SEMESTER I

Discipline : CIVIL ENGINEERING
Stream : CE5

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TCE100	PROBABILITY AND STATISTICS	DISCIPLINE CORE	3	0	0	3

Preamble: The objective of this course is to expose the students to the fundamental concepts of probability and statistics. The course aims to equip the students to find solutions for many real-world civil engineering problems and to understand basic data analysis tools by applying the principles of statistics.

Course Outcomes: After the completion of the course, the student will be able to

CO 1	To create an awareness of the concepts of statistics and probability distributions
CO 2	To formulate and test hypotheses for civil engineering problems
CO 3	To apply statistical data analysis tools such as ANOVA and experimental designs
CO 4	To build regression models for civil engineering applications and to identify the principal components
CO5	To apply the concepts of data analysis for a time series

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	2		3			2
CO 2	3	2	2	3	3		2
CO 3	3	2	2	3	3		2
CO 4	3	2	2	3	3		2
CO5							

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIA	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 marks

Micro project/Course based project	:	20 marks
Course based task/Seminar/Quiz	:	10 marks
Test paper, 1 no.	:	10 marks

The project shall be done individually. Group projects are not permitted. The project may include the implementation of theoretical computation using software packages.
The test papers hall include a minimum 80% of the syllabus.

End Semester Examination: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

Syllabus

Module 1- Introduction to probability distributions

Sample Space and Events, Axioms of Probability, Addition rules, Conditional Probability, Multiplication and Total Probability rules, Independence. Random Variables–discrete and continuous random variables, Probability mass functions and probability density functions. Cumulative distribution functions, Mathematical Expectations, mean and variance.

Standard discrete distributions-Binomial and Poisson distribution. Standard continuous distributions –Exponential and Normal distribution, Mean and variance (derivation is not required). Computing probability using the above distributions, Fitting of binomial and Poisson distributions.

Module 2- Statistical Inference

Populations and samples. Sampling distribution of the mean(sigma known and unknown), Sampling distribution of the variance(sigma known and unknown).Interval estimation:-Confidence interval for mean and variance.-Tests of hypotheses:-Null hypothesis and alternative hypothesis, Type I and Type II errors.-Test of significance of (i) Mean (ii) Mean of two samples (iii)Proportions (iv) Variance (v) Two variance (vi) Paired t-test (vii) Chi-square test of goodness of fit (viii) Chi-square test for independence

Module 3- Analysis of variance

Analysis of variance. Completely randomized designs and randomized block designs.- Latin square designs -Factorial experiments: Two-factor experiments (overview only)

Module 4- Correlation and regression models

Linear regression and correlation, method of least squares, normal regression analysis, normal correlation analysis, correlation coefficient- Multiple linear regression, normal equations -Principal components (brief overview only)

Module 5-Time Series Models

Components of time series. Identifying linear trend: semi averages method and least squares method. Smoothing: moving averages, weighted moving averages, exponential smoothing using one smoothing coefficient. Forecasting, measuring forecasting accuracy

Course Plan

No	Topic	No. of Lectures
1	**Introduction to probability distributions**	
1.1	Sample Space and Events, Axioms of Probability, Addition rules, Conditional Probability, Multiplication and Total Probability rules, Independence.	1
1.2	Random Variables–discrete and continuous random variables, Probability mass functions and probability density functions. Cumulative distribution functions, Mathematical Expectations, mean and variance.	2
1.3	Standard discrete distributions-Binomial and Poisson distribution. Standard continuous distributions –Exponential and Normal distribution, Mean and variance (derivation is not required). Computing probability using the above distributions, Fitting of binomial and Poisson distributions.	5
2	**Statistical Inference**	
2.1	Populations and samples. Sampling distribution of the mean(sigma known and unknown), Sampling distribution of the variance(sigma known and unknown).Interval estimation:- Confidence interval for mean and variance.	2
2.2	Tests of hypotheses:-Null hypothesis and alternative hypothesis, Type I and Type II errors.	2

2.3	Test of significance of (i) Mean (ii) Mean of two samples (iii)Proportions (iv) Variance (v) Two variance (vi) Paired t-test (vii) Chi-square test of goodness of fit (viii) Chi-square test for independence	4
3	**Analysis of variance**	
3.1	Analysis of variance. Completely randomized designs and randomized block designs.	4
3.2	Latin square designs	2
3.3	Factorial experiments: Two-factor experiments (overview only)	2
4	**Correlation and regression models**	
4.1	Linear regression and correlation, method of least squares, normal regression analysis, normal correlation analysis, correlation coefficient	4
4.2	Multiple linear regression, normal equations	2
4.3	Principal components (brief overview only)	2
5	**Time Series Models**	
5.1	Components of time series. Identifying linear trend: semi averages method and least squares method.	2
5.2	Smoothing: moving averages, weighted moving averages, exponential smoothing using one smoothing coefficient.	3
5.3	Forecasting, measuring forecasting accuracy	3
	Total hours	40

Reference Books

1. Gupta. S. C. and Kapoor. V. K, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2020
2. Benjamin, Jack.R and Comell.C, Allin, Probability, Statistics and Decision for Civil Engineers, Mc- McGraw-Hill.
3. Johnson RA , Miller I, Freund J. Miller and Freund's Probability and Statistics for Engineers (9th edition) Pearson. 2018.
4. Response Surface Methodology: Process and Product Optimization Using Designed Experiments, 4th EditionRaymond H. Myers, Douglas C. Montgomery, Christine M. Anderson-Cook ISBN: 978-1-118-91601-8 February 2016.
5. Introduction to Time Series Analysis and Forecasting Second Edition, DOUGLAS C. MONTGOMERY, CHERYL L. JENNINGS, MURAT KULAHCI, John Wiley & Sons, 2015.
6. Papoulis A, Pillai SU Probability, Random Variables and Stochastic Processes McGraw Hill 2022
7. Schiller J, Srinivasan RA, Spiegal M Schaum's Outline of Probability and Statistics, 2012 McGraw Hill
8. Ross S Introduction to Probability and Statistics for Engineers and Scientists Elsevier 6th Edition 2021

Model Question Paper CIVIL ENGINEERING-CE5

XXXX PROBABILITY AND STATISTICS

Time: 3 Hrs Max. Marks:60

PART A

(Answer all Questions: Each question carries 5 marks)

1. Explain the concept of mean, median and mode, and its applicability in various contexts with suitable examples.

2. Explain Type I and Type II errors with example.

3. What are the assumptions involved in Analysis of Variance (ANOVA)?

4. Obtain Karl Pearson's correlation coefficient for Stress and Performance.

Observation no.	1	2	3	4	5
Performance	75	80	85	90	95
Stress	80	75	80	60	55

5. Explain briefly the components of time series.

PART B

(Answer any five questions: Each carry 7 marks)

6. The number of products sold by a shop keeper follows Poisson distribution, with a mean of 2 per week. (i) Find the Probability that in the next 4 weeks the shop keeper sells exactly 3 products. (ii) The shop keeper monitors sales in periods of 5 weeks. Find the probability that in the next 15 of these 5-week period, there are exactly 10 periods in which more than 5 products are sold.

7. After conducting series test on ProbabilityandStatistics the following scores were obtained for Batch A and Batch B. Conduct a hypothesis testing for checking the equality of variance in scores of two batchesat a significant level corresponding to a β error probability of 0.9.

A	35	40	42	30	12	50	45	28	26	30
B	20	24	28	26	18	50	50	48	48	09

8. In order to evaluate safety performance of employees across 3 departments, 5 employees across each department were randomly monitored and their safety behaviour on a hundred scale is given below. Do the departments differ in their safety behaviour?

