FACULTY OF ENGINEERING

Scheme of Instruction & Examination

(AICTE Model Curriculum for the Academic Year 2020-2021)

and

Syllabus

M.E. III to IV Semester

of

Two Year Post Graduate Degree Programme

in

Civil Engineering

Specialization in Transportation Engineering

(With effect from the academic year 2020– 2021)

(As approved in the faculty meeting held on ……)

Issued by

Dean, Faculty of Engineering

Osmania University, Hyderabad – 500 007

2020

SCHEME OF INSTRUCTION & EXAMINATION
M.E. (Civil Engineering) – III Semester
Specialization in Transportation Engineering

S. No.	Course Type/Code	Course Name	Scheme of Instruction				Scheme of Examination			Credits
			L	T	P/D	Contact Hrs/Wk	CIE	SEE	Duration in Hrs	
Theory Courses										
1	Elective	Professional Elective – IV	3	-	-	3	30	70	3	3
2	Elective	Professional Elective – V	3	-	-	3	30	70	3	3
3	PC 1456 TE	Major Project Phase – I	-	-	20	20	100	-	3	10
		Total	**06**	**-**	**20**	**26**	**160**	**140**		**16**

M.E. (Civil Engineering) – IV Semester
Specialization in Transportation Engineering

S. No.	Course Type/Code	Course Name	Scheme of Instruction				Scheme of Examination			Credits
			L	T	P/D	Contact Hrs/Wk	CIE	SEE	Duration in Hrs	
Theory Courses										
1	PC 1457 TE	Major Project Phase – II (Dissertation)	-	-	32	32	-	200	3	16
		Total	**-**	**-**	**32**	**32**	**-**	**200**		**16**

PC: Program Core **PE:** Professional Elective **OE**: Open Elective **AD**: Audit Course
MC: Mandatory Course **HS**: Humanities and social science

L: Lecture **T**: Tutorial **P**: Practical **D**: Drawing
CIE: Continuous Internal Evaluation **SEE:** Semester End Examination (Univ. Exam)

Note:

1. Each contact hour is a Clock Hour
2. The practical class can be of two and half hour (clock hours) duration as per the requirement of a particular laboratory.
3. ** Open Elective Subject is not offered to the students of Civil Engineering Department.
4. The students who are willing to register for MOOCs in the M. Tech (TE) III – semester instead of Professional Electives – IV & V, should register for those of the courses, approved by the CBoS, OU and respective college MOOCs Coordinator. Those students are strictly not permitted to appear for either CIE or SEE of Professional Electives – IV & V if they abstain from attending the semester class work. Further, for students willing to appear for both MOOCS and Professional Electives, they should fulfil the minimum attendance criteria.

List of subjects of Professional Electives I to V

S. No.	Course Code	Course Title
1	PE 1416 TE	Traffic Engineering
2	PE 1417 TE	Intelligent Transportation System
3	PE 1418 SE	Finite Element Methods
4	PE 1419 TE	Analysis of Transportation Systems
5	PE 1420 TE	GIS and GPS Application to Transportation Engineering
6	PE 1421 TE	Rural Roads
7	PE 1422 TE	Economic Evaluation and Analysis of Transportation Projects
8	PE 1423 TE	Transportation Modelling and Simulation
9	PE 1424 TE	Airport Planning and Design
10	PE 1425 TE	Pavement Evaluation Maintenance and Management
11	PE 1426 TE	Railway Engineering
12	PE 1427 TE	Transportation Structures
13	PE 1428 TE	Statistical Techniques
14	PE 1429 TE	Behavioural Modelling
15	PE 1430 TE	Ground Improvement Techniques

List of subjects of Professional Core

S. No.	Course Code	Course Title
1	PC 1456 TE	Major Project Phase – I
2	PC 1457 TE	Major Project Phase – II (Dissertation)

Course Code	Course Title						Core/Elective
PE 1416 TE	**Traffic Engineering**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives:

- To introduce fundamental knowledge of traffic engineering so that students can understand and be able to deal with traffic issues including safety, planning, design, operation and control.
- To describe basic techniques for collecting and analysing traffic data, diagnosing problems.

Course Outcomes

1. Use statistical concepts and applications in traffic engineering.
2. Identify traffic stream characteristics and Identify level of services
3. Design a pre-timed signalized intersection, and determine the signal splits.

UNIT-I

Basic Aspects of Traffic Engineering Aim of traffic engineering, traffic stream components and characteristics, road user characteristics, vehicle characteristics, acceleration characteristics, measure of quality, measures of separation, relationship among traffic parameters and empirical relationships, mechanics of traffic flow, macroscopic approach, microscopic approach and human factors approach, discrete distributions, binomial distribution, Poisson's distribution, exponential distribution, exponential distribution, normal distribution.

UNIT-II

Traffic Studies, Measurement and Analysis; Volume studies, speed studies, parking studies, Accident studies. Travel forecasting principles and techniques, design hourly volumes and speed, origin and destination studies, presentation of data and analysis, testing of hypothesis relating to improvements.

UNIT-III

Travel Time amid Delay Studies; Various uses, travel time and delay studies, various methods, data collection and analysis, density studies and headways, gap acceptance studies, intersection delay studies, traffic flow theory, queuing theory and simulation models.

UNIT-IV

Capacity Analysis of Traffic Facilities; Uninterrupted facilities, interrupted facilities, Level of Service, quality of service as per HCM, factors affecting LOS, computation of capacity and LOS, Measure of effectiveness, highway capacity and performance characteristics, intersection design.

UNIT-V

Traffic Control, Design and Regulation; Traffic signals, types, principles of phasing, tune diagram, signalized intersection, saturation flow, saturation headway, capacity of lane group, concept of critical lane group, signal timing, phase plan, phase diagram, splitting of phase, clearance interval, pedestrian requirement, guidelines for protected movements, signal coordination, emerging themes, inter-modalism, access management, congestion management, environmental impact assessment.

