

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT/CENTRE: **CIVIL ENGINEERING**

1. Subject code: **CEN-561** Course Title: **Traffic Analysis and Design**
2. Contact Hours: **L: 3 T: 1 P: 0**
3. Examination Duration (Hrs): Theory: **3** Practical: **0**
4. Relative Weightage: CWS: **20-35** PRS: **0** MTE: **20-30** ETE: **40-50** PRE: **0**
5. Credits: **04**
6. Semester: **Autumn**
7. Subject Area: **PCC**
8. Pre-requisite: **Nil**
9. **Objective:** To introduce the advances in traffic engineering analysis and design and to make the students conversant with relevant field applications.

10. Details of Course:

S. No.	Particulars	Contact Hours
1	Introduction: Elements of traffic engineering, issues for traffic engineers; road users, vehicles, highways and control devices.	04
2.	Traffic Stream Characteristics: Traffic stream parameters, Time Space diagram, relationship among q,k,u, Macroscopic Fundamental Diagrams (MFD).	04
3.	Traffic Studies: Traffic volume studies, speed, travel time and delay studies, parking studies, RSI Survey, WTP Survey, accident data collection, pedestrian studies.	04
4.	Traffic design: Capacity analysis concepts – urban streets and rural highways, design of parking facilities, street design.	06
5.	Statistical application in Traffic Engineering: Overview of Probability Functions and Statistics, Normal Distribution and application, Confidence Bounds, Sample Size, Binomial Distribution, Poisson Distribution, Hypothesis Testing.	08
6.	Microscopic Modeling: Classification of Time Headway, Random Headway State, Constant Headway State, Intermediate Headway State, Car Following Theory.	06
7.	Time Series Analysis: Basic Components of Time Series, Smoothing and Decomposition Methods, Data Filters, Auto Correlations and Moving Averages.	04
8.	Management Techniques: Traffic calming; Congestion and road user pricing; priority movements; traffic regulations and control systems; use of intelligent systems.	06
<b>TOTAL</b>		<b>42</b>

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1.	William R. Mcshane and Roger P. Roess, "Traffic Engineering", Pearson (4 <sup>th</sup> Edition).	2013
2.	Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers.	2012
3.	C A O'Flaherty, Ed , "Transport Planning and Traffic Engineering", Butterworth Heinemann, Elsevier, Burlington, MA	2006
4.	May, A.D., "Fundamentals of Traffic Flow", Prentice Hall, Inc. 2 <sup>nd</sup> Ed.	1990
5.	Carlos F. Daganzo. "Fundamentals of Transportation and Traffic Operations", Pergamon	1997
6.	Simon P. Washington, Matthew G. Karlaftis and Fred L. Mannering, "Statistical and Econometric Methods for Transportation Data Analysis", Second Edition, CRC Press	2011

  
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## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Civil Engineering Department**

1. Subject Code: **CEN-562** Course Title: **Pavement Analysis and Design**  
 2. Contact Hours: **L: 3 T: 1 P: 0**  
 3. Examination Duration (Hrs.): **Theory 3 Practical 0**  
 4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**  
 5. Credits: **4** 6. Semester: **Autumn** 7. Subject Area: **PCC**  
 8. Pre-requisite: **Nil**  
 9. Objective: To impart knowledge to students related to analysis and design with respect to Highway Pavement.

10. Details of Course:

S. No.	Perticulars	Contact Hours
1.	<b>Introduction:</b> Components of pavement structure, importance of subgrade soil properties on pavement performance. Functions of subgrade, subbase, base course and wearing course.	<b>4</b>
2.	<b>Stresses in Pavements:</b> Flexible pavements - Stresses in homogeneous masses and layered systems, deflections, shear failures, equivalent wheel and axle loads; Rigid pavements - Westergaard's and Thomlinson's analysis of warping stresses, Combination of stresses due to different causes, Effect of temperature variation on Rigid Pavements	<b>8</b>
3.	<b>Design Elements of Flexible Pavements:</b> Loading characteristics-static, impact and repeated loads, effects of dual wheels and tandem axles, area of contact and tyre pressure, modulus or CBR value of different layers, equivalent single wheel load, equivalent stress and equivalent deflection criterion, equivalent wheel load factors, climatic and environmental factors.	<b>6</b>
4.	<b>Design Methods for Flexible Pavements:</b> California bearing ratio (CBR) adopted in various countries, IRC: 37-2018, AASHTO Design Guide, Triaxial method, Boussinesq's and Burmister's analysis, Pavement designing software (IITPAVE, KENPAVE, MICH-PAVE); Design of flexible pavements for low volume roads.	<b>8</b>
5.	<b>Rigid Pavements:</b> Design of rigid pavement using IRC: 58-2015 and AASHTO guidelines, Wheel load stresses, Role of modulus of subgrade reaction, Westergaard's analysis, Bradbury's approach Arlington test, Pickett's corner load theory and charts for liquid, elastic and soil of finite and infinite depths of subgrade.	<b>8</b>
6.	<b>Types of Concrete Pavements:</b> Roller Compacted Concrete Pavement, Plain Jointed Concrete Pavement, Continuously Reinforced Concrete Pavement, Prestressed concrete pavement, Design of Tie Bars and Dowel Bars, Role of Dry Lean Concrete; Rigid pavement design for low volume roads	<b>8</b>
<b>Total</b>		<b>42</b>

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1	Yoder, E.J. and Witczak, M.W., "Principles of Pavement Design 2 <sup>nd</sup> Ed", John Wiley & Sons, Inc.	1975
2	O'Flaherty, A. Coleman, "Highways : the Location, Design, Construction and Maintenance of Road Pavements", 4 <sup>th</sup> Ed., Elsevier	2006
3	Fwa, T.F., "The Hand Book of Highway Engineering", CRC Press Taylor & Francies Group.	2006
4	Khanna, S.K. and Justo, C.E.G., "Highway Engineering Nem Chand Jain & Bros, 8 <sup>th</sup> Ed.	2005
5	Papagiannakis, A.T. and Masad, E.A., "Pavement Design and Materials, John Wiley & Sons Inc.	2008
6	Yang H. Huang, " Pavement Analysis and Design" Second Edition, Pearson Education Inc.	2004



INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Civil Engineering**

1. Subject Code: **CEN-563** Course Title: **Urban Mass Transit Systems**  
 2. Contact Hours: **L: 3 T: 1 P: 0**  
 3. Examination Duration **Theory: 3 Practical: 0**  
 4. Relative Weightage: **CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**  
 5. Credits: 4 6. Semester **Autumn**  
 7. Prerequisite: **NIL** 8. Subject Area: **PCC**  
 9. Objective of Course: To introduce the students to urban mass transit systems, their types, suitability, planning, operation and management aspects.