Department	1	2	3	4	5
A1	68	73	75	65	78
A2	85	85	78	86	79
A3	73	77	72	70	76

9. Develop a Regression Equation between A and Busing Method of Least Square. Consider B as the dependent variable. Explain the significance of estimated slope.

Observation no.	1	2	3	4	5
A	75	80	85	90	95
B	80	75	80	60	55

10. Foodgrain production (in lakh tones) is given below. Find the Trend by using 3-yearly and 4-yearly movingaverage method, tabulate the trend values and predict the production for the year 2022.

Years	Production
2008	40
2009	60
2010	45
2011	85
2012	130
2013	135
2014	150
2015	120
2016	200

11. An evaluation of teaching methods shows the following outcomes.

Method of Teaching	No of students	Average marks obtained	Population Standard Deviation
Chalk and Talk Method	32	70	5
PPT and Talk Method	29	65	8

Conduct hypothesis testing for the mean difference of the teaching methods at a significant level corresponding to a Type I error probability of 0.01.

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CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TCE009	URBAN TRANSPORTATION PLANNING	PROGRAM CORE1	3	0	0	3

Preamble: The course aims to introduce to the students the concept of transportation planning and impart in-depth knowledge on the four stage planning process and to highlight the need for sustainable transportation

Course Outcomes: After the completion of the course the student will be able to

CO 1	To identify the need for transportation planning, the issues and challenges related to transportation and its interaction with urban structure and land use
CO 2	To apply the concept of delineation of study area, sampling of data, and data collection techniques for the four-stage planning process
CO 3	To apply and analyse the techniques for predicting trip generation
CO 4	To analyse the methods for estimating trip distribution
CO 5	To examine the methods for predicting mode split and traffic assignment

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	3	2		
CO 2			3	1	2		
CO 3			3	2	3		
CO 4			3	2	3		
CO 5			3	2	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	10
Understand	15
Apply	20
Analyse	15
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which
student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M.Tech Degree Examination

Branch: **Civil Engineering**

Specialisation: **Transportation Engineering**

Subject: **URBAN TRANSPORTATION PLANNING**

Time: 2.5 Hrs Max. Marks: 60

PART A

(Answer **All** Questions)

1. The goal of an urban community is to "Promote Safe travel". List two objectives and two standards related to each of the objectives to orient the urban transportation planning process towards the stated goal.
2. Discuss about the need to collect data in the transportation planning process. What are the various types of data that are required to be collected?
3. List down the various factors governing trip generation and trip attraction. Explain the influence of each of them in trip generation and trip attraction.
4. What are diversion curves? How are these used in traffic assignment?
5. Discuss the non-transport solutions for transport problems.

(5x5 = 25 marks)

PART B
(Answer any 5 Questions)

6. With the help of a flow chart, discuss the various steps of system approach to transportation planning process. Explain the same with an example.
7. Prepare a sampling plan for conducting an O-D survey in an urban area with 500,000 residents.
8. A study area represented by seven traffic analysis zones has the following characteristics.

TAZ	A	B	C	D	E	F	G
Trip Produced	1000	920	650	520	430	275	800
Vehicle Ownership	750	625	300	270	190	110	430

Develop a model for trip generation and check the goodness of fit.

9. What is cross-classification analysis? With an example, explain how it is applied to trip generation modelling?
10. What are the principles of traffic assignment? Outline the procedure for the equilibrium trip assignment technique.

11. (a) What are the factors affecting the choice among alternative modes of transport. (b) Discuss application of probit models in modal split analysis.
12. Illustrate and explain the sequence of activities and equation systems of Lowry Model.

(5x7=35 marks)

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Urban Transportation Planning Process & Concepts (8 hrs)**	
1.1	Role of transportation and changing concerns of society in transportation planning	2
1.2	Systems approach to urban transportation planning concepts; flow chart for transportation planning process	2
1.3	Trip-based and Activity-based approaches	1
1.4	Concept of Travel Demand and its Modelling based on Consumer Behaviour of Travel Choices- Independent Variables, Travel Attributes.	3
2	**Study Area and TAZ (7 hrs)**	
2.1	Definition of the study area, Cordon line, screen line, zoning	2
2.2	Data needs for planning process, Data collection techniques, sample size determination, O-D surveys, Use of secondary data	3
2.3	Introduction to sequential travel demand modelling- trips, types.	2
3	**Trip Generation and Trip Distribution Analysis (9 hrs)**	
3.1	Trip Generation Models- Zonal Models, Category analysis, Household Models	2
3.2	Trip Attractions of Work Centres & Commercial Trips	1
3.3	Trip End and Trip Interchange Models	1
3.4	Trip Distribution Models - Growth Factor Models - Fratar and Furness models.	3
3.5	Synthetic Models – Gravity Models, Opportunity Models and their calibration	2
4	**Mode Split and Route Split Analysis (8 hrs)**	
4.1	Modal split analysis, Modelling travel behaviour. Aggregate and Dis-aggregate Models	2
4.2	Probabilistic models- Probit and logit models.	3
4.3	Trip assignment models. Minimum path assignment. All or nothing assignment, Equilibrium assignment, Capacity restrained assignment, Multiple path assignment. Diversion curves.	3
5	**Land use-transport models (8 hrs)**	
5.1	Land use-transport models. Lowry model. Lowry Garin model. Iterative solutions.	3
5.2	Non-Transport solutions for transport problems	2
5.3	Introduction to transport planning softwares.	3

Reference Books

1. Hutchinson. B. G, Principles of urban transportation planning, McGraw Hill, New York

2. Dickey. J. W, Metropolitan transportation planning, McGraw Hill, New York.

3. Meyer D Michael and Miller Eric J, Urban transportation planning: a decision-oriented approach, McGraw Hill

4. Bruton M.J, Introduction to transportation planning, Hutchinson, London

5. Partha Chakroborty, Principles of Transportation Engineering, Animesh Das Prentice-Hall, India.

6. Kadiyali L.R, Traffic Engineering and Transport Planning, Khanna Publishers, New Delhi.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TCE010	ANALYSIS AND DESIGN OF PAVEMENT SYSTEMS	PROGRAM CORE 2	3	0	0	3

Preamble: This course is aimed at providing a thorough understanding of the fundamentals of pavement design - factors involved, stress analysis, design approaches in the major types of pavements, and that has better performance and longer service life.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the different component parts of pavements and various factors affecting design of pavements
CO 2	Understand the fundamentals of stress distribution within a pavement system
CO 3	Analyse the stresses and design flexible pavements with better performance and longer service life
CO 4	Analyse the stresses and design rigid pavements with better performance and longer service life
CO 5	Design the reinforcements in cement concrete pavements

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3	1	2		
CO 2			2	2	3		
CO 3	3		3	3	3		
CO 4	3		3	3	3		
CO 5	3		3	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	10
Understand	15
Apply	20
Analyse	15
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

APJ Abdul Kalam Technological University

M.Tech Degree Examination

Branch: **Civil Engineering**

Specialisation: **Transportation Engineering**

Subject: **221TCE010 ANALYSIS AND DESIGN OF PAVEMENT SYSTEMS**

Time: 2.5 Hrs Max. Marks: 60

PART A

(Answer **All** Questions)

1. Explain Dynamic modulus and flow number of bituminous mixes.
2. What are the assumptions in Burmister's theory? What are the advantages of Burmister's theory over Boussinesq's?
3. Discuss the similarities and the differences between the Asphalt Institute and IRC method of flexible payment design.
4. Compare the mechanism used in rigid and flexible pavements for handling stresses due to decrease in temperature.
5. Discuss the similarities and differences in the process of designing jointed plain concrete pavements and jointed reinforced concrete pavements as per PCA design method.

