APPENDIX A

CE405X Course Materials

CE 405X: Highway Design

C-2004 Syllabus

Course Description

This course provides a background in the geometric design of modern highways. Students gain proficiency in the design of horizontal curves, vertical curves, cross-sections, and other geometric features using a series of field and laboratory exercises. Recommended Background: CE 2020, CE 3050.

Meeting Times

MTRF 3:00 pm to 3:50 pm in KH 204

Staff Information

Instructor: Mrs. Jennifer Weir, P.E.
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Textbooks

- American Society of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets*, Fourth Edition, 2001. (commonly referred to as the "Green Book;" available from AASHTO for $90)
- Federal Highway Administration (FHWA), U.S. Department of Transportation, *Flexibility in Highway Design*, Publication Number FHWA-PD-97-062, 1997. (free from instructor!)

Goals & Learning Objectives

My overall goals are that students in this course will understand and be able to apply principles of highway design, and will recognize the complexity of real-world problems.

By the end of this course, each student will demonstrate the skills shown in the following list. These specific learning objectives are closely related to the major topics identified in the course outline.

1. Choose or determine appropriate design controls (design vehicle, speed, volume, etc.).
2. Design a roadway cross-section.
3. Estimate earthwork volumes.
4. Calculate required sight distances for road segments and intersections.
5. Design a vertical curve.
6. Design a horizontal curve.
7. Design a bicycle lane, sidewalk, and/or crosswalk.

Course Policies

Teaching/Learning Methods

This course will be comprised of reading assignments, short lectures, in-class activities, and group work. Students should expect to be active in learning and applying the material.

Assessment

The course learning objectives will be assessed through in-class discussion and activities, quizzes, and a group design project.

Class participation will be 20% of the final grade. A student will lose 1 point (1%) for each unexcused absence and ½ point for each session in which he or she is present but non-participatory. Participation means that you are prepared for and active in the discussion. Absences for illness, family emergencies, or other unavoidable reasons may be excused by the instructor.

Homework assignments will be given regularly but not graded. They will be used primarily as a starting point for class discussions. Each student is expected to complete the homework assignments and be prepared to discuss them in the next class.

Approximately five *quizzes* will be given during the course (announced in advance). Make-up quizzes will only be given if arrangements are made in advance. The average of the quiz grades will count as 30% of the final grade.

A *group design project* will be assigned at the beginning of the term and worked on both inside and outside of class. Groups will be assigned by the instructor. The final project report will be 50% of the final grade.

Academic Honesty

Quizzes: All quizzes will be closed-book, meaning you may use only the materials provided by the instructor for that quiz. Using any other materials will be considered cheating. You are expected to work independently, so you cannot copy other students' work or discuss the questions during the quiz.

Homework: I encourage you to work together on homework problems. The interaction between students who are trying to understand new material is an important and effective way of learning. Each student is, however, responsible for his or her own work and understanding.

Group projects: Each student is responsible to contribute to his or her group work. If any member of the group persists in not contributing, his or her name should not appear on the project submissions as a contributor.

Additional Resources

The WPI Library has the following Institute of Transportation Engineers publications:

- *Traffic Engineering Handbook*, 1999
- *Highway Capacity Manual*, 2000

On the Web: The MassHighway Highway Design Manual and other manuals are available for download at www.state.ma.us/mhd/publications/manuals.htm. Other websites of interest will be listed on MyWPI.

Final Course Outline

Week #1, Starting 1-15-04: Introduction

Day	Lecture Topic	Reading Due	Events
Th	Introduction	none	
F	Design process	FHD pp. 1-26	

Week #2, Starting 1-19-04: Design Controls

Day	Lecture Topic	Reading Due	Events
M	Functional class & the Green Book	GB pp. 1-7, FHD pp. 41-44	
Tu	Design controls	FHD pp. 55-62	
Th	Sight distance	GB pp. 109	
F	Sight distance (measuring)	GB pp. 127-130	

Week #3, Starting 1-26-04: Cross-Sections

Day	Lecture Topic	Reading Due	Events
M	Roadway	GB pp. 309-315	Quiz 1
Tu	Roadside and median	GB pp. 322-335, 341-343	
Th	Roadside safety	GB pp. 335-340	
F	Bicycles and pedestrians	GB pp. 361-371, 100-101	

Week #4, Starting 2-2-04: Route Selection

Day	Lecture Topic	Reading Due	Events
M	Route selection	FHD pp. 63-71	Quiz 2
Tu	Intersection issues	GB pp. 654-681	
Th	Intersection issues	FHD pp. 113-130	
F	Earthwork	Handout	

Week #5, Starting 2-9-04: Vertical Alignment

Day	Lecture Topic	Reading Due	Events
M	Earthwork		
Tu	Grades & vertical curves	GB pp. 235-249	Quiz 3
Th	Vertical curves	GB pp. 269-282	
F	Layout of vertical curves		

Week #6, Starting 2-16-04: Vertical & Horizontal Alignment

Day	Lecture Topic	Reading Due	Events
M	Horizontal curves	GB pp. 131-134, 141-142	Quiz 4
Tu	Simple horizontal curves		
Th	NO CLASS – Academic Advising Day		
F	Layout of simple horizontal curves		

Week #7, Starting 2-23-04: Horizontal Alignment

Day	Lecture Topic	Reading Due	Events
M	Superelevation transition	GB pp. 168-176	
Tu	Transition curves	GB pp. 176-183	
Th	Horizontal & vertical coordination	GB pp. 233-235, 282-286	Quiz 5
F	Case studies	FHD pp. 131-166	

Week #8, Starting 3-1-04: Coordination of Alignment

Day	Lecture Topic	Reading Due	Events
M	Case studies	FHD pp. 167-192	
Tu	Highway design/analysis software	Handout	
Th	Course debriefing		Reports due

Discussion Guidelines

Responsibilities of instructor:

- Assign appropriate reading or homework assignments as needed, as preparation for discussion.
- Provide a clear task to be accomplished or question to be answered.
- Guide and/or encourage discussion as needed.

Responsibilities of students:

- Read or complete assignments prior to class.
- Participate in discussion.
- Take notes as needed for later use in the project.

The purpose of in-class discussion is to promote learning. In order to have effective discussions in this course:

- One person will speak at a time. The rest will listen and attempt to understand the speaker's comments or viewpoint. The point is not for everyone to express opinions, but to explore a topic or solve a problem together.

- Contributions to the discussion should:
  - be relevant to the topic;
  - be specific and accurate, referring to sources or appropriate evidence; **AND**
  - use sound reasoning.

- You may respond to what others have said by
  - asking questions or seeking to clarify someone's comments,
  - agreeing and further developing the idea, **OR**
  - disagreeing and presenting a rational argument. Remember that you are disagreeing with or challenging a position/opinion, not a person, and try not to get emotional about the topic.

- Deviations from these guidelines may be respectfully pointed out by the students or instructor and should be corrected promptly.

CE 405X Introductory Survey

What is your name? _____

What is your major (CE, ME, etc.)? _____

If you are a civil/environmental engineering major, what is your primary area of concentration? _____

What is your class year (expected year of graduation)? _____

Which of the following undergraduate courses have you taken?

- ❑ Transportation Engineering (CE 3050) – which term? _____
- ❑ Pavement Materials, Design and Management (CE 3051)
- ❑ Asphalt Technology (CE 3054)
- ❑ Hydraulics (CE 3062)
- ❑ AutoCAD (CE 3030 or similar)
- ❑ Others related to transportation:

  _____

  _____

Are you interested in working in the field of transportation engineering? _____

Lecture Topics & In-Class Exercises/Discussions

Lecture Topics

- *Highway design overview*
  - Design process (in general and at MassHighway)
- *Design controls*
  - Functional class & the Green Book
  - Design controls (design vehicle, design volume and service flow rate, design speed)
  - Sight distance (required stopping, decision, and passing sight distances; measuring available sight distance)
- *Cross-sections*
  - Roadway (roadway components, cross slope / crown, lane widths, shoulders)
  - Roadside / median (roadside components, side slopes, curbs, clear zone; medians)
  - Traffic barriers (determining if a barrier is needed; brief intro to selecting a barrier)
  - Bicycles and pedestrians (design considerations for bicycle lanes, sidewalks, ped crossings)
- *Route Selection*
  - Considerations in selecting routes
  - Intersection issues (layout, sight distance)
  - Estimating earthwork volumes
- *Vertical alignment*
  - Max and min grades; facilities for trucks
  - Crest vertical curves
  - Sag vertical curves
  - Layout of vertical curves
- *Horizontal alignment*
  - Simple curves
  - Layout of a simple curve
  - Superelevation transition
  - Transition (spiral and compound) curves
- *Coordination of horizontal and vertical alignment*
  - Aesthetics
  - Case studies from FHD

Exercises/Discussions (all followed by class discussion)

- *Objective: Explain how characteristics of drivers and vehicles affect the design of roads.*

  1. Given the information in the planning study report, choose an appropriate functional class for your roadway.
  2. Calculate the DHV and choose a design vehicle. How will these two values affect the design?
  3. Discuss choices of design speed and design LOS for project road (chosen as HW).