Suggested Readings:

1. McShane, W.R., Roess, R.P. and Prassas, E.S., Traffic Engineering. Prentice Hall, Englewood Cliffs, 1997.
2. Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., 2000.
3. Daganzo, C.R, Fundamentals of Transportation and Traffic Operations, Pergamon, Elsevier Science Inc., New York, 1997.
4. Salter, R.J., Traffic Engineering: Worked Examples, Macmillan, London, 1989.
5. Pignataro, L.J., Traffic Engineering: Theory and Practice, Prentice Hall, Englewood lifts, 1973.
6. Wohl, M. and Martin, B.V, Traffic System Analysis for Engineers and Planners, McGraw Hill, New York, 1983.
7. Drew, D.R., Traffic Flow Theory, McGraw Hill, New York, 1964.

Course Code	Course Title						Core/Elective
PE 1417TE	**Intelligent Transportation Systems**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Learn the objectives, benefits and the telecommunications in ITS.
- Learn about the functional areas, user needs and services in ITS.
- Learn the concepts of ITS operations and applications.

Course Outcomes

1. Able to appreciate the advantages of ITS and suggest the appropriate technologies for field conditions.
2. Able to suggest the appropriate system/s in various functional areas of transportation.
3. Able to amalgamate the various systems, plan and implement the applications of ITS

UNIT I

Introduction to Intelligent Transportation Systems (ITS): Definition, Objectives, Historical Background, Benefits of ITS -ITS Data collection techniques – Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), Geographic Information Systems (GIS), video data collection**.**

UNIT II

Telecommunications in ITS: Information Management, Traffic Management Centres (TMC). Application of sensors to Traffic management; Traffic flow sensor technologies; Transponders and Communication systems; Data fusion at traffic management centres; Sensor plan and specification requirements; Elements of Vehicle Location and Route Navigation and Guidance concepts.

UNIT III

Its Functional Areas: Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control Systems (AVCS), Advanced Public Transportation Systems (APTS), Advanced Rural Transportation Systems (ARTS). ITS User Needs and Services – Travel and Traffic management, Public Transportation Management, Electronic Payment, Commercial Vehicle Operations, Emergency Management, Advanced Vehicle safety systems, Information Management.

UNIT IV

ITS Operations: Regional and Project ITS architecture; Concept of operations; ITS Models and Evaluation Methods; Planning and human factor issues for ITS, Case studies on deployment planning and system design and operation; ITS and safety, ITS and security, ITS as a technology deployment program, research, development and business models, ITS planning

UNIT V

ITS Applications: Traffic and incident management systems; ITS and sustainable mobility, travel demand management, electronic toll collection, ITS and road-pricing.; Transportation network operations; commercial vehicle operations; public transportation applications; Automated Highway Systems- Vehicles in Platoons –ITS in World – Overview of ITS implementations in developed countries, ITS in developing countries. [Case study]

Suggested Readings:

1. Choudury M A and Sadek A, "Fundamentals of Intelligent Transportation Systems Planning" Artech House.
2. Kan Paul Chen, John Miles, "Recommendations for World Road Association (PIARC)" ITS Hand Book 2000.
3. Sussman, J. M., "Perspective on ITS", Artech House Publishers, 2005.
4. US Department of Transportation, "National ITS Architecture Documentation", 2007 (CDROM).
5. Turban. E and Aronson. J. E, "Decision Support Systems and Intelligent Systems", Prentice Hall Dept.

Course Code	Course Title						Core/Elective
PE 1418 SE	**Finite Element Methods**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Learn the rudiments of finite element analysis
- Study the fundamentals of domain discretization, interpolation, application of boundary conditions, assembly of global matrices, and solution of the resulting algebraic systems.
- Explain the core concepts of variational and weighted residual methods in FEM
- Derive the element stiffness matrix for 1-D, 2-D and 3-D problems.
- Formulate the simple structural problems in to finite elements

Course Outcomes

1. Build and analyse the FEA models for various engineering problems.
2. Identify the information requirements and sources for analysis, design and evaluation
3. Use the standard finite element software to solve the structural engineering problems.
4. Interpret the results obtained from FEA software, not only in terms of conclusions but also awareness of limitations.

UNIT – I

Introduction to FEM: Types of problems – Types of materials – Elastic, inelastic situations – Types of forces - Body forces, surface traction, point loads – Deformable bodies – Types of deformations – Homogeneous, non-homogeneous problems – Equations of equilibrium for elastic 2-D, 3-D continua - Equilibrium equations for 2-D, 3-D boundary elements – Boundary conditions – Strain-displacement relation for 2-D, 3-D problems – Stress-strain relation for 2-D, 3-D problems – Plane stress, plane strain problems. Virtual work formulation: Application to problems of plane trusses with static indeterminacy not exceeding three. Finite difference method with central differences: Solving ODE's and PDE's with central differences - Application to beam and plate bending problems of simple geometry.

UNIT – II

Variational formulation: Finite element formulation - Stationarity of functional - Given the functional or differential equation – Number of elements limited to two.

1-D Elements: Strain-displacement relation matrix - Stiffness matrix - Minimum potential energy approach - Rayleigh-Ritz Method - Introduction to natural coordinates - Stiffness matrix of second order bar element - Axial bar subjected to point loads, body forces and surface traction forces - Problems with kinematic indeterminacy not exceeding two.

2-D Triangular elements: Displacement models - Criterion for convergence - Geometric invariance - Conforming and non-conforming elements - 3-node triangular (CST) element - Strain-displacement matrix - Area coordinates, shape functions - Element stiffness and load matrices – Assembly of global stiffness and load matrices - Problems with kinematic indeterminacy not exceeding three. 2nd Order triangular elements: Shape functions – Degradation technique - Strain-displacement matrix - Expression for stiffness matrix - Load matrices due to body forces and surface traction.