10. Details of the Course.

S. No.	Course Description	Contact hours
01	<b>Introduction:</b> Mass transit systems, Elements / components of transit systems; Urban Mass Transit systems, types, characteristics, suitability and adaptability of these systems; Evolution of urban transportation.	3
02	<b>Transit System Planning:</b> Planning needs; Short-range and long-range planning; Planning procedures and methodology, Data collection; Medium performance transit systems and high-performance transit systems; trends in transit planning.	6
03	<b>Transit Demand Estimation and Evaluation:</b> Transit demand forecasting; transit mode evaluation; comparison and selection of most suitable transit mode.	8
04	<b>Transit System Operations:</b> Basic operational elements; transit travel characteristics; transit scheduling; transit line analysis – planning objectives, geometry, types and their characteristics, capacity of transit lines, system procedures for improving transit line capacity.	10
05	<b>Transit Networks and System Analysis:</b> Transit networks – types and their characteristics; transfers in transit networks; system analysis in transit – conceptual models, modeling procedures; terminal or station location planning – issues, objectives, station spacing decisions.	8
06	<b>Economics and Financing of Transit Systems:</b> Transit system performance and economic measures; transit fares – structure, collection and levels; financing of transit services; public and private integration of transit services.	6
	Total	42

**Suggested Books:**

S. No	Authors / Title // Publisher	Year of publication
1	Vukan R. Vuchic, "Urban Transit – Operations, Planning and Economics", John Willey and Sons, Inc., USA	2004
2	Vukan R. Vuchic, "Urban transit systems and technologies", John Willey and Sons, Inc., USA	2007
3	C A O'Flaherty, 'Transport Planning and Traffic Engineering', Butterworth-Heinemann, Burlington	2006
4	C Jotin Khisty and B Kent Lall, "Transportation Engineering" Prentice-Hall of India Pvt Ltd., New Delhi	2003

  
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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT/CENTRE : **Civil Engineering**

1. Subject Code : **CEN-564**      Course Title : **Geometric Design**
2. Contact Hours : **L: 3    T : 1    P: 0**
3. Examination Duration (Hrs) :      **Theory : 3    Practical : 0**
4. Relative Weight : **CWS : 20-35    PRS: 0    MTE: 20-30    ETE: 40-50    PRE: 0**
5. Credits : **04**      6. Semester: **Autumn**      7. Subject Area : **PCC**
8. Pre-requisite: **Nil**
9. Objective: To introduce concepts and design procedures for different types of roads and associated facilities.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	<b>Introduction:</b> Design Controls - Topography and physical features, traffic, vehicular characteristics, speed and safety; Space standards for urban, rural and hill roads, Sight distance requirements, Access controls	6
2.	<b>Cross-section Elements :</b> Single lane, Two lane, Multi-lane highways, Expressways, Urban roads; Street design concepts, bicycle tracks, pedestrian facilities, street furniture, Design of Speed Breaker	6
3.	<b>Alignment :</b> Horizontal Alignment - Curve design, Super-elevation design, Transition curve design, Attainment of super-elevation, Pavement widening, Sight distance on horizontal curves; Vertical Alignment - Gradients, Grade compensation, Design of vertical curves, Combination of horizontal and vertical alignment, vertical clearance for underpasses and elevated structures	6
4.	<b>Highway Capacity:</b> Two lane, Four lane, Six lane non-urban highways, Urban roads, Expressways, HCM USA and IRC Specifications	8
5.	<b>Intersection Geometry:</b> Visibility requirements, Principles of channelization, Layout design for types of intersections, on-ramps and off-ramps (flyovers and Access controlled facilities), Acceleration and deceleration lanes, Two-way turn lanes,	6
6.	<b>Design of Facilities:</b> Design of on-street and off-street parking facilities, multi-storied Parking; Design of bus shelters and bus lay-bye, Bus terminal, Truck terminals and truck lay-bye, Container terminal, Toll Plaza, Foot-over bridge and sky-walk	10
<b>Total</b>		<b>42</b>

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Wright, P.H. & Dixon, K.K., "Highway Engineering", 7 <sup>th</sup> Ed., John Wiley & Sons.	2004
2.	Transportation Research Board (TRB), Highways Capacity Manual, National Research Council, Washington D.C.	2010
3.	Khisty, C.J. and Lal, B.K., "Transportation Engineering - An Introduction", Prentice Hall of India Pvt. Ltd.	2006
4.	Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers.	2008

  
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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: CEN- 565 Course Title: **Planning, Design and Construction of Rural Roads**
2. Contact Hours: L: 3 T: 1 P: 0
3. Examination Duration Theory: 3 Practical: 0
4. Relative Weightage: CWS: 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0
5. Credits: 4
6. Semester **Autumn**
7. Prerequisite: NIL
8. Subject Area: **PEC**
9. Objective of Course: To introduce the concepts of Planning, Geometric Design, Pavement Design, Construction and Maintenance of Rural Roads