- *Objective: Design a roadway cross-section.*
  1. Draw a typical cross-section for your highway (just the roadway portion). How wide a median would be needed for your roadway (assume it is divided) to avoid installing a median barrier?
  2. Add roadside components to your roadway cross-section.
  3. Determine the recommended clear zone distance for a typical cut section of your highway. How does that differ from the recommended distance for a typical fill section?
- *Objective: Calculate required sight distances for road segments and intersections.*
  1. Determine SSD, decision sight distance, and passing sight distance (if appropriate) for your roadway.
  2. Measure the available sight distance at the curves shown on the plan (handout). What is the maximum acceptable design speed?
  3. What traffic controls might you use at your intersections? How would you decide? (intersection sight distance, volumes, …)
  4. For the intersection of W. Main St. and Hartford Ave. South in Upton, determine the intersection sight distance required for each type of control (yield, 2-way stop, all-way stop, and signal). Assume the design speed of W. Main St. (the major road) is 50 mph.
  5. Discuss intersection issues / design alternatives for the project.
- *Objective: Design a vertical curve.*
  1. Determine maximum and minimum grades for your road. Are the grades on the example profile acceptable? How about the existing ground profile?
  2. Draw vertical tangents on your profile of the existing ground; determine/choose grades.
  3. Determine the minimum length of one crest vertical curve on your road. What length will you use?
  4. Determine the location of the PVI, PVC, and PVT on your curve (station and elevation).
  5. Lay out the vertical curve.
- *Objective: Design a horizontal curve.*
  1. Design one simple horizontal curve on your road (determine radius and length).
  2. Lay out the simple horizontal curve.
  3. Determine minimum lengths of superelevation runoff and tangent runout for the horizontal curve.
  4. Determine the location of the superelevation runoff for the horizontal curve.
  5. If you used a spiral curve to transition to your horizontal curve, how long would it be? Sketch what it would look like. How would you draw it in AutoCAD?
  6. Identify guidelines for coordination of horizontal and vertical alignment from GB and Lamm that apply to your project.

- *Objective: Design a bicycle lane and/or crosswalk.*
    1. How well do Worcester streets accommodate bicycles? Pedestrians? How about the existing roads at the project site? (see handout with photos)
    2. Does your highway need to accommodate bicycles or pedestrians? How will you do that?
- *Objective: Estimate earthwork volumes.*
    1. Draw cross-sections at given stations. Calculate cut and fill areas.
    2. Make table on the board of cut and fill areas; calculate the volumes between each pair of stations.
    3. As a class: Draw a mass diagram for the example. Draw a balance line to minimize the waste and additional material.
- *Other topics:*
    1. Look at the characteristics of the study area using the MassGIS data viewer online: maps.massgis.state.ma.us/massgis_viewer/index.htm
    2. Select and sketch a route for your highway. Discuss and choose two or more alternatives.
    3. Discuss case studies from FHD. Questions for discussion (for each case study):
        - What might a conventional design for this road look like?
        - How is the chosen solution "flexible"?
        - Why was this design chosen? Who was involved in the choices?
        - What drawbacks or possible problems do you see in the design?
        - What benefits do you see in the design compared to a conventional design?
    4. Try analyzing your project road using IHSDM.

Multiple-choice Questions for Use in Lectures

What document contains the transportation improvement projects selected by the state for funding?

A. long-range plan
B. EIS
C. STIP

A roadway that primarily provides mobility (rather than access) is called:

A. a collector
B. an arterial
C. a primary road

For a two-lane highway with a design speed of 55 mph and level terrain, what is the design stopping sight distance required?

A. 495 ft
B. 290.3 ft
C. 75 ft

What is the term used for the portion of the roadway for the movement of vehicles, exclusive of shoulders?

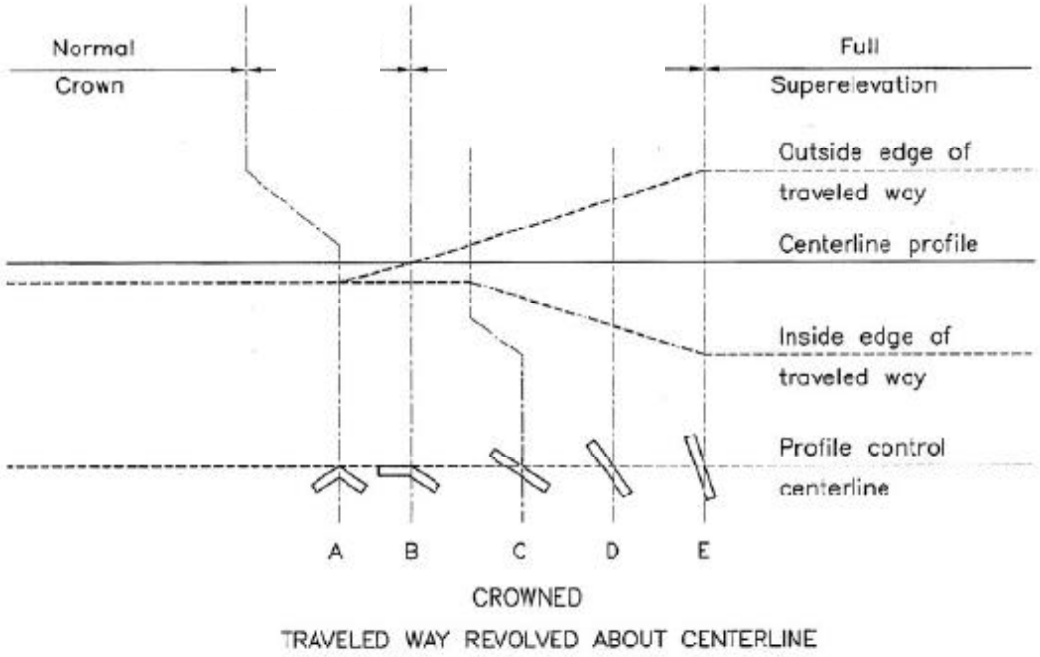
A. highway
B. traveled way
C. pavement

Which of the following would be acceptable on a high-speed roadway without a traffic barrier?

A. a sloping curb
B. a vertical curb
C. a 1V:2H sideslope

The distance between points A and B in the figure below represents which of the following?

A. Superelevation runoff
B. Tangent runout
C. Curve widening



CE 405X – C04

Quiz 1: Sight Distance

Instructions: Circle the letter (a-d) of the most correct answer.

A two-lane highway segment has a design speed of 55 mph and grade of +3 percent. Refer to the tables and other information on the next page.

1. What is the assumed driver reaction time?
   a. 1.0 sec
   b. 1.5 sec
   c. 2.0 sec
   d. 2.5 sec

2. What is the expected braking distance?
   a. 290 ft
   b. 315 ft
   c. 265 ft
   d. 202 ft

3. What is the required stopping sight distance?
   a. 469 ft
   b. 492 ft
   c. 495 ft
   d. 520 ft

4. If the available sight distance were only 410 feet, what would be the maximum recommended design speed?
   a. 40 mph
   b. 45 mph
   c. 50 mph
   d. 55 mph

References (Quiz 1)

Metric					US Customary				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance		Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance	
			Calculated (m)	Design (m)				Calculated (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

Metric							US Customary						
Design speed (km/h)	Stopping sight distance (m)						Design speed (mph)	Stopping sight distance (ft)					
	Downgrades			Upgrades				Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%		3%	6%	9%	3%	6%	9%
20	20	20	20	19	18	18	15	80	82	85	75	74	73
30	32	35	35	31	30	29	20	116	120	126	109	107	104
40	50	50	53	45	44	43	25	158	165	173	147	143	140
50	66	70	74	61	59	58	30	205	215	227	200	184	179
60	87	92	97	80	77	75	35	257	271	287	237	229	222
70	110	116	124	100	97	93	40	315	333	354	289	278	269
80	136	144	154	123	118	114	45	378	400	427	344	331	320
90	164	174	187	148	141	136	50	446	474	507	405	388	375
100	194	207	223	174	167	160	55	520	553	593	469	450	433
110	227	243	262	203	194	186	60	598	638	686	538	515	495
120	263	281	304	234	223	214	65	682	728	785	612	584	561
130	302	323	350	267	254	243	70	771	825	891	690	658	631
							75	866	927	1003	772	736	704
							80	965	1035	1121	859	817	782

$$SSD = 1.47Vt + \frac{V^2}{30\left(0.35 \pm G\right)}$$

Quiz 2: Cross-Sections

An undivided rural arterial has a design speed of 70 mph and design volume of 20,000 vpd. Refer to the accompanying tables.

4. What is the minimum usable shoulder width that should be provided?
    a. 2 ft
    b. 4 ft
    c. 6 ft
    d. 8 ft

5. For a two-lane roadway, what lane width should be provided?
    a. 10 ft
    b. 11 ft
    c. 12 ft
    d. 13 ft

6. If the sideslope were a 1V:10H foreslope, what would be the minimum width of the recommended clear zone?
    a. 26 ft
    b. 28 ft
    c. 30 ft
    d. 34 ft

7. Which of the following would be acceptable on this roadway without a traffic barrier?
    a. A sloping curb
    b. A vertical curb
    c. A row of trees 4 ft from the shoulder
    d. A 1V:2H sideslope

Metric					US Customary				
Design speed (km/h)	Minimum width of traveled way (m)[a] for specified design volume (veh/day) under 400	400 to 1500	1500 to 2000	over 2000	Design speed (mph)	Minimum width of traveled way (ft)[a] for specified design volume (veh/day) under 400	400 to 1500	1500 to 2000	over 2000
60	6.6	6.6	6.6	7.2	40	22	22	22	24
70	6.6	6.6	6.6	7.2	45	22	22	22	24
80	6.6	6.6	7.2	7.2	50	22	22	24	24
90	6.6	6.6	7.2	7.2	55	22	22	24	24
100	7.2	7.2	7.2	7.2	60	24	24	24	24
110	7.2	7.2	7.2	7.2	65	24	24	24	24
120	7.2	7.2	7.2	7.2	70	24	24	24	24
130	7.2	7.2	7.2	7.2	75	24	24	24	24
All speeds	Width of usable shoulder (m)[b] 1.2	1.8	1.8	2.4	All speeds	Width of usable shoulder (ft)[b] 4	6	6	8

[a] On roadways to be reconstructed, an existing 6.6-m [22-ft] traveled way may be retained where alignment and safety records are satisfactory.