UNIT – III

Iso-parametric elements: Quadrilateral elements: Shape functions using natural coordinates - Strain-displacement matrices - Load matrices for body force and surface traction - Stiffness matrix - Load matrices for 4-node quadrilateral elements - Gauss quadrature of numerical integration - Problems with rectangular elements, kinematic indeterminacy not exceeding three.

2nd Order Quadrilateral elements: - Shape functions for 2nd order quadrilateral elements and for elements of with serendipity – Strain displacement matrix - Load matrices for body force and surface traction.

UNIT – IV

Method of weighted residuals: Galerkin's method of weighted residuals: Application to problems of mathematics and structural engineering, number of trial functions not exceeding two.

Galerkin's finite element method: Weak form of trial function - Application to problems of mathematics and structural engineering, number of elements limited to two.

Axi-symmetric problems: Strain-displacement matrix - Stress-strain relationship - Stiffness matrix for 3-noded ring element - Load matrices for body force and surface traction - Problems with kinematic indeterminacy not exceeding three.

UNIT – V

Tetrahedron elements: Volume coordinates Strain-displacement matrix - Stiffness matrix - Load matrices due to body force and surface traction - Introduction to hexahedron (brick) elements. Non-linear Finite element analysis: Introduction – Problems with material non-linearity – Problems with geometric non-linearity – Problems with both material and geometric non- linearity. Introduction to MSC Nastran: Illustration on different modules of Nastran - Structural engineering applications of the package - Creation of a simple 1-D model, 2-D model and a 3-D model - Analysis and post processing of the results.

Suggested Readings:

1. R.D. Cook, "Concepts and Application of Finite Element Analysis", John Wiley and Sons, 1981.
2. O.C. Zienkiewicz and R.L. Taylor, "The Finite Element Method, Volume 1: The Basis", McGraw-Hill, London, 1989.
3. J.N. Reddy, "An Introduction to the Finite Element Method", McGraw-Hill, New York, 1993.
4. David V. Hutton, "Fundamentals of Finite Element Analysis", Tata McGraw-Hill, New Delhi, 2005.

Course Code	Course Title						Core/Elective
PE 1419 TE	**Analysis of Transportation Systems**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To discuss various components of urban transportation systems and its innovation
- To understand the concepts of linear programming formulation and various methods
- To review different transportation and assignment formulations and problems
- To examine various nonlinear programming and decision theories

Course Outcomes

1. To describe and evaluate various transportation systems impacts on society and economy
2. To identify the different solutions for linear programming problems including sensitivity analysis.
3. To demonstrate effective way of understanding transportation and assignment problems
4. To explain various issues related to uncertainty and decision theories

UNIT – I

Introduction to Transportation Systems: Goals and Scope of Transportation System Analysis, components of transportation system, Transportation innovations, Social and economic impacts of transportation, Decision makers and their options, Vehicle factors and Human factors.

UNIT- II

Linear Programming for Transportation: Formulation of Linear Programming, Graphical solutions, Simplex method, revised simplex method, Duality simplex problem, degeneracy, Big M method, sensitivity analysis and computer solutions for linear programming problems.

UNIT- III

Transportation and Assignment Problem: Introduction, mathematical model formulation, Types of Transportation problem - North West corner cell, least cost cell and Vogel's Approximation. Assignment Problem-Introduction, Zero- one programming model. Types of Assignment Problem-Hungerian Method, Branch and Bound Technique.

UNIT-IV

Analysis of Network Flows: Introduction, Types of network techniques -shortest path model, minimum spanning tree model and maximal flow model. Project management- CPM and PERT.

UNIT-V

Non Linear Programming and Decision Theory: Formulation, Characteristics of non-linear programming, convexity of a function, unconstrained single and multivariable problems, constrained optimization, quadratic programming, convex programming-gradient search, frank wolf algorithm and golden search code. Decision theory - introduction, game theory, terminologies of game theory, game with pure strategies, game with mixed strategies, dominance property and graphical solutions.

Suggested Readings:

1. Hillier, F.S and Lieberman, G. J, Introduction to Operations Research, McGraw-Hill, Seventh Edition, 2001.
2. Ravindran, A, Philips, D.T and Solberg, J. J, Operations Research: Principles and Practice, John Wiley and Sons, Second Edition 2000.
3. Render, B, Stair, R. M, Quantitative Analysis for Management, Prentice Hall of India Private Limited, Seventh Edition, 2000.

Course Code	Course Title						Core/Elective
PE 1420 TE	**GIS and GPS Applications to Transportation Engineering**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Description about various spatial and non-spatial data types and data base management methods
- Development of the concepts and professional skills in utility of GIS techniques
- Enhancement of knowledge of GIS to transportation field problems

Course Outcomes

1. GIS related data acquiring and processing that is associated with geographic locations
2. Application of GIS techniques in the decision support systems useful for decision makers and community services in Transportation field
3. Utility of GIS techniques in the fields of natural resource management, environment, transportation planning and development, etc.

UNIT -I

Introduction to GIS; Introduction, GIS over view, use of GIS in decision making. Data processing, components of GIS, The GIS and the organization, Data Input-Key board entry, Manual digitizing, scanning, Remotely and sensed data, existing digital data, census related data sets, Data output - Hard copy and soft copy devices.

UNIT-II

Data Acquisition and Data Management; Platforms, sensors used for the remote sensing data acquisition, data processing, radiometric, geometric corrections. Components of data quality - Micro level, Macro level components. Sources of error, a note about data accuracy. Management: The data base approach, 3 classic data models, Nature of geographic data, spatial data models. Databases for GIS.

UNIT- III

GIS Analysis and Functions; Organizing geographic data for analysis, Maintenance and analysis of the spatial data and non-spatial attribute data and its integration output formatting.

UNIT-IV

Implementation of GIS; Awareness, Developing system requirements, Evaluation of alternative systems, System justification and Development of an implementation plan, System acquisition and start-up, Operation of the system.

