementation, Routledge, 2017, Second Edition.
3. William R. Black, Sustainable Transportation: Problems and Solutions, Guilford Press, New York, 2010.

Reference Books:

1. Carey Curtis (Ed), Handbook of Sustainable Transport, Edward Elgar, 2020.
2. Mehrdad Ehsani, Fei-Yue Wang and Gary L. Brosch (Eds.), Transportation Technologies for Sustainability, Springer-Verlag, New York, 2013.
3. Robert Cervero, Accessible Cities and Regions: A Framework for Sustainable Transport and Urbanism in the 21st Century, Center for Future Urban Transport, Institute of Transportation Studies, University of California, Berkeley, 2005.
4. Rodney Tolley (Ed), Sustainable Transport: Planning for Walking and Cycling in Urban Environments, CRC Press, 2003.

Online Resources

1. https://onlinecourses.nptel.ac.in/noc21_ce74/preview
2. https://www.cutr.usf.edu/workforce/education/sustainable-transportation-course/

CE66033 **3-0-0 (3)**

Traffic Control and Management

Pre-Requisites: **NIL**

Course Outcomes:

CO-1	Select traffic regulations and control strategies.
CO-2	Identify and suggest speed control measures.
CO-3	Design traffic control systems for roads.
CO-4	Develop traffic management strategies on local and regional roads.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	1	-	-	1
CO-2	-	2	2	3	2	1
CO-3	3	3	3	3	2	1
CO-4	2	3	3	3	2	1
CO-5	3	3	2	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Traffic Control Concepts and Regulations: Traffic control and its necessity, types, emerging technologies, benefits, strategies, legislation related to traffic control, highway and urban road traffic acts, traffic control warrants, traffic control aids, road signs and signals for traffic control, and sign placement.

Speed Control Measures: Free speed and speed limits, road works speed limit, highway speed control, speed control in residential areas, countermeasures; speed humps, speed cushions, speed tables, raised intersection, Centre Island, surface treatments and markings, in-roadway warning lights, community awareness and education, speed enforcement, signs for speed control, case studies.

Urban and Interurban Traffic Control: Control variables, mid-block and intersection traffic control studies, arterial roads and network controls, traffic at isolated intersections and control, signals and controllers, basic signal design, bicycle and pedestrian considerations, and work zones.

Traffic Control for Vulnerable and Disabled Road Users: School zone traffic control, control systems, special controls, measure of effectiveness, public transport priorities, signal coordination, interurban highways, high-speed corridors, design of rural highways and control systems, high-speed expressways, access control, design examples, and case studies.

Traffic Management and Strategies: Traffic system and management centres, communication and information dissemination, urban traffic management, residential neighbourhood traffic management, traffic management methods, integrated traffic management system, ramp metering analysis, Local-level traffic planning and management, traffic management case studies.

Learning Resources:

Textbooks:

1. H. Gene Hawkins, Guidelines for Conducting a Traffic Signal Warrant Analysis, Texas Transportation Institute, 2008, Second Edition.
2. Nicholas J. Garber, Lester A. Hoel; Traffic and Highway Engineering, Cengage Learning India, 2024, Fifth Edition.

3. Roger P Roess, William R McShane, Elena S Prassas; Traffic Engineering, Pearson Education, 2020, Fifth Edition.

Reference Books:

1. Hamada Alshaer, Demanding Traffic Control and Management in Next Generation Networks, Lap Lambert Academic Publishing, 2010.
2. IRC:67-2012, Code of Practices for Road Signs, Indian Roads Congress, India, 2012, Third Revision.
3. USDOT, Manual on Uniform Traffic Control Devices for Streets and Highways, Federal Highway Administration, 2023, Eleventh Edition.

Online Resources

1. https://ops.fhwa.dot.gov/publications/fhwahop08024/chapter4.htm
2. https://www.fhwa.dot.gov/publications/research/operations/its/06108/02.cfm
3. https://www.valleytraffic.ca/news/types-of-traffic-control-equipment/
4. www.trafficinfratech.com/area_traffic_control_system_improving_traffic_in_the_island_city/

CE66035 **3-0-0 (3)**

Transport and Environment

Pre-Requisites: NIL

Course Outcomes:

CO-1	Examine the effect of transportation on the environment.
CO-2	Differentiate various environmental standards.
CO-3	Estimate air pollution and noise pollution due to surface transportation.
CO-4	Carry out an environmental impact assessment.
CO-5	Apply various measures to mitigate the pollution caused by transportation.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	2	1	1	1	-
CO-2	3	3	1	1	2	-
CO-3	2	2	1	1	2	2
CO-4	3	2	1	1	1	2
CO-5	3	2	2	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Transport and Environment: environment and its interaction with human activities; air and noise pollution due to transportation; environmental imbalances- attributes, impacts, indicators, and measurements; the concept of environmental impact assessment; and environmental impact statement

Environmental Standards, Laws, and Regulations: Laws protecting the environment include environmental protection, air and noise pollution, motor vehicle acts, town and country planning, and development control regulation.

Prediction of Air and Noise Pollution: Factors affecting air pollution from road traffic - vehicle characteristics, engine types, vehicle age and maintenance, driving conditions, average speed, temperature, meteorological conditions; emission inventory; dispersion of pollutants; inverse air quality models; emission and dispersion models; driving cycles; macroscopic and microscopic modelling at the microscopic level of air pollution from road traffic; road traffic noise model (RTNM), Calixto model, acoustical assessment.

Environmental Impact Assessment and Statement: Objectives of EIA, advantages and limitations of EIA, an overview of methodologies, Ad Hoc checklist, matrix, network, overlays, benefit-cost analysis, choosing a methodology, review criteria, and IRC code.

Mitigation Measures and Policies: Cleaner fuels, vehicle technology, and replacement strategies improving fuel efficiency, encouraging non-motorized and public transport; taxation on emissions; noise barriers, land use planning; resurfacing roads with low-noise materials; managing traffic flows; advanced construction methods

Learning Resources:

Textbooks:

1. Louis Franklin Cohen and Gary Richard McVoy, Environmental Analysis of Transportation Systems, John Wiley & Sons, 1982.
2. Peter Morris, Riki Therivel, Graham Wood (Eds); Methods of Environmental and Social Impact Assessment, Routledge, 2018, Fourth Edition.

Reference books:

1. David A. Hensher, Kenneth J. Button (Eds), Handbook of Transport and the Environment, Elsevier Science Ltd., 2003.
2. David Banister, Transport Policy and Environment, E&FN Spain,1999
3. Sudhakar Yedla, Urban Transportation and the Environment, Springer, 2015.
4. IRC:104-1988, Guidelines for Environmental Impact Assessment for Highway Projects, Indian Roads Congress, India, 1988.
5. NCHRP Report 541, Consideration of Environmental Factors in Transportation Systems Planning, TRB, 2005.
6. NCHRP Synthesis 272, Best Management Practices for Environmental Issues Related to Highway and Street Maintenance: A Synthesis of Highway Practice, National Research Council, TRB, 1999.
7. IRC: SP21-2009, Guidelines on Landscaping and Tree Plantation, Indian Roads Congress, India, 2009.
8. IRC: SP93-2017, Guidelines on Requirements for Environmental Clearances for Road Projects, Indian Roads Congress, India, 2017.
9. IRC: SP108-2015, Guidelines on Preparation and Implementation of Environment Management Plan, Indian Roads Congress, India, 2015.

Online Resources:

1. http://courses.washington.edu/cee412/
2. http://www.nap.edu/catalog/10354.html

CE66037 **3-0-0 (3)**

Transportation Data Analysis

Pre-Requisites: NIL

Course Outcomes:

CO-1	Select a suitable method for processing and presentation of transportation data.
CO-2	Apply probability distributions to analyse transportation data.
CO-3	Choose appropriate hypothesis testing measures.
CO-4	Analyse multivariate transportation data.
CO-5	Differentiate various curve fitting techniques.
CO-6	Develop Time Series models using various methods.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	-	-
CO-2	3	3	2	3	-	-
CO-3	3	3	2	2	-	-
CO-4	3	3	3	1	-	-
CO-5	3	3	2	2	-	-
CO-6	3	3	2	2	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Data Description and Presentation: Type of data, a center of data, quartiles, five-number summary, the spread of data, coefficient of variation and standard deviation, a measure of dispersion, shape of data, coefficients of skewness and kurtosis, descriptive data statistics, sampling techniques, presentation of categorical, quantitative and qualitative variable, data frequency and histogram,

Probability Laws and Distributions: Basic probability theory, concept and rules, Bayes' theorem, type of statistical distribution and characteristic, probabilistic distributions- Binomial, Poisson, Normal, Lognormal, Weibull, Gamma, Beta, Erlang, Student's t and F distribution, Geometric and Hypergeometric distribution, applications in transportation engineering.

Statistical Inference and Tests of Significance: Hypothesis testing, types of error in hypothesis, confidence interval, significance tests for comparing variances and means, tests with small and large samples, two-tail and one-tail student's t-test, analysis of variance (ANOVA), non-parametric tests (Chi-square test and Kolmogorov–Smirnov test), central limit theorem, practice with transportation data.

Parameter Estimation and Curve Fitting Techniques: Least square, generalised least squares, method of moments, maximum likelihood, algebraic and geometric curve fit, linear and non-linear curve fitting (polynomial, exponential, logarithmic, power, etc.), overfit, and underfit.

Regression and Correlation: Simple linear regression, residuals and variances, multiple linear regression, two-stage regression, forward, backward, and stepwise regression, residual analysis, correlation analysis, type of correlations, coefficient of correlation, Karl-Pearson's coefficient, multivariate data analysis, factor analysis, applications in transportation engineering.

Time Series Models: Time series concept and components, utility, time series models, measurement of time series, graphical method, method of semi-average, moving average, least square, linear, parabolic and logarithmic trends, growth curves, ratio-to-trend and link relative method for seasonal variation, exercises with transportation data.

Learning Resources:

Textbooks:

1. Simon P. Washington, Matthew G. Karlaftis, Fred Mannering, Panagiotis Anastasopoulos; Statistical and Econometric Methods for Transportation Data Analysis, CRC Press, 2020, Third Edition.
2. Kumar Molugaram, G Shanker Rao, Anil Shah, Naresh Davergave; Statistical Techniques for Transportation Engineering, Butterworth-Heinemann, 2017, First Edition.

Reference books

1. Alfredo H-S. Ang, Wilson H. Tang; Probability Concepts in Engineering Planning and Design, Volume I & II, John Wiley & Sons, Singapore, 2007.
2. Bovas Abraham, Quality Improvement through Statistical Methods, Springer Science & Business Media, 2012.
3. Joseph F. Hair, William C. Black, Barry J. Babin, Rolph E. Anderson; Multivariate Data Analysis, Prentice Hall, 2018, Eighth Edition.
4. Robert V. Hogg, Elliot Tanis, Dale Zimmerman; Probability and Statistical Inference, Pearson, 2021, Tenth Edition.

Online resources

1. http://courses.washington.edu/cee412/
2. https://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability

CE66039 **3-0-0 (3)**

Transportation Demand and Systems Management

Pre-Requisites: NIL

Course Outcomes:

CO-1	Choose an appropriate TSM action for a given problematic area.
CO-2	Propose a suitable method to improve transit system efficiency.
CO-3	Distinguish transportation demand management strategies for their applicability.
CO-4	Evaluate the functioning of UMTA.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	1	3	-	3	-
CO-2	-	1	3	-	3	-
CO-3	-	1	3	-	3	-
CO-4	-	1	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Transportation System Management: Objectives; Need for TSM Long–Range vs. TSM Planning; TSM Actions: Traffic Management Techniques for Improving Vehicular Flows, Preferential Treatment for High occupancy Modes; Promoting Non–Auto and High Occupancy vehicles; Transit and Intermediate Public Transport Service Improvements, Demand Management Techniques for Reduced Traffic Demand, Staggered working Hours, Vehicular Restrictions, Intersection Management Techniques – Signal Progression – Optimisation.