10. Details of the Course:

S. No.	Course Description	Contact hours
01	<b>Planning of Rural Roads:</b> Classification of Roads, Brief introduction to earlier 20 year Plans, System's Approach, NATPAC Model, Gravity Model, CRR I Model, FBRNP Model, Concepts of PMGSY	08
02	<b>Geometric Design:</b> Geometric Design Standards for Rural Roads with special reference to PMGSY, Hill Road Standards.	04
03	<b>Pavement Design:</b> Various pavement design methods for Rural roads including Flexible and Rigid pavements using IRC:SP-20, IRC-72, IRC-37, IRC:SP-62, CRR I Nomograms	04
04	<b>Mix Design Methods:</b> CRR I Method, Triangular Chart Method, Fuller's Method, Rothfuch method, PI based Method	06
05	<b>Materials:</b> Brief introduction to conventional materials, Marginal and Waste Materials including Fly Ash, GBFS, BFS, SMS, Bagasse, CRMB, etc	06
06	<b>Construction:</b> Case Studies of Waste Material Utilization in Rural Roads, Low Cost Techniques for Rural Road Construction, Tractor Bound Technology, Special Considerations for Hill Areas	06
07	<b>Drainage:</b> Transverse and Longitudinal Drainage, Design of drains, Minor CD Works, Filter Design etc.	04
08	<b>Maintenance:</b> Type and Causes of Failures, Remedies	04
	Total	42

**Suggested Books:**

S. No	Authors / Title // Publisher	Year of publication
1	Rural Roads Manual , SP-20, IRC	2002
2	Document on Rural Road Development, Vol I & II, CRR I	1990
3	PMGSY Operation Manual, NRRDA, Govt of India	2005
4	Specifications for Rural Roads, MoRD, IRC	2004
5	Khanna S.K., Justo C.E.G., Highway Engineering, Nem Chand & Bros, Roorkee	2004
7	Quality Assurance Handbook for Rural Roads, NRRDA, Govt. of India	2007



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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: **CE-566** Course Title: **Airport Planning and Design**  
 2. Contact Hours: **L: 3 T: 1 P: 0**  
 3. Examination Duration Theory 3 Practical 0  
 4. Relative Weightage: CWS: **20-35** PRS: **0** MTE: **20-30** ETE: **40-50** PRE: **0**  
 5. Credits: 4 6. Semester **Autumn**  
 7. Prerequisite: NIL 8. Subject Area: **PEC**  
 9. Objective of Course: To familiarize students on various techniques related to airport planning and design.

10. Details of the Course.

S. No.	Course Description	Contact hours
01	<b>Airport Planning:</b> Airport master plan, aircraft characteristics related to airport planning and site selection, air traffic demand analysis, planning surveys, airport zoning.	08
02	<b>Geometric Design:</b> Airport classification, runway and taxiway geometric standards, exit taxiways, separation and clearances.	06
03	<b>Terminal Areas:</b> Facilities, space requirement, number and size of gate positions, aircraft parking system.	06
04	<b>Visual Aids :</b> Airport day time markings, airport lighting, visibility, visual aids	03
05	<b>Structural design of airport pavements:</b> Design Factors, Design of flexible and rigid pavements	06
06	<b>Airside capacity and delay:</b> Mathematical models for capacity and delay, space time concept, models for mixed traffic	06
07	<b>Air Traffic Control:</b> Importance of flight rules, navigational aids, air traffic controls, obstruction and clearance requirements	04
08	<b>Airport Drainage :</b> Design run-off, inlet size and location design, surface and subsurface design	03
	<b>Total</b>	<b>42</b>

**Suggested Books:**

S. No.	Authors / Title // Publisher	Year of publication
1	Robert Horonjeff and Francis X. McKelvey, "Planning & Design of airports, McGraw Hill, Inc, 4 <sup>th</sup> edition	1993
2	S. K. Khanna, M. G. Arora and S. S. Jain, "Airport Planning & Design", Nem Chand and Bros, Roorkee	2000
3	Ashford, N. and Wright, P. H., "Airport Engineering, Wiley, 3 <sup>rd</sup> edition.	1992
4	ICAO, "Aerodrome design manual", International Civil Aviation Organization, Montreal, Canada	1983

  
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INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: **Civil Engineering**

1. Subject Code: **CEN- 567** Course Title: **Transportation Systems Analysis**  
 2. Contact Hours: **L: 3 T: 1 P: 0**  
 3. Examination Duration Theory 3 Practical 0  
 4. Relative Weightage: CWS: **20-35** PRS: **0** MTE: **20-30** ETE: **40-50** PRE: **0**  
 5. Credits: 4 6. Semester **Autumn**  
 7. Prerequisite: NIL 8. Subject Area: **PEC**  
 9. Objective of Course: To introduce the students to the analysis of different transportation systems, their components, operations, systems analysis approaches and economics.

10. Details of the Course:

S. No.	Course Description	Contact hours
01	<b>Introduction:</b> Scope of transportation and impact on society; System planning process and problem solving process; transportation problems.	06
02	<b>Transportation Technologies:</b> Transportation technologies, suitability and adaptability; Transportation system components; Transportation system characteristics – technological and operational; Path – vehicle interaction; Volume – Density relationship for containers.	10
03	<b>Analysis of Systems:</b> Generation of alternatives; Performance evaluation of system and performance functions; Operational planning and analysis of components; Transportation network analysis and Minimum path algorithms; Travel in space and time; Planning for non-motorized transportation; Freight transportation planning–models and methods; Residential location choice models, Car-ownership models; transportation software.	12
04	<b>Transportation Economics:</b> Transportation demand and supply; Equilibrium between supply and demand, transportation system equilibrium; Elasticity – direct and cross; concept of consumer surplus; transport demand models – sketch planning, incremental demand model, model estimation from traffic counts; transportation cost, travel – market equilibrium.	08
05	<b>Sustainable Transportation Planning:</b> Sustainable transportation – issues and principles; non-motorized transportation planning; Impact evaluation and impact models.	06
	Total	42

**Suggested Books:**

S. No	Authors / Title // Publisher	Year of publication
1	Marvin L Manheim, “Fundamentals of Transportation Systems Analysis”, The MIT Press, Cambridge, Massachusetts	1980
2	Adib Kanafani, “Transportation Demand Analysis”, McGraw Hill Inc, New York, U.S.A.	1983
3	Steenbrink, P.A., Optimization of Transport Network, John Wiley & Sons, NY.	1974
4	Konstadinos G Goulias, “Transportation System Planning – Methods and Applications”, CRC Press, London	2002
5	C Jotin Khisty and B Kent Lall, “Transportation Engineering – An Introduction”, Prentice Hall of India Pvt Ltd., New Delhi	2003
6	Thomas A Domencich and Daniel McFadden, “Urban Travel Demand – A Behavioural Analysis”, North-Holland Publishing Company, Amsterdam	1975

  
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## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: **CEN- 568** Course Title: **Advanced Highway Material Characterization**
2. Contact Hours: **L: 3 T: 1 P: 2/2**
3. Examination Duration **Theory 3 Practical 0**
4. Relative weight **CWS 15-30 PRS 20 MTE 15-25 ETE 30-40 PRE 0**
5. Credits: 04
6. Semester **Autumn**
7. Prerequisite: NIL
8. Subject Area: **PEC**
9. Objective of Course: To introduce the advanced technologies in pavement engineering materials and to make the students conversant with characterization of various conventional and alternative road construction materials.