[b] Usable shoulders on arterials should be paved; however, where volumes are low or a narrow section is needed to reduce construction impacts, the paved shoulder may be reduced to 0.6 m [2 ft].

Exhibit 7-3. Minimum Width of Traveled Way and Usable Shoulder for Rural Arterials

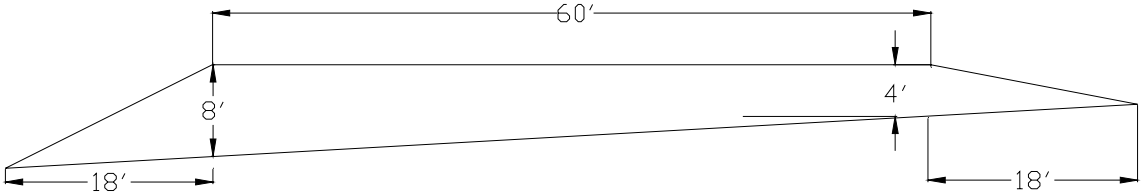
Table 3.1. Clear-zone distances from edge of through traveled way, U.S. customary units. (from *Roadside Design Guide*, 2002)

[U.S. Customary Units]

DESIGN SPEED	DESIGN ADT	FORESLOPES 1V:6H of flatter	FORESLOPES 1V:5H TO 1V:4H	FORESLOPES 1V:3H	BACKSLOPES 1V:3H	BACKSLOPES 1V:5H TO 1V:4H	BACKSLOPES 1V:6H or Flatter
40 mph or less	UNDER 750	7 – 10	7 – 10	**	7 – 10	7 – 10	7 – 10
	750 – 1500	10 – 12	12 – 14	**	10 – 12	10 – 12	10 – 12
	1500 – 6000	12 – 14	14 – 16	**	12 – 14	12 – 14	12 – 14
	OVER 6000	14 – 16	16 – 18	**	14 – 16	14 – 16	14 – 16
45–50 mph	UNDER 750	10 – 12	12 – 14	**	8 – 10	8 – 10	10 – 12
	750 – 1500	12 – 14	16 – 20	**	10 – 12	12 – 14	14 – 16
	1500 – 6000	16 – 18	20 – 26	**	12 – 14	14 – 16	16 – 18
	OVER 6000	18 – 20	24 – 28	**	14 – 16	18 – 20	20 – 22
55 mph	UNDER 750	12 – 14	14 – 18	**	8 – 10	10 – 12	10 – 12
	750 – 1500	16 – 18	20 – 24	**	10 – 12	14 – 16	16 – 18
	1500 – 6000	20 – 22	24 – 30	**	14 – 16	16 – 18	20 – 22
	OVER 6000	22 – 24	26 – 32 *	**	16 – 18	20 – 22	22 – 24
60 mph	UNDER 750	16 – 18	20 – 24	**	10 – 12	12 – 14	14 – 16
	750 – 1500	20 – 24	26 – 32 *	**	12 – 14	16 – 18	20 – 22
	1500 – 6000	26 – 30	32 – 40 *	**	14 – 18	18 – 22	24 – 26
	OVER 6000	30 – 32 *	36 – 44 *	**	20 – 22	24 – 26	26 – 28
65–70 mph	UNDER 750	18 – 20	20 – 26	**	10 – 12	14 – 16	14 – 16
	750 – 1500	24 – 26	28 – 36 *	**	12 – 16	18 – 20	20 – 22
	1500 – 6000	28 – 32 *	34 – 42 *	**	16 – 20	22 – 24	26 – 28
	OVER 6000	30 – 34 *	38 – 46 *	**	22 – 24	26 – 30	28 – 30

Quiz 3: Earthwork

8. What is the approximate cut or fill area of the cross-section shown below?



a. 470 ft^2 of fill
b. 470 ft^2 of cut
c. 360 ft^2 of fill
d. 360 ft^2 of cut

For questions 2 and 3, refer to the following table:

Station (ft)	*Cut area (ft^2)*	*Fill area (ft^2)*
15+00		300
16+00		155
17+00	13	
18+00	235	
19+00	176	

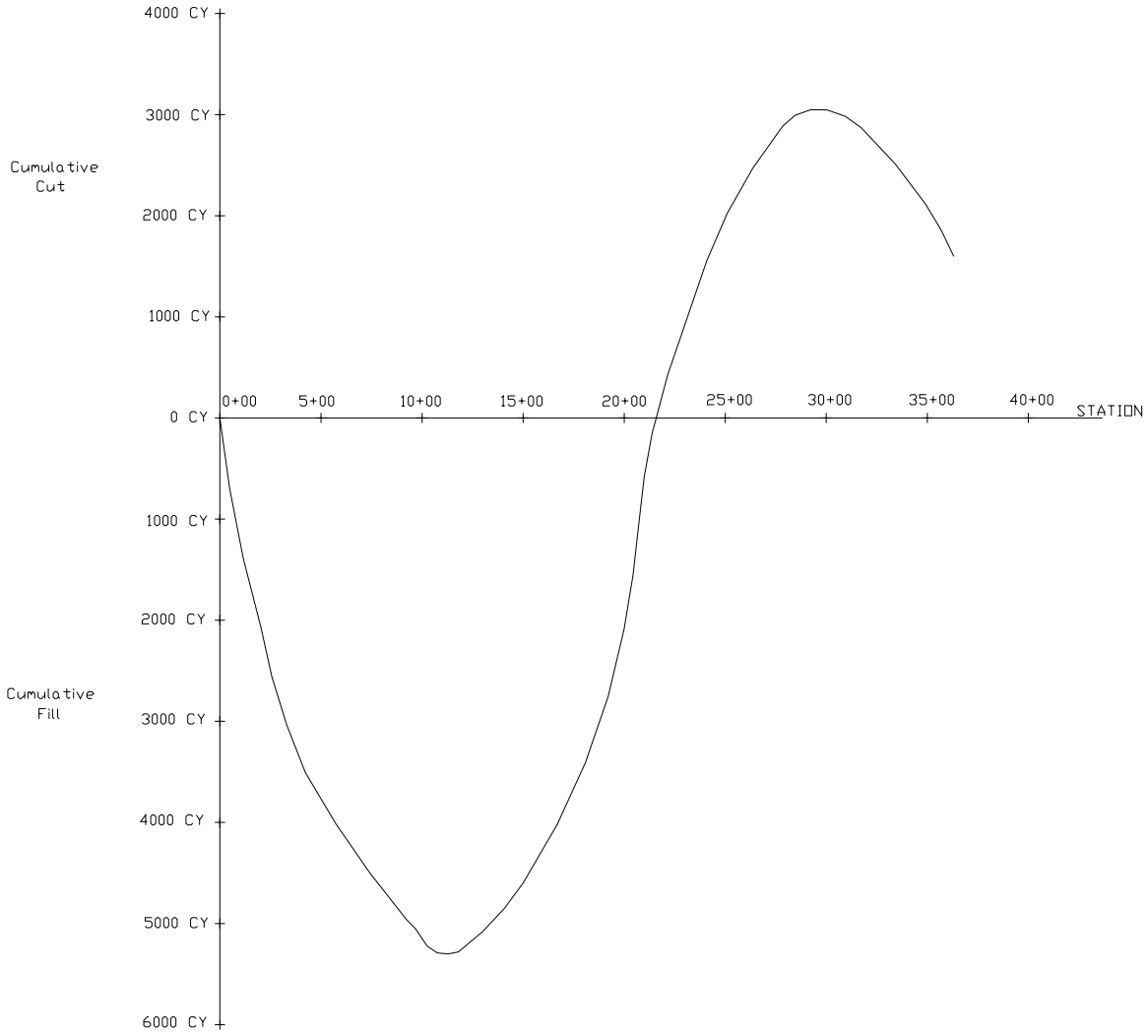
9. What is the approximate total volume of fill required for this section of road, assuming 15% shrinkage?

a. 1020 yd^3
b. 1020 ft^3
c. 1170 yd^3
d. 1170 ft^3

10. What is the approximate total volume of cut required for this section of road?

a. 1220 ft^3
b. 1220 yd^3
c. 1400 ft^3
d. 1400 yd^3

11. Based on the mass diagram shown below, how much extra material will have to be hauled away from the project?



a. 5200 CY
b. 3000 CY
c. 0 CY
d. 1500 CY

Quiz 4: Vertical Alignment

A roadway with a 35 mph design speed has a -2% grade followed by a +3% grade. The PVI is located at station 3+20, at an elevation of 1000 ft. Refer to the table below and equations on the next page.

1. What is the minimum length of vertical curve needed to satisfy the stopping sight distance criterion?
    a. 250 ft
    b. 245 ft
    c. 49 ft
    d. 1670 ft

2. If a curve length of 300 ft is used, what is the elevation of the PVC?
    a. 1000.0 ft
    b. 1004.5 ft
    c. 1050.0 ft
    d. 1003.0 ft

3. If a curve length of 300 ft is used, what is the station of the PVC?
    a. 0+20
    b. 1+70
    c. 4+70
    d. 6+20

4. If a curve length of 300 ft is used, what is the elevation on the curve at station 3+20?
    a. 1002
    b. 1000
    c. 1005
    d. 998

Metric				US Customary			
Design speed (km/h)	Stopping sight distance (m)	Rate of vertical curvature, K[a]		Design speed (mph)	Stopping sight distance (ft)	Rate of vertical curvature, K[a]	
		Calculated	Design			Calculated	Design
20	20	2.1	3	15	80	9.4	10
30	35	5.1	6	20	115	16.5	17
40	50	8.5	9	25	155	25.5	26
50	65	12.2	13	30	200	36.4	37
60	85	17.3	18	35	250	49.0	49
70	105	22.6	23	40	305	63.4	64
80	130	29.4	30	45	360	78.1	79
90	160	37.6	38	50	425	95.7	96
100	185	44.6	45	55	495	114.9	115
110	220	54.4	55	60	570	135.7	136
120	250	62.8	63	65	645	156.5	157
130	285	72.7	73	70	730	180.3	181
				75	820	205.6	206
				80	910	231.0	231

[a] Rate of vertical curvature, K, is the length of curve (m) per percent algebraic difference intersecting grades (A). K = L/A

Exhibit 3-79. Design Controls for Sag Vertical Curves

(Equation sheets from FE Handbook were also provided.)