Transit System Management: Multimodal traffic management, reducing transportation needs, reducing dependence on the car, improving traffic flow, Improving road safety, Route Planning, and Scheduling.

Transportation Demand Management: Use of Personal Vehicles, Non-motorized Transport, Public Transit, Policies to Control Vehicle Growth Rate, Alternative work schedules, Congestion pricing, Employer incentives and disincentives, Land-use reorientation, and ICT applications.

Institutional Framework: Legislative Authority; Functional Responsibilities; Organization – UMTA – State Highway Department; Traffic Records; Research Bodies; Citizen Participation, Asset Management.

Learning Resources:

Textbooks:

1. C. Jotin Khisty, B Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. FHA, Transportation System Management and Operations in Action, US DOT Federal Highway Authority, 2017.

Reference Books:

1. Institute of Transportation Engineers, Traffic Engineering Handbook, John Wiley and Sons, 2016, Seventh Edition.
2. TRB Special Report 172, Transportation System Management, Program Committee for the Conference on Transportation System Management, Transportation Research Board, Washington DC, 1977.
3. USDOT, Transportation System Management, State of the Art, UMTA, USDOT, 1991.

Online Resources:

1. https://crp.trb.org/nchrpwebresource1/16-0-transportation-system-management-and-operations/
2. https://dot.ca.gov/programs/traffic-operations/tsmo
3. https://ops.fhwa.dot.gov/plan4ops/focus_areas/planning_prog.htm
4. https://ops.fhwa.dot.gov/publications/fhwahop14019/fhwahop14019.pdf
5. https://ops.fhwa.dot.gov/publications/fhwahop16037/index.htm
6. https://ops.fhwa.dot.gov/tsmo/
7. https://ops.fhwa.dot.gov/tsmo/
8. https://www.nymtc.org/en-us/Regional-Planning-Activities/Mobility-and-Safety-Planning/TSMAO

2nd Semester

CE66002 **3-1-0 (4)**

Advanced Travel Demand Modelling

Pre-Requisites: CE66001

Course Outcomes:

CO-1	Assess Qualitative Variables.
CO-2	Develop discrete choice models.
CO-3	Assess travel demand using Stated Preference data.
CO-4	Estimate Travel Demand using activity-based analysis.
CO-5	Test model aggregation and transferability.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	1	1	-	1
CO-2	3	3	2	2	-	2
CO-3	3	3	2	2	-	2
CO-4	3	3	2	2	-	2
CO-5	2	2	1	1	-	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Discrete Choice Analysis: Utility Concept; Mode choice; Logit Models; Dogit Model; Nested Logit Model; Probit Model; Route Choice Modelling; Combined Travel Demand Modelling; Model Parameter Estimation – Maximum Likelihood and Maximum Entropy Estimates.

Stated Preference Methods: Stated preference vs. Revealed Preferences; Design Issues; Survey Methods, Conjoint Analysis; Functional Measurement; Trade-off Analysis, Transfer Price Method

Activity-Based Travel Demand Models: Activity patterns; Activity scheduling; Activity Time Allocation studies; Activity Episode Analysis; Travel Duration Analysis

Qualitative Variables: Role of Soft variables in Travel Demand Forecasting; Attitudes; Psychometric scaling Techniques – One-dimensional Scaling – Multidimensional Scaling; Basic Rating Scales: Comparative Rating Scales, Non – Comparative Rating scale, Itemized rating scale, graphic rating scale; Specific Attitude scales; Successive Categories; Principal Components Factor Analysis; Attitudinal Models.

Model Aggregation and Model Transferability: Aggregation bias and forecasting; Aggregation Methods; Temporal Stability and geographical stability of Models; transfer model updating procedures—transferring with Aggregate and Disaggregate sample data; Transferability Measures.

Simplified Transport Demand Models: Sketch planning Methods; Incremental Demand Models; Model estimation from traffic Counts; IVF Models, Marginal and Corridor Models; Gaming Simulation, Quick Response Techniques.

Introduction to Advanced Modeling Techniques: GO Models; Entropy Models; Equilibrium Assignment Techniques, Multipath Assignment – Dial's Algorithm, Knowledge-Based Expert System; Neuro-Fuzzy Application; ANN Techniques; Genetic Algorithms; Object-Oriented Programming; Decision Support Systems; Goal Programming.

Learning Resources:

Textbooks:

1. Luis G. Willumsen, Juan de Dios Ortuzar; Modelling Transport, Wiley, 2024, Fifth Edition.
2. Norbert Oppenheim, Urban Travel Demand Modelling: From Individual Choices to General Equilibrium, John Wiley and Sons, Inc., 1995 (Digitized 29 June 2011).

Reference Books:

1. Alan Geoffrey Wilson, Optimization in Location and Transport Analysis, John Wiley & Sons, 1981 (Digitized: 31 March 2011).
2. Harry Timmermans (Ed), Progress in Activity-Based Analysis, Elsevier Science, 2005.
3. Joe Castiglione, Mark Bradley, John Gliebe; Activity-Based Travel Demand Models: A Primer, TRB, Washington, DC, 2015
4. Laurie A. Garrow, Discrete Choice Modelling and Air Travel Demand: Theory and Applications, Routledge, 2010
5. Moshe Ben-Akiva, Steven R. Lerman, Discrete Choice Analysis: Theory and Application to Travel Demand, MIT Press, 2018
6. Transportation 26, Special Issue, Time use Analysis, Kluwer Academic Publishers, 1999.

Online Resources:

1. http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_C46.pdf
2. https://www.nap.edu/download/13678

CE66004 **3-1-0 (4)**

Geometric Design of Transportation Facilities

Pre-Requisites: **CE66003**

Course Outcomes:

CO-1	Examine geometric characteristics and design elements of highways and streets
CO-2	Analyse and design uncontrolled and signalised intersections.
CO-3	Plan and Design parking facilities.
CO-4	Design a street lighting system for roads.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	1	1	1
CO-2	3	3	3	3	3	2
CO-3	3	3	3	3	3	1
CO-4	3	3	3	3	3	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Geometric Design of Highway Facility: Elements of geometric design, design considerations, factors affecting design, performance-based geometric design, alignment and topography, design of horizontal alignment, reverse and compound curves, design of vertical curves, tangent grade, controls and criteria for expressway, landscaping, freeway and multilane highways and expressways criteria, weaving segments configurations and ramp roadways, auxiliary lanes, and design practices.

Geometric Design of Intersections: Design considerations, factors affecting the design of elements, intersections geometric suitability, alignment, and profile, functional and physical area, data requirement, types of turning roadway, curb radii and turning path, pedestrian considerations in design, design of channelisation, median opening and islands, rotary and modern roundabout design, auxiliary lanes at intersection, ramp roadways and weaving segment design examples.

Design of Street Lighting: Definitions and background, pavement luminance and measurement, illumination level, Veiling Luminance, longitudinal uniformity, utilisation factor, depreciation factor, maintenance factor, traffic criteria, warranting conditions, and design practices.

Pedestrian Facilities, Parking Facilities: Elements of pedestrian facility design, sign of pedestrian facility at junctions, street and corner, pedestrian signals, design examples, Parking influencing factors, types, parking angles and aisle width, on-street parking design, various parking layouts and vehicle circulation, design of off-street parking facilities.

Traffic Interchanges and Terminals: Classification and types, layouts of interchange, warrants, design elements, Interchange evaluation based on delay, Cross-section design of logistic terminals, elements, Location considerations terminal concourse, cross-section design elements, terminal concourse, multiple interchange and vertical separation, traffic circulation, multiple interchange and vertical separation, traffic circulation, design examples.

Learning Resources:

Textbooks:

1. L.R. Kadiyali, Traffic Engineering and Transportation Planning, Khanna Publishers, 2024, Ninth Edition.
2. Partha Chakraborty, Animesh Das; Principles of Transportation Engineering, PHI Learning, 2017, Second Edition.

Reference Books:

1. C. Jotin Khisty, B Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2019, Seventh Edition.
3. NASEM, TRB, Highway Capacity Manual: A Guide for Multimodal Mobility Analysis, The National Academies Press, Washington, DC, 2022, Seventh Edition.
4. Nicholas J. Garber, Lester A. Hoel; Traffic and Highway Engineering, Cengage Learning India, 2024, Fifth Edition.

Online Resources

1. https://nptel.ac.in/courses/105/101/105101008
2. https://nptel.ac.in/courses/105/104/105104098
3. https://www.classcentral.com/course/edx-intro-to-traffic-flow-modeling-and-intelligent-transport-systems-12728
4. https://www.crridom.gov.in/sites/default/files/Indo-HCM%20Snippets.pdf
5. https://www.monash.edu/engineering/its/publications/tem2017

CE66006 **0-1-2 (2)**

Pavement Materials and Evaluation Laboratory

Pre-Requisites: **CE66005**

Course Outcomes:

CO-1	Characterise the pavement materials.
CO-2	Perform quality control tests on pavement and pavement materials.
CO-3	Evaluate functional response characteristics of in-service pavements.
CO-4	Estimate structural response characteristics of in-service pavements.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	2	3	2
CO-2	2	1	2	2	3	3
CO-3	3	2	1	3	2	1
CO-4	3	2	2	3	2	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Tests on Soils: Liquid limit, plastic limit, soil classification (dry and wet), maximum dry density and moisture, content, and CBR test.

Tests on Aggregate: Aggregate gradation, shape tests, specific gravity, water absorption, Los Angeles abrasion, value, aggregate impact value, and soundness test.

Tests on Bitumen: Penetration, absolute and kinematic viscosity, flash and fire point, ductility, elastic recovery, softening point, specific gravity, the apparent viscosity of bitumen using a rotational viscometer, and short-term ageing of bitumen.

Field Tests: Field density using sand replacement method and rapid moisture meter.

Tests on Bituminous Mixes: Stripping value of aggregate, determination of Gmm of given bituminous mixtures using the CoreLok system, Marshall mix design, bitumen content and gradation using centrifuge extractor and NCAT ignition oven; determination of tensile strength ratio for a given bitumen mix; Roller compaction and permanent deformation using wheel tracking equipment.

Field Evaluation: Pavement condition rating, unevenness using MERLIN, Dynamic Cone Penetrometer and Clegg Impact Test, overlay design using Benkelman Beam Deflection; FWD.

Learning Resources:

Textbooks:

1. S.K. Khanna, C.E.G. Justo, and A. Veeraragavan, Highway Materials and Pavement Testing, Nem Chand and Bros, Roorkee, India, 2014, Fifth Edition.
2. D.V. Bhavana Rao, G. Venkatappa Rao, K. Ramachandra Rao, Kaushik Pahari; Highway Material Testing and Quality Control, Wiley, 2019.

Reference Books:

1. Ajay K. Duggal, Laboratory Manual in Highway Engineering, New Age International Private Limited, 2017, Second Edition.