10. Details of the Course.

S. No.	Course Description	Contact hours
1	<b>Soil:</b> Classification of soil, Identification and strength tests- Atterberg limits, compaction tests, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), Modulus of subgrade reaction, Resilient Modulus, Permeability, Free Swelling Index (FSI), Deleterious materials, sand equivalent test, Soil stabilization techniques.	06
2	<b>Aggregates:</b> Origin and Classification, physical, mechanical and durability properties, sampling techniques, aggregate texture and skid resistance, Polish Stone Value, Alkali-aggregate reactivity.	06
3	<b>Binders:</b> (i) <b>Bitumen:</b> Bitumen sources and manufacturing, Bitumen constituents and its properties, Structure and Rheology, tests on bitumen-emulsions & cutback, modified bitumen and its types, goals of modification, properties of modified bitumen, separation test, long-term and shorter aging of bitumen, Elastic recovery test of modified bitumen (ii) <b>Cement:</b> Origin, composition, Types of cement, physical properties of cement (consistency, setting times, soundness and strength of cement), flow test.	10
4	<b>Bituminous and Concrete Mix Designs:</b> Design of Granular Sub-base and their desirable properties; Design of Wet Mix Macadam and their desirable properties; Design of Bituminous Mixtures & reports- Desirable properties of mixes, Moisture susceptibility, stripping value, Fillers, Theory of fillers and specifications; Marshall Method MS-2; Foamed Asphalt Mix Design; Cold Mix Design. Concrete Mix Design - Constituents and their requirements, Physical, plastic and structural properties of concrete, Factors influencing mix design, Design of concrete mixes, porosity of concrete; Dry Lean Concrete; Pavement Quality Concrete (PQC)	12
5	<b>Alternative Pavement Materials:</b> Recycled Concrete aggregates, Reclaimed asphalt pavement materials, use of industrial and agricultural wastes for pavement construction, chemical and mineral admixtures	08
<b>Total</b>		<b>42</b>

### LABORATORY TESTS

S. No.	Course Description
1	<b>Soil and Aggregate testing:</b> Free Swelling Index (FSI) and Deleterious material content, CBR test, Unconfined Compression test, Sand equivalent test, aggregate polishing and skid resistance test, soundness test.
2	<b>Straight-run bitumen/Modified bitumen Tests:</b> Penetration value test, Elastic recovery test of binders & Dynamic Shear Rheometer (DSR)
3	Formulation of design mixes for sub-base and unbound base course (Granular Sub-base & Wet mix Macadam)



4	<b>Bituminous Mixture:</b> Proportioning of aggregates, preparation of test specimens, and testing, formulations of bituminous mixtures (conventional bituminous mixtures for bound base courses)
5	<b>Concrete mixes:</b> Proportioning of aggregates, preparation of test specimens, and testing, design of dry lean concrete mix, design of pavement quality concrete mix
6	<b>Alternative pavement materials:</b> Design of cement treated sub-base and base using reclaimed asphalt pavement materials.

**Suggested Books:**

S. No	Authors / Title // Publisher	Year of publication
1	P. Kumar Mehta, Paulo J.M. Monteiro, "Concrete microstructure, properties, and materials, Third Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.	2006
2	Dr. L.R. Kadyali and Dr. N.B. Lala, "Principles and Practices of Highway Engineering", Khanna Publishers, New Delhi.	2010
3	Paul H. Wright and Karen K. Dixon, "Highway Engineering" Seventh Edition John Wiley & Sons, Inc.	2004
4	Yang H. Huang, "Pavement Analysis and Design", Second Edition, Pearson Prentice Hall.	2004
5	T.F. Fwa, "The Handbook of Highway Engineering", CRC, Taylor & Francis Group.	2006
6	S.K. Khanna, C.E.G. Justo and A.Veeragavan, "Highway Engineering" Revised 10 <sup>th</sup> Edition, Nem Chand & Bros., Roorkee.	2015
7	Read, J. And Whiteoak, D., "The Shell Bitumen Handbook", Fifth edition, Shell Bitumen, Thomas Telford Publishing, London	2003



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**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: **CEN- 661**
2. Course Title: **Advanced Highway Construction and Maintenance**
3. Contact Hours: **L: 3 T: 1 P: 2/2**
4. Examination Duration **Theory 3 Practical 0**
5. Relative weight **CWS 15-30 PRS 20 MTE 15-25 ETE 30-40 PRE 0**
6. Credits: **4**
7. Semester **Spring**
8. Prerequisite: **NIL**
9. Subject Area: **PEC**
10. Objective of Course: To introduce the advances in highway construction and evaluation, making the students conversant with the different construction and evaluation techniques.