Quiz 5: Horizontal Alignment

A two-lane roadway with a 40 mph design speed has a horizontal curve extending for 400 feet along its centerline. The intersection angle is 45°, and the long chord is 390 feet long. Refer to the equations on the next page from the FE Handbook.

5. What is the degree of curvature?
    a. 45°
    b. 5.6°
    c. 11.2°
    d. 22.5°

6. If the point of curvature (PC) is located at station 12+50, where is the PT located?
    a. Station 16+40
    b. Station 16+50
    c. Station 14+61
    d. Station 16+72

7. What superelevation rate is needed if the side-friction factor is 0.15 and the radius is 510 ft?
    a. 4%
    b. 6%
    c. 8%
    d. 10%

8. What is the minimum required length of spiral transition if the radius is 510 ft, according to the FE Handbook?
    a. 9 ft
    b. 40 ft
    c. 778 ft
    d. 395 ft

9. BONUS: When using a spiral transition curve, where should the superelevation runoff be located?
    a. Partly on the circular curve and partly on the spiral curve
    b. Partly on the spiral curve and partly on the tangent
    c. Entirely on the spiral curve
    d. Entirely on the circular curve

(Equation sheets from FE Handbook were provided.)

CE405X Term Project Overview

The Problem: Area population growth and changing travel patterns have resulted in increased east-west traffic demand in the Blackstone Valley area of Massachusetts, causing congestion and reduced mobility.

Background: The Central Massachusetts Regional Planning Commission (CMRPC) initiated the "Blackstone Valley Corridor Planning Study" in 2002 to "identify and analyze transportation alternatives that might improve mobility and reduce traffic congestion in the Blackstone Valley in the near term as well as 10 to 20 years into the future, while respecting the cultural and environmental heritage of the Blackstone Valley." CMRPC staff worked on the study in conjunction with a Citizens Advisory Committee, which met monthly during 2002 to review the problems and discuss possible solutions. They produced a Final Report in September 2003 that will serve as the primary resource for this project.

Alternatives: The planning study identified five alternatives for examination, in addition to a no-action scenario. The alternatives discussed below are discussed in much more detail in the report.

- A: Intersection improvements and possible roadway widening in order to increase roadway capacity between West Upton and I-495.
- B: Intersection improvements in Northbridge and Upton, possible spot-widening of roadways, and repair/replacement of a bridge in order to decrease congestion and accommodate projected future traffic.
- C: Intersection improvements and road widening in Mendon and Bellingham in order to improve mobility and reduce congestion between the intersection of Route 16 and Hartford Ave West in Mendon and Hartford Ave and Route 126 in Bellingham.
- D: Construct a new roadway link between the intersection of Route 122 and Sutton St in Northbridge and Hartford Ave South and Route 140 in Upton following the lowest impact route. Alternative A must be implemented for D to be viable.
- N: Improve the directional signage between town centers and the regional highway system.

Scope of this course project: If the towns were to select Alternative D for further development, the project would proceed to the design phase. Your assignment is to provide a preliminary design for this roadway link, to include location, typical cross-sections, plan and profile views, etc. You will work on some specific tasks in class and complete others outside of class as a group. Near the end of the term, you will submit a project report, the details of which will be provided later in the course.

Project Report Guidelines

Project Overview

- Background (see handout)
- Scope of this project (see handout)
- Map of the project area

Design controls

- Identify the functional classification of your roadway.
- Give values for design speed, vehicle, volume, etc. and explain why/how you chose them.

Typical cross-sections

- Draw a typical cut cross-section and a typical fill cross-section. Show elements of roadway and roadside, including clear zone.
- If any values do not meet or exceed MassHighway's minimums, explain why you chose them (why there should be a design exception).
- Explain briefly how your design accommodates pedestrians and bicyclists.

Route selection

- Show your chosen route on a topographic map.
- Briefly explain the alternatives you considered and why you chose this route.
- Identify any major issues that will need to be addressed or discussed at a public meeting (environmental, social, etc.).
- Include a profile view of your chosen route, indicating existing ground elevation and proposed centerline elevation at each station.
- Estimate the quantities of cut and fill required by your design. Include a mass diagram.

Intersection layout

- Include a plan view of the intersections at each end of the new road.
- Identify the traffic controls to be used and explain why.

Alignment

- Include a plan view (horizontal alignment) and profile view (vertical alignment) of your roadway design. Indicate lengths of tangents and curves, radii of curves, and grades.

Project Overview

Background

Area population growth and changing travel patterns have resulted in increased east-west traffic demand in the Blackstone Valley area of Massachusetts, causing congestion and reduced mobility. The Central Massachusetts Regional Planning Commission (CMRPC) initiated the "Blackstone Valley Corridor Planning Study" in 2002 to "identify and analyze transportation alternatives that might improve mobility and reduce traffic congestion in the Blackstone Valley in the near term as well as 10 to 20 years into the future, while respecting the cultural and environmental heritage of the Blackstone Valley." CMRPC staff worked on the study in conjunction with a Citizens Advisory Committee, which met monthly during 2002 to review the problems and discuss possible solutions. They produced a Final Report in September 2003 that served as the primary resource for this project. The report discussed five alternatives for examination, in addition to a no-action scenario. Alternative D was to "construct a new roadway link between the intersection of Route 122 and Sutton St in Northbridge and Hartford Ave South and Route 140 in Upton following the lowest impact route."

Scope of this project

If the towns were to select Alternative D for further development, the project would proceed to the design phase. The goal of this project, part of an undergraduate course in highway design, was to develop a preliminary design for this roadway link. Design guidelines used in the project were AASHTO's *A Policy on Geometric Design of Highways and Streets (2001)* and MassHighway's *Highway Design Manual (1997)*.

Grading Rubric for
Project Report

Total Score: ____/100

Project Overview (__/5)

__/1 Background (see handout)
__/1 Scope of this project (see handout)
__/3 Map of the project area

Design controls (__/10)

__/5 Functional classification
__/5 Design speed, vehicle, volume, etc. and explanation of why/how chosen

Typical cross-sections (__/20)

__/10 Typical cut cross-section *(5 pts)* and typical fill cross-section *(5 pts)*, showing elements of roadway and roadside, including clear zone
__/5 Identification and explanation of any values that do not meet or exceed MassHighway's minimums (design exceptions)
__/5 Brief explanation of how the design accommodates pedestrians and bicyclists

Route selection (__/25)

__/5 Chosen route shown on a topographic map, with brief explanation of alternatives considered and why this route was chosen
__/5 Identification of any major issues that will need to be addressed or discussed at a public meeting (environmental, social, etc.)
__/5 Profile view of chosen route, indicating existing ground elevation and proposed centerline elevation at each station
__/10 Estimated quantities of cut and fill required, with a mass diagram

Intersection layout (__/20)

__/10 Plan view of the intersections at each end of the new road *(5 pts for each)*
__/10 Traffic controls to be used, with explanation *(5 pts for each)*

Alignment (__/20)

__/10 Plan view (horizontal alignment) indicating lengths of tangents and curves, radii of curves.
__/10 Profile view (vertical alignment) indicating lengths of tangents and curves, grades.

The IDEA Short Form Report for **WEIR, JA**

Civil Engineering 0005 (MTUF 03:00), Spring 2003-2004
WORCESTER POLYTECHNIC INSTITUTE

Number Enrolled: 6 Number Responding: 6 100.0 % Responding	The number of students responding is so low that your results are unreliable; re-rating by the same students could produce substantially different results. The percentage of enrollees who provided ratings is high; results can be considered representative of the class as a whole.

Sections and Purposes of the Report

Page	Section	Purpose
2	I. Overall Measures of Teaching Effectiveness	Provides **global assessment** of teaching effectiveness. Use with pages 3 and 4 for administrative use in making personnel recommendations.
3	II. Student Ratings of Progress on Relevant Objectives	Provides student **self-report of learning** on objectives identified as relevant (*Important* or *Essential*) by the instructor
4	III. Course Description/Context	Primarily to **assist in interpreting** the results by considering the context in which the course was taught
4	IV. Statistical Detail	Primarily to provide details which may help you or your consultants to **understand or interpret** the report accurately

Definitions

Raw Score: Results obtained by using students' numerical ratings, all of which are based on a scale of 1 (low) to 5 (high).

Adjusted Score: Ratings have been statistically adjusted to take into account factors that affect ratings but are not under the instructor's control: student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

T Score: A statistically derived score that makes it easy to compare various measures. Unlike raw scores which have different averages and standard deviations (variabilities), T Scores all have an average of 50 and a standard deviation of 10. This means that 40% of all T Scores will be in the range of 45-55, while less than 2% will be below 30 or above 70.

Understanding the Graphs

Most results are presented on graphs. Unadjusted T Scores are shown by the symbol ×; adjusted T Scores are shown by the symbol ◆. In most cases, we use a line on both sides of a symbol to indicate that ratings have a "margin of error"; the line represents ± one standard error of measurement, a statistical indication of the reliability of the measure.