(5x5 = 25 marks)

PART B

(Answer **any 5** Questions)

6. Explain Marshal Stability test method of mix design for bituminous mixes. Plot the sample graphs to determine optimum binder content. List out the standard specifications.

7. A pavement structure is comprised of the following layers – 5.75 inch asphalt concrete surface E= 400,000 psi, 23 inches of granular base, E = 20,000 psi and a sub grad having an E= 10,000psi. All layers are assumed to have μ=0.5. Calibrate the horizontal tensile strain at the bottom of Asphalt concrete layer and the vertical compressive strain at the top of the sub grade layer under the centerline of a 40,000 pound wheel load, 150 psi pressure.

8. A pavement structure is comprised of the following layers – 5.75 inch asphalt concrete surface E= 400,000 psi, 23 inches of granular base, E = 20,000 psi and a sub grad having an E= 10,000psi. All layers are assumed to have μ=0.5. Calibrate the horizontal tensile strain at the bottom of Asphalt concrete layer and the vertical compressive strain at the top of the sub grade layer under the centerline of a 40,000 pound wheel load.

9. Design a suitable concrete pavement (4.5x 3.5cm) as per IRC, situated at Kanpur, for design wheel load of 4100 kg and tyre pressure of 7 kg/cm2. The CBR value of the sub grade soil is found to be 4. 5%. The forecasted traffic intensity at the end of design life is 1000 CV/ day. Assume other parameters wherever necessary.

10. Explain the need and requirements of joints in cement concrete pavements. What are the various types of joints? Explain the need of spacing in concrete pavements.
11. Explain in detail the AASHTO design procedure of flexible pavement design.
12. What are the various factors affecting the design of highway pavements. Explain in detail the effect of traffic.

(5x7=35 marks)

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction to Pavements and Pavement Design (8 hrs)**	
1.1	Types of pavements, Flexible and rigid pavements, Functions of individual layers, Highway and airport pavements	2
1.2	Design of bituminous mixes using Marshall method, and SUPERPAVE method, Dynamic modulus, flow time, flow number, fatigue of bituminous mixes.	2
1.3	Variables Considered in Pavement Design: Traffic factors, Material properties, Climatic effects	2
1.4	Traffic Analysis: ADT, AADT, Truck Factor, Growth Factor, Lane Distribution and Vehicle Damage Factor	2
2	**Stresses and strains in flexible pavements (7 hrs)**	
2.1	Stress inducing factors in flexible pavements, Vehicle-Pavement interaction, Stresses and deflections in homogeneous soil mass.	3
2.2	Burmister's layer theory: Solutions for one, two and three layered pavement systems.	4
3	**Methods of flexible pavement design (8 hrs)**	
3.1	Principles of Mechanistic- Empirical Pavement Design (MEPD)	2
3.2	Methods of flexible pavement design: IRC Method.	2
3.3	Asphalt Institute Method, AASHTO Method.	4
4	**Stresses in rigid pavements (9hrs)**	
4.1	Westergaard's theory and assumptions.	2
4.2	Types of stresses: Wheel load stresses, Temperature stresses, Critical combination of stresses.	3
4.3	Rigid pavement design methods: IRC method, AASHTO method and PCA method.	4
5	**Design of reinforcements in cement concrete pavements (8 hrs)**	
5.1	Types of joints in cement concrete pavements, functions and requirements Joint spacing	3
5.2	Design of dowel bars and tie bars (IRC method).	3
5.3	Introduction to softwares for design of pavements	2

Reference Books

1. Yang H. Huang, Pavement Analysis and Design, Prentice Hall, 2004
2. Yoder and Witczak, Principles of Pavement Design, John Wiley and sons, 2007
3. Rajib B. Mallick and Tahar El-Korchi, Pavement Engineering – Principles and Practice, CRC Press (Taylor and Francis Group)
4. Khanna S.K., Justo C.E.G. and Veeraraghavan A, "Highway Engineering", Nem Chand & Bros., Roorkee, 2014
5. Latest revisions of IRC codes: IRC: 37 and IRC: 58

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221LCE004	PAVEMENT ENGINEERING LAB	LABORATORY	0	0	2	1

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	To evaluate characteristics of aggregates used for pavement construction
CO 2	To grade and evaluate the characteristics bituminous binder used for pavement construction
CO 3	To carry out mix design and to evaluate bituminous mixtures
CO 4	To carry out pavement condition survey and its functional evaluation

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1							
CO 2							
CO 3							
CO 4							

Note: 1: Slightly; 2: Moderately; 3: Substantially

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	100	–	–

Continuous Internal Evaluation Pattern:

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department.

LIST OF EXPERIMENTS

A. Tests on aggregates
   1. Familization of the basic tests of aggregate- Aggregate impact test, Los Angeles abrasion test, shape test to ensure the suitability of aggregates as per MoRTH
   2. Gradation of coarse aggregates, fine aggregates and filler material
   3. Specific gravity of coarse aggregates, fine aggregates and filler

B. Tests on bitumen
   1. Specific gravity
   2. Absolute and kinematic viscosity
   3. Apparent viscosity of bitumen using a rotational viscometer
   4. Short term aging of bitumen
   5. Ductility and elastic recovery
   6. Softening point test of unaged and aged bitumen
   7. Tests on emulsion- Residue by evaporation, storage stability, coating ability, Saybolt viscosity

C. Tests on Bituminous Mixtures
   1.Determination of optimum binder content using Marshall mix design
   2.Determination of Gmm using CORELOK system
   3. Bitument content and gradation using centrifuge extraction and Ignition oven method
   4. Determination of Indirect Strength Ratio of a given bituminous mix
   5. Permanent deformation using wheel tracking test
   6. Preparation of samples using gyratory compactor

D. Pavement Evaluation
   1. Pavement condition rating
   2. Roughess measurement using Roughometer and MERLIN
   3. Benkelman beam deflection method
   4. Dynamic cone penetrometer
   5. Field CBR

Any three/four sub experiments listed above can be made optional

Syllabus and Course Plan

No	Topic	No. of Hrs
1	**Tests on aggregates (2 sessions)**	
1.1	Familization of the basic tests of aggregate- Aggregate impact test, Los Angeles abrasion test, shape test to ensure the suitability of aggregates as per MoRTH	1
1.2	Gradation and specific gravity of coarse aggregates, fine aggregates and filler (need to plan such that it can be used as input for mix design)	2
2	**Tests on bitumen (3 sessions)**	
2.1	Specific gravity	0.5
2.2	Absolute and kinematic viscosity	1.5
2.3	Apparent viscosity of bitumn using a rotational viscometer	1
2.4	Short term aging of bitumen	1
2.5	Ductility and elastic recovery	1
2.6	Softening point test- unaged and aged sample	1

2.7	Determination of grade of given unmodified bitumen based on above test resultsand discussion on grading of modified bitumen	1
2.8	Tests on emulsion- Residue by evaporation, storage stability, coating ability, Saybolt viscosity	2
3	**Tests on Bituminous Mixtures (5 sessions)**	
3.1	Determination or discussion of mixing and compaction temperature Sample preparation for Marshall mix design	2
3.2	Determination of Flow and stability of samples and determination of optimum binder content using Marshall mix design	1
3.3	Determination of Gmm using CORELOK system	1
3.4	Bitument content and gradation using centrifuge extraction and Ignition oven method	2
3.5	Determination of Indirect Strength Ratio of a given bituminous mix	2
3.6	Permanent deformation using wheel tracking test	2
3.7	Preparation of samples using gyratory compactor	2
4	**Pavement Evaluation (3 sessions)**	
4.1	Pavement condition rating	1
4.2	Roughess measurement using Roughometer and MERLIN	2
4.3	Benkelman beam deflection method(demonstration and calculation with given values)	1
4.4	Dynamic cone penetrometer	1
4.5	Field CBR	2

References:

1. Relevant IS, IRC, ASTM and AASHTO Codes.

(i)MORTH V (2013), IRC codes: IRC: 81(2012), IRC SP 11 (1984), IRC SP 16 (2019)

(ii) IS codes: IS 73: 2018, IS 15462: 2004, IS 2386: 2002, IS 3117: 2019 and IS 8887: 2020.