UNIT-V

Application of GIS for Transportation Engineering; Intelligent information system for road accessibility study, GIS database design for physical facility planning. Decision support systems for land use planning.GIS applications in environment impact assessment, GIS based Highway alignment, GIS based road network planning, GIS based traffic congestion analysis and accident investigation.

Suggested Readings:

1. GIS for Urban & Regional Planning, Scholten &Stillwen1990, Kulwer Academic Publisher.
2. Lilles and Kiefer, Remote Sensing Principles and Interpretation, John Wiley & Sons, New York, 2000.

Course Code	Course Title						Core/Elective
PE 1421 TE	**Rural Roads**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Introduction to various factors affecting road alignment and planning
- Introduction to inputs required for pavement design
- Concepts of mechanistic empirical methods of flexible and rigid pavements

Course Outcomes

1. Application of basic principles in pavement design for rural roads
2. Assimilation of mechanistic principles for the pavement design
3. Explain about appropriate quality control measures during construction and evaluation and maintenance measures

UNIT - I

Planning and Alignment: Planning of Rural roads, concept of network planning, rural road plan, road alignment and surveys. Governing factors in route selection, factors considered for alignment.

UNIT - II

Materials and Pavement Design: Introduction, Soil material surveys, embankment and Sub grade materials, stabilized soils, road aggregates, aggregate for base courses, new materials as stabilizers, materials for desert areas, materials for bituminous constructions and surfacing; Materials for rigid pavements, special pavement, climatic suitability of concrete material. Introduction, Design procedure, pavement components, design of flexible and rigid pavements, Special pavements design. Types of drainage, General criteria for road drainage, system of drainage, surface and subsurface systems.

UNIT- III

Construction and Specifications: Introduction, Selection of materials and Methodology, Embankment and Sub grade, sub-base (granular), base(granular), shoulder, Bituminous concrete, Semi-rigid pavements construction, and Concrete pavements. Construction of special pavements, Equipment required for different procedures.

UNIT - IV

Waste Materials for Pavement Construction: Introduction, Fly ash for road construction, Design & Construction of Fly ash embankments, Lime flyash stabilized soil. Lime fly ash bound Macadam, Lime fly ash concrete, rolled compacted fly ash pavements. Control of compaction, concrete stabilized fly ash with admixtures.

UNIT - V

Quality Control in Construction and maintenance: Introduction, Prerequirements, organizational setup, specification and code of practice, Laboratory equipment. Earth and Granular layers, bituminous courses, Semi rigid and rigid pavements, special requirements, recovered of quality control data. Distresses/Defects in rigid and flexible pavements, Maintenance and Evaluation, Inventory of roads and inspections, Types of maintenance activities. Maintenance.

Suggested Readings:

1. IRC manual for rural roads. Special Publication -20 (2002).
2. HMSO, Soil Mechanics for Road-Engineers, London
3. IRC related code books
4. NRRDA -Guidelines and code books

Course Code	Course Title						Core/Elective
PE 1422 TE	**Economic Evaluation and Analysis of Transportation Projects**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Provide knowledge in project formulation and economic evaluation highway infrastructure projects
- To understand the principles and methods of economic analysis

Course Outcomes

1. Formulate and prepare Detailed Project Report for a highway project
2. Apply the methods of economic analysis for highway projects
3. Prepare Environmental Impact Assessment Report

UNIT – I

Transportation Projects Formulation and Development: Requirements in project formulation. Components of project, Non- monetary and monetary Criteria in formulation of project. Decision making Criteria input in Project formulation. Preparation of DPR – Guidelines Transport Projects and development: preparation of Project, Highway Planning, Traffic infrastructure, Project formulation, Road Network project development.

UNIT- II

Economic evaluation of Transportation plans: Need for Economic Evaluation; Principles of economic evaluation; Welfare economics; Social costs, Vest change, Rate of return. Value of Travel Time Savings; Economic concept of evaluation of travel time savings, Issues connected with evaluation of travel time savings. Vehicle operating costs; Components of VOC, Road user Cost study in India; Accident costs; Methodologies for economic evaluation of an accident; Factors involved.

UNIT-III

Methods of Economic Analysis: Cash flow diagrams, Time value of money, Inflation, Interest, Depreciation, Cost and benefit components, discounting criteria. Equivalent Uniform Annual Cost Method; Present worth of cost method; Equivalent uniform annual net return method; Net-present value method; Benefit cost ratio method; Rate of Return Method; Application of these methods to numerical examples.

UNIT-IV

Analysis of variable costs and Transportation Asset Management: Types of Capital Financing; valuation; Project appraisal by shadow pricing with case studies. Economic Analysis of BOT and BOOT projects and allocations. Introduction and scope of asset management in India.

UNIT-V

Environmental Impact Assessment: Basic concepts, Objectives, Transportation related Environmental Impacts - Vehicular Impacts - Safety and Capacity Impacts - Roadway Impacts – Construction Impacts, Environmental Impact Assessment-Environmental Impact Statement, Environment Audit, Typical case studies.

Suggested Readings:

1. Transportation Engineering Economics - Heggie. I.G., McGraw Hill Publishers.
2. Economic Analysis for Highways - Winfrey. R; International Text Book Company.
3. Traffic Engineering and Transport Planning - L. R. Kadiyali, Khanna Publishers.
4. Road User Cost Study, CRRI.
5. Road Project Appraisal for Developing Countries, J. W. Dickey, John Wiley & Sons
6. Construction Management & Planning, B. Sengupta, H. Guha, Tata McGraw Hill, New Delhi.

Course Code	Course Title						Core/Elective
PE1423 TE	**Transportation Modelling and Simulation**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Introduction to various models of simulation
- Describe data processing techniques of simulation
- Explain exact sampling distributions and testing

Course Outcomes

1. Understand various models of simulation
2. Build models for transportation simulation
3. Evaluate and validate the models

UNIT-1

Introduction of Modelling: Fundamentals of systemic approach. System modelling, Model structure, Variables, controllable variables, uncontrollable variables, parameters, coefficients and other statistical methods for testing of models and data.