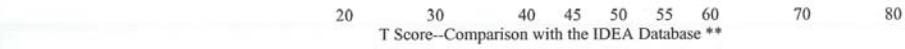
A Few Words of Caution

1. Normative information was updated using classes rated during the 1998-99, 1999-2000, and 2000-2001 academic years. **Exercise caution when comparing T Scores with those for classes processed prior to December 1, 2001.** The new norms have slightly higher item averages. Therefore, T Scores for a given average will be somewhat lower than those for past years. If results are being summarized with classes processed prior to December 1, 2001, review both T Scores and raw scores to determine if differences are due to a more competitive normative group or if the item averages have actually changed.
2. The process for adjusting scores was updated on October 7, 2002. Use caution when comparing adjusted scores with classes processed prior to that date.
3. Student ratings can make a useful contribution to the appraisal of teaching effectiveness and to the development of improvement strategies. However, they have distinct limitations that need to be acknowledged before appropriate use can be made of them. Please read ***Overview of Student Ratings: Value and Limitations***. (www.idea.ksu.edu)

Section I. Overall Measures of Teaching Effectiveness

This section compares your results with those for other instructors and courses in the national database on four OVERALL MEASURES OF TEACHING EFFECTIVENESS. **The primary value of this information is to aid in making administrative recommendations; if this is the only use you will make of the report, you need to consult only these results along with page 3 and the context provided by Section III, page 4.** Please remember that most of the classes included in the database have been taught in a reasonably successful manner; therefore, a rating which is "below average" does not necessarily mean that the quality of instruction was unacceptable. Additional sources of evidence should always be used to review teaching effectiveness.

Overall Measure of Effectiveness	T Score Unadj. / **Adj.**	2% of all classes	28% of all classes	40% of all classes (Avg. range)	28% of all classes	2% of all classes	Your Average * (5-Point Scale) Raw	Adjusted	IDEA Average
1. Progress on Relevant (Essential and Important) Objectives	61 / **53**						NA_1	NA_1	NA_1
2. Improved Student Attitude	69 / **61**						5.0	4.6	3.9
3. Overall Excellence of Teacher	58 / **53**						4.7	4.4	4.2
4. Overall Excellence of Course	60 / **50**						4.5	3.9	3.9



T Score--Comparison with the IDEA Database **

⊢×⊣ Unadjusted T Score ± one standard error of measurement
⊢◆⊣ Adjusted T Score ± one standard error of measurement: adjusted for student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

You may wish to assign these ratings to categories like those that have been used historically with the IDEA system. Simply assign T Scores to categories as follows: **Low** (lowest 10%)=T Score below 37; **Low Average** (next 20%)=T Score 37-44; **Average** (middle 40%)=T Score 45-55; **High Average** (next 20%)=T Score 56-63; and **High** (highest 10%)=T Score above 63.

1. Progress on Relevant (Essential and Important) Objectives. Because student learning is the central purpose of teaching, and because you chose the objectives considered by this measure, this is probably the most vital measure of effectiveness. A double weight is given to student ratings of progress on objectives you chose as ***Essential***, and a single weight to those chosen as ***Important***; objectives identified as being of ***Minor or No Importance*** were ignored in developing this measure.

2. Improved Student Attitude. The graph shows the average response of students to item 16, "As a result of taking this course, I have more positive feelings toward this field of study." This rating is most meaningful for courses that are taken by many non-majors. Most teachers hope that such students will develop a respect and appreciation for the discipline even if they choose to take no additional courses in it. The IDEA national average for this item is 3.9.

3. Overall Excellence of Teacher. This shows the average response to item 17, "Overall, I rate this instructor an excellent teacher." Overall impressions of a teacher affect student attitudes, effort, and learning. The IDEA national average for this item is 4.2.

4. Overall Excellence of Course. This shows the average response to item 18, "Overall, I rate this course as excellent." This evaluation is likely determined by a number of factors (e.g., teaching style, student satisfaction with course outcomes, and characteristics such as organization, selection of readings and/or other influences). The IDEA national average for this item is 3.9.

NA_1: Based on a combination of ratings where an average on a 5-point scale is not comparable.

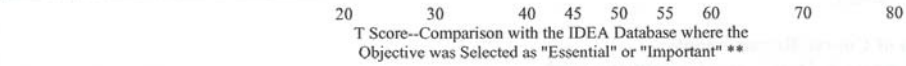
* Statistically, adjustments can exceed 5.0 on the 5-point scale. If this occurs, "Your Average," reported in the table above, will be rounded to 5.0. However, the T Score reported will reflect the actual adjusted score, which may exceed 5.0. Therefore, identical adjusted scores of 5.0 may have different adjusted T Scores.

** Normative information (T Scores) was updated on December 1, 2001. See page 1 for "A Few Words of Caution."

Section II. Student Ratings of Progress on Relevant Objectives

This graph shows student progress ratings on the objectives you chose as ***Essential*** (Part A) and those you chose as ***Important*** (Part B). To the degree that students make progress on the objectives you stress, your teaching has been effective.

Part A. Essential Objectives	T Score Unadj. / **Adj.**	2% of all classes	28% of all classes	40% of all classes (Avg. range)	28% of all classes	2% of all classes	Your Average * (5-Point Scale) Raw	Adjusted	IDEA Average
4. Professional skills, viewpoints	59 **51**						4.5	4.1	4.0
Part B. Important Objectives									
1. Factual knowledge	60 **53**						4.5	4.2	4.0
3. Apply course material	66 **59**						4.8	4.5	4.0



T Score--Comparison with the IDEA Database where the Objective was Selected as "Essential" or "Important" **

Unadjusted T Score ± one standard error of measurement

Adjusted T Score ± one standard error of measurement: adjusted for student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

Similar to Section I, you may wish to assign ratings to categories. Simply assign T Scores to categories as follows: **Low** (lowest 10%)=T Score below 37; **Low Average** (next 20%)=T Score 37-44; **Average** (middle 40%)=T Score 45-55; **High Average** (next 20%)=T Score 56-63; and **High** (highest 10%)=T Score above 63.

These graphs are intended to help you identify a focus for improving your instructional effectiveness. If student progress ratings on ***Important*** or ***Essential*** objectives are disappointing, you are encouraged to discuss improvement strategies with your department head, the campus faculty development specialist, or a colleague. Such strategies could focus on matters such as teaching methods/styles, class activities and assignments, the text and other readings, assessment/feedback, and the need for course pre-requisites. You might also consider using the IDEA Diagnostic Form the next time you solicit student ratings, since it is designed to help identify specific teaching methods to use in improvement efforts.

Note: Students in your class also rated their progress on the objectives that you classified as being of ***Minor or No Importance.*** These ratings are considered irrelevant in judging your teaching effectiveness. However, a review of student ratings on these objectives, found in **Section IV** (Statistical Detail), may provide you with insights about some "unintended" or "additional" effects of your instruction.

* Statistically, adjustments can exceed 5.0 on the 5-point scale. If this occurs, "Your Average," reported in the table above, will be rounded to 5.0. However, the T Score reported will reflect the actual adjusted score, which may exceed 5.0. Therefore, identical adjusted scores of 5.0 may have different adjusted T Scores.

** Normative information (T Scores) was updated on December 1, 2001. See page 1 for "A Few Words of Caution."

Section III. Course Description/Context

This section describes several aspects of your course. This description summarizes information you supplied when you administered the IDEA form. Information on this page provides the context in which the class was taught, which should guide the interpretation of the ratings. The IDEA Center will conduct additional research on these data to determine more precisely how they can improve interpretation of the report.

Course Description:

Primary Instructional Type: *Lecture*
Secondary Instructional Type: *Discussion/recitation*
Team Taught: *No*
Distance Learning: *No*
Principal Type of Student: *Upperclassmen, majors*

Instructor's Ratings of Special Circumstances:

Positive Impact on Learning: *Desire to teach course, Control over course management decisions, Student enthusiasm, Student effort*
Neither Positive nor Negative Impact: *Physical facilities and/or equipment, Adequacy of students' background/preparation*
Negative Impact on Learning:

Instructor's Ratings of Course Requirements:

Much Required: *Group work, Mathematical/quantitative work*
Some Required: *Writing, Oral communication, Critical thinking, Creative/artistic/design endeavor*
None (or little) Required: *Computer applications*

Section IV. Statistical Detail: Item Frequencies, Averages, and Standard Deviations

Items 1-12: Progress on Objectives

Key: 1=Low 2=Low Average 3=Average 4=High Average 5=High

	1	2	3	4	5	Omit	Avg.	s.d.
1.	**0**	**0**	**1**	**1**	**4**	**0**	**4.5**	**0.8**
2.	0	0	0	1	5	0	4.8	0.4
3.	**0**	**0**	**0**	**1**	**5**	**0**	**4.8**	**0.4**
4.	**0**	**0**	**0**	**3**	**3**	**0**	**4.5**	**0.5**
5.	0	0	1	0	5	0	4.7	0.8
6.	1	0	1	3	1	0	3.5	1.4
7.	3	2	1	0	0	0	1.7	0.8
8.	2	2	2	0	0	0	2.0	0.9
9.	0	1	2	1	2	0	3.7	1.2
10.	2	2	1	0	1	0	2.3	1.5
11.	1	1	2	2	0	0	2.8	1.2
12.	0	1	1	1	3	0	4.0	1.3

Bold items were selected as ***Essential*** or ***Important***.

Items 13-18: Self-Ratings

Key: 1=Definitely False 2=More False Than True 3=In Between 4=More True Than False 5=Definitely True

	1	2	3	4	5	Omit	Avg.	s.d.
13.	0	0	1	4	1	0	4.0	0.6
14.	0	1	1	3	1	0	3.7	1.0
15.	0	0	2	1	3	0	4.2	1.0
16.	0	0	0	0	6	0	5.0	0.0
17.	0	0	0	2	4	0	4.7	0.5
18.	0	0	0	3	3	0	4.5	0.5

File: WPI4690.SFR
Class ID: 216090
March 23, 2004

Student Comments

"Direct application of theories taught in class must be applied in a computer drafting package."