(iii) ASTM codes: ASTM D2172/D2172M,D6307 – 10, D113 – 07, D2170/D2170M – 18, D2171/D2171M – 18, D70 – 18a, C128 –15, C127 – 15 , C136/C136M –14, D6930 –19, D6927 –15, D6926 –16

(iv) AASHTO T 283

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

3. Highway Materials and Pavement Testing, S.K. Khanna, C.E.G. Justo, and A. Veeraragavan, Nem Chand and Bros, Roorkee, India, 2014, Fifth Edition.

4. Highway Material Testing and Quality Control, G.V Rao, I.K International Publishing House Pvt. Ltd., New Delhi, India, 2015.

SEMESTER I

PROGRAM ELECTIVE I

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE049	OPERATIONS RESEARCH IN TRANSPORTATION ENGINEERING	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Objective of the course is to impart an awareness on the methods of Operations Research and mathematical procedures of linear and nonlinear programming

Course Outcomes: After the completion of the course the student will be able to

CO 1	To create an awareness on concepts and tools in optimization
CO 2	To build models for simple problems in transportation engineering
CO 3	To utilise proper mathematical methods to solve the developed models
CO 4	To apply OR techniques constructively to make effective decisions in the area of transportation and management

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	2		3			2
CO 2	3	2	2	3	3		2
CO 3	3	2	2	3	3		2
CO 4	3	2	2	3	3		2

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Course Code & Name:

221ECE049 OPERATIONS RESEARCH IN TRANSPORTATION ENGINEERING

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Write the dual of the following i. Maximise $Z= x_1+ 2 x_2$
   Subject to: $2x_1 +3x_2 \geq 4$; $3x_1 +4x_2 =5$; $x_1 \geq 0$ and x_2 unrestricted

   ii) Minimise $Z= 4x_1+ 5 x_2-3x_3$; Subject to: $x_1 +x_2 + x_3 = 22$;
   $3x_1 +5x_2 - 2x_3 \leq 65$; $x_1 +7x_2 +4x_3 \geq 120$ $x_1,x_2 ,\geq 0$ and x_3 unrestricted

2. Explain the steps involved in Two-Phase Simplex Method

3. A company has a demand of 12000 units/year for an item and it can produce 2000 such items per month. The cost of one set up is Rs 400 and the holding cost/unit/month is Rs 0.15. Find the optimum lot size and total cost per year, assuming the cost of one unit as Rs 4.

4. Differentiate between constrained and unconstrained problem with the help of an example.

5. Describe the procedure involved in the application of gradient projection method.

PART B

(Answer any *five* questions: Each carries 7 marks)

6. Using Big M Method Maximise $Z= 3X_1+ 2 X_2 + X_3$
   Subject to: $-3 X_1 +2X_2 + 2X_3 =8.$, $-3 X_1 +4X_2 + X_3 =7$, $X_1, X_2 , X_3\geq 0$

7. The standard weight of a special brick is 5 kg and it contains two ingredients ‘A’ and ‘B’. ‘A’ costs Rs 5/kg and ‘B’ costs Rs 8/kg. Strength considerations dictate that the brick contains not more than 4 kg of ‘A’ and a minimum of 2 kg of ‘B’ since the demand for the product is likely to be related to the price of the brick. Formulate the problem and solve it graphically. Also write the Dual.

8. Maximise $Z= 4x_1 + 3 x_2$
   Subject to: $x_1 + 2x_2 \leq 4$; $2x_1 +x_2 \leq 6$; $x_1, x_2 \geq 0$ and integers

9. Formulate the inventory model with demand rate non uniform and production rate infinite.

10. Determine the optimum solution of the nonlinear programming problem and check whether it maximises or minimises the objective function.
    Optimise f (x) = $x_{12}+x_{22}+3\ x_1x_2 - x_1 + 3\ x_2$;
    Sub to = $x_{12}+ x_{22} = -1$; $x_1,x_2 \geq 0$

11. Apply Wolfe's method to formulate the initial basic feasible solution.
    Maximise $Z= 2x_1 + x_2 - x_{12}$
    Subject to: $2x_1 + 3x_2 \leq 6$; $2x_1 + x_2 \leq 4$., $x_1, x_2 \geq 0$

12. Determine whether the following functions are convex, concave or neither.
    i. $f(x)= 4x_{12} +3\ x_{22} +x_{32} - 6x_1x_2 +x_1x_3 - 0.5\ x_1 - 2\ x_2 +15$;
    ii) $f(x)= x_1 +2\ x_3 +x_2x_3 - x_{12} - x_{22} - x_{32}$

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Introduction to Operations Research	
1.1	Basics definition, scope, objectives, phases, models and limitations of Operations Research	2
1.2	Linear Programming Problem – Formulation of LPP, Simplex Method, Artificial variables, Big-M method, two-phase method, degeneracy and unbound solutions.	4
1.3	Duality Theory, The Primal Vs- Dual-Solutions	2
2	Sensitivity Analysis and Integer programming	
2.1	Sensitivity Analysis: Changes in Objective-Function Changes in RHS.- revised simplex method –parametric programming	2
2.2	Integer programming: Relevance of integer variables and relevance of integer programming	2
2.3	Formulation of problems with binary variables-cutting plane method	2
2.4	Mixed integer programming-branch and bound methods	2
3	Inventory models	
3.1	Inventory costs	2
3.2	Models with deterministic demand – demand rate uniform and production rate infinite - demand rate non-uniform and production rate infinite - demand rate uniform and production rate finite	6
4	Nonlinear programming	
4.1	Multi-variable optimisation with equality constraints- Langarange multiplier method	2

4.2	Optimisation in the presence of inequality constraints	2
4.3	Convexity and role in optimization	2
4.4	Kuhn Tucker conditions	2
5	Quadratic programming	
5.1	Wolf's method- Beale's method-Frank &Wolfe Method	2
5.2	Reduced Gradient method	2
5.3	Gradient projection method	2
5.4	Convex simplex method	1
5.5	Case studies on applications of OR in transportation engineering	1
	Total hours	40

Reference Books

1. Bazaraa M S, Jarvis & herali H D ,Linear Programming and Network flows, John Wiley & Sons, Singapore 1990.
2. Bazaraa M S, Sherali H D & Shetty, C. M., Non Linear Programming, Theory & Algorithms 2nd edition, John Wiley &Sons, Singapore 1995.
3. Goel B S and Mittal S K ' Operations Research' 1999
4. Taha, Hamdy, Operations Research, 7th edition, (USA: Macmillan Publishing Company), 2003

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE050	SUSTAINABLE TRANSPORTATION	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Objective of the course is to introduce the principles and practice of sustainability on transportation systems and development of an eco-friendly transport system.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understanding the importance and principles of sustainability
CO 2	Analyse Transportation network for eco-friendliness and quantify the levels.
CO 3	Apply the basic principles of demand management and alternate modes
CO 4	Apply concepts of sustainability in developing green fuels and vehicles.
CO 5	Design for sustainability in public transport

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2		2	3			
CO 2		3		2			
CO 3	3			2			
CO 4		2		3			
CO 5	2		3				

Assessment Pattern

Bloom's Category	End Semester Examination (%)
Apply	20
Analyse	30
Evaluate	25
Create	25

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed

Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks. Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question paper

Course Code & Name:

221ECE050 Sustainable Transportation

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. What are problems of present transportation systems?
2. Discuss the basic concepts of sustainable network planning?
3. Explain the necessity of Multi Modal Transport.
4. Write a brief note on alternate fuels.
5. Explain the ways to improve sustainability in public transport.