UNIT - II

Classification of Models: Classification of models - Linear models, Nonlinear models, Time-invariant models, Time-variant models, State-space models, Distributed. Parameter models. System Synthesis- - Direct and Inverse Problems, Role of optimization and examples from transportation engineering.

UNIT-III

Preliminary Data Processing: data collection, Regression Analysis-Linear multiple regression analysis; Analysis of residues, Tests of goodness of fit. Spatial Distribution- Polynomial surfaces, Spline functions, Cluster. Analysis sand Numerical production of contour maps. Time Series Analysis-Autocross. Correlation analysis, Identification of trend, spectral analysis, Identification of dominant cycles, smoothening techniques, Filters and forecasting.

UNIT-IV

Model Building: Choice of Model Structure- A priori considerations, Selection based upon preliminary data analysis, Comparing model structures. Model Calibration- Role of historical data, Direct and Indirect methods of solving inverse problem. -Model Validation.

UNIT-V

Simulation: Random variables, Basic concepts. Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation, commonly used theoretical Probability distributions: Uniform, Normal, Binomial, Poisson, Negative exponential. Fitting distributions to raw data: Chi-square and Kolmogrov-Smirnov's tests of the goodness of fit. Central limit theorem, various algorithms for generation of Random numbers. Queuing theory: Elements, Deterministic queues. Applications of Monte, Carlo simulation:" Basic concepts. Generation-of synthetic observations, -Statistical interpretation of the output, Evaluation of definite integrals and examples.

Suggested Readings:

1. Bratley, P., Fox B. L., Schrage, L. E. B., Guide to Simulation, Springer-Verlag, New York 1983.
2. Leigh, J. R., Modeling and Simulation, Peter Peregrinus, London, 1983.
3. Bernard, Z., Theory of Modeling and Simulation, John- Wiley, New York, 1976.
4. Ortuzar, J. and Willumsen, L.G, Modeling Transport, Wiley, Chinchestor, 1994.
5. Hansher, D. A., and Button. K. J., Handbook of Transport Modeling, Pergamon, Oxford, UK, 2000

Course Code	Course Title						Core/Elective
PE 1424 TE	**Airport Planning and Design**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To understand basic terminology and standards relate Airport Engineering
- To know the various components of airport and runway components
- To understand the various methods of air travel demand analysis

Course Outcomes

1. Conduct surveys, develop and design new airports with ICAO/FAA geometric standards
2. Investigate and explore the failures of runway pavements and suggest remedial design measures
3. Develop plans for installation of various types of devices pertaining to Air Traffic Controls

UNIT-I

Airport Planning: Growth of Air Transport, Technological Developments, Institutional Development for Planning, Regulatory Practices; Aircraft characteristics related to airport planning and design, Future trends in Aircraft design and Airport Planning; Airport master plan, site selection, planning surveys etc. Airport Obstructions: Zoning Laws, Classification, Approach and Turning Zones.

UNIT-II

Runway Design and Airport Capacity: Runway Orientation, Basic Runway Length and Factors affecting, Correction for elevation, temperature and gradient as per ICAO and FAA, Run way Geometric Design. Airport

Capacity: Classification and Standards; Capacity of Airport, Runway, Taxiway and Gate; Delays; Configuration of Airport and Configuration; Runway Intersection Design; Terminal Facilities and Standards: Planning Concepts. Taxiway Design: Factors affecting Taxiway Design, Geometric Design as per ICAO, Exit taxiways, Fillets, Separation clearance, Holding Apron, Turn Around.

UNIT-III

Design of Airport Pavements: Design factors, Calculation of ESWL with different wheel load configurations and methods, Repetition of loads, failure criteria; Flexible Pavements Design: US corps of Engineers Method, FAA method; Rigid Pavement Design methods: US corps of Engineers method, PCA Method, FAA method, LCN Method and CAN-PCN System.; Overlays; Drainage: Surface and subsurface methods, filter materials, Special characteristics and requirements of Airport Drainage. Airfield Pavement Maintenance and Rehabilitation: Need, Failures, Evaluation of flexible and Rigid Pavements, Strengthening of Airfield Pavements and maintenance operations.

UNIT-IV

Air Travel Demand Analysis: The Demand Analysis, Microanalysis of Air Travel Demand, Calibration of Macro analysis of Air Travel Demand, Disaggregate Models Route Frequency planning. Air travel choice Models, Simultaneous Models of Demand and supply. Optimal Route Frequency Planning.

UNIT-V

Air Traffic Controls (ATC): Visual Aids: marking and lighting; Need, Network and Aids for ATC, Radio equipment; Design of Heliports and STOLPORTS: Design Factors, Planning, Site selection. Geometric Designs, Visual Aids.

Suggested Readings:

1. Principles of Pavement Design, Yoder E.J. and Witczak M. W. John Wiley &-Sons, 1975.
2. Elementary Hand Book of Aircraft Engines, A. W. Judge, Chapman and Hall ltd, London.
3. Airplanes Structures, A.S. Nil.es and J.S. Newell, M. W. John Wiley &Sons, New York.
4. Relevant IRC codes.
5. Air Port Engineering, Norman Ashford and Paul H Wright, M. W. John Wiley& Sons.
6. The Planning and Design of Airports, Robert Horojeff, McGraw Hill Book Co.
7. Airport Planning and Design, S.K. Khanna, Arora and S.S. Jain, Nem Chand & Bros. Roorkee.