2. IRC: SP112-2017, Manual for Quality Control in Road and Bridge works, Indian Road Congress, New Delhi, 2017.
3. IRC: SP16-2019, Guidelines on Measuring Road Roughness and Norms, Indian Road Congress, New Delhi, 2019, Second Revision.
4. IRC:115-2014, Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique, Indian Road Congress, New Delhi, 2014.
5. IRC:81-2012, Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique, Indian Road Congress, New Delhi, 2012.
6. Laboratory Testing Manual, Central Materials Laboratory, Ministry of Works, the United Republic of Tanzania, 2000.
7. Yang Hsien Huang, Pavement Analysis and Design, Pearson Education, 2012, Second Edition.
8. Relevant IS and ASTM Codes.

Online Resources:

1. https://www.youtube.com/watch?v=UWmAabRxR6w
2. https://nptel.ac.in/courses/105/105/105105107
3. https://www.youtube.com/watch?v=C10dkIH12W0

CE66008 **0-1-2 (2)**

Transportation Software Laboratory

Pre-Requisites: CE66001, CE66003, CE66005, CE66009

Course Outcomes:

CO-1	Estimate Travel Demand using transportation planning packages.
CO-2	Design isolated and coordinated traffic signals using micro-simulation tools.
CO-3	Demonstrate Ken layer and Ken slab for pavement design.
CO-4	Simulate traffic facilities using VISSIM.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	--	2	--	2
CO-2	3	3	--	2	--	2
CO-3	3	3	--	2	--	2
CO-4	3	3	--	2	--	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Transportation Planning Software: Basic understanding and knowledge of transportation planning and logistics software. Software used: Cube, VISUM, Logistic models, Sidra trip, VISTRO, TRANSIMS,

Traffic Engineering Software: Concepts and theory on software development, Basic and advanced practices on microscopic and macroscopic traffic flow modelling software. It includes signal time optimisations and pedestrian flow modelling. Software used: VISSIM, VISWALK, Junction 10, Sidra, Pramaics, Amisun, Sumo, TRANSYT.

Highway and Pavement Engineering Software: This module includes the software commonly used for highway geometric design and pavement analysis. The software used is Mx road, open road, HDM-4, Ken-layer, and Ken-slab.

Learning Resources:

Textbooks:

1. User manuals of each software

Reference Books:

1. Coleman A. O 'Flaherty (Editor), Transport Planning and Traffic Engineering, Butterworth-Heinemann, 2009.
2. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2019, Seventh Edition.

Online Resources

1. https://company.ptvgroup.com/en/expertise/microsimulation
2. https://trlsoftware.com/products/junction-signal-design/
3. https://trlsoftware.com/products/traffic-control/

Professional Electives – 3, 4, 5

CE66022 **3-0-0 (3)**

Artificial Intelligence and Machine Learning in Transportation

Pre-Requisites: **CE66001, CE66003**

Course Outcomes:

CO-1	Identify a suitable AI and ML technique for transportation applications.
CO-2	Apply supervised Algorithms for traffic engineering and road crash data.
CO-3	Develop convolutional neural network models for vehicle detection.
CO-4	Choose an apt clustering technique for transportation planning.
CO-5	Select an appropriate neural network model for traffic prediction.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	1	3	1	1
CO-2	1	2	2	1	2	2
CO-3	1	2	2	3	2	1
CO-4	2	2	2	3	2	1
CO-5	1	1	2	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Artificial Intelligence (AI) Background: Introduction, History, and Evolution Agents of Artificial Intelligence, Introduction to Fuzzy System (FS), Artificial Neural Network (ANN), Evolutionary Computing (EC), Genetic Algorithm (GA), Particle Swarm Algorithm (PSO).

Machine Learning Background: Introduction, Historical context, Machine Learning: Unsupervised Learning, Supervised Learning, Semi-supervised Learning, Reinforcement Learning, Recapitulation of linear regression, logistic regression, Necessities, ML in Transportation engineering, and Real-world application examples.

Shallow Supervised Algorithms: Nearest Neighbor, Neural Networks Learning, Backpropagation, Support Vector Machines, Applications to traffic engineering, road crash classification, K Nearest Neighbor (KNN), ANN, Fuzzy Rule-Based, and other Classifiers.

Convolutional Neural Networks: Introduction to ConvNets, activation functions, hyper-parameter tuning, dropout, batch normalisation. Applications to camera-based classification and object detection related to driver behaviour, vehicle detection, pavement distress detection, Deep Learning and Transfer Learning: Deep Neural Networks (DNN), Fuzzy Neural Networks (FNN), etc.

Unsupervised Clustering: Hierarchical clustering, K-means clustering, Density-based clustering. Applications on transportation mode inference, level of service of roads. Fuzzy c-means (FCM), Self-organizing maps (SOM), and other Clustering Algorithms

Recurrent Neural Networks: Recurrent Neural Networks, Long-Short Term Memory. Applications to traffic state (speed, volume) prediction, traffic crash prediction, traffic flow modeling, etc.

Learning Resources:

Textbooks:

1. Trevor Hastie, Robert Tibshirani, Jerome Friedman; The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer, 2009, Second Edition.
2. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2016.
3. Ian Goodfellow, Yoshua Benjio, and Aaron Courville, Deep Learning, The MIT Press, 2016.

Reference Books:

1. Manaranjan Pradhan, U Dinesh Kumar; Machine Learning using Python, Wiley, 2020.
2. Paresh Chandra Deka, A Primer on Machine Learning Applications in Civil Engineering, CRC Press, 2019, First Edition.
3. Stuart J. Russell and Peter Norvig; Artificial intelligence: A Modern Approach, Prentice Hall, 2022, Fourth Edition.

Online Resources

1. https://onlinecourses.nptel.ac.in/noc22_cs56/preview
2. https://nptel.ac.in/domains/discipline/106?course=106_0

CE66024 **3-0-0 (3)**

Airport Infrastructure Planning and Design

Pre-Requisites: NIL

Course Outcomes:

CO-1	Analyze effects of atmospheric variables on aircraft performance.
CO-2	Determine the orientation of runways.
CO-3	Design geometrics of the airport infrastructure.
CO-4	Design thickness of the runway, taxiway, and apron.
CO-5	Plan airside and landside elements of an airport.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	2	1
CO-2	2	3	2	3	2	1
CO-3	2	3	2	3	2	1
CO-4	2	3	3	3	2	1
CO-5	2	3	3	3	2	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Aircraft Characteristics: Landing gear configurations, aircraft weight, engine types; atmospheric conditions affecting aircraft performance: air pressure, temperature, wind speed, and direction; aircraft performance characteristics: speed, payload, range, declared distances, wingtip vortices.

Air Traffic Management: Air traffic separation rules include vertical separation, flight altitudes, longitudinal separation, and lateral separation; navigational aids include ground-based systems and satellite-based systems.

Geometric Design of the Airfield: Airport classification; runway configurations, runway orientation, the wind rose; estimating runway length; sight distance and longitudinal profile, transverse gradient, airfield separation requirements, obstacle clearance requirements; taxiway and taxi lane separation requirements, sight distance, and longitudinal profile, exit taxiway geometry, location of exit taxiways, design of taxiway curves and intersections, end-around taxiways; aprons.

Structural Design of Airport Pavements: FAA pavement design methods include equivalent aircraft and cumulative damage failure methods. These methods are used to design flexible pavements, rigid pavements, joints, joint spacing, continuously reinforced concrete pavements, and pavement overlays.

Airport Lighting, Marking, and Signage: Requirements, approach lighting system configurations, visual approach slope aids, threshold lighting, runway and taxiway lighting, runway and taxiway marking, and airfield signage.

Planning and Design of the Terminal Area: Passenger terminal system; design considerations: terminal demand parameters, facility classification, level of service criteria; terminal planning process: overall space requirements, concept development, horizontal distribution concepts, vertical distribution concepts; apron gate system: number of gates, ramp charts, gate size, aircraft parking type, apron layout, apron circulation, passenger conveyance to aircraft, apron utility requirements.

Airport Planning and Forecasting: Airport planning studies: airport system plan, airport site selection, airport master plan, airport project plan; forecasting methods: time series method, market share method, econometric modeling; forecasting requirements and applications: airport system plan, airport master plan.

Learning Resources:

Textbooks:

1. Norman J. Ashford, Saleh A. Mumayiz, and Paul H. Wright; Airport Engineering: Planning, Design and Development of 21st Century Airports, Wiley India Pvt. Ltd., New Delhi, India, 2012, Fourth Edition.
2. Robert Horonjeff, Francis X. McKelvey, William J. Sproule, and Seth B. Young; Planning and Design of Airports, McGraw-Hill, New York, USA, 2010, Fifth Edition.

Reference Books:

1. Antonin Kazda, Robert E. Caves; Airport Design and Operation, Emerald Group Publishing Ltd., Bingley, UK, 2015, Third Edition.
2. Richard de Neufville, Amedeo R. Odoni, Peter P. Belobaba, Tom G. Reynolds; Airport Systems: Planning, Design, and Management, McGraw-Hill Education, New York, USA, 2013, Second Edition.
3. S.K. Khanna, M.G. Arora, and S.S. Jain; Airport Planning and Design, Nem Chand and Bros, Roorkee, India, 2012, Sixth Edition.
4. Seth B. Young, Alexander T. Wells; Airport Planning and Management, McGraw-Hill Education, New York, USA, 2019, Seventh Edition.

Online Resources:

1. https://www.aai.aero/
2. https://www.faa.gov/
3. https://www.icao.int
4. https://www.nasa.gov/topics/aeronautics/

CE66026 **3-0-0 (3)**

Big Data Analytics in Transportation

Pre-Requisites: NIL

Course Outcomes:

CO-1	Formulate an effective approach to capture transportation data.
CO-2	Apply predictive and prescriptive analytics to transportation problems.
CO-3	Examine the relevance of machine learning to transportation system operations.
CO-4	Identify appropriate algorithms for data mining and machine learning.
CO-5	Apply Big Data concepts in transportation engineering.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	3	1	1
CO-2	3	3	3	2	2	2
CO-3	3	3	3	3	2	1
CO-4	2	3	3	3	2	1
CO-5	3	3	2	2	2	2

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Basics of Big Data: Introduction to Big Data, Exponential growth and the new availability of data, Structured and unstructured data, Rapid acceleration in many dimensions (volume, velocity, variety, variability, and complexity), 3 V's of the Gartner's definition of big data, i.e., high volume, high velocity or high variety, veracity, value.

Data Exploration and Data Visualization: Data types: Sensor data, audio, video data, combinations of data, Predicting and Forecasting methods, Sampling errors, Smart data management: Manage and understand the data. Anonymisation, Aggregation, Interpretation, Processing, Modeling, Time Patterns, Spatial Signature, Flows Patterns, Open Data concepts.

Data Mining Strategies: Operations in Data Mining, Descriptive analytics, Preparing and analysing historical data, identifying patterns from samples for reporting of trends, Predictive analytics, predicting future probabilities and trends, Relationships in data that may not be readily apparent with descriptive analysis, Prescriptive analytics, Evolution of Computer Processors and storage methods.

AI and Machine Learning: AI for Big data analysis, Hadoop Concepts, and application for Big Data, Scaling Out, Supported Vector Machine, Tree-based Methods, Clustering, Text Mining, Topic Modeling Sentiment Analysis, Machine learning, and TSMO, Historical performance reporting, Mechanisms related to transportation demand and supply, Future Transportation Demand and Supply, Automated transportation back office, Machine learning, and big data, Neural Network Deep Learning, Network Analysis.

Big Data Applications in Transportation: Exploring Regularity and Structure in Travel Behavior Using Smart Card Data Estimating a Rail Passenger Trip Origin-Destination Matrix Using Automatic Data Collection Systems, Automatic Data for Applied Railway Management: A Case Study on the London Overground, Trip Detection Using Sparse CDR Data based on Supervised Statistical Learning, Demand Management in Public Transit: Design and Evaluate Crowding Reduction Strategies in Hong Kong.