PART B

(Answer any *five* questions: Each carries 7 marks)

6. Discuss how the land use and travel behaviour affect sustainability.
7. Explain the difference between Elastic and Fixed Networks
8. Discuss the various strategies for travel demand management.
9. Explain the concept and design principles of Green pathways.
10. Discuss the Non Motorised Transport Policy of India.
11. Suggest various strategies to improve public transport
12. What is Green logistics and why does it matter?

Syllabus and Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Introduction to sustainable transportation**	
1.1	Introduction to sustainable transportation, definition, necessity	1
1.2	Problems of present transportation system	1
1.3	Fundamental Principles, Quantifying sustainability	2
1.4	Sustainable transportation planning: Paradigm shift in planning	2
1.5	Land use and Travel behaviour	2
2	**Sustainable Transportation Networks**	
2.1	Sustainable Network planning and design	3
2.2	Elastic and fixed demands on networks	2
2.3	Measurement of network performance, factors and parameters	2
2.4	Viability of networks	1
3	**Demand Management and Alternate Modes**	
3.1	Demand Management – need, strategies for demand management	3
3.2	Alternate modes – various modes, benefits	2
3.3	Multi modal transport – necessity, advantages, multimodal transport linkages, pricing strategies	3
4	**Emerging Concepts in Sustainable Transportation**	
4.1	Eco friendly transport – Environmental issues, alternate fuels, green fuels	3
4.2	Green pathways, introduction, design concepts	2
4.3	Energy and emission standards	2
4.4	Non Motorised Modes	1
5	**Sustainable Public Transport**	
5.1	Sustainability in personal and public transport	1
5.2	Methods to promote public transport	1
5.3	Transit Oriented Developments – introduction only	2
5.4	Freight and Green logistics	4

Reference

1. Sustainable and Efficient Transport: Incentives for Promoting a Green Transport Market Edited by Ellen Eftestøl-Wilhelmsson, et al, Edward Elgar

2. Thomas Abdallah: Sustainable Mass Transit: Challenges and Opportunities in Urban Public Transportation.

3. McClintock, H. Planning for Cycling – principles, practice and solutions for urban planners. Cambridge: CRC Press.

4. Frumkin, H.; Frank, L. and Jackson, R. Urban Sprawl and Public Health, designing, planning, and building for healthy communities. Washington DC: Island Press

5. Green Transportation Logistics: The Quest for Win-Win Solutions Editors: Psaraftis, Harilaos N. (Ed.), Springer

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE051	GEOSYNTHETICS AND GROUND IMPROVEMENT TECHNIQUES FOR PAVEMENT	PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course describes the fundamental aspects of geosynthetics and their applications in infrastructure development including foundations, embankments, earth retaining structures, pavements and slope stabilization. This course also describes the basic concepts of different ground improvement techniques for varied subsoil types and profiles. Upon completion of this course, the student will be able to select and design appropriate technique for a given soil condition, type of structure and type of loading.

Course outcomes: After the completion of the course the student will be able to

CO 1	Analyse the various type of geotextiles and its functions
CO 2	Evaluate the various properties of geotextiles and its testing methods
CO 3	Apply the design principles of reinforced soil structures in field
CO 4	Analyse specific applications of geotextile in pavement Construction
CO 5	Analyse various other ground improvement techniques available

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2	1	1	3	3	1	
CO 2	2	1	1	3	3	1	
CO 3	3	2	2	3	3	1	
CO 4	3	1	2	3	3	1	
CO 5	3	1	2	3	3	1	

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Course Code & Name:

221ECE051 Geosynthetics and Ground Improvement Techniques for Pavements

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Write a brief note on geosynthetics and various potential area of applications.
2. List the various functions of geotextiles and explain the separation function in the context of pavement application.
3. Discuss the internal and external stability of retaining wall design.
4. Enlist the various Mechanical properties of geotextiles?
5. Explain the test procedure to find tensile strength of geosynthetics.

PART B

(Answer any *five* questions: Each carries 7 marks)

6. Write a brief note on coir geotextiles and its special areas of application.
7. Explain the concept of Giroud and Noiray approach and its practical significance.
8. Explain the test procedure to find tensile strength of geosynthetics.
9. Explain the basic concept of dynamic compaction.
10. Discuss the features and design principles of stone column.
11. Write a brief note on vibro floatation technique.
12. Illustrate the mechanism and method on fly ash stabilization.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Geo synthetics -overview**	
1.1	Introduction, types manufacturing methods (brief description)	3
1.2	Functions of Geo synthetics- Reinforcement,separation, filtration, Drainage, Fluid transmission, protection	4
2	**Natural Geotextiles**	
2.1	Types –jute- coir- Factors governing the usage of natural geotextiles, Importance	2
2.2	Functions-of natural geotextiles	2
2.3	Civil Engineering Applications of natural geotextiles	2
3	**Testing and Evaluation**	
3.1	Importance of testing, test conditions, sampling, Various testing standards	2
3.2	Basic Properties- physical(Mass per unit area, thickness, compressibility, apparent opening size, width and length),Hydraulic properties-Permeability-in plane& cross plane, Filtration and Drainage: geotextile filter requirements, drain and filter properties design criteria	4
3.3	Mechanical properties (Tensile strength, narrow strip tensile test, grab test, strip wide width tensile test, seam testing, interface friction, creep resistance)- constructability/survivability (puncture test, CBR push through test, trapezoidal tear test, diaphragm bursting strength test, cone drop test), durability (abrasion resistance, ultraviolet resistance, temperature stability, chemical stability)	4
4	**Design principles**	
4.1	Principle of reinforced earth- soil retaining structures-type-components- load calculation- Design of reinforced Retaining wall, Internal and external stability	3
4.2	Embankments in soft soil: stability analysis influence of reinforcement extensibility, relationships for design, settlement analysis	3
4.3	Design of unpaved road by Giroud-Noiray method	2
5	**Specific Applications & ground improvement techniques**	
5.1	Geotextiles for separation and reinforcement - application in flexible pavements, Rehabilitation, Reflective Crack Treatment for Pavements -Ground improvement using stone columns-Prefabricated vertical drains-	3
5.2	Improvement of bearing capacity using Geocell- Use of geotextiles for construction of heavy container yards and railway lines.	3
5.3	Ground improvement techniques-principle of compaction-shallow stabilization with additives-lime-fly ash-cement-dynamic compaction- vibro-floatation- electro osmosis; Grouting..	3