"I learned more in this course than basically all the other civil courses I've taken. Project was very helpful to understanding material. Quizzes could be re-formatted to make them tougher."

"#'s 7 and 10 should be taken off this evaluation or another evaluation should be used." [referring to item 7, "gaining a broader understanding and appreciation of intellectual/cultural activity," and item 10, "developing a clearer understanding of, and commitment to, personal values"]

Teaching Methods Survey – CE 405X, C-2004

Since this was a new course for 2004, your instructor would like some feedback on the various teaching methods/tools that were used. Please respond thoughtfully. Your answers will not affect your grade for the course. The "course material" referred to in the questions included:

- Choosing appropriate design controls (design vehicle, speed, volume, etc.).
- Designing a roadway cross-section.
- Estimating earthwork volumes.
- Calculating required sight distances for road segments and intersections.
- Designing vertical curves.
- Designing horizontal curves.
- Designing bicycle lanes, sidewalks, and crosswalks.

For questions 1-10, indicate whether you agree or disagree with each statement by circling SD (strongly disagree), D (disagree), N (neutral), A (agree), or SA (strongly agree).

1. ___(1a-1j)___ helped me understand the course material.

1a. Textbooks	*SD / D / N / A / SA*
1b. Other reading assignments	*SD / D / N / A / SA*
1c. Lectures	*SD / D / N / A / SA*
1d. Multiple-choice questions in lectures	*SD / D / N / A / SA*
1e. Lecture notes on MyWPI	*SD / D / N / A / SA*
1f. Quizzes	*SD / D / N / A / SA*
1g. Discussion of quizzes	*SD / D / N / A / SA*
1h. In-class activities (group work)	*SD / D / N / A / SA*
1i. In-class discussion	*SD / D / N / A / SA*
1j. Group project (outside of class)	*SD / D / N / A / SA*

1k. Which of the choices listed was most helpful?

_____

2. ___(2a-2f)___ helped me assess my understanding of the course material.

2a. Multiple-choice questions in lectures	*SD / D / N / A / SA*
2b. Quizzes	*SD / D / N / A / SA*
2c. Discussion of quizzes	*SD / D / N / A / SA*
2d. In-class activities (group work)	*SD / D / N / A / SA*
2e. In-class discussion	*SD / D / N / A / SA*
2f. Group project (outside of class)	*SD / D / N / A / SA*

2g. Which of the choices listed was most helpful?

_____

3. ___(3a-3f)___ encouraged me to read the reading assignments before class.

3a. Lectures	*SD / D / N / A / SA*
3b. Multiple-choice questions in lectures	*SD / D / N / A / SA*
3c. Quizzes	*SD / D / N / A / SA*
3d. In-class activities (group work)	*SD / D / N / A / SA*
3e. In-class discussion	*SD / D / N / A / SA*
3f. Group project (outside of class)	*SD / D / N / A / SA*

3g. Which of the choices listed most encouraged you to read?

_____

4. The textbooks were well-suited to this course. *(SD / D / N / A / SA)*

5. The textbooks will be useful references after completing this course. *(SD / D / N / A / SA)*

6. The instructor lectured too much. *(SD / D / N / A / SA)*

7. I often used MyWPI to view or download the notes from the lectures. *(SD / D / N / A / SA)*

8. I enjoyed the in-class discussions. *(SD / D / N / A / SA)*

9. I liked working on project-related activities in class. *(SD / D / N / A / SA)*

10. I think the in-class activities were a waste of class time. *(SD / D / N / A / SA)*

11. How often did you read the assignments before class?
    - □ *Always*
    - □ *Usually*
    - □ *Sometimes*
    - □ *Never*

12. How has your interest in working in highway design changed after taking this course?
    - □ *More interested now*
    - □ *No change*
    - □ *Less interested now*

13. How could the teaching methods be changed to improve the course (all suggestions welcome!)?

14. Other comments?

APPENDIX B

CE3050 Course Materials

CE 3050: Introduction to Transportation Engineering

A-2003 Syllabus

Course Description

This course provides an introduction to the field of transportation engineering with particular emphasis on traffic engineering. Topics covered include the transportation industry and transportation modes; characteristics of drivers, pedestrians, vehicles and the roadway; traffic engineering studies; transportation planning; highway safety; principles of traffic flow; intersection design and control; and capacity and level of service analyses.

Meeting Times

MTWR 3:00 pm to 3:50 pm in KH 116

Staff Information

Instructor: Jennifer Weir

Email: skwirl@wpi.edu
Work phone: 508-831-6174
Office: Kaven Hall 207R (next to 207)
Office hours: M-F by appointment
Webpage: http://alum.wpi.edu/~skwirl/professional.htm

Teaching Assistant: Meredith Campbell

Email: mlsoup@wpi.edu
Office: Kaven Hall TA office
Office hours: 2-3, MTWR

Textbook

Nicholas J. Garber and Lester A. Hoel, *Traffic and Highway Engineering*, Brooks/Cole Publishing Company, Third Edition, 2002. (abbreviated "G&H" in this syllabus)

Goals & Learning Objectives

My overall goals for students in this class are:

- You will be exposed to the theory and practice of transportation engineering and will be able to assess whether you are interested in pursuing it as a career.
- You will know which reference to use to solve a transportation engineering problem or find an answer to a question.
- You will understand basic principles such as capacity, level of service, and sight distances.
- You will be able to apply these principles to solve basic problems in traffic engineering.
- You will recognize the complexity of real-world problems and your need for more study and practice.

By the end of this course, each student is expected to be able to demonstrate the concepts and skills shown in the following list. These specific learning objectives are closely related to the major topics identified in the course outline. They will be assessed through the exams or laboratory reports.

1. Identify organizations and careers involved in the design, construction and maintenance of transportation systems.
2. Explain how characteristics of people and vehicles affect transportation operations.
3. Determine the functional classification of a road.
4. Collect and analyze traffic data.
5. Apply the travel demand forecasting process to a basic planning scenario.
6. Use traffic flow models to illustrate the relationships among volume, speed and capacity.
7. Identify data needed to determine the level of service of a basic highway or freeway segment; describe or perform a level-of-service analysis.
8. Choose an appropriate control type for an intersection.
9. Develop a signal timing plan for a signalized intersection.
10. Determine the capacity of lane groups at a signalized intersection.
11. Identify data needed to determine the level of service of a signalized intersection; describe or perform a level-of-service analysis.
12. Use data to assess safety at an existing roadway segment or intersection.

Course Policies

Assessment

Homework problems -- will be assigned on Tuesday and Thursday and will be due at the beginning of class on Tuesday and Thursday (e.g., a problem assigned on Tuesday is due on Thursday and a problem assigned on Thursday is due Tuesday). Late homeworks will not be accepted. Each student's lowest homework grade will be dropped, and the average of the other homework grades will be 20% of the final grade.

Exams -- will be given twice during the term. The dates for the exams are given in the schedule. No make up exams will be given, so students should check their schedules at the beginning of the term to make sure there are no conflicts with the scheduled times. Arrangements must be made in advance for alternate testing times. Each exam grade will be 30% of the final grade. After the midterm exam is returned to the student, incorrect exam problems may be reworked as an extra homework assignment, to replace one low homework score.

Field Laboratories -- will be assigned twice during the term. Lab groups will be assigned by the instructor. Each lab grade will be 10% of the final grade.

Final grades will be calculated as follows:

Exams	
#1	30%
#2	30%
Average Homework Grade	20%
Field Laboratories	
#1	10%
#2	10%
Total	**100%**

Required Homework Format

Civil engineers have a long tradition of doing precise, careful and well-organized work. The care you take in preparing engineering documents leaves an impression with your clients about your professionalism, care for detail and organization. I expect carefully prepared homework that reflects the appropriate degree of organization, neatness and completeness. All homework assignments are expected to adhere to the following format:

- Write or type your name on all pages.
- Staple any assignment with multiple pages.
- Number all pages.
- Write down the problem statement for each question.
- State the equation(s) used.
- Refer to any tables or figures used (ex. f=0.29 from Table 3.3 for u=60mph).
- Show ALL work.
- Be neat.
- Place a box around your answer.

A sample homework assignment is attached to this syllabus. Points may be deducted for deviations from the required format.

Academic Honesty

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Additional Resources

Library Reserve

Institute of Transportation Engineers publications:

- *Traffic Engineering Handbook*, 1999
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- *Highway Capacity Manual*, 2000

World Wide Web

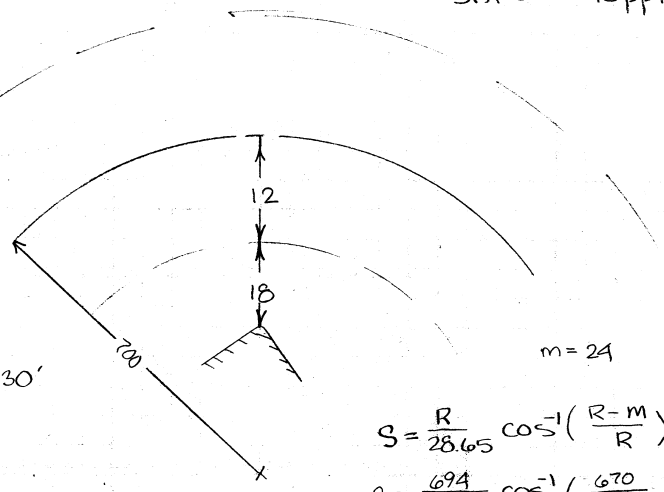
The Federal Highway Administration's *Manual on Uniform Traffic Control Devices* (MUTCD) 2000 is at http://mutcd.fhwa.dot.gov/kno-millennium.htm.