11. Details of the Course.

S. No.	Course Description	Contact hours
1	<b>Embankment &amp; Subgrade</b> Setting Out. Clearing and Grubbing, Road formation width, Borrow Pits, Quarries, Construction under special cases, Embankment Construction, Subgrade construction, Backfilling, Preparation of cut formation, Surface and subsurface drains.	06
2	<b>Flexible Pavements</b> <i>Subbase:</i> Granular Subbase (GSB); <i>Unbound Courses:</i> Water Bound Macadam (WBM), Wet Mix Macadam (WMM); <i>Bound Courses:</i> Bituminous Macadam (BM), Dense Bituminous Macadam (DBM); <i>Wearing Courses:</i> Bituminous Concrete (BC), Semi Dense Bituminous Concrete (SDBC).	06
3	<b>Cement Concrete Pavement</b> Dry Lean Concrete (DLC), Roller Compacted Concrete Pavement (RCCP), Pavement Quality Concrete (PQC), Continuously Reinforced Concrete Pavement (CRCP), Cement Concrete Pavement Construction Techniques: Manual, Automated (Fixed Form, Slip Form).	10
4	<b>Highway Maintenance &amp; Evaluation:</b> Need of Highway maintenance, methods of maintenance for flexible and rigid pavement layers; Load man, Different Types of Falling Weight Deflectometers (FWD) for evaluation of rigid and flexible pavements, Distress Modes - Cracking, Rutting etc. Factors influencing deflections, Back-calculation of Pavement Layer Moduli and detection of loss of bonding of cement concrete pavements using FWD data; Destructive Structural Evaluation; Different Methods of NDT(Working Principles): Benkelman Beam, Pavement Safety Evaluation: Skid Resistance, Purposes, functional Evaluation: Serviceability concepts, Distress types: Bituminous and Concrete pavements; Visual Rating; PSI; Methods of Measuring Roughness:	08
5	<b>Quality Control in Highway Construction:</b> Execution and quality control prior to construction, during construction and post construction: Standard deviation, mean, normal distribution, control chart – Quality audit of finished pavement – Performa of quality assurance records.	06
	<b>Total</b>	<b>42</b>

**LABORATORY TESTS:**

S. No.	Course Description
1	<b>Aggregate testing:</b> Aggregate polishing value and skid resistance test
2	<b>Straight-run bitumen/Modified bitumen Tests:</b> Emulsion and Cutback, PAV (Pressure ageing vessel) and RTFOT (Rolling thin film oven test) – video class & demonstration, bitumen viscosity test (Rotational viscometer) – video class & demonstration
3	<b>Bituminous Mixture:</b> Resilient modulus of bituminous mixture (video class & demonstration), foamed asphalt mixture, cold mixture), fatigue and rutting tests (video class and demonstration)



4	<b>Concrete mixes:</b> Abrasion resistance test on hardened concrete (video class & demonstration), Concrete permeability test, Mercury Intrusion Porosimetry (MIP) –video class & demonstration
5	<b>Highway Maintenance related experiments:</b> Benkelman Beam tests, Merlin Test, Falling Weight Deflectometer, Axle Load Survey, Roughness survey of roads using Roughometer

**Suggested Books:**

S. No.	Authors / Title // Publisher	Year of publication
1	Hou Xiangshen, Ma Songlin, "Highway maintenance and management" China communication Press.	2016
2	Sanford Eleazer Thompson, "Concrete in Highway Construction- A text book for highway engineers and supervisors" Forgotten Books Publisher	2018
3	Dr. L.R. Kadiyali and Dr. N.B. Lala, " Principles and Practices of Highway Engineering", Khanna Publisher.	2005
4	Richard Robinson, Uno, Danielson, Martin Snaith, "Road Maintenance Management" Concepts and Systems, Palgrave publisher	1998
5	Kandhal Prithvi Singh, "Bituminous Road Construction in India", PHI Learning Private Limited, Delhi- 110092.	2016

  
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## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: **CEN-662**                      Course Title: **Intersection Design and Analysis**  
 2. Contact Hours:    **L: 3**                      **T: 1**                      **P: 0**  
 3. Examination Duration    **Theory 3**                      **Practical 0**  
 4. Relative weightage    **CWS 20-35**                      **PRS 0**                      **MTE 20-30**                      **ETE 40-50**                      **PRE 0**  
 5. Credits: **4**                                      6. Semester **Spring**  
 7. Prerequisite: **NIL**                              8. Subject Area: **PEC**

9. Objective of Course: To discuss various methods of design and analysis of different types of road intersections and interchanges.

10. Details of Course

Sl No.	Topics to be covered	Contact hours
1	Types of intersections, Principles of design, types of maneuvers, relative speed, conflict points and area	6
2	Intersection geometrics and their influence on design/operation	3
3	Operational analysis of two-way and all-way stop controlled intersections and roundabouts by US and Indian methods, mini roundabouts	6
4	Analysis of signal controlled intersections by US, British and Swedish methods, delay and its evaluation	12
5	Types of signals, Design of signals by Indian, US and British methods, signal coordination	6
6	Grade separated intersections and interchanges	4
7	Weaving sections and their operational evaluation	3
8	Intersection signs, marking and lighting	2

### Suggested Books:

S. No.	Name of Books / Authors / Publisher	Year of Publication
1	Transportation Engineering & Planning, by C. S. Papacostas and P. D. Prevedouros, Prentice Hall of India Private Limited, New Delhi	2001
2	Principles of Highway Engineering and Traffic Analysis, by Fred L Mannering, Walter P. Kilareski and Scott S. Washburn, Wiley India Edition	2007
3	Transportation Engineering, by C. Jotin Khisty and B. Kent Lall Prentice Hall of India Private Limited, New Delhi	2006
4	Transport Planning and Traffic Engineering, by C A O Flaherty, Hodder Headline Group, London	1997
5.	Highway Capacity Manual of US, by Transportation research Board, Washington DC	2000



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## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Civil Engineering Department**