Learning Resources:

Textbooks:

1. Sara Moridpour, Big Data Analytics in Traffic and Transportation Engineering: Emerging Research and Opportunities, IGI Global, 2019, First Edition.
2. Satish V. Ukkusuri, Chao Yang; Transportation Analytics in the Era of Big Data, Springer, 2019, First Edition.

Reference Books:

1. Arshdeep Bahga, Vijay Madisetti; Big Data Science and Analytics: A Hands-On Approach, VPT, 2016, First Edition.
2. Bob McQueen, Big Data Analytics for Connected Vehicles and Smart Cities, Artech House, 2017, First Edition.
3. Kevin Patrick Murphy, Probabilistic Machine Learning: An Introduction, MIT Press, 2022, Second Edition.
4. Mashrur Chowdhury, Amy Apon, and Kakan Dey, Data Analytics for Intelligent Transportation Systems, Elsevier, 2017, First Edition.

Online Resources:

1. https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1156&context=trec_reports
2. https://policy.transportation.org/wp-content/uploads/sites/35/2018/09/Street-Light-Data-Big-Data-Analytics-for-Active-Transportation-and-Multimodal-Planning.pdf
3. https://policy.transportation.org/wp-content/uploads/sites/35/2018/09/Street-Light-Data-Big-Data-Analytics-for-Active-Transportation-and-Multimodal-Planning.pdf
4. https://static1.squarespace.com/static/59f9cdc2692ebebde4c43010/t/5b49c213352f534ffb42e3d8/1531560480749/20180711_D1.1_Understanding+and+mapping+big+data+in+transport+sector_LeMO.pdf
5. https://transportationops.org/event/big-data-analytics-transportation-systems-management-and-operations
6. https://www.e-education.psu.edu/geog855/node/695
7. https://www.hcltech.com/blogs/future-transportation-real-time-analytics
8. https://www.ptvgroup.com/en/solutions/products/ptv-maps-data/data-analytics/
9. https://www.springer.com/journal/42421
10. https://www.supplychain247.com/article/3_ways_data_analytics_enables_smarter_transportation_management

CE66028 **3-0-0 (3)**

Freight Transportation

Pre-Requisites: CE66001

Course Outcomes:

CO-1	Distinguish characteristics of passenger and freight demand.
CO-2	Develop freight demand models.
CO-3	Analyze freight moment based on mode and route.
CO-4	Deploy ITS technologies for an efficient flow of freight.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	1	-	-	-
CO-2	3	2	2	-	-	-
CO-3	3	2	2	3	-	-
CO-4	2	2	2	1	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Characteristics of Freight Transport: Freight Characteristics, Factors influencing Freight Travel, operators, problems in freight transportation, regional vs. urban goods travel, intermodal freight travel issues, the difference between passenger and freight demand models.

Freight Demand Estimation: Operations, Planning, purpose, process, Data, Freight Agents, costs, Planning Models and Methods, demand estimation and forecasting at the regional and urban level, Freight Generation and Freight Trip Generation, Trend and time series models, freight trip rate models, and IO models.

Freight Transport Planning and Operations: Freight supply – capacity issues; freight productivity and performance; distribution of freight flows; production/consumption to origin/destination, competing modes for specific commodity choice, route planning, scheduling, collection storage, distribution centers, regulation, and enforcement of freight transport.

Urban Freight Model Forms: Sources of data availability: proprietary, semi-public, and public; data granularity; connecting various data sources to freight demand models; freight models in practice and decision-making; sustainable solutions for urban freight transport.

Inter-Intra Freight Transport Models: Modeling local freight, GPS-based freight data, urban freight last-mile delivery, ITS applications for urban freight data.

Learning Resources:

Textbooks:

1. Lorant Tavasszy, Gerard De Jong; Modelling Freight Transport, Elsevier Publishers, 2013, First Edition.
2. Moshe E. Ben-Akiva, Hilde Meersman, Eddy Van de Voorde (Eds); Freight Transport Modelling, Emerald Group Publishing, 2013.

Reference Books:

1. David Lowe, Intermodal Freight Transport, Elsevier Butterworth Heinemann Publishers, 2006, First Edition.
2. Eiichi Taniguchi, City Logistics: Modelling, planning and evaluation, Routledge, 2017, First Edition.
3. Marwan Al-Azzawi, Freight and Logistics Transport Modelling and Planning, LAP Lambert Academic Publishing, 2012,
4. Meyer Kutz (Editor), Handbook of Transportation Engineering, Volume I: Systems and Operations, McGraw Hill Education, 2011, Second Edition.
5. Meyer Kutz (Editor), Handbook of Transportation Engineering, Volume II: Applications and Technologies, McGraw Hill Education, 2011, Second Edition.

Online Resources:

1. https://ocw.mit.edu › courses › lecture-notes ›Freight demand - MIT OpenCourseWare
2. https://ocw.tudelft.nl/wp-content/uploads/transportation-lecturenotes.pdf

CE66030 **3-0-0 (3)**

Geoinformatics for Transportation

Pre-Requisites: NIL

Course Outcomes:

CO-1	Develop GIS-T Data Models.
CO-2	Represent Transportation Data in a GIS Environment.
CO-3	Analyse Transport Networks.
CO-4	Model spatial and transportation facilities in GIS.
CO-5	Integrate ITS with GIS.
CO-6	Map transportation-related environmental pollutants and accidents in the GIS platform.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	-	1	-	-
CO-2	3	3	-	1	-	-
CO-3	2	3	-	1	-	1
CO-4	2	3	-	1	-	1
CO-5	-	2	1	1	2	1
CO-6	-	2	2	1	2	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

GIS-Transportation Data Models: Data Domains and Data Modelling in GIST; Data Modelling Techniques; Data Modelling and Design Issues; Graph Theory and Network Analysis; Network representation of a Transportation System; Linear referencing methods and systems; Transportation Data Models for ITS and related Applications.

Transportation Data Sources and Integration: Basic Mapping Concepts; Transportation Data Capture and Data Products; Transportation Data Integration; Spatial Data Quality; Spatial and Network Aggregation.

Shortest Paths and Routing: Fundamental Network Properties; Fundamental Properties of Algorithms; Shortest Path Algorithms; Routing Vehicles within Networks.

Network Flows and Facility Location: Flow-through Uncongested Networks; Flow-through Congested Networks; Facility location within Networks; Spatial Aggregation in Network Routing and location problems.

GIS-Based Spatial Analysis and Modeling: GIS and spatial analysis; Urban sprawl; GIS Analytical functions; Coupling Transportation Analysis and Modelling with GIS; Customizing GIS; Supporting Advanced Transportation Analysis in GIS.

Transportation Planning: Transportation Analysis Zone Design, Travel demand Analysis, land-transportation modelling, Route Planning, and Decision Support for Transportation Planning.

Intelligent Transportation Systems: ITS Applications; ITS Architectures and Geographic Information; Integrating GIS and ITS.

Transportation, Environment, and Hazards: Mapping sensitive Environmental features; GIS and Transportation Air Quality; Accidents and Safety Analysis; Transportation of hazardous materials; GIS in Asset Management

Learning Resources:

Textbooks:

1. Harvey J. Miller, Shih-Lung Shaw; Geographic Information Systems for Transportation (GIST): Principles and Applications, Oxford University Press, 2001, First Edition.
2. Henk J. Scholten, John Stillwell; Geographical Information Systems for Urban and Regional Planning, Springer, 2013.

Reference Books:

1. Chor Pang Lo, Albert K.W. Yeung; Concepts and Techniques of Geographic Information Systems, Pearson, 2016, Second Edition.
2. NCHRP Report 359, Adaptation of Geographic Information Systems for Transportation, TRB, Washington, DC, 1993.
3. NCHRP RRD180, Implementation of Geographic Information Systems (GIS) in State DOTs, TRB, 1991.
4. NCHRP Synthesis 446, Use of Advanced Geospatial Data, Tools, Technologies, and Information in Department of Transportation Projects: A Synthesis of Highway Practice, TRB, 2013.
5. TCRP Synthesis 55, Geographic Information Systems Applications in Transit: A Synthesis of Transit Practice, TRB, 2004.
6. Thill JC (Ed.), GIS in Transportation, Transportation Research Part C, 2000.

Online Resources:

1. https://transportgeography.org/contents/methods/geographic-information-systems-transportation/
2. https://www.esri.com/en-us/industries/transportation/overview
3. https://www.esri.com/library/bestpractices/urban-regional-planning.pdf48
4. https://www.gis.fhwa.dot.gov/documents/gis_assetmgmt.pdf

CE66032 **3-0-0 (3)**

Intelligent Transportation Systems

Pre-Requisites: NIL

Course Outcomes:

CO-1	Identify and differentiate ITS user services and their components.
CO-2	Propose appropriate ITS technology to solve real-life traffic problems.
CO-3	Estimate traffic congestion by the acquisition of big data using advanced devices.
CO-4	Design and implement suitable ITS and services for effective transportation.
CO-5	Select suitable standards for effective implementation of ITS.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	2	2	1
CO-2	3	3	2	2	1	1
CO-3	3	3	2	2	1	2
CO-4	3	2	2	2	2	1
CO-5	3	2	2	2	1	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

ITS History and Applications: ITS Background and Telemetric Systems: Definitions, features, and objectives of ITS, History of ITS, ITS taxonomy, ITS application areas, uses, and application overview.

ITS User Services: Infrastructure-based services, aerial management and integration, freeway/highway management, crash prevention and safety, road weather management, roadway operation and maintenance, transit management, emergency management, electronic payment and pricing, traveler information, COV, Intelligent vehicle-based services, collision notification and avoidance system, driver assistance system, and examples.

ITS Components, Tools, and Strategies: Components of user services: advanced traffic management system, advanced traveler information system, advanced vehicle control system, commercial vehicle operational management, advanced public transportation system, electronic payment system, advanced rural transportation, security and safety systems, urban traffic control, SCOOT, SCAT and CosiCost systems, Benefits and limitations.

Design and Implementation: Design components; data acquisition methods, Radar and sensor, detectors, vehicle identifiers, and GPS; Communication tools; Dedicated Short-Range Communication, Data handling, processing, and management; Worldwide ITS implementation and challenges; Traffic Command and Control Center design and implementation, System Integrator and Smart Transportation Management, Case studies.

ITS Standards: ITS standards, development process, legal issues, financial issues, mainstream ITS, integration and upgradation, future of ITS, Case studies.

Learning Resources:

Textbooks:

1. Joseph M. Sussman, Perspectives on Intelligent Transportation Systems (ITS), Springer, 2005, First Edition.
2. Mashrur A. Chowdhury, Adel Sadek; Fundamentals of Intelligent Transportation Systems Planning, Artech House, 2010, First Edition.
3. Pradip Kumar Sarkar, Amit Kumar Jain; Intelligent Transport Systems, PHI Learning, 2018, First Edition.

Reference Books:

1. Bob Williams, Intelligent Transport Systems Standards, Artech House Publishers, 2008.
2. E. Bekiaris, Y.J. Nakanishi (Eds); Economic Impacts of Intelligent Transportation Systems: Innovations and Case Studies, Elsevier, 2004.
3. IET Intelligent Transport Systems and 15th International IEEE Conference on Intelligent Transportation Systems (ITSC), 2012.
4. Ljubo Vlacic, Michel Parent, Fumio Harashima (Eds), Intelligent Vehicle Technologies – Theory and Applications, Butterworth-Heinemann, 2010.
5. Roger R. Stough, Intelligent Transport Systems: Cases and Policies, Edward Elgar, 2001.
6. The Implication of Intelligent Transport Systems for Road Safety, Austrians Incorporated, 1999.