Course Code	Course Title						Core/Elective
PE 1425 TE	**Pavement Evaluation Maintenance and Management**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Understand the basic working principles of various equipment used for pavement evaluation
- Describe design aspects of overlay thickness of pavements
- Impart knowledge regarding the different types of distresses and LCCA of pavements

Course Outcomes

1. Awareness about various NDT equipment used for pavement evaluation
2. Applications of pavement management principles
3. Knowledge regarding the different levels maintenance treatment options

UNIT-I

Pavement Inventories and Evaluation: Purposes, functional Evaluation: Serviceability concepts, Distress types: Bituminous and Concrete pavements; Visual Rating; PSI; Methods of Measuring Roughness: Response type &Profile type; IRI: Quarter Car Model, Riding Number; Pavement Safety Evaluation: Skid Resistance, measurement of skid, skid resistance, Change of Skid resistance with time, traffic and climate; Control of Skid Resistance; Distress Modes - Cracking, Rutting etc.

UNIT-II

Structural Evaluation: Pavement Deflection: Different Methods of NDT(Working Principles): Benkelman Beam, LaCroix Deflectometer, Dynaflect, Road Ratar, Rolling Dynamic Deflectometer, Loadman, Different Types of Falling Weight Deflectometers (FWD) for evaluation of rigid and flexible pavements; 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; Pavement Performance Prediction Models for Flexible and Rigid Pavements.

UNIT-III

Pavement Management System (PMS): Components of PMS and their activities; Major steps in implementing PMS; Inputs; Design construction and maintenance; Rehabilitation and Feedback systems; Examples of HDM and RTIM packages; Evaluating alternate strategies and Decision criteria based on Structural section, Material type, Construction policy, maintenance policy, Overlay and seal coat; Pavement performance prediction models; Techniques and Tools, Expert Systems and Pavement Management.

UNIT - IV

Pavement Maintenance Management: Components of maintenance management and related activities-Network and project level analysis-Budgeting; Prioritization Techniques and Formulation of Maintenance Strategies, Pavement Preservation. Pavement Life Cycle Cost Analysis (LCCA): Cost Components, Methods of LCCA-Components involved, Brief Description - Items considered - Case studies.

UNIT - V

Highway Maintenance: Need of Highway maintenance, methods of maintenance for flexible and rigid pavement layers; WBM, Bituminous and Cement Concrete pavements.

Suggested Readings:

1. Haas and Hudson W.R. Pavement management systems - McGraw Hill publications.
2. Sargious, M.A. - Pavements and surfacing for highways and airports -Applied Science Publishers Ltd.
3. Bridge and Pavement maintenance - Transportation Research RecordNo.800, TRB.
4. Shahin M.Y. 1994 - Pavement Management for airports, roads and parking lots.
5. Bent Thagesan, 1996- Highway and Traffic engineering for developing countries.
6. Principles of Pavement Design, Yoder J. &Witzac Mathew W., John Wiley& Sons.
7. Pavement Analysis & Design, Yang H. Huang, Prentice Hall Inc.

Course Code	Course Title						Core/Elective
PE 1426 TE	**Railway Engineering**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To understand basic terminology related to Railway Engineering
- To know the various components of track
- To understand the various methods of signalling interlocking methods

Course Outcomes

1. Develop and design of railway tracks with geometric standards
2. Investigate and explore the failures of railway embankments and suggest remedial measures
3. Design points and crossings with modern signalling system

UNIT-I

General Features of Railways: development in Indian railways, modes of transport, organization of Indian railways, finances and their control commission of railway safety, long term planning process, classification of railway lines, general features of Indian railways, impartment statistics.,. Alignment of railway lines, railway track gauge, engineering surveys.

UNIT-II

Rails, Sleepers, Track and Track Stresses: requirements of good track, maintenance of permanent way, track as an elastic structure, coning of wheels, tilting of rails. Functions of creep, creep adjuster, measures to reduce creep. Sleepers, requirements, sleeper density, types; wooden, steel channel, steel of rails, types, requirements for an ideal rail section, rail manufacture, rail wear, defects in rails, rail failure, and rail flaw detection. Creep: causes, effects of creep, measurement trough, cast iron, concrete etc.

UNIT-III

Geometric Design of Railway Track; Necessity of Geometric design details of geometric design of track, circular curves, super elevation, transition curve, reverse curve, extra clearance of curves, widening of gauge on curves, vertical curves, cutting rails on curves, check rails on curves.

UNIT-IV

Sub grade Formation and Ballast; Slope of formation, execution of earthwork in embankments and cuttings, blanketing Material, Failure of railway embankment, site investigations. Ballast: functions, types, sizes of ballast, requirement, design of ballast section, collection and transportation of ballast, methods of measurement, laboratory tests for physical properties of ballast. Guidelines for provision of sub-ballast.

UNIT – V

Points and Crossings, Level Crossings, Signalling and Interlocking; Crossings, switches, number and angle of crossing, reconditioning of worn out crossings, turnouts, turnout with curved switches, layout of turnout, trends in turnout design on Indian Railways, inspection and maintenance of points and crossings. Level crossing: types, dimensions, accidents and remedial measures, maintenance of LC, inspection-LC by PWI. Signalling and interlocking: types, signalling systems, systems for controlling train movement, interlocking, modern signalling installations.

Suggested Readings:

1. Chandra, S.and Agarwal.M.M. "Railway Engineering". Oxford University Press, New Delhi, 2007.
2. Rangwala, K. S. "Principles of Railway Engineering". Charotar Publishing House, India (1991)

Course Code	Course Title						Core/Elective
PE 1427 TE	**Transportation Structures**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- Classify the various transportation structures, explain the principles of design methods and list the steps involved in the design of various transportation structures.
- Identify the input parameters required for design of transportation structures and design and evaluate a transportation structures based on the data given.

Course Outcomes

1. Decide the selection of transportation structures, list the factors affecting design of various transportation structures and generate the input parameters required for design.
2. Summarize the design methodology and arrive at design values for various transportation structures.

UNIT-I

Introduction: Principles of Planning of Elevated Rail Transit System, grade separation structures, pedestrian crossing and sub- ways.

UNIT-II

Loads on Bridges: Dead loads, live loads, dynamic effects of vehicles, longitudinal forces, centrifugal forces, wind loads, earth quake forces, stream flow pressure, load combinations, design examples.