1. Subject Code: **CEN-663** Course Title: **Pavement Evaluation and Management**  
 2. Contact Hours: **L: 3 T: 1 P: 0**  
 3. Examination Duration (Hrs.): **Theory 3 Practical 0**  
 4. Relative weightage **CWS 20-35 PRS 0 MTE 20-30 ETE 40-50 PRE 0**  
 5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC**  
 8. Pre-requisite: **Nil**  
 9. Objective: To provide knowledge related to Evaluation and Management with respect to Road Development.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	<b>Pavement Evaluation:</b> General concept of pavement evaluation, Evaluation of pavement performance; Evaluation of pavement structural capacity; Evaluation of pavement distress - Structural and functional, serviceability, fatigue cracking, pavement deformation and low temperature shrinkage cracking; Evaluation of pavement safety – Skid resistance, measurement, variation with time, traffic and climate, control.	6
2.	<b>Pavement Performance Evaluation:</b> Factors affecting performance, relation between performance and distress; Visual ratings, PSI, Methods of measuring roughness, response and profile; IRI – Quarter Car Model, riding number; Pavement performance prediction models for flexible and rigid pavements.	6
3.	<b>Pavement Structural Evaluation:</b> Different methods of NDT - Benkelman Beam, Bump Integrator, Dynaflect, LaCroix Deflectometer, Road Ratar, Rolling Dynamic Deflectometer, Loadman, Falling weight deflectometers; Factors influencing deflection; Back calculation of Pavement Layer Moduli; Flexible overlays and determination of overlay thickness. Rigid overlays and determination of overlay thickness. Design of Overlay by Benkelman Beam and Falling Weight Deflectometer.	12
4.	<b>Design Alternatives – Analysis, Evaluation and Selection:</b> Framework for pavement design, design objectives and constraints, Basic structural response models, characterization of physical design inputs, Generating alternative pavement design strategies. Economic evaluation of alternative pavement design strategies, analysis of alternative design strategies. Predicting distress, predicting performance, selection of optimal design strategies.	6
5.	<b>Pavement Management System (PMS):</b> Components and related activities, steps in implementation of a PMS; Design, construction and maintenance; Rehabilitation and Feedback data system; Examples of Working Design and Management Systems; Evaluation of alternate strategies and decision making; Techniques, tools and use of expert system in PMS.	8
6.	<b>Pavement Maintenance Management:</b> Components and related activities, Budgeting, Maintenance strategies and prioritization, Pavement life cycle cost analysis – components and methods.	4
<b>Total</b>		<b>42</b>

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1	Hass, R., Hudson, W.R. and Zaniewski, J. "Modern Pavement Management" Krieger.	1994
2	Fwa, T.F., "The Hand Book of Highway Engineering", CRC Press, Taylor & Francies Group.	2006
3	Shain, M.Y., "Pavement Management for Airports, Roads and Parking Lots", Kluwer Academic Publishers Group.	2004

4	Khanna, S.K. and Justo, C.E.G., "Highway Engineering" Nem Chand & Bros, Roorkee (U.A.) 8 <sup>th</sup> Ed.	2005
5	Hudson, W.R., Haas, R. and Uddin, W., "Infrastructure Management", McGraw Hill.	1997
6	Hass R. & Hudson, W.R., "Pavement Management System", Mc Graw Hill Company, Inc. New York	1978

  
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**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN -664** Course Title : **Transportation Planning**  
 2. Contact Hours : **L: 3 T: 1 P: 0**  
 3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**  
 4. Relative Weight : **CWS : 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**  
 5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PCC**  
 8. Pre-requisite: **Nil**  
 9. Objective of Course: To introduce the concept of travel demand modeling using four-stage sequential transportation planning.

10. Details of the Course.

S. No.	Contents	Contact Hours
1	<b>Introduction to Transportation:</b> Fields of Transportation, Role in Society, System-Environment Ensemble, Transportation Problems	05
2	<b>Planning Process:</b> Hierarchical Structure; Characteristics and objectives of planning, Problem solving and its morphology, Planning methodologies; Overview of urban transportation planning; Urban structure interaction and concepts.	08
3	<b>Transportation Data:</b> Data needs and sources; Survey methodology, Quality v/s quantity, Errors, Data collection methods, Attitudinal surveys, Questionnaire design and standardization, Study area and analysis zones, Sample size, Sampling units, frames and techniques.	07
4	<b>Trips:</b> Aggregate and disaggregate analysis, Definitions, Types of trips, Factors affecting trip generation, Methods of trip generation, Methods of trip distribution – Growth Factor methods, Synthetic methods, merits and demerits.	08
5	<b>Modal Analysis and Assignment:</b> Mode choice sets, Modal split models – First and second generation, Stochastic models, Choice theories, Discrete choice analysis, Logit models, Model specification, estimation and validation; Network analysis, Route or tree building algorithms, Network assignments methods.	08
6	<b>Sustainable Transportation:</b> Issues and Guidelines of sustainable transportation, Planning for Mass Transit systems, Planning for Non-Motorized vehicles.	06
	<b>Total</b>	<b>42</b>

11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	B. G. Hutchinson, "Principles of Urban Transport Systems Planning" Scripta Book Co., Washington	1974
2	Anthony J. Richardson, Elizabeth S. Ampt and Arnim H. Meyburg, "Survey Methods for Transport Planning" Eucalyptus Press, Australia.	1995
3	Roy Thomas, "Traffic Assignment Techniques", Avebury Technical, Aldershot, England	1991
4	C A O'Flaherty, ed, "Transport Planning and Traffic Engineering", Butterworth Heinemann, Elsevier, Burlington, MA	2006

  
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**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

6. Subject Code : **CEN -665** Course Title : **Road Traffic Safety**

7. Contact Hours : **L: 3 T: 1 P: 0**

8. Examination Duration (Hrs) : **Theory : 3 Practical : 0**

9. Relative Weight : **CWS : 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

10. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**

12. Pre-requisite: **Nil**

13. Objective: To introduce the concepts of traffic safety on highways and to make students familiar with related analytical methods and remedial measures.