Reference Books

1. Koerner, R.M. Designing with Geo synthetics, Prentice Hall, New Jersey, USA, 4th edition, 1999.
2. G.V. Rao, PK Banerjee, J.T. Shahu, G.V. Ramana. Geo synthetics - New Horizons, Asian Books Private Ltd., New Delhi, 2004.
3. G. Venkatappa Rao, Geo synthetics-An Introduction, Sai Master Geo environmental Services Pvt Ltd., Hyderabad, 2011.
4. G. Venkatappa Rao & Goutam K. Pothal, Geo synthetics Testing-A Laboratory Manual, Sai Master Geo environmental Services Pvt Ltd., Hyderabad, 2008.
5. Hausmann M R, Engineering Principles of Ground Modification, McGraw Hill (2013).
6. Jie H, Principles and Practice of Ground Improvement, John Wiley & Sons (2015)
7. J.N. Mandal, ―Geo synthetics World‖, Willey Eastern Ltd., New Delhi.
8. G.L Siva Kumar Babu, ―An Introduction to Soil Reinforcement and Geo synthetics‖, university press(India) private limited hyderabad,2006
9. (2015). 3. Shukla S K, Geosynthetics and their Applications, Thomas Telford (2002

SEMESTER I

PROGRAM ELECTIVE II

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE054	TRANSPORTATION ECONOMICS	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Objective of the course is to impart an awareness on the fundamentals of transportation economics and techniques of economic analysis.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the fundamentals of economic analysis
CO 2	Understand the benefits and cost components of transportation projects
CO 3	Develop generalized cost for transportation projects
CO 4	Conduct economic analysis of transportation infrastructure projects

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2			3	3		
CO 2	2			3	3		
CO 3	2			3	3		
CO 4	2			3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed
Original publications (minimum 10 publications shall be referred) : 15 marks
Course based task/Seminar/Data collection and interpretation : 15 marks
Test paper, 1 no. : 10 marks
Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Course Code & Name:

221TCE054 **TRANSPORTATION ECONOMICS**

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Explain various parameters used in Economic Analysis.
2. What is opportunity cost? Explain with example.
3. Write a note on social accounting.
4. Compare IRR and NPV methods of economic analysis.
5. Compare user optimal assignment and system optimal assignment.

PART B

(Answer any *five* questions: Each carries 7 marks)

6. The cost of construction of a road is Rs 250 crore at current price and is met with by raising a loan. What is the annual payment of equal amount for 20 years to repay the loan? Assume 4.5% rate of interest.
7. Calculate the internal rate of return of an investment of 21 lakh which yields the following cash inflows of 5 lakh, 7 lakh, 8 lakh, 3 lakh in first 4 years respectively. Is it viable to invest here if the market interest rate is 11.5%?
8. Explain incremental analysis with suitable examples.
9. Explain Private Public Partnership with Toll collection as example.
10. Compare economic cost and financial cost.
11. Explain the concept of Build-Operate-Transfer Schemes in transportation projects.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Introduction to transportation economics	
1.1	Need for economic evaluation, costs and benefits of transport project, time horizon.	2
1.2	Basic principles, interest rate, time value of money. Supply and demand Models, Consumer's surplus and social surplus criteria.	4
1.3	Framework of social accounting: accounting rate of interest, social opportunity cost, rate of interest, social time preference rate of interest.	2
2	Transportation cost	
2.1	Accounting prices of goods and services, measuring input costs, applications of social accounting frame work.	2
2.2	Transport Costs: Fixed and Variable costs, cost of improvement.	2
2.3	Maintenance cost and other related costs, cost estimating methods.	2
2.4	Accounting for inflation, theory of transport supply and road planning.	2
3	Transportation benefits	
3.1	Benefits due to Transport Improvements: Direct Benefits: Reduced vehicle operation costs.	2
3.2	Value of travel time savings, value of increased comfort and convenience, cost of accident reduction, reduction in maintenance cost.	6
4	Techniques of economic analysis	
4.1	The generation and screening of project ideas. Different methods of economic analysis.	2
4.2	Annual cost and benefit ratio methods, discounted cash flow method, determination of IRR and NPV.	2
4.3	Examples of economic analysis of (i) different types of road surfaces (ii) different options for intersection improvement (iii) proposals for bypass to a city (iv) different strategies of pavement maintenance.	2
5	Economic analysis of projects	
5.1	Application of economic theory in traffic assignment problem - user optimal assignment and system optimal assignment.	2
5.2	Economic analysis of projects-Financing of road projects	2
5.3	Methods of Private Public Partnership (PPP)	2

5.4	Toll collection Economic viability of Build-Operate-Transfer Schemes, Risk Analysis.	1
5.5	Case Studies.	1
	Total hours	**38**

Reference Books

1. Hensher, David, and Ann Brewer. "Transport: an economics and management perspective." OUP Catalogue (2000).
2. Quinet, Emile, and Roger William Vickerman. Principles of transport economics. Northampton, MA, 2004.
3. Wright, Paul H., and Norman J. Ashford. "Transportation engineering." (1989).
4. Wright, Paul H., and Radnor Joseph Paquette. Highway engineering. 1987.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE055	PAVEMENT MATERIAL CHARACTERISATION AND CONSTRUCTION PRACTICES	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Objective of this course is to make the students aware of the characterization of different materials, to understand the constituents and behaviour of bitumen and to study the different bituminous mix design procedures used in pavement construction. To understand the construction practices for bituminous and concrete pavements.

Course outcome: After the completion of the course the student will be able to

CO 1	Characterize the pavement materials including soil and aggregate
CO 2	Understand the constituents and behaviour of bitumen, also characterise and grade binder
CO 3	Understand the mix design procedure; evaluate different mix design approaches and understand mixture performance tests
CO 4	Understand the operations, construction practises and quality control aspects of subgrade, unbound and bound granular layers
CO 5	Understand asphalt paving operations and construction of various types of bituminous layers and concrete pavements

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	1	3	3	2	2	1
CO 2	3	1	3	3	2	2	1
CO 3	3	1	3	3	2	2	1
CO 4	3	1	3	3	2	2	1

Note: 1: Slightly; 2: Moderately; 3: Substantially

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed

Original publications (minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End semester examination pattern

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over theaverage ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is40+20 = 60 %.

Model Question Paper

Course Code & Name:

221ECE055 PAVEMENT MATERIAL CHARACTERISATION AND CONSTRUCTION PRACTICES

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Briefly discuss the test procedure to find resilient modulus of soils and aggregate materials.

2. Describe the importance of bitumen grading system. Why the grading system adopted in India and US are different.

3. Explain the balanced mix design procedure

4. Describe the use of crack relief layer and SAMI layer in pavements.

5. Explain the definition and selection criteria for White toppings, Thin and ultra thin.

PART B

(Answer any five questions: Each carries 7 marks)

6. Discuss the methods used for grading aggregates to use in different layers.

7.List the step-by-step procedure for aging asphalt binders to simulate long term aging in the laboratory. What are the assumptions?

8. How do you conduct a creep test in laboratory for asphalt mixtures and how will you relate it to the rutting occurring in the field?

9. Explain briefly the procedure of Marshal Mix design including the volumetric calculations

10. How do we select a rehabilitation process for an existing damaged pavement? Explain the significance of FDR in Indian scenario.

11. Explain the methodology of design and construction of subgrade for receiving the pavement layers including the quality control.

12. One of the existing four-lane highways in Kerala, which is a bituminous pavement, is proposed to be converted as a six lane concrete pavement. Compare the relative merits of the options listed below and explain the construction and quality control steps of your recommended choice.

(i) Conventional Concrete Pavement

(ii) Continuous Reinforced Concrete Pavement

(iii) White topping

(iv) Pre-cast Concrete Pavement

Syllabus

MODULE 1

Introduction to Pavement Materials: with emphasis on bitumen, bituminous concrete, cement concrete and granular materials and need for characterisation.