UNIT-III

Design of Bridge Slabs: Longitudinally reinforced deck slabs, transversely reinforced bridge slabs.

UNIT-IV

Design of Reinforced Concrete Bridges: Design procedures for T- beam, box girder bridges design examples.

Design of Prestressed Concrete Bridges: Design code, design examples

UNIT-V

Segmental Box bridges - precast sections, criteria, design examples

Sub-Structure Design: Foundation investigation, bearings, bridge pier design, and abutment design, Examples.

Suggested Readings:

1. Raina, R.K, 'Principles of Design of RCC Bridges, Tata McGraw Hill,1999.
2. Krishna Raju ‘Bridge Engineering‘, UPD Publishers, New Delhi, 2000.
3. Conrad P. Heins and Richard A. Lawrie, `Design of Modern Concrete Highway Bridges, John Wiley and Sons, 1999.
4. Baider Bakhtand Leslie, G. Jaeger, `Bridge Analysis Simplified, McGraw-Hill Book Co,1998.
5. Johnson Victor, `Bridge Engineering', Oxford IBH, New Delhi, 2000.

Course Code	Course Title						Core/Elective
PE 1428 TE	**Statistical Techniques**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To introduce fundamental knowledge of sampling technique
- To describe basic statistical techniques such as statistical distributions and correlation methods
- To impart knowledge on exact sampling distributions and the tests of significance

Course Outcomes

1. Use sampling techniques for conducting various surveys related to transportation Engineering
2. Decide best fit and develop the regression equations for the given variables
3. Applications of sampling distributions in Highway and Traffic Engineering problems

UNIT-I

Introduction: Frequency distribution; Measures of central tendency; Measures of dispersion; Standard error, Moments (about mean, arbitrary numbers and origin); Skewness; Kurtosis; Sampling-Definitions and Applications; Simple random sampling; Stratified sampling; Systematic sampling; Sample size determination; Applications in Highway and Traffic Engineering.

UNIT-II

Statistical Distribution; Probability, Bayes' Theorem; Binomial, Poisson, Exponential and Normal distributions; Fitting of distributions; Mean and variance; Chi-square test of goodness-of-fit; Applications in Highway and traffic Engineering. Mathematical expectation.

UNIT-III

Regression and Correlation: Linear regression and correlation; Multiple correlation; Multiple correlation coefficient; Standard error of estimate; Analysis of variance; Curvilinear regression; Applications in Transportation Engineering.

UNIT-IV

Multi Variate Data Distributions: Types of data; Basic vectors and matrices; Simple estimate of centroid, Standard deviation Variance and covariance; Correlation matrices; Principal component analysis; Time series analysis. Estimation-Point Estimation Interval Estimation, Box Plot, Maximum likelihood estimation, Biased &Non Biased Estimation.

UNIT - V

Exact Sampling Distributions and Tests of Significance; Chi-square distribution; student's t-distribution; Snedectors F-distribution. Large sample and small sample tests; Tests for single mean. Means of two samples, Proportions, two variances, two observed correlation coefficients, paired T-tests, Applications. Intervals for mean, variance and regression Coefficients; Applications in Highway and Traffic Engineering Problems.

Suggested Readings:

1. Basic Statistics - Simpson and Kafks; Oxford and IBH Calcutta,1969.
2. Fundamentals of Mathematical Statistics - Gupta, S.C. and Kapoor, K.V. Sultanchand
3. Multivariate Data Analysis – Cootey W.W &Cochens P.R; John Wiley & Sons.

Course Code	Course Title						Core/Elective
PE 1429TE	**Behavioural Modelling**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To review the background of discrete choice analysis and its applications to transportation.
- To understand the frame work of choice theories and probabilistic theories
- To establish aggregate forecasting techniques and various sampling theories.
- To discuss multidimensional choice sets and estimation of the nested logit model.

Course Outcomes

1. To demonstrate the methods of estimation of discrete choice theory and statistics for model estimation
2. To explain binary logit model and multinomial logit models including random utility theory
3. To identify various aggregate forecasting techniques and comparing with traditional methods
4. To describe derivation of nested logit model from generalised extreme value model

UNIT -I

Introduction & Review of the statistics of Model Estimation: Background of Discrete Choice-analysis, Transportation applications of Discrete Choice Analysis. The estimation problem, small sample properties, asymptotic properties, methods of estimation, key statistical tests.

UNIT-II

Theories of Individual Choice Behaviour: Introduction, A frame work for choice theories, rational behaviour, economic consumer theory, discrete choice theory, probabilistic theory.

UNIT-III

Binary and Multinomial Choice Models: Random utility theory, binary choice models, examples, maximum likelihood estimation, examples. Theory of multinomial choice, multinomial logit models, properties logit, specification of multinomial logit model, estimation of multinomial logit, examples of estimation results.

UNIT-IV

Aggregate Forecasting Techniques & Theory of sampling: Problem of aggregation across individuals, typology of aggregation methods, a comparison of methods for aggregate forecasting. Basic sampling concepts, sampling strategies, overview, choosing a sample design for discrete choice analysis.

UNIT-V

Nested Logit and Models of Travel Demand: Multidimensional choice sets, estimating the nested logit model, multinomial probit model, measure of accessibility, derivation of the nested logit model from the generalized extreme value model. Components of travel demand modelling process, behavioural theory, measurement, statistical model structure and estimation.

Suggested Readings:

1. Ben-Akiva, M and Lerman, S. R. "Discrete Choice Analysis: Theory and Application to Travel Demand"'. The MIT press, Cambridge, Massachusetts, London.
2. Train, K. E. "Discrete Choice Methods with Simulation". Cambridge University Press, London.