Online resources

1. http://digital-library.theiet.org/content/journals/iet-its
2. http://digital-library.theiet.org/content/journals/iet-its
3. http://www.tandfonline.com/toc/gits20/current
4. https://www.its.dot.gov/history/pdf/HistoryofITS_book.pdf
5. https://www.its.dot.gov/research_areas/data_access.htm
6. https://www.its.dot.gov/research_areas/emerging_tech.htm
7. https://www.sciencedirect.com/topics/engineering/intelligent-transportation-system
8. https://www.wevolver.com/article/a.review.of.autonomous.vehicle.safety.and.regulations

CE66034 **3-0-0 (3)**

Land Use and Regional Transportation Planning

Pre-Requisites: CE66001

Course Outcomes:

CO-1	Develop land use models.
CO-2	Prepare integrated land use and transportation plans for a city.
CO-3	Delineate regions
CO-4	Estimate regional passenger demand
CO-5	Estimate regional goods travel demand
CO-6	Develop regional road network

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	2	-	-
CO-2	3	3	3	2	2	-
CO-3	2	2	3	2	-	-
CO-4	3	1	3	-	-	-
CO-5	3	1	3	-	-	-
CO-6	3	3	3	3	2	-

Slightly; 2: Moderately; 3: Substantially

Syllabus:

Land Use Models: Von Thunen's regional land use model, Concentric urban land use model, Sector land use model, multiple nuclei land use model, hybrid land use models, Cellular automata models, and land rent theory; Christaller central place theory- Losch's improvements; Urban regions

Land Use Transportation Models: Classification of LUT Models, Economic Base Mechanism, Allocation Mechanism, Spatial Allocation, Employment Relationships, Garin Lowry Models, Contribution by Putman and Wilson, Issues Related to Land use Transport - Interaction, Case Study Examples.

Delineation of Regions: Concept of Region, Types of regions, Hierarchy of activities &Issues Related to Regional Planning, Hierarchy of Regions, mega-region development, Methods of Delineation Regions – Qualitative approaches – Quantitative approaches, Formal regions – weighted index method and factor analysis method; Functional regions – flow analysis & gravitational analysis.

Regional Passenger Travel Demand Estimation: Comparison of Urban and Regional Travel; Factors Affecting Passenger Flows; Use of Mathematical Models to Estimate Passenger Travel Demand; Direct Demand Models; Abstract Mode Models; Mode Specific Models; Case Studies. Definition of Intercity Travel; Dimensions of Intercity Travel Decision Making; Aggregate and Disaggregate Models.

Regional Goods Travel Demand Estimation: Factors Affecting Goods Flows; Characteristics of freight travel; Use of Mathematical Models to Estimate Freight Demand; Aggregate and disaggregate models – Freight Generation, trip distribution, mode choice & traffic assignment; Input-output model, MIT Model.

Regional Network Planning: Problems in Developing Countries, Network Characteristics - Circuitry, Connectivity, Mobility, Accessibility and Level of Service Concepts - Network Structures and Indices – Network Planning – Evaluation - Graph Theory – Cut sets – Flows & Traversing – Optimum Network - Inter-modal Co-ordination. Special features of low volume Roads – Rural Road Network Planning.

Learning Resources:

Textbooks:

1. Jotin Khisty, B Kent Lall; Transportation Engineering: An Introduction, Pearson Education India, 2016, Third Edition.
2. Michael D. Meyer, Transportation Planning Handbook, Institute of Transportation Engineers, John Wiley & Sons, 2016, Fourth Edition.
3. Ruben Cordera, Angel Ibeas, Luigi dell Olio, Borja Alonso, Land Use – Transport Interaction Models, CRC Press, 2019.
4. Tomas de la Barra, Integrated Land Use and Transport Modelling: Decision Chains and Hierarchies, Cambridge University Press, 2010.

Reference Books:

1. Alan G. Wilson, Urban and Regional Models in Geography and Planning, Pion Press, 1974.
2. C.S. Papacostas, P.D. Prevedouros; Transportation Engineering and Planning; Pearson, 2015, Third Edition.
3. Jean-Paul Rodrigue, The Geography of Transport Systems, Routledge, 2024, Sixth Edition.
4. John W. Dickey, Metropolitan Transportation Planning, CRC Press, 2018, Second Edition.
5. Meyer Kutz (Editor), Handbook of Transportation Engineering, Volume I: Systems and Operations, McGraw Hill Education, 2011, Second Edition.
6. Meyer Kutz (Editor), Handbook of Transportation Engineering, Volume II: Applications and Technologies, McGraw Hill Education, 2011, Second Edition.
7. S Raghava Chari, Land use Transportation Planning Lecture Notes, REC, Warangal, 1988.
8. W.R. Blundon, J.A. Black; The Land Use Transport System, Australian Natl Univ Press, 1984, Second Edition.

Online Resources:

1. http://www.tod.org/
2. https://nptel.ac.in/courses/124/105/124105016/
3. https://transportgeography.org/
4. https://www.classcentral.com/course/swayam-urban-landuse-and-transportation-planning-20017
5. https://www.nap.edu/download/22338#
6. https://www.nap.edu/download/25319
7. https://www.nap.edu/download/25332
8. https://www.vtpi.org/tdm/tdm45.htm

CE66036 **3-0-0 (3)**

Pavement Evaluation and Rehabilitation

Pre-Requisites: **CE66005**

Course Outcomes:

CO-1	Evaluate pavement based on surface conditions.
CO-2	Assess the structural strength of pavements.
CO-3	Select appropriate pavement rehabilitation options.
CO-4	Prioritise pavement maintenance strategies.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	3	3	3
CO-2	2	1	2	2	3	3
CO-3	3	3	3	2	3	2
CO-4	3	2	2	2	1	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Functional Evaluation of Pavements: The importance of pavement evaluation; functional condition evaluation techniques: network, project level, and roughness measurement methods; identification of uniform section; serviceability concepts; visual and rating procedures; data collection technologies; pavement deterioration: factors affecting pavement deterioration, modelling, and comparison of different deterioration models.

Structural Evaluation of Pavements: Structural condition evaluation: static, semi-static, moving deflection measuring devices; rebound deflection; deflection bowl measurement and analysis: AASHTO AND IRC overlay design method; back-calculation of layer moduli; ground-penetrating radar evaluation of pavement safety: skid resistance, mobile devices measuring skid resistance and hydroplaning.

Pavement Rehabilitation: The benefits of recycling: methods, recycling strategies, cold milling, ripping, crushing, recycling batch plant, drum mix plant, mix design, hot in-place recycling techniques, cold in-place recycling; full-depth reclamation, and current practices for improving riding quality.

Pavement Maintenance: Surface distresses, types, causes and redial measures, types of maintenance, classification of maintenance activities, pavement maintenance norms maintenance, development of decision tree, decision matrix, selection of treatment strategies, local, global maintenance and rehabilitation strategies, HDM-4 applications, and life cycle cost analysis.

Learning Resources:

Textbooks:

1. Prithvi Singh Kandhal, A. Veeraragavan, Rajan Choudhary; Bituminous Road Construction in India, PHI Learning Pvt. Ltd., New Delhi, India, 2023, Second Edition.
2. David Croney, Paul Croney; Design and Performance of Road Pavements, Chapman and Hall, 1997, Third Edition.
3. M.Y. Shahin, Pavement Management for Airport, Roads and Parking Lots, Springer, 2006, Second Edition

Reference Books:

1. A.T. Papagiannakis, E.A. Masad; Pavement Design and Materials, John Wiley and Sons, 2017, First Edition.
2. Ministry of Road Transport and Highways, Specifications for Road and Bridge Works, Indian Roads Congress, New Delhi, India, 2013, Fifth Edition.
3. Rajib B. Mallick, Tahar El-Korchi, Pavement Engineering – Principles and Practice, CRC Press, 2023, Fourth Edition.
4. Ralph Haas, W. Ronald Hudson, John P. Zaniewski, Modern Pavement Management, Krieger Publishing Company, Malabar, Florida, USA, 1994.
5. Relevant Indian Road Congress codes, Bureau of Indian Standards, and international standards such as ASTM and AASHTO.
6. Yang H. Huang, Pavement Analysis and Design., Dorling Kindersley (India) Pvt. Ltd., New Delhi, India, 2008, Second Edition.

Online Resources:

1. https://www.pavementinteractive.org/
2. https://www.appliedpavement.com/pavement-evaluation-and-design.html
3. https://freevideolectures.com/course/91/introduction-to-transportation-engineering/40

CE66038 **3-0-0 (3)**

Pavement Management System

Pre-Requisites: **CE66005**

Course Outcomes:

CO-1	Identify and select suitable database strategies for a given pavement.
CO-2	Determine the pavement condition using functional and structural methods.
CO-3	Decide the type and timing of maintenance required for a given pavement.
CO-4	Estimate the life cycle cost of pavements and implementation strategies.
CO-5	Develop the PMS software and treatment selection criteria.

Course Articulation Matrix:

CO/PO	PO-1	PO-2	PO-3	PO-4	PO-5
CO-1	3	3	2	2	3
CO-2	3	3	1	2	2
CO-3	3	3	3	3	1
CO-4	3	3	2	1	2
CO-5	2	2	1	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Pavement Management System (PMS): The importance of managing pavement networks effectively, the basic framework of PMS, the benefits of using pavement management, and the role of PMS in asset management.

Pavement Inventory and Condition Assessment: types of inventory information needed to support PMS, referencing systems, Data integration approaches, Role of GIS in PMS type of Pavement condition data to be collected, Data collection techniques, Pavement distress identification and quantification, sampling intervals, developing condition indices.

Pavement Performance Modelling: data requirements in Pavement performance modelling, Performance modelling approaches – Deterministic and Probabilistic models, Family modelling

Pavement Preservation Strategies: identifying the treatment needs, treatment trigger rules, optimal timing of maintenance, techniques for project and treatment selection -Ranking, Multiyear prioritisation techniques, Illustrating the impact of different funding scenarios.

Implementation of PMS: PMS software selection, Implementation steps and Institutional Issues

Learning Resources:

Textbooks:

1. M.Y. Shahin, Pavement Management for Airport, Roads and Parking Lots, Springer, 2006, Second Edition
2. Ralph Haas, W. Ronald Hudson, John P. Zaniewski, Modern Pavement Management, Krieger Publishing Company, Malabar, Florida, USA, 1994.

Reference Books:

1. W Hudson, Ralph Haas, Waheed Uddin; Infrastructure Management: Integrating Design, Construction, Maintenance, Rehabilitation, and Renovation, McGraw Hill Education, 1997.
2. Southeast Michigan Council of Governments, Pavement Management System, SEMCOG, 1997.

Online Resources

1. https://www.youtube.com/watch?v=lDv67Eppaos
2. https://ocw.mit.edu/courses/civil-and-environmental-engineering/

CE66040 **3-0-0 (3)**

Public Transportation Systems

Pre-Requisites: **CE66001**

Course Outcomes:

CO-1	Differentiate different transit systems
CO-2	Estimate transit demand
CO-3	Analyse bus route network and prepare bus schedules.
CO-4	Identify mass transit corridors.
CO-5	Evaluate transit performance

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	2	2	1
CO-2	3	1	3	1	1	1
CO-3	2	2	2	3	3	2
CO-4	2	2	2	2	2	2
CO-5	3	3	3	2	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Transit Systems: Role of Transit - Types of Transit Modes - Buses - LRT, RTS - Air-cushioned and Maglev System – S-Bahn Dual Mode Busses, Para Transit - Dial - a- Ride-Taxi- Jitney and Ridesharing – PRT Networks - DRTS Technological Characteristics – Resistances, acceleration & velocity Profiles – Operational characteristics speed, capacity & payloads – Route capacity – Comfort conditions - Performance relationships - Public and Private Operations - Modes for Intercity Transport; Coefficient of rolling friction, modes comparison, system configurations, system performance calculations

Estimation of Transit Demand: Data requirements and collection techniques, Conventional Methods—destination Survey—bus Stop Surveys and Analysis—mode Split Models—captive and Choice Riders—attitudes of Travelers—patronage Determination.