14. Details of course:

S. No.	Contents	Contact Hours
01	Introduction: Road traffic accidents scenario in India, characteristics of accidents, accident vs. crash, effect of human factors, planning for road network, land use and road environment for safety, designing for road safety – links and junctions, road safety engineering, road safety improvement strategies, elements of a road safety plan.	06
02	Crash investigation and analysis: Steps in treatment of crash locations, diagnosing crash problem and solutions, accident report form, storing of data, using and interpreting crash data, identifying and prioritizing hazardous locations, condition and collision diagrams; Vulnerable road users: crashes related to pedestrian and bicyclists, their safety, provision for disabled; Crash reconstruction: understanding basic physics, calculation of speed for various skid, friction, drag, and acceleration scenarios.	08
03	Statistical analysis of accidents: Descriptive statistics, confidence interval, hypothesis testing, models related to accident frequency, accident severity, accident duration, various methodological issues – over/under dispersion, time-varying explanatory variables, unobserved heterogeneity, endogeneity, under-reporting, spatial and temporal correlation, etc; Accident prediction model.	08
04	Before -after methods in crash analysis: Before and after study, before and after study with control sites, comparative parallel study, before, during and after study, Empirical Bayes method.	04
05	Economic analysis of accidents: Accident costing-economic appraisal, EUAC, PWOC, B/C ratio, IRR, NPV.	04
06	Traffic management system: Traffic flow improvements, expressway patrol, public transit, ridesharing, mobility rest areas, park-and-ride lots, bus bays, signage, markings; ITS applications - vehicular navigation, crash avoidance system, incident management, traffic management centre, highwayside communication.	06
07	Road safety audits: Procedure, aims and objectives, roles and responsibility, history of road safety audit, design standards, tasks, various stages of safety audits; common identifiable problems, structuring of report, identifying common problems.	06
<b>Total</b>		<b>42</b>

11. Suggested books

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	American Association of State Highway and Transportation Officials (AASHTO), "Highway Safety Manual", 1 <sup>st</sup> Edition, AASHTO.	2010
2	Simon P. Washington, Matthew G. Karlaftis, Fred L. Mannering, "Statistical and Econometric Methods for Transportation Data Analysis", 2 <sup>nd</sup> Edition, Chapman & Hall/CRC Press,	2010
3	Ezra Hauer, "Observational Before -After Studies in Road Safety", Pergamon Press.	1997



4	Limpert, Rudolf. "Motor Vehicle Accident Reconstruction and Cause Analysis", 5 <sup>th</sup> Edition, Lexas Publishing, Charlottesville, VA.	1999
5	Indian Roads Congress, "Highway Safety Code", IRC: SP-44:1996	1996
6	Indian Roads Congress, "Road Safety Audit Manual", IRC:SP-88-2010	2010



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**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT/CENTRE : **Department of Civil Engineering**

1. Subject Code : **CEN-666** Course Title : **Transport Economics**

2. Contact Hours : **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs) : **Theory : 3 Practical : 0**

4. Relative Weight : **CWS : 20-35 PRS: 0 MTE: 20-30 ETE: 40-50 PRE: 0**

5. Credits : **04** 6. Semester: **Spring** 7. Subject Area : **PEC**

8. Pre-requisite: **Nil**

9. Objective of Course: The course provides an outline of demand and supply side concepts and their application to transport policy and planning issues.

10. Details of the Course.

S. No.	Contents	Contact Hours
01	<b>Introduction and Overview:</b> Basic components of transport, economic development and urban development. Economic theory, transport as an economic activity, demand and supply issues in transportation sector, demand - supply equilibrium, cost and pricing of transport, law of diminishing returns, elasticity and consumer surplus, costs, pricing and subsidy policies, elements of engineering economics.	06
02	<b>Transportation Demand and Congestion:</b> Demand - Demand forecasting methods, factors influencing transport demand, direct and cross - price elasticity of demand, factors that cause shifts in demand function; Congestion - Main causes of traffic congestion, Mechanisms to deal with traffic congestion - congestion pricing, road space rationing, capacity expansion.	07
03	<b>Transport Supply and Regulation:</b> Supply - Supply of transport services, development of systems supply function; Regulation - Command and control type of regulation, fiscal measures such as road pricing and environmental taxation, safety and economic regulations in the context of transport services provided by public, issues of social, geographical and temporal equity.	06
04	<b>Transport Costs and Pricing:</b> Costs-Direct and external costs of transport, concept of generalized costs, social aspects of transport, joint and common costs of infrastructure, average and marginal cost principle, short-term and long-term costs of supply, congestion costs, external costs, Road User Cost and it's components; Pricing- Pricing principles, the marginal cost pricing rule, efficient pricing, cost complexities and cost recovery, peak-load pricing, second-best pricing, Transport subsidies, price discrimination.	10
05	<b>Appraisal and Evaluation of Transportation Projects:</b> Feasibility and evaluation, cost, impacts and performance levels, evaluation of alternatives, analysis techniques, cost-benefit analysis, social and financial benefits, Internal Rate of return method for economic and financial viability, valuation of time, measures of land value and consumer benefits from transportation projects, prioritization of projects, multi-criteria decision assessment.	08
06	<b>Funding and Financing of Transportation Projects:</b> Methods for raising funds for maintenance, improvement and expansion of transportation networks, taxation and user fee, financing through loans, bonds, PPPs and concessions.	05
	<b>Total</b>	<b>42</b>

  
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11. Suggested Books:

S. No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Mccarthy, P.S., "Transportation Economics – Theory and Practice : A Case Study Approach", Blackwell Publishing.	2001
2	E. Quinet; R. Vickerman and R. W. Vickerman, "Principles of Transport Economics", Edward Elgar Publishing.	2004
3	Button, K. J., "Transportation Economics", 3 <sup>rd</sup> Ed., Edward Elgar Publishing.	2010



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**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPARTMENT: Civil Engineering

1. Subject Code: **CEN-667** Course Title: **Transportation Studies and Analysis Lab**

2. Contact Hours: **L:0 T:0 P:4**

3. Examination Duration (Hrs.): **Theory : 0 Practical : 3**

4. Relative Weight: **CWS: 0 PRS: 50 MTE: 0 ETE: 0 PRE: 50**

5. Credits : **02** 6. Semester : **Spring** 7. Subject Area: **PEC**

8. Pre-requisite: **Nil**

9. Objective : To make students conversant with the analysis and design using traffic and transportation planning data, either manually or using a dedicated software

10. Details of the Course:

S.N.	Contents	Contact Hours
	<b>Observational Studies</b>	<b>24</b>
1	Traffic Volume and Intersection/ Turning Movement Study	
2	Spot Speed, Travel Time and Delay Study	
3	Origin Destination Study and Household Survey	
4	Parking and Pedestrian Study	
5	Accident and Traffic Noise Study	
	<b>Software Based Analysis</b>	<b>32</b>
6	Alignment and Profile Design	
7	Four-Step Travel Demand Estimation	
8	Video-metric Volume and Speed Analysis	
9	Logit Analysis and Modelling	
	<b>Total</b>	<b>56</b>