Other websites of interest are listed on the MyWPI class web page.

MALCOLM RAY
CE 140

MARCH 31, 1982

1 WHAT IS THE MAX. DESIGN SPEED WHICH WILL PROVIDE SAFE STOPPING?



$M = 18 + 12 = 30'$
$R = 700'$

$$S = \frac{R}{28.65}\cos^{-1}\left(\frac{R-m}{R}\right)$$

$$S = \frac{694}{28.65}\cos^{-1}\left(\frac{670}{694}\right) = 366'$$

THE safe STOPPING DIST. IS 412 feet.

$$SSD = (PRT)V + \frac{V^2}{30f} \qquad \text{assume } f = 0.38 \text{ AND } PRT = 2\,\text{sec}$$

$$412 = 2V + 0.088V^2 \Rightarrow V^2 + 22.73V - 4681.8 = 0 \Rightarrow V^2 + 15.46V - 21666.6 = 0$$

$$V = \frac{-15.46 \pm \sqrt{239.09 + 4(21666.6)}}{2} = 78.9 \ \frac{ft}{sec} = 53.68 \text{ mph}$$

THE maximum speed permitable which provides safe STOPPING IS

50 mph ✓

Topic Outline (as of 8/27/03)

Week #0, Starting 8-28-03

Day	Lecture Topic	Reading Due	HW Due	Events
Th	Introduction	none	None	

Week #1, Starting 9-1-03: Overview

Day	Lecture Topic	Reading Due	HW Due	Events
M	*NO CLASS (Labor Day)*			
Tu	Organizations & Careers	G&H 9-14, 32-36	#1	
W	Human Characteristics	G&H 44-48		
Th	Vehicle Characteristics	G&H 48-57	#2	

Week #2, Starting 9-8-03: Transportation Networks

Day	Lecture Topic	Reading Due	HW Due	Events
M	Networks and Route Systems	G&H 17-18, 672-675		
Tu	Transportation Planning	G&H 497-502	#3	
W	Traffic Engineering Studies	G&H 99-114		
Th	Traffic Engineering Studies	G&H 84-92, 115-121	#4	

Week #3, Starting 9-15-03: Road Segments

Day	Lecture Topic	Reading Due	HW Due	Events
M	Travel Demand Forecasting	G&H 514-521 and 527-529		
Tu	Travel Demand Forecasting		#5	
W	Traffic Flow	G&H 173-197		
Th	Traffic Flow		#6	

Week #4, Starting 9-22-03: Road Segments

Day	Lecture Topic	Reading Due	HW Due	Events
M	Capacity of Highway Segments			
Tu	LOS Analysis of Highway Segments	G&H 329-334	#7	
W	Review of Objectives 1-6			
Th	none			Exam #1

Week #5, Starting 9-29-03: Intersections

Day	Lecture Topic	Reading Due	HW Due	Events
M	Intersection Control	G&H 277-282; MUTCD 1A		
Tu	Intersection Control		#8	
W	Intersection Signalization	G&H 291-295		Lab #1 due
Th	Intersection Signalization		#9	

Week #6, Starting 10-6-03: Intersections

Day	Lecture Topic	Reading Due	HW Due	Events
M	Capacity of Intersections			
Tu	LOS Analysis of Intersections	G&H 401-406 and 474	#10	
W	LOS Analysis of Intersections			
Th	Highway Safety	G&H Ch. 5	#11	

Week #7, Starting 10-13-03: Safety

Day	Lecture Topic	Reading Due	HW Due	Events
M	Highway Safety			
Tu	Review of Objectives 7-12		#12	
W	TBD			Lab #2 due
Th	none			Exam #2

CE 3050: Introduction to Transportation Engineering

A-2004 Syllabus

Course Description

This course provides an introduction to the field of transportation engineering with particular emphasis on traffic engineering. Topics covered include the transportation industry and transportation modes; characteristics of drivers, pedestrians, vehicles and the roadway; traffic engineering studies; transportation planning; highway safety; principles of traffic flow; intersection design and control; and capacity and level of service analyses.

Meeting Times

MTWR 3:00 pm to 3:50 pm in KH 116

Staff Information

Instructor: Jennifer Weir

Email: skwirl@wpi.edu
Office phone: 508-831-6174
Office: Kaven Hall 207R (next to 207)
Office hours: M-F afternoons by appointment
Webpage: http://alum.wpi.edu/~skwirl/professional.htm

Teaching Assistant: Joe Krajewski

Email: joek@wpi.edu
Office: Kaven Hall TA office
Office hours: TBA

Textbook

Nicholas J. Garber and Lester A. Hoel, *Traffic and Highway Engineering*, Brooks/Cole Publishing Company, Third Edition, 2002. ("G&H")

Goals & Learning Objectives

My overall goals for students in this class are:

- You will be exposed to the theory and practice of transportation engineering and will be able to assess whether you are interested in pursuing it as a career.
- You will know which reference to use to solve a transportation engineering problem or find an answer to a question.
- You will understand basic principles such as capacity, level of service, and sight distances.
- You will be able to apply these principles to solve basic problems in traffic engineering.
- You will recognize the complexity of real-world problems and your need for more study and practice.

By the end of this course, each student is expected to be able to demonstrate the concepts and skills shown in the following list. These specific learning objectives are closely related to the major topics identified in the course outline. They will be assessed through the exams or laboratory reports.

1. Identify organizations and careers involved in the design, construction and maintenance of transportation systems.
2. Explain how characteristics of people and vehicles affect transportation operations.
3. Determine the functional classification of a road.
4. Collect and analyze traffic data.
5. Apply the travel demand forecasting process to a basic planning scenario.
6. Use traffic flow models to illustrate the relationships among volume, speed and capacity.
7. Identify data needed to determine the level of service of a basic highway or freeway segment; describe or perform a level-of-service analysis.
8. Choose an appropriate control type for an intersection.
9. Develop a signal timing plan for a signalized intersection.
10. Determine the capacity of lane groups at a signalized intersection.
11. Identify data needed to determine the level of service of a signalized intersection; describe or perform a level-of-service analysis.
12. Use data to assess safety at an existing roadway segment or intersection.

Course Policies

Assessment

Homework problems -- will be assigned on Tuesday and Thursday and will be due at the beginning of class on Tuesday and Thursday (e.g., a problem assigned on Tuesday is due on Thursday and a problem assigned on Thursday is due Tuesday). Late homeworks will not be accepted. Each student's lowest homework grade will be dropped, and the average of the other homework grades will be 20% of the final grade.

Exams -- will be given twice during the term. The dates for the exams are given in the schedule. No make up exams will be given, so students should check their schedules at the beginning of the term to make sure there are no conflicts with the scheduled times. Arrangements must be made in advance for alternate testing times. Each exam grade will be 30% of the final grade. After the midterm exam is returned to the student, incorrect exam problems may be reworked as an extra homework assignment, to replace one low homework score.

Field Laboratories -- will be assigned twice during the term. Lab groups will be assigned by the instructor. Each lab grade will be 10% of the final grade.

Final grades will be calculated as follows:

Exams	
#1	30%
#2	30%
Average Homework Grade	20%
Field Laboratories	
#1	10%
#2	10%
Total	**100%**

Required Homework Format

Civil engineers have a long tradition of doing precise, careful and well-organized work. The care you take in preparing engineering documents leaves an impression with your clients about your professionalism, care for detail and organization. I expect carefully prepared homework that reflects the appropriate degree of organization, neatness and completeness. All homework assignments are expected to adhere to the following format:

- Write or type your name on all pages.
- Staple any assignment with multiple pages.
- Number all pages.
- Write down the problem statement for each question.
- State the equation(s) used.
- Refer to any tables or figures used (ex. f=0.29 from Table 3.3 for u=60mph).
- Show ALL work.
- Be neat.
- Place a box around your answer.

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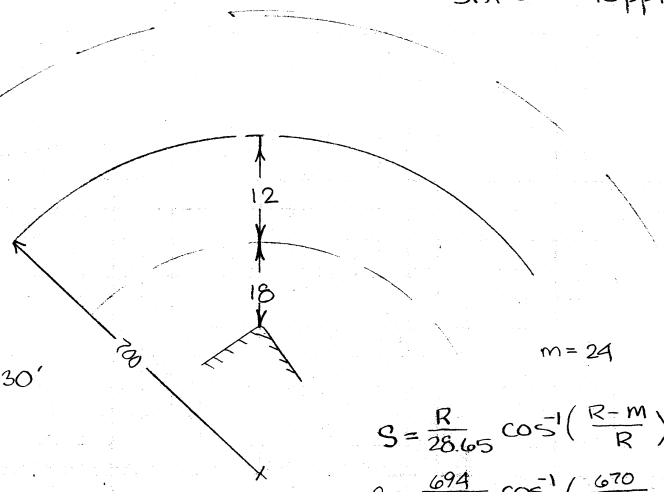

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Topic Outline (as of 8/26/04)

Week #0, 8-26-04

Day	Lecture Topic	Reading Due	HW Due	Events
Th	Introduction	none	None	

Week #1, Starting 8-30-04: Overview

Day	Lecture Topic	Reading Due	HW Due	Events
M	Organizations & Careers	pp. 9-14, 32-36		
Tu	Characteristics of Humans, Vehicles, and Roadways	pp. 44-48	#1	
W		pp. 48-62		
Th	Networks and Route Systems	pp. 17-18, 672-675	#2	