Bus Route Network Planning: Route Systems - Route Location, Route Structure, Route Coding Techniques, Route Capacity - Planning of Transit Network - Different Types - Service Area Coverage - Evaluation - Selection of Optimal Network - Path Building Criteria - Integration with UTPS.

Bus Scheduling: patterns of Bus Services, Frequency of Services, Special Services, Single Route Bus Scheduling, Fleet Requirement, Marginal Ridership Concept, Use of Optimisation Technique, Load Factor, Depot Location, and Spacing of Bus Stops.

Mass Transit Corridor Identification and Planning: Corridor identification - Network Compression Method - Planning of Rapid Transit System - System Selection - Supporting and Enclosing Structures - System Evaluation - Track Structures - Signal System - Aesthetics and Noise Consideration - Cost of Construction - Station Arrangements - Platform Capacity - Fare Collection, Transit Marketing.

Public Transport Management Measures: RTC Act - ASRTU System Efficiency and Effectiveness Measures - Performance Indicators – LOPTS - Preferential Treatment to HOV: Exclusive Bus Lanes - Bus Streets - Contra Flows - Reversible Lanes - Bus Bypass - Bus Pre-emption Signals for Bus Operations.

Transit Terminals and Performance Evaluation: Transit Terminal Planning and Design – Performance Evaluation – Efficiency, Capacity, Productivity and Utilization – Performance Evaluation Techniques and Application – System Network Performance; Safety and security, hazard analysis of Bus transit.

Learning Resources:

Textbooks:

1. Peter R. White, Public Transport: Its Planning, Management, and Operation, London New York, 2008, Fifth Edition.
2. Vukan R. Vuchic, Urban Transit: Operations, Planning, and Economics, Wiley, 2017.

Reference Books:

1. Alan Black, Urban Mass Transportation Planning, McGraw-Hill International, 1995.
2. Ashish Verma, T.V. Ramanayya; Public Transport Planning and Management in Developing Countries, CRC Press, 2014.
3. Barry John Simpson, Urban Public Transport Today, Taylor & Francis Routledge Publisher, 2003.
4. Carlos F Daganzo, Yanfeng Ouyang; Public Transportation Systems: Principles of System Design, Operations Planning and Real-time Control, World Scientific Publishing Company, 2019.
5. David A. Hensher, Bus Transport: Economics, Policy, and Planning, Research in Transportation Economics Volume 18. Elsevier Publications, 2007.
6. David Johnson Victor, S. Ponnuswamy; Urban Transportation: Planning, Operation and Management, McGraw-Hill Education, 2012.
7. Geetam Tiwari, Urban Transport for Growing Cities: High-Capacity Bus System, MacMillan India Ltd., 2002.
8. George E. Gray and Lester A. Hoel, Public Transportation: Planning, Operation and Management, Prentice Hall; 1992, Second Edition.

Online Resources

1. https://ocw.mit.edu/courses/civil-and-environmental-engineering/1-258j-public-transportation-systems-spring-2017/index.htm?utm_source=OCWCourseList&utm_medium=CarouselSm&utm_campaign=FeaturedCourse
2. https://www.apta.com/
3. https://www.uitp.org/

CE66042 **3-0-0 (3)**

Railway Infrastructure Planning and Design

Pre-Requisites: NIL

Course Outcomes:

CO-1	Plan the railway network.
CO-2	Determine factors governing the design of railway infrastructure.
CO-3	Design the railway track system and identify a suitable signal system.
CO-4	Develop maintenance strategies for the railway track system.
CO-5	Recommend suitable measures for the safety of the railway network.
CO-6	Assess requirements of high-speed railway track.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	3	2	1
CO-2	2	3	3	3	2	1
CO-3	2	3	3	3	2	1
CO-4	2	3	3	3	2	1
CO-5	2	3	3	3	2	1
CO-6	2	3	3	3	2	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Introduction to Rail Transportation: Overview of Indian Railways; Characteristics of rail transport; Comparison between rail transport and air transport; Comparison between rail transport and road transport.

Components of Railway Track: Railway track gauge; permanent way; forces acting; coning of wheels; tilting of rails; rails: functions, types, characteristics, standard rail sections; sleepers: functions, sleeper density, types; ballast: functions, types, sizes, requirements, specifications; formation; blanket layer; track fittings and fastenings.

Points and Crossings: Terminologies; components of turnout and switch; Switches: terms, types; tongue rails; crossing: terminologies, movable crossing, number and angle; design of turnouts: Cole's method, IRS method, with curved switches.

Track Junctions and Layouts: Turnout of similar flexure, contrary flexure, symmetrical split, three-throw switch with contrary flexure and similar flexure, tandem turnout with contrary and similar flexure, crossover between parallel tracks, diamond crossing including single slip and double slip, scissors crossing, gauntleted track, gathering line, triangle, double junctions; level crossings.

Geometric Design of Railway Track: Gradients; grade compensation on curves; horizontal curves; superelevation and related terminologies; safe speed on curves; maximum permissible speed on curves; transition curve; length of transition curve; extra clearance on curves, between curved tracks, curved tracks with structures in between; widening of gauge on curves; vertical curves; length of vertical curves; cutting rails on curves; check rails.

Rolling Stock: Locomotives: classification, salient features of Indian locomotives; coaching stock: classification, passenger coaching vehicles, other coaching vehicle; goods wagons: types, codes, wagon tipplers; train resistance and tractive power: various forces, locomotive tractive effort, hauling power.

Railway Station and Yards: Railway station: purpose, site selection, facilities required, classification; railway station platforms; types of yards: sick line yard, marshalling yard; catch sidings; slip sidings; equipment at railway stations.

Signalling and Interlocking: Railway signaling objectives, classification based on operational characteristics, classification based on functional characteristics, classification based on locational characteristics, signs and symbols; interlocking: track circuits, axle counter, standards; types of interlocking: key interlocking, mechanical interlocking, panel interlocking, route relay interlocking, electronic interlocking; automatic warning system.

Track Construction and Maintenance: Track laying, inspection and maintenance, maintenance tools, maintenance of rail surface, track drainage, track tolerances, mechanised method, ballast confinement and directed track maintenance, bridge maintenance, renewal, classification of renewal works, mechanised relaying, track renewal trains.

Railway Accidents and Safety: Train accidents, collisions, derailments, and derailment mechanisms; causes; restoration of traffic; safety measures; disaster management; classification of level crossings; accidents at level crossings; remedial measures; maintenance of level crossings.

High-Speed Railways: Modernization of railways, the effect of high-speed track, vehicle performance on the track, railway track design for high speeds, dedicated freight corridors, high-speed ground transportation system, ballast less track, elevated railways, underground and tube railways.

Planning of Railway Lines: Need for a new railway line; preliminary investigations; types of surveys; rail passenger and freight demand; forecast of demand for rail transportation; systems approach for railways; feasibility studies and financing methods; levels of planning; master plans; business plans.

Learning Resources:

Textbooks:

1. JS Mundrey, Railway Track Engineering, McGraw-Hill Education, New Delhi, India, 2017, Fifth Edition.
2. Satish Chandra, M.M. Agarwal; Railway Engineering, Oxford University Press, New Delhi, India, 2022, Second Edition (Tenth Reprint).

Reference Books:

1. Christos N. Pyrgidis, Railway Transportation Systems: Design, Construction, and Operation, CRC Press, Taylor and Francis Group, Boca Raton, Florida, US, 2022, Second Edition.
2. M.M. Agarwal, Indian Railway Track, Prabha & Co., New Delhi, India, 2023, Twentieth Edition (Golden Jubilee Reprint Edition).
3. S.C. Saxena, S.P. Arora; A Textbook of Railway Engineering, Dhanpat Rai Publications, New Delhi, India, 2017, Eighth Edition.
4. V.A. Profillidis, Railway Planning, Management, and Engineering, Routledge, Taylor and Francis Group, Abingdon, Oxfordshire, UK, 2022, Fifth Edition.

Online Resources

1. https://rdso.indianrailways.gov.in
2. https://uic.org/
3. https://www.iricen.gov.in

CE66044 **3-0-0 (3)**

Road Safety Engineering

Pre-Requisites: **CE66003**

Course Outcomes:

CO-1	Analyze the effect of user, roadway, and environmental characteristics on traffic safety.
CO-2	Plan and design of road safety improvement programs.
CO-3	Evolve safety measures using accident data.
CO-4	Conduct road safety audit.
CO-5	Interpret accident data using statistical analysis.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	3	2	1
CO-2	3	3	3	2	2	3
CO-3	3	3	3	3	2	3
CO-4	2	3	3	3	2	3
CO-5	3	3	2	2	2	3

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Basics of Road Safety: Road accidents, Trends, Global and Indian level, Crash Causes, Collision diagrams, highway safety, human factors and road user limitations, speed and its effect on road safety, vehicle factors, and highway safety in India.

Statistical Interpretation and Analysis of Crash Data: Before-after methods in crash analysis, Recording of crash data, Accident Investigation and Analysis, Statistical testing and the role of chance, Black Spot Identification and Investigations, Hot spot analysis, and Case Studies.

Road Safety Management System: Multi-causal dynamic systems approach to safety; Crash Vs. Accident; Road safety improvement strategies; Elements of a road safety plan; Speed management; Safety data Needs; Intersection Safety; Safe vehicle design.

Road Safety Audits: Key elements of a road safety audit, Road Safety Audits & Investigations, Work zone safety audit, Crash investigation and analysis, Methods for identifying hazardous road locations, and Case Studies.

Crash Reconstruction: Describe the basic information obtained from the roadway surface, 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, and Case Studies.

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; Design of Forgiving roads and self-explaining roads, Effective Road Signs and Street Lighting, Safety in urban areas; Public transport and safety; Road safety policymaking, Stakeholders involvement; Road safety law.

Learning Resources:

Textbooks:

1. Leonard Evans, Traffic Safety, Science Serving Society, 2006.
2. Geetam Tiwari, and Dinesh Mohan, Transport Planning and Traffic Safety: Making Cities, Roads, and Vehicles Safer, CRC Press, 2016, First Edition.
3. Ezra Hauer, Observational Before-After Studies in Road Safety, Pergamon Press, 1997 (Reprinted 2002).

Reference Books:

1. Athelstan C. Popkess, Traffic Control and Road Accident Prevention, Chapman and Hall, 1997 (Digitised in 2007).
2. ITE, The Traffic Safety Toolbox: A Primer on Traffic Safety, ITE, 1999.
3. Kenneth S Baker, J Stannard Baker, Traffic Collision Investigation, Northwestern University Center for Public Safety, 2002
4. Lynn B. Fricke, Traffic Accident Reconstruction, Northwestern University Center for Public Safety, 1990.
5. Rune Elvik, Truls Vaa, Alena Hoye, Michael Sorensen, The Handbook of Road Safety Measures, Emerald Group Publishing, 2009, Second Edition.
6. TRL, Towards Safe Roads in Developing Countries, TRL–ODA, 2004.