11. Suggested Books

S. N	Name of Authors/Books/Publishers	Year of Publication
1.	Roger P Roess, Elcna S Prassas, William R McShane, "Traffic Engineering" 4 <sup>th</sup> Ed, Prentice Hall.	2011
2.	May, A.D., "Fundamentals of Traffic Flow", Prentice Hall, Inc. 2 <sup>nd</sup> Ed.	1990
3.	C Jotin Khisty and B Kent Lall, "Transportation Engineering – An Introduction", Prentice Hall India	2006
4.	Kadiyali, L.R., "Traffic Engineering and Transport Planning", Khanna Publishers.	2008
5.	Relevant software available in IIT Roorkee	



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## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Name of the Dept.: Department of Civil Engineering

1. **Subject code:** CEN-668      **Course Title:** Multi-agent transport simulation framework
2. **Contact hours:**      L: 0              T: 0              P: 4
3. **Examination duration (hrs):**      Theory: 0      Practical: 3
4. **Relative weight:** CWS: 0    PRS: 50    MTE: 0    ETE: 0    PRE: 50
5. **Credits:** 02              6. **Semester:** Spring              7. **Subject area:** PEC
8. **Pre-requisite:** Nil
9. **Objectives of the course:** To Introduce agent-based simulation and its applications regarding co-evolutionary algorithms, dynamic traffic assignment, transport economics and travel behavior analysis, and policy inferencing.
10. **Details of the course:**

S. No.	Contents (Software)	Contact hours
1	<b>Scenario Generation: (MATSim, QGIS)</b> - Writing first program, basics of Java; coordinate system, MATSim controller, inputs - network generation, travel demand generation, facilities, behavioral parameters, GIS and importance in travel demand	12
2	<b>Network loading algorithm: (MATSim, VIA)</b> - queue model, kinematic wave model - mixed traffic simulation, - computational performance	12
3	<b>Analysis: (MATSim, VIA)</b> - understanding standard output - reading and analyzing events	08
3	<b>Re-planning: (MATSim, VIA)</b> - choice dimensions (e.g. time choice, route choice, mode choice etc.) - scoring (utility function) - impact of socio-demographic attributes	12
4	<b>Policy cases: (MATSim, VIA)</b> - user welfare, system welfare - pricing schemes - non-motorized modes	12
	<b>Total</b>	<b>56</b>

### 11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication
1	Stefania Bandini, Sara Manzoni, Giuseppe Vizzari, "Agent based modeling and Simulation"	2012
2	Klügl, Franziska, Bazzan, Ana, Ossowski, Sascha (Eds.), "Application of agent technology in Traffic and Transportation"	2005
3	Andreas Horni, Kai Nagel, Kay W. Axhausen, "The multi-Agent Transport Simulation"	2016

  
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# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPARTMENT/CENTRE:** Department of Civil Engineering

1. **Subject Code:** CEN-639 **Course Title:** Transportation Data Analysis Techniques
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To provide the concepts of statistical modelling techniques and its possible applications in modelling transportation data.

**10. Details of the Course**

S.No.	Contents	Contact hours
1.	<b>Overview of transportation data</b> Transportation data; Data collection sources; Applications of quantitative and qualitative data in transportation studies; Data preparation; Visualization	6
2.	<b>Inferential statistics</b> Descriptive statistics; Hypothesis testing and confidence intervals; Sample size estimation; Statistical tests for comparing sample means and variances; Non-parametric statistics	6
3.	<b>Multivariate distributions in modelling traffic stream parameters</b> Univariate and multivariate distributions; Distribution fitting; Correlation coefficients; Concept of copulas; Families of copulas - Elliptical, Archimedean, and Extreme-value copulas; Joint and Conditional probabilities; Multivariate model development in R and MATLAB; Application of copulas in microscopic traffic flow model development, travel time prediction, travel behavior modelling, driver behavior modelling	8
4.	<b>Statistical techniques in modelling transportation data</b> Applications of regression, non-linear regression, and symbolic regression techniques in traffic studies; Logistic regression models for multinomial and ordinal variables; Reliability analysis; Classification and clustering algorithms in modelling urban traffic patterns, level-of-service; Concepts of neural networks and its applications in driver behavior analysis	8
5.	<b>Modelling user perception data</b> Factor analysis; Concepts of structural equation modelling (SEM); Applications of SEM in evaluating passenger/drivers' perception, satisfaction, and other travel behavior related analysis; Overview of discrete choice models and applications in travel mode choice analysis and other travel behavioral data	6
6.	<b>Interpretation of transportation data using statistical software</b> Transportation case studies - vehicle trajectory analysis, user perception data, transportation mode choice classification; Applications of probability distributions and modeling techniques using statistical software (such as R, SPSS, Minitab, Biogeme); Error metrics for model performance prediction; Interpretation of model output	8
<b>Total</b>		<b>42</b>



## 11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Simon Washington, Mathew Karlaftis, Fred Mannering, Panagiotis Anastasopoulos “Statistical and Econometric Methods for Transportation Data Analysis” CRC Press	2020
2.	Matt Wiley, Joshua F. Wiley “Advanced R Statistical Programming and Data Models” Apress	2019
3.	Roger P. Roess, Elena S. Prassas, William R. McShane “Traffic Engineering” 5th Edition, Pearson	2019
4.	Marius Hofert, Ivan Kojadinovic, Martin Mächler, Jun Yan “Elements of Copula Modelling with R” Springer	2018
5.	Harry Joe “Dependence Modelling with Copulas”, CRC Press	2015
6.	Charu C. Aggarwal “Data Classification: Algorithms and Applications” CRC Press	2014
7.	Juan de Dios Ortúzar, Luis G. Willumsen “Modelling Transport” Wiley	2011
8.	Kenneth E. Train “Discrete Choice Methods with Simulation” Cambridge University Press	2009
9.	John C. Loehlin “Latent Variable Models: an introduction to factor, path, and structural equation analysis” Taylor & Francis	2004