Subgrade Soil

Characterization of subgrade soil for pavement design: compaction characteristics; stiffness and strength of soil, resilient modulus (Mr);

Aggregates: aggregate gradations for pavement layers; aggregate packing characteristics: Fuller Thomson; aggregate blending;

Factors affecting the performance of unbound aggregate layers; non-linear behavior of granular materials; permanent deformation behavior of unbound aggregate layers;recycled aggregates and marginal aggregates in pavement construction.

MODULE II

Bituminous Binder:

Types of bituminous binder: unmodified and modified binder, bituminous emulsion, and cutback

Constitution and structure of bitumen; physical characterization; requirements and specifications of paving grade binder;binder grading: penetration, viscosity, and performance grading;

Rheology of bitumen: concept of linear viscoelasticity; rheological characterization of binders, performance tests to assess rutting, cracking, healing and aging susceptibility.

MODULE III

Bituminous mix design and performance tests: Objectives of bituminous mix design; volumetrics of compacted bituminous mixes; Marshall mix design; Superpave mix design; Balanced mix design concept;

Mechanical characterization of bituminous mixtures for Design and Distress - dynamic modulus, resilient modulus and flexural modulus. Fatigue, creep and moisture-induced damage.

Pavement rehabilitation

Rehabilitation options: Recycled pavement mixtures- hot recycling and cold recycling, full depth reclamation

MODULE IV

Construction of Subgrade: Earthwork grading; compaction requirement for subgrade; subgrade stabilization: compaction equipment, curing and opening to construction operation; subgrade construction.

Construction of Unbound and Bound Granular Layers:

Gradation and material quality requirement for granular subbase and base layers, blending and proportioning, mix design, placing, laying and compaction requirements; field quality control; crack relief and SAMI layer; construction of subsurface drainage for highways;

MODULE V

Asphalt Paving Operation: Preparing for paving: new construction/overlay, prime coat, tack coats: recommended applications, distribution, verifying the application rates; asphalt pavers and compaction;
Screed operations and control; joints; roller types; sequence of rolling: tender mixes and compaction troubleshooting; quality assurance: sampling methods for asphalt mixtures
Construction procedures for various pavement component layers and types.
Non-destructive tests: nuclear gauge, geogauge, ground penetrating radar (Introduction only)
Construction of concrete pavements:
Concrete production; preparation of subgrade and base; reinforcement presetting for JPCP and CRCP; PCC slab constructions: slip form paving, fixed form paving; curing process; Roller compacted concrete, white topping, Thin and ultra-thin white topping, Interlocking concrete block pavements

Course Plan

Sl. No	Topic	No. of hrs
MODULE 1 (8 hrs)		
1	Introduction to Pavement Materials with emphasis on bitumen, bituminous concrete, cement concrete and granular materials and need for characterization	2
2	Characterization of subgrade soil for pavement design: compaction characteristics;	1
3	Stiffness and strength of soil, resilient modulus (Mr);	1
4	Aggregate gradations for pavement layers; Aggregate packing characteristics: Fuller Thomson; aggregate blending;	2
5	Factors affecting the performance of unbound aggregate layers; non-linear behavior of granular materials; permanent deformation behavior of unbound aggregate layers	1
6	Recycled aggregates and marginal aggregates in pavement construction.	1
MODULE 2 (8hrs)		
7	Types of bituminous binder: unmodified and modified binder, bituminous emulsion, and cutback	2
8	Constitution and structure of bitumen; physical characterization;	1
9	Requirements and specifications of paving grade binder	1
10	binder grading: penetration, viscosity, and performance grading;	1
11	Rheology of bitumen: concept of linear viscoelasticity	1
12	Aging phenomena;performance tests to assess rutting, cracking, healing	2
MODULE III (11 hrs)		

13	Objectives of bituminous mix design; volumetrics of compacted bituminous mixes;	1
14	Marshall mix design;	2
15	Superpave mix design; Balanced mix design concept;	2
16	Mechanical characterization of bituminous mixtures for Design and Distress - dynamic modulus, resilient modulus and flexural modulus.	2
17	Fatigue, creep and moisture-induced damage. Relation between binder and mixture mechanical response.	2
18	Rehabilitation options: Recycled pavement mixtures- hot recycling and cold recycling, full depth reclamation	2
MODULE IV (7 hrs)		
19	Construction of Subgrade:Earthwork grading; compaction requirement for subgrade; subgrade stabilization:	2
20	Preparation, compaction equipment, curing and opening to construction operation; subgrade construction.	1
21	Gradation and material quality requirement for granular subbase and base layers, blending and proportioning, mix design,	2
22	Placing, laying and compaction requirements; field quality control;	1
23	Crack relief and SAMI layer; construction of subsurface drainage for highways,	1
MODULE V (8 hrs)		
24	Preparing for paving: new construction/overlay, prime coat, tack coats: recommended applications, distribution, verifying the application rates; asphalt pavers and compaction;	1
25	Screed operations and control; joints; roller types; sequence of rolling: tender mixes and compaction troubleshooting; quality assurance: sampling methods for asphalt mixtures	1
26	Construction procedures for various pavement component layers and types; quality control tests	2
27	Non-destructive tests: nuclear gauge, geogauge, ground penetrating radar	1
28	Concrete production; preparation of subgrade and base; reinforcement presetting for JPCP and CRCP;	1
29	PCC slab constructions: slip form paving, fixed form paving; curing process;	1
30	Roller compacted concrete, white topping and ultra-thin white topping, Interlocking concrete block pavements	1

References

1. James G Speight,Asphalt Science and Technology, Elsevier
2. Asphalt Institute. Asphalt Mix Design Methods Manual Series No. 2 (MS-2), SeventhEdition, Asphalt Institute, Kentucky, USA, 2014.
3. Atkins, H.N. Highway Materials, Soils, and Concretes, Reston Publishing Company,Virginia, USA, 1980.
4. Huang, Y.H. Pavement Analysis and Design, Pearson Prentice Hall, New Jersey, USA,2004.

5. IRC:44-2017 Guidelines for Cement Concrete Mix Design for Pavements, The IndianRoads Congress, New Delhi, India, 2017.
6. Kandhal, P.S. Bituminous Road Construction in India, PHI Learning Pvt. Ltd., NewDelhi, India, 2016.
7. Kim, Y.R. Modeling of Asphalt Concrete, ASCE Press, New York, USA, 2009. Mallick, R.B. and T. El-Korchi Pavement Engineering – Principles and Practice, CRCPress, Taylor and Francis Group, Florida, USA, 2018.
8. Ministry of Road Transport and Highways. Specifications for Road and Bridge Works,Fifth Edition, Indian Roads Congress, New Delhi, India, 2013.
9. Papagiannakis, A.T. and E.A. Masad Pavement Design and Materials, John Wiley andSons, New Jersey, USA, 2008.
10. P. H. Wrightand Karen Dixon, Highway Engineering, John Wiley & Sons, 1996
11. Hunter, R.N., Self, A. and J. Read The Shell Bitumen Handbook, Sixth Edition, ICEPublishing, London, UK, 2015.
12. Sherwood, P.T. Alternative materials in road construction, Thomas Telford, New York,USA, 1997.
13. Relevant IRC, IS, and ASTM codes,

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE056	GEOINFORMATICS IN TRANSPORTATION ENGINEERING	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Objective of the course is to impart an awareness on the applications of Geoinformatics in the context of intelligent transportation system, land use and transportation planning

Course Outcomes: After the completion of the course the student will be able to

CO 1	To conduct surveys for land use and transportation planning by applying suitable sampling techniques
CO 2	To estimate travel demand in various traffic analysis zones
CO 3	To develop database for transportation analysis in GIS environment
CO 4	To create and analyse transportation networks and maps in GIS platform
CO 5	To illustrate the applications of GIS in transportation and ITS

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	3	3	3	3		
CO 2	3		3	3	3		
CO 3	3		3	3	3		
CO 4	3		3	3	3		
CO 5	3		3	3	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Course Code & Name:

221ECE056 GEOINFORMATICS IN TRANSPORTATION ENGINEERING

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Define Capacity and Level of Service. Explain the factors affecting level of service.
2. Substantiate the statement "Transportation and land use are interconnected"
3. What is the importance of road networks and maps in GIS?
4. Illustrate ITS architecture.
5. How traffic management can be done with GIS-ITS integration?