Online Resources:

1. http://tripp.iitd.ernet.in/publication/report
2. https://atpio.org/webinar-on-addressing-road-safety-worldwide-vulnerable-road-users-human-factors-rs-in-lmic/
3. https://ebrdelearning.com/course
4. https://morth.nic.in/reports-working-group-4-es-road-safety-0
5. https://vimeo.com/294277710
6. https://www.ptvgroup.com/en/solutions/products/ptv-visum/ptv-visum-safety/
7. https://www.who.int/data/gho/data/themes/road-safety
8. https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/decade-of-action-for-road-safety-2021-2030

CE66046 **3-0-0 (3)**

Traffic Flow Modelling and Simulation

Pre-Requisites: **CE66003**

Course Outcomes:

CO-1	Distinguish methods of traffic flow modelling.
CO-2	Explore pedestrian stream models.
CO-3	Analyse shock waves and queuing patterns.
CO-4	Develop and validate traffic simulation models.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	3	-	1
CO-2	3	3	3	3	-	1
CO-3	3	3	3	3	-	2
CO-4	3	3	3	3	-	2

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Traffic Flow Modeling: Basic concepts, time-dependent and independent models, advanced macroscopic models, microscopic models modelling approach, lane changing models, N-T curves, gap acceptance models, inhomogeneous highway, moving bottlenecks, LWR models and its extension, car-following models, traffic based probabilistic and stochastic models

Pedestrian Flow Modeling: Pedestrian behaviour-based modelling, pedestrian behavioural models, pedestrian interactions models, microscopic and macroscopic models, pedestrian simulation concepts, and pedestrian stream model examples.

Shockwave Analysis: Shock wave theory, shockwave propagation and speeds, shock waves at various facilities, signalised intersections, shockwaves due to special causes, shockwave modelling, case studies, and examples.

Queuing Analysis: Queuing theory, queue discipline and patterns, deterministic analysis, stochastic analysis, single-channel, multiple channels, moving queue at bottlenecks and junctions, queuing examples for practices.

Simulation Methodologies: Fundamentals and concepts, components of traffic simulation, mathematical simulation model development, macroscopic, microscopic, and mesoscopic simulation models, software for simulation, calibration and validation simulation model, examples.

Learning Resources:

Textbooks:

1. Carlos F. Daganzo, Fundamentals of Transportation and Traffic Operations, Emerald, Inc., 2008.
2. Boris S. Kerner, Introduction to Modern Traffic Flow Theory and Control, Springer, 2009, First Edition.
3. Donald R. Drew, Traffic Flow Theory and Control, McGraw Hill Book Company, 1976.

Reference Books:

1. Adolf Darlington May, Traffic Flow Fundamentals, Prentice Hall, 1990 (Digitized in 2011).

2. Daniel L. Gerlough, Matthew J. Huber; Traffic Flow Theory: A Monograph, TRB special report 165, 1992.
3. Fred L. Mannering, Scott S. Washburn; Principles of Highway Engineering and Traffic Analysis, Jhon Wiley & Sons, 2019, Seventh Edition.
4. NASEM, TRB, Highway Capacity Manual: A Guide for Multimodal Mobility Analysis, The National Academies Press, Washington, DC, 2022, Seventh Edition.
5. Roger P Roess, William R McShane, Elena S Prassas; Traffic Engineering, Pearson Education, 2020, Fifth Edition.

Online Resources

1. https://www.rms.nsw.gov.au/business-industry/partners-suppliers/documents/technical-manuals/modellingguidelines.pdf
2. https://www.cityservices.act.gov.au/__data/assets/pdf_file/0009/1539576/ACT-Traffic-Microsimulation-Modelling-Guidelines.pdf

CE66048 **3-0-0 (3)**

Transport Economics and Project Appraisal

Pre-Requisites: **CE66003**

Course Outcomes:

CO-1	Differentiate macro and microeconomic principles.
CO-2	Quantify benefits and costs of transport projects and carry out economic analysis.
CO-3	Evaluate transport projects.
CO-4	Estimate the life cycle cost of transport projects.
CO-5	Appraise various financial models for the development of transport infrastructure.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	1	-	-	-
CO-2	3	3	2	-	-	-
CO-3	3	3	2	2	1	-
CO-4	3	3	3	1	-	-
CO-5	3	3	2	2	1	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Transport Economics: Review of Engineering Economics and Microeconomics, Welfare Theory and Equilibrium Conditions, Consumer Behavior: Utility Maximization, Perfect / Imperfect Competition in Transport Markets, Principles of Economic Analysis.

Methods of Economic Analysis: Discounted Cash Flows: Analysis of User Costs and Benefits, Fixed, variable, marginal, and average cost, opportunity cost, shadow price, the value of time, social cost of transportation, congestion as well as pollution cost, The Value of Travel Time, RUCS Models for Costs and Benefits, Methods of Economic Analysis; Suitability, Analysis for Null Alternative.

System Selection and Evaluation: Framework of Evaluation, Measures of effectiveness of economic analysis, Other Evaluation Procedures - Traditional Economic Analysis, the concept of consumer surplus, equity issues in investment, decision making, Delphi Technique, Multi-Criteria Evaluation, Case Studies.

Life Cycle Cost Analysis: Factors considered for Life Cycle Cost Analysis; data requirements for highway project feasibility analysis; the establishment of technical/ economic/ financial feasibility of a highway project; social benefits; fundamental aspects of depreciation; conventional and modified depreciation methods; examples of depreciation methods.

Financial Analysis – Private Sector Participation: BOT, BOOT, BOLT Projects – Case history – Project Planning – Project System Management – Project Implementation, financial analysis in the public and private sector, revenue generation enhancement techniques, Budgetary and Control; Viability Gap Funding-Highway project, corridor project, and system projects, special purpose vehicles financing.

Learning Resources:

Textbooks:

1. David A. Hensher, Transport Economics (Critical Concepts in Economics), Routledge 2011, First Edition.
2. Robley E. Winfrey, Economic Analysis for Transportation: A Guide for Decision Makers, International Textbook Co., Northwestern University, 1971 (Digitized in 2011).
3. Vinay Maitri, P.K. Sarkar; Theory and Applications of Economics in Highway and Transport Planning, Standard Publishers Distributors, 2010, First Edition.

Reference Books:

1. ADB, Financial Analysis and Evaluation: Technical Guidance Note, Asian Development Bank, 2019.
2. Andre de Palma, Robin Lindsey, Emile Quinet, Roger Vickerman; A Handbook of Transport Economics, Edward Elgar, 2013.
3. IRC: SP30-2019, Manual on Economic Evaluation of Highway Projects in India, Indian Roads Congress, New Delhi, 2019.
4. Kara M. Kockelman, T. Donna Chen, Katie A. Larsen, Brice G. Nichols; The economics of transportation systems: A Reference for Practitioners, CreateSpace, 2013.
5. NCHRP Synthesis 494, Life-Cycle Cost Analysis for Management of Highway Assets, TRB, Washington DC, 2016.

Online Resources

1. https://dspace.mit.edu/bitstream/handle/1721.1/107706/11-540j-fall-2006/contents/lecture-notes/index.htm
2. https://nptel.ac.in/courses/105/107/105107067/

CE66050 **3-0-0 (3)**

Transportation Network Analysis

Pre-Requisites: CE66001

Course Outcomes:

CO-1	Apply different traffic assignment techniques.
CO-2	Estimate Trip tables.
CO-3	Determine network reliability.
CO-4	Design transportation networks.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	1	-	1
CO-2	3	3	-	-	-	-
CO-3	2	2	-	-	-	1
CO-4	2	3	1	1	-	1

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Basics of Transport Networks: Network representation, Network equilibrium, Link and Cost Functions, Incidence matrices, Network capacity, shortest path algorithm.

Optimality and Cost Functions: Matrix operations, Objective functions, Traffic representation, Junction costs, Priority junctions, Signal controlled junctions.

Assignment Techniques: User Equilibrium—existence and Uniqueness, Deterministic user equilibrium assignment, Most Likely paths, Elastic demand, Time-Dependent Networks, stochastic user equilibrium assignment, User Equilibrium with variable demand models, Space-time networks, Case Studies.

Trip Table Estimation: Maximum entropy, Generalized least squares, Linear path-flow estimations, Log-linear path-flow estimations, Time-dependent methods, Case Studies.

Network Reliability: connectivity, Structure functions, reliability value; Heuristic methods; Travel time reliability; sample size considerations; experiment design for demand forecasting and transportation operations analysis.

Network Design: Bi-level Programming-Iterative design, Sensitivity-based algorithm, Sensitivity of user equilibrium, and stochastic user equilibrium methods. Combined trip distribution and assignment, Combined mode choice, assignment, discrete choice models, Application to route choice, Estimating OD matrices, Estimating demand functions, Theory of congestion pricing, Path flows, link flows, Path-based and origin-based methods.

Learning Resources:

Textbooks:

1. Michael G.H. Bell, Yasunori Lida; Transportation Network Analysis, John Wiley & Sons, 1997.
2. Yosef Sheffi, Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods, Prentice Hall Publishers, 1985.

Reference Books:

1. Michel Gendreau, Patrice Marcotte; Transportation and Network Analysis: Current Trends: Miscellanea in Honor of Michael Florian, Michael Alexander Florian, Springer Publisher, 2002.
2. Ravindra K. Ahuja, Thomas L. Magnanti, James B. Orlin; Network Flows, Creative Media Partners, LLC, 2018.

Online Resources:

1. https://sboyles.github.io/teaching/ce392c/index.html
2. https://transportgeography.org/contents/chapter2/geography-of-transportation-networks/
3. https://trid.trb.org/view/573501

CE66096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **CE66001, CE66003, CE66005**

Course Outcomes:

CO-1	Identify a field problem.
CO-2	Assimilate literature on the identified problem
CO-3	Investigate causes for the identified problem
CO-4	Conduct surveys/experiments and analyze the data
CO-5	Develop a suitable solution for the identified problem

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	2	-	-	2
CO-2	3	3	2	-	-	-
CO-3	3	3	2	-	-	2
CO-4	-	3	3	3	-	3
CO-5	3	3	3	3	3	3

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

There is no specific syllabus for this course. However, a student can choose any relevant and current real-world problem related to Transportation Engineering. Students must assimilate their knowledge to investigate and solve the identified field problem. They must conduct suitable field studies or laboratory experiments, analyse the data, and develop cost-effective solutions for the identified problem.

Evaluation Criteria:

The panel will evaluate the student based on the criteria below.