Course Code	Course Title						Core/Elective
PE 1430 TE	**Ground Improvement Techniques**						**Elective**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**3**	**-**	**-**	**-**	**30**	**70**	**3**

Course Objectives

- To understand the objectives, necessity and scope of ground improvement techniques
- To learn different methods of in situ densification of cohesive, cohesion less soil
- To learn the classification, functions and applications of Geosynthetics in ground improvement
- To learn the process of identification of necessity for ground improvement, finding alternative methods and recommendation of the ideal technique through case studies

Course Outcomes

1. Ability to understand the necessity of ground improvement and potential of a ground for improvement
2. To gain comprehensive understanding about the improvement of in-situ cohesive soils as well as Cohesion less soils
3. Competence to analyse an in-situ ground, identification of ground improvement techniques feasible, selection of the ideal method, its planning , design, implementation and evaluation of improvement level

UNIT - I

Ground Modification: Need and objectives of Ground Improvement, Classification of Ground Modification Techniques - suitability and Feasibility, Emerging Trends in ground improvement.

UNIT - II

Mechanical and Hydraulic Modification: Methods of compaction, Shallow compaction, Deep compaction techniques - Vibro floatation, Blasting, Dynamic consolidation, pre-compression and compaction piles, Field compaction control. Hydraulic Modification: Methods of dewatering- open sumps and ditches, Well-point system, Electro-osmosis, Vacuum dewatering wells; pre-loading without and with sand drains, strip drains and rope drains.

UNIT-III

Physical and Chemical modification: Stabilisation with admixtures like cement, lime, calcium chloride, fly ash and bitumen, Grouting: categories of grouting, Art of grouting, Grout materials, Grouting techniques and control.

UNIT-IV

Reinforced Earth Technology: Concept of soil reinforcement, Reinforcing materials, and Backfill criteria, Art of reinforced earth technology, Design and construction of reinforced earth structures.

UNIT -V

Soil Confinement Systems and Miscellaneous techniques: Concept of confinement, Gabbion walls, CRB walls, Sand bags, Evergreen systems and fabric formwork. Miscellaneous Techniques: Design, Construction and applications of stone columns lime columns and cofferdams, Applications of Geo-textiles in Highway construction.

Suggested Readings:

1. Manfred R. Hansmann - Engineering principles of ground modification - Me Graw-Hill pub. Co., New York.
2. Robert M. Koerner - Construction and Geotechnical methods in Foundation Engineering- McGraw-Hill Pub. Co., New York.
3. Winterkorn and Fang - Foundation Engineering Hand book -Van Nostrand Reinhold Co., New York.
4. Aris C.Stamatopoulos & Panaghiotis C.Kotzios - Soil Improvement by Preloading - John Wiley & Sons Inc. Canada .
5. R. Pumshothama Rao - Ground Improvement Techniques – Laxmi Publications (P) Limited.

Course Code	Course Title						Core/Elective
PC 1456 TE	**Major Project Phase – I**						**Core**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	**-**	**-**	**-**	**20**	**100**	**-**	**10**

Course Outcomes

At the end of this course, students will be able to

1. Exposed to self-learning various topics.
2. Learn to survey the literature such as books, journals and contact resource persons for the selected topic of research.
3. Learn to write technical reports.
4. Develop oral and written communication skills to present.
5. Defend their work in front of technically qualified audience

Guidelines:

- The Project work will preferably be a problem with research potential and should involve scientific research, design, generation/collection and analysis of data, determining solution and must preferably bring out the individual contribution.
- Seminar should be based on the area in which the candidate has undertaken the dissertation work.
- The CIE shall include reviews and the preparation of report consisting of a detailed problem statement and a literature review.
- The preliminary results (if available) of the problem may also be discussed in the report.
- The work has to be presented in front of the committee consists of Chairperson-BoS, O.U and Head, Supervisor & Project coordinator from the respective Department of the Institute.
- The candidate has to be in regular contact with his supervisor and the topic of dissertation must be mutually decided by the guide and student.

Guidelines for awarding marks in CIE (Continuous Internal Evaluation): Max. Marks: 100		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
Supervisor	30	Project Status / Review(s)
	20	Report
Departmental Committee (Chairperson BoS, O.U. and Head, Supervisor & Project coordinator from the respective department of the institution)	10	Relevance of the Topic
	10	PPT Preparation
	10	Presentation
	10	Question and Answers
	10	Report Preparation

Note: The Supervisor has to assess the progress of the student regularly.

Course Code	Course Title						Core/Elective
PC 1457 TE	**Major Project Phase – II (Dissertation)**						**Core**
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
-	-	-	-	**32**	-	**200**	**16**

Course Outcomes

At the end of this course, students will be able to

1. Use different experimental techniques and will be able to use different software/ computational /analytical tools.
2. Design and develop an experimental set up/ equipment/test rig.
3. Conduct tests on existing set ups/equipments and draw logical conclusions from the results after analysing them.
4. Either work in a research environment or in an industrial environment.
5. Conversant with technical report writing and will be able to present and convince their topic of study to the engineering community.

Guidelines:

- It is a continuation of Major Project Phase – I started in semester -III.
- The student has to submit the report in prescribed format and also present seminar.
- The dissertation should be presented in standard format as provided by the department.
- The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, methodology (experimental set up or numerical details as the case may be) of solution and results and discussion.
- The report must bring out the conclusions of the work and future scope for the study. The work has to be presented in front of the examiners panel consisting of an approved external examiner and Chairperson BoS, & Head, O.U.and Supervisor from the Institute.
- The candidate has to be in regular contact with his/her Supervisor / Co- Supervisor

Guidelines for awarding marks in SEE (Semester End Examination): Max. Marks: 200		
Evaluation by	**Max. Marks**	**Evaluation Criteria / Parameter**
Supervisor	10	Regularity and Punctuality
	10	Work Progress
	30	Quality of the work which may lead to publications
	10	Analytical / Programming / Experimental Skills Preparation
	10	Report preparation in a standard format
External Examiner and Chairperson, BoS &Head, O.U. and together	20	Power Point Presentation
	60	Quality of thesis and evaluation
	30	Innovations, application to society and Scope for future study
	20	Viva-Voce