PART B

(Answer any *five* questions: Each carries 7 marks)

6. What is sampling? Why is it needed? Explain any two random sampling techniques which can be adopted in transportation surveys.
7. What is the importance of trip generation in four stage planning process? Explain any two methods of trip generation in detail.
8. Differentiate primary and secondary data. What are the different types of surveys in planning? Explain any two in detail.
9. Illustrate any one land use model in detail.
10. How is road network mapping procedure done? Explain in detail with a flowchart.
11. How travel time analysis can be done by integrating GPS and GIS? Explain with a case study.
12. What is ITS? Explain the components of ITS in detail.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Traffic Engineering Studies and data collection	
1.1	Sampling in traffic studies-random and non-probability sampling techniques, sample size determination	2
1.2	Data collection techniques- Spot speed, Speed and delay, Volume, Origin Destination and Parking surveys	3
1.3	Concept of PCU, Capacity and level of service	2
1.4	Types of manoeuvres and conflict points	1
2	Transportation Planning process	
2.1	Travel Demand Estimation, Traffic Analysis Zone (TAZ), screen lines and desire lines	1
2.2	Four Stage Planning Process (Description only)	4
2.3	Land use and Transport Planning- Introduction of TLUM models- Lowry models	3
3	Role of GIS in Land use and Transportation Planning	
3.1	Introduction to GIS, Spatial and Non spatial data for land use and transportation, spatial database management system	1
3.2	Transport Network, Network representation - incidence matrices	1
3.3	Map and Network creation in GIS - steps involved - geo referencing, digitisation of the road network, topology creation, database development, overlay of maps (Introduction with any available GIS software), Route building in GIS	4
3.4	Shortest Path determination- shortest path algorithm, network analysis tool in GIS	1
3.5	Introduction of GIS-T- Software (CUBE, TRANSCAD, EMME)	1
4	Intelligent Transportation system and GIS	
4.1	Introduction to Intelligent Transport System- ITS architecture, Components of ITS- Advanced traffic management system, Advanced traveller information system, Advanced vehicle control system, Advanced public transport system, Commercial vehicle operation	2
4.2	Applications of ITS- electronic toll collection, Incident management system (IMS)-components, benefits and stages of IMS	2
4.3	Application of GIS in accident management – Accident database, GIS based accident analysis, black spot identification	1
4.4	Integration of ITS and GIS - In-vehicle navigation, emergency response management	1

4.5	Automatic number plate recognition, vehicle information and communication system	1
4.6	Case studies on applications of ITS	1
5	Integration of GPS and GIS in transportation	
5.1	Types of positioning Systems, Applications of GPS-GIS integration- Route guidance, emergency response, Fleet Management, Automated Highway Systems	2
5.2	Travel time analysis using GPS-GIS integration	2
5.3	Case studies on Integration of GPS and GIS in transportation	2
5.4	Application of GIS in land use and transportation planning-case studies	2
	Total hours	40

Reference Books

1. Hensher D. A., Button K. J., Haynes K. E., and Stopher P. R. (Eds.), Handbook of Transport Geography and Spatial Systems", Elsevier,2004.
2. Thill Jean-Claude, Geographical Information Systems in Transportation Research, Pergamon, 2000.
3. Longley P. A., Barnsley M. J., Donnay Jean-Paul, Remote Sensing and Urban Analysis, Taylor & Francis, 2001.
4. Caliper Corporation, Travel Demand Modelling with TransCAD, 2009.
5. Hutchinson, B. G., Principles of Urban Transportation Planning, Mc Graw Hill, 1979
6. Kadiyali, L.R.Traffic Engineering and Transportation Planning, Khanna Publishers

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221ECE057	PUBLIC TRANSPORT SYSTEM	PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Objective of the course is to enable the students to understand the objectives, principles and geometric characteristics of transit networks, concepts and principles to plan, design and evaluate the transit networks and infrastructure facilities.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Discuss the relevance of Public Transit Units.
CO 2	Undertake planning activities connected with Transit operations.
CO 3	Plan and prepare transit routes and schedules and the transit fares.
CO 4	Design transit infrastructure facilities.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2						
CO 2	2		3	3			
CO 3	2		3	3			
CO 4	2		3	3			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed Original publications (minimum 10 publications shall be referred)	:	15 marks
Course based task/Seminar/Data collection and interpretation	:	15 marks
Test paper, 1 no.	:	10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Course Code & Name:

221ECE057 PUBLIC TRANSPORT SYSTEM

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer all Questions: Each question carries 5 marks)

1. Explain the characteristics of basic ROW categories.
2. Describe transit planning process with the help of a flowchart.
3. Illustrate and describe various route configurations.
4. List out the major components of schedule development that are influenced by service standards and policies.
5. Describe the influence of fare increase on operating cost.

PART B

(Answer any *five* questions: Each carries 7 marks)

6. Describe the Semi-Rapid transit system with an example.
7. Explain the need for comprehensive planning.
8. Define interlining and explain its significance.
9. Explain the various factors affecting the layout of bus terminals.
10. Discuss the advantages & disadvantages of far side bus stop placement.
11. Describe the influence of fare increase on operating cost.
12. Explain the benefits of integrated public transport systems

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Introduction to public transport systems.	
1.1	Historical Growth, Modes of public transport and comparison.	2
1.2	Public transport travel characteristics.	2
1.3	The technology of bus, rail, rapid transit systems, basic operating elements.	4
2	Transit Network Planning	
2.1	Objectives and principles.	2
2.2	Transit lines: types, geometry and characteristics.	2
2.3	Transit routes and their characteristics- Timed transfer networks.	2
2.4	Prediction of transit usage, network evaluation, accessibility consideration.	2
3	Transit Scheduling	
3.1	Components, determination of service requirements, scheduling procedure	2
3.2	marginal ridership, crew scheduling	6
4	Transit Infrastructure Facilities	
4.1	Design of bus stops, design of terminals– principles of good layout.	2
4.2	Types of layouts, depot location.	2
4.3	Twin depot concept, crew facilities and amenities.	2
5	Transit Agency and Economics	
5.1	Organizational structure of transit agency.	2
5.2	Management and personnel Transit system statistics.	2
5.3	Performance and economic measures.	2
5.4	Operations.	1
5.5	Fare structure.	1
	Total hours	38

Reference Books

1. Vukan R. Vuchic, “Urban Transit: Operations, Planning and Economics”, Wiley Sons Publishers.
2. Kadiyali L.R., “Traffic Engineering and Transport Planning”, Khanna Publishers
3. TCRP Report 30, TCRP Report 95, TCRP Report100
4. Papacostas, C. S and P.D. Prevedouros., “Transportation Engineering and Planning”, Pearson.