Criteria	Description	Weightage
I	Identification of Problem	10%
II	Study of Existing Systems and establishing clear objectives	15%
III	Planning of project and Methodology Development	15%
IV	Field Data Collection / Lab Experimentation and Analysis	15%
V	Model Development and Solution Generation	15%
VI	Documentation and Technical Writing	15%
VII	Presentation	15%

Learning Resources:

Textbooks:

1. Relevant Textbook based on the field problem identified.

Reference Books:

1. Research Articles / Reports available on the Internet
2. Transportation Engineering Journals
3. Transportation Engineering Textbooks and Handbooks

3rd Semester

CE67089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: NIL

Course Outcomes:

CO-1	Identify and choose the appropriate topic of relevance.
CO-2	Assimilate literature on technical articles.
CO-3	Write a technical report.
CO-4	Design and develop a presentation on a given technical topic.
CO-5	Deliver technical presentations on a specified topic.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	-	1	-	-
CO-2	3	2	-	2	-	-
CO-3	2	3	-	2	-	-
CO-4	2	2	-	2	-	-
CO-5	2	3	-	2	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

There is no specific syllabus for this course. However, a student can choose any topic related to Transportation Engineering. The topic should be relevant and currently researched. Students are advised to refer to articles published in current Transportation Engineering journals to choose their seminar topics. The student should review at least ten research papers relevant to the selected topic in addition to standard textbooks and handbooks. Students are required to prepare a seminar report in the standard format and give a presentation to the Seminar Assessment Committee (SAC) in the presence of their classmates. All the students must attend the presentations of their classmates.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightage
I	Organisation of Seminar Report	20%
II	Background Content (Literature Reviewed)	20%
III	Representation of Figures, Tables and Graphs	10%
IV	Spelling and Grammatical Correctness	10%
V	PowerPoint Slides preparation	10%
VI	Elocution	10%
VII	Eye Contact / Confidence Level	10%
VIII	Knowledge of the topic and understanding	10%

Each of the above criteria will be assessed at four levels of achievement as indicated below:

a) Unsatisfactory / Inadequate : (0% to 40%)
b) Basic / Satisfactory : (40% - 60%)
c) Proficient / Good : (60% - 80%)
d) Distinguished / Excellent : (80% - 100%)

Learning Resources:

Reference Books:

1. Research Articles / Reports available on the Internet
2. Transportation Engineering Journals
3. Transportation Engineering Textbooks and Handbooks

Online Resources:

1. Guidelines for the Preparation and Delivery of a Seminar Presentation: https://eopcw.com/find/downloadFiles/12
2. Guidelines on Seminar Presentations: https://foodsci.rutgers.edu/Graduate/GSA/pdf/SeminarGuidelines.pdf
3. http://onlinepubs.trb.org/onlinepubs/circulars/ec194.pdf
4. Instructor Resources: Seminar Proposal Guidelines, SAE International; http://www.sae.org/training/seminars/instructorzone/proposalguidelines.pdf

CE67091 **0-0-0 (2)**

Summer Internship / Research Experience (SIRE)

Pre-Requisites: NIL

Course Outcomes:

CO-1	Identify a field / Research Problem
CO-2	Apply engineering principles to real-world problems, gaining practical experience.
CO-3	Conduct surveys/experiments and analyse the data with ethical considerations.
CO-4	Develop a suitable sustainable solution for the identified problem.
CO-5	Communicate the learnings through reports and presentations.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	2	-	-	2
CO-2	3	3	2	-	-	-
CO-3	-	3	3	3	-	3
CO-4	3	3	3	3	3	3
CO-5	2	3	2	2	2	2

1: Slightly; 2: Moderately; 3: Substantially

Description:

There is no specific syllabus for this course. Students are expected to undergo at least eight weeks of training in an industry. Alternatively, he can work on a research project under the guidance of a faculty member in any HEI. Students must work on an assigned topic. The topic should be relevant and current. Students must assimilate their knowledge to investigate and find sustainable solutions to the identified field problem. They need to conduct suitable field studies/laboratory experiments. They must analyse the data and develop cost-effective solutions for the identified problem. Students must submit a report and present the work before an evaluation committee.

Evaluation Criteria:

The panel will evaluate the student based on the criteria below. The panel will determine the weightage for each criterion and inform the students.

Criteria	Description	Weightage
I	Relevance of the area of work	10%
II	Performance of the Task	30%
III	Crucial learnings from the work	20%
IV	Report Preparation	20%
V	Presentation	20%

Each of the above criteria will be assessed at four levels of achievement as indicated below:

a) Unsatisfactory / Inadequate : (0% to 40%)
b) Basic / Satisfactory : (40% - 60%)
c) Proficient / Good : (60% - 80%)
d) Distinguished / Excellent : (80% - 100%)

Learning Resources:

Textbooks:

1. Relevant Textbook based on the field problem identified.

Reference Books:

1. Research Articles / Reports available on the Internet
2. Transportation Engineering Journals
3. Transportation Engineering Textbooks and Handbooks

CE67093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **All Courses in I & II Semesters**

Course Outcomes:

CO-1	Assimilate knowledge of different courses studied.
CO-2	Develop overall comprehension of Transportation Engineering.
CO-3	Analyse real-life transportation problems with theoretical knowledge learned.
CO-4	Interpret and Articulate solutions to real-life transportation problems.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	3	1
CO-2	2	2	2	-	3	1
CO-3	2	3	2	-	3	2
CO-4	1	2	3	-	3	1

1: Slightly; 2: Moderately; 3: Substantially

Description:

In a Comprehensive viva voce, each student will be evaluated for their overall comprehension of the coursework and laboratory training they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots and schematics, write simple code, etc., as questioned by the panel. The panel will assess the students based on their responses.

Syllabus:

The entire course of study (All the required courses studied) up to the second semester of the I Year.

Learning Resources:

Textbooks:

1. Reading Material of all the courses.

Reference Books:

1. Case Studies / Consultancy Reports.

CE67097 **0-0-0 (8)**

Dissertation Part - A

Pre-Requisites: None

Course Outcomes:

CO-1	Appraise Research Problem Statement.
CO-2	Evaluate literature critically in a chosen area of research & establish Scope of work.
CO-3	Employ the ideas from the literature and Develop Research Methodology.
CO-4	Plan and carry out a pilot study.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	3	1	3	-	-
CO-2	3	3	1	3	-	3
CO-3	2	2	2	3	-	3
CO-4	3	3	1	3	3	3

1: Slightly; 2: Moderately; 3: Substantially

Description:

Students are required to search, collect, and review various research articles published in their chosen area of research. A student has to select a topic for his dissertation based on his/her interest and the available facilities at the commencement of dissertation work. A student shall be required to submit a dissertation report on the research work carried out by him/her.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the student's progress and finally give his/her assessment of the student's work.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightage:

Sub-component	Weightage
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

A committee constituted by the department head will conduct the midterm review and the end-semester viva voce examination.
iv. The marks may be distributed among various components, such as the selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done, and performance in viva-voce examination.
v. If the performance of the student in Dissertation Part-A is not satisfactory, he/ she will be awarded 'F' grade. The student has to repeat the dissertation work by registering in the next semester. Such students may be given an option either to continue with the same topic and with the same guide or change the guide and the topic of his/ her dissertation.

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightage
I	Introduction / Dissertation Statement	10%
II	Quality of Information / Evidence	10%
III	Support of Ideas / Analysis	10%
IV	Organisation / Development of Ideas	10%
V	Language Conventions	10%
VI	Documentation (Report Preparation)	20%
VII	Thesis Defense (Presentation + Questions & Answers)	30%

Each of the above criteria will be assessed at four levels of achievement as indicated below:

a) Unsatisfactory / Inadequate : (0% to 40%)
b) Basic / Satisfactory : (40% - 60%)
c) Proficient / Good : (60% - 80%)
d) Distinguished / Excellent : (80% - 100%)

Learning Resources:

Textbooks:

1. Derek Swetnam, Writing Your Dissertation, Oxford, UK, 2000, Third Edition.
2. Mark Stephan Felix and Ian Smith, A Practical Guide to Dissertation and Thesis Writing, Cambridge Scholars Publishing, 2019.

Reference Books:

1. Conference / Seminar Proceedings.
2. Handbooks / Research Digests.
3. Journal Publications.

Online Resources:

1. https://www.bolton.ac.uk/leaponline/Documents/LEAP-Printables/Writing-a-Dissertation.pdf
2. https://www.grammarly.com/blog/how-to-write-a-dissertation/
3. https://www.scribbr.co.uk/category/thesis-dissertation/
4. https://www.unk.edu/academics/gradstudies/admissions/grad-files/Grad%20Files/ThesisGdlnsFinal08.pdf

4th Semester

CE67098 **0-0-0 (12)**

Dissertation Part - B

Pre-Requisites: CE67097

Course Outcomes:

CO-1	Appraise Research Problem Statement.
CO-2	Evaluate literature critically in a chosen area of research & Establish a Scope of work.
CO-3	Formulate Study Methodology.
CO-4	Compile database with relevant field studies/laboratory tests.
CO-5	Develop appropriate models and discuss solutions.

Course Articulation Matrix:

CO\PO	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	3	1	3	-	-
CO-2	3	3	1	3	-	3
CO-3	2	2	2	3	-	3
CO-4	3	3	-	-	3	3
CO-5	3	3	3	3	3	3

1: Slightly; 2: Moderately; 3: Substantially

Description:

Students are required to search, collect, and review various research articles published in their chosen area of research. A student has to select a topic for his dissertation based on his/her interest and the available facilities at the commencement of dissertation work. A student shall be required to submit a dissertation report on the research work carried out by him/her.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the student's progress and finally give his/her assessment of the student's work.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weights:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

A committee constituted by the department Head will conduct the midterm review. An external examiner, along with the evaluation committee constituted by the Department head, will also conduct the end-of-semester examination.

iv. A student will be permitted to submit the dissertation only if he/she completes all the courses as required in the program.
v. The marks may be distributed among various components, such as the selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done, and performance in the end-of-semester examination.
vi. Dissertation and Viva-Voce: A student shall be required to submit a report on the Dissertation work carried out by him/her. The template for the dissertation report may be downloaded from

(https://www.nitw.ac.in/main/PGForms/NITW/). The students are required to submit a report showing that plagiarism is within 20%. Three/four bound copies along with a soft copy of the dissertation shall be submitted to the Head of the Department/Centre within the last date prescribed in the Academic Calendar for the purpose. Dissertation viva - voce will be held within the date fixed in the academic calendar and the grades will be finalized by the committee.

vii. If the performance of the student in Dissertation Part-B is not satisfactory, he/ she will be awarded 'F' grade. The student must repeat the dissertation work by registering in the next semester.

viii. Extension of dissertation work (Part-B) beyond the deadline of submission in very special case may be granted by the Dean (Academic) on recommendation of the department/center for a maximum period of 3 months and he/she will be awarded "I" Grade. The viva-voce must be completed within the extension period. The student shall not be eligible either for an award of scholarship during the extension period or any medal/prize. However, if the student had been absent on medical grounds and his/her dissertation had been extended, he/she may be eligible for award of medal or prize, if any. If the above-mentioned extension period encroaches into the next semester, the student will have to pay the tuition fee on par with full time student.

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightage
I	Introduction / Dissertation Statement	10%
II	Quality of Information / Evidence	10%
III	Support of Ideas / Analysis	10%
IV	Organisation / Development of Ideas	10%
V	Language Conventions	10%
VI	Documentation (Report Preparation)	20%
VII	Thesis Defense (Presentation + Questions & Answers)	30%

Each of the above criteria will be assessed at four levels of achievement as indicated below:

a) Unsatisfactory / Inadequate : (0% to 40%)
b) Basic / Satisfactory : (40% - 60%)
c) Proficient / Good : (60% - 80%)
d) Distinguished / Excellent : (80% - 100%)

Learning Resources:

Textbooks:

1. Derek Swetnam, Writing Your Dissertation, Oxford, UK, 2000, Third Edition.
2. Mark Stephan Felix and Ian Smith, A Practical Guide to Dissertation and Thesis Writing, Cambridge Scholars Publishing, 2019.

Reference Books:

1. Conference / Seminar Proceedings.
2. Handbooks / Research Digests.
3. Journal Publications.

Online Resources:

1. https://www.bolton.ac.uk/leaponline/Documents/LEAP-Printables/Writing-a-Dissertation.pdf
2. https://www.grammarly.com/blog/how-to-write-a-dissertation/
3. https://www.scribbr.co.uk/category/thesis-dissertation/
4. https://www.unk.edu/academics/gradstudies/admissions/grad-files/Grad%20Files/ThesisGdlnsFinal08.pdf