Week #2, Starting 9-6-04: Transportation Networks

Day	Lecture Topic	Reading Due	HW Due	Events
M	*NO CLASS (Labor Day Holiday)*			
Tu	Transportation Planning	pp. 497-502	#3	
W	Traffic Engineering Studies	pp. 99-114		
Th		pp. 84-92, 115-121	#4	

Week #3, Starting 9-13-04: Transportation Networks

Day	Lecture Topic	Reading Due	HW Due	Events
M	Travel Demand Forecasting	pp. 514-521 and 527-546		
Tu		pp. 547-561	#5	
W	Traffic Flow	pp. 173-197		
Th			#6	

Week #4, Starting 9-20-04: Road Segments

Day	Lecture Topic	Reading Due	HW Due	Events
M	Capacity & LOS of Highway Segments	pp. 329-334, 353-356, 360-366		
Tu			#7	
W	Review of Objectives 1-6			
Th	none			Exam #1

Week #5, Starting 9-27-04: Intersections

Day	Lecture Topic	Reading Due	HW Due	Events
M	Intersection Control	pp. 277-291; MUTCD 1A		Lab #1 due
Tu			#8	
W	Intersection Signalization	pp. 291-295		
Th			#9	

Week #6, Starting 10-4-04: Intersections

Day	Lecture Topic	Reading Due	HW Due	Events
M	Capacity of Intersections	pp. 401-404, 462		
Tu	LOS Analysis of Intersections	pp. 404-406, 474	#10	
W				
Th	Highway Safety	pp. 131-138	#11	

Week #7, Starting 10-11-04: Safety

Day	Lecture Topic	Reading Due	HW Due	Events
M	Highway Safety			
Tu	Review of Objectives 7-12		#12	
W	TBD			Lab #2 due
Th	none			Exam #2

Entrance Survey: Introduction to Transportation Engineering (CE 3050)

Your answers on this survey will not affect your course grades in any way.

1. What is your major (CE, ME, etc.)? _____

2. If you are a civil/environmental engineering major, what is your primary area of concentration?
    a. Construction Project Management
    b. Environmental
    c. Geotechnical
    d. Structural
    e. Transportation
    f. Undecided / other
    g. I'm not a civil!

3. What is your class year (expected year of graduation)?
    a. 2004
    b. 2005
    c. 2006
    d. 2007
    e. 2008

4. What is your primary means of transportation in Worcester (off campus)?
    a. Walking
    b. Bicycling
    c. Riding a bus/shuttle
    d. Driving a vehicle
    e. Riding in a vehicle (not driving)

5. Which of the following affected your decision to take this course? Choose all that apply.
    a. Interest in transportation engineering as a career option
    b. Curiosity about transportation engineering
    c. Interesting course description in the course catalog
    d. Good student course evaluation results
    e. Course reputation for being easy
    f. Course reputation for being fun/interesting
    g. Good instructor reputation

For each of the following statements, indicate if you disagree or agree with the statement. (1 = strongly disagree, to 5 = strongly agree)

6. I expect this course to be boring.
7. I expect the material covered in this course to be useful to me in my career.

8. I expect this course to be challenging.
9. Transportation engineering is a rewarding career.
10. Traffic engineers have an easy job.
11. Traffic engineering requires a significant amount of specialized knowledge.
12. I am interested in working in the field of transportation engineering.

CE 3050 Pretest (A-03/A-04)

Instructions: This is a knowledge survey, not an exam. Your score will not affect your course grades in any way. The purposes of this survey are to (1) assess your initial knowledge of the material to be covered in this course, (2) help you to monitor your own learning as you proceed through the course, and (3) provide a benchmark by which to assess how much you learn in this course. This survey will be given again during the last week of the course.

In this survey, do not try to actually answer any of the questions. Instead, rate your confidence to answer the questions with your present knowledge. Read each question and mark A, B, or C on your answer sheet according to the following guidelines:

- Choose "A" if you feel confident that you can now answer the question sufficiently for graded test purposes. In other words, you would most likely earn full credit if you encountered this question on a real exam.
- Choose "B" if you can now answer at least 50% of the question OR if you know precisely where you could quickly find the necessary information and could then completely answer the question or solve the problem.
- Choose "C" if you are not confident that you could adequately answer the question for graded test purposes at this time.

Do your best to provide a totally honest assessment of your present knowledge. It is perfectly acceptable not to be able to answer these questions at this time, since there are no prerequisites for this course. When you mark an "A" or "B," you are stating that you have sufficient familiarity to address that item. You should be prepared to demonstrate that capability by actually answering the question if requested.

Answer Sheet

1.	A	B	C
2.	A	B	C
3.	A	B	C
4.	A	B	C
5.	A	B	C
6.	A	B	C
7.	A	B	C
8.	A	B	C
9.	A	B	C
10.	A	B	C
11.	A	B	C
12.	A	B	C
13.	A	B	C
14.	A	B	C
15.	A	B	C

Questions 1 and 2 refer to the following information:

Massachusetts Route 49, known locally as the Podunk Pike, connects Route 9 in Spencer to Route 20 in Sturbridge (see map below). The Podunk Pike is a two-lane highway; the picture below shows a typical view of the road.

PHOTO: DAVID NILES

1. What is the functional classification of Route 49? (urban or rural arterial, collector, or local road)

2. What is the name of the organization that is responsible for maintaining Route 49?

3. Given the traffic data on the following page, determine the 85th percentile speed and ADT (average daily traffic) for the traffic count period.

Counter #: 4598
Counted by: Sgt. Brown
Weather: Sunny

WPI Dept. of Civil & Environmental Engineering
Worcester, MA

Site Code: 00000000000005040101
Station ID: 00000000000000000000

Northbound, Southbound

Start Time	0 15	16 20	21 25	26 30	31 35	36 40	41 45	46 50	51 55	56 60	61 65	66 70	71 75	76 999	Total
05/08/01	0	2	9	17	5	0	0	0	0	0	0	0	0	0	33
01:00	0	1	5	4	5	1	0	0	0	0	0	0	0	0	16
02:00	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
03:00	0	0	3	7	11	1	1	1	0	0	0	0	0	0	24
04:00	0	0	2	9	5	1	0	0	0	0	0	0	0	0	17
05:00	1	1	6	30	18	4	0	0	0	0	0	0	0	0	60
06:00	3	1	30	112	110	11	0	0	0	0	0	0	0	0	267
07:00	6	4	39	246	218	21	0	0	0	0	0	0	0	0	534
08:00	7	7	64	238	143	13	1	0	1	2	0	0	0	0	476
09:00	5	6	58	163	106	10	0	0	0	0	1	1	2	0	352
10:00	1	2	40	167	102	12	2	1	0	0	0	0	0	0	327
11:00	6	5	72	207	108	8	1	1	0	0	0	0	0	0	408
12 PM	7	2	74	249	124	14	3	0	0	0	0	1	0	0	474
13:00	2	4	58	218	129	18	0	1	0	0	0	0	0	0	430
14:00	4	6	63	235	156	6	1	1	1	1	0	0	0	0	474
15:00	13	7	69	294	172	20	5	0	0	0	0	2	0	0	582
16:00	21	9	92	321	191	18	2	1	0	0	2	1	1	0	659
17:00	23	11	76	357	180	16	4	1	0	0	0	0	1	0	669
18:00	6	2	58	247	109	27	2	0	0	1	0	0	0	0	452
19:00	3	3	59	202	81	13	2	1	0	0	0	1	0	0	365
20:00	3	3	56	143	71	6	1	1	1	0	1	0	0	0	286
21:00	3	3	39	94	35	3	0	0	0	1	0	0	0	0	178
22:00	0	2	21	51	17	4	0	0	0	0	0	0	0	0	95
23:00	0	1	13	33	18	2	0	0	0	0	0	0	0	0	67
Total	114	82	1006	3645	2115	229	25	9	3	5	4	6	4	0	7247
Grand Total	114	82	1006	3645	2115	229	25	9	3	5	4	6	4	0	7247

Questions 4-7 refer to the following information:

A horizontal curve on a 2-lane rural highway has a posted speed limit of 55 mph, an uphill grade of 2 percent, a radius of 800 feet, and superelevation of 6 percent. The available sight distance on the curve is limited to 400 feet due to some trees and brush that obstruct the view. Assume that the driver's perception-reaction time is 2.5 seconds.

4. What is the stopping sight distance required?
5. What is the maximum safe speed on the curve?
6. Do your answers to *a* and *b* suggest any safety problems? If so, identify the problems and suggest one possible countermeasure for each problem.
7. Under what circumstances would it be appropriate to use a different perception-reaction time?

---

8. Data are collected about vehicles traveling on a 500-foot section of roadway. The average space headway between vehicles is 20 feet, and the space mean speed is 35 mph. Calculate the density (in veh/mi) and flow (in veh/hr).

9. Calculate the PTSF (percent time spent following) and LOS (level of service) for a Class II two-lane highway segment with the following characteristics: rolling terrain, 10 % trucks, 5% RVs, V = 1955 veh/h, PHF = 0.85, 50%-50% directional split, 40% no-passing zones.

Questions 10-13 *refer to a cross intersection of 2 two-lane roads meeting at a 90-degree angle.*

10. If the speed limits on the two roads are both 45 mph and the available intersection sight distance is 200 feet due to permanent obstacles or road geometry, what type of intersection control would be most appropriate?

11. Crash data were collected for three years at this intersection as shown in the table to the right. During the same time period, the combined ADT on all four approaches was 41,000 veh/day. Calculate the average crash rate per million entering vehicles (RMEV) for this intersection.

Year	*Number of Crashes*
1998	17
1999	11
2000	16

12. Due to the high number of crashes at the intersection, a traffic signal was installed. Find the optimum cycle length of the traffic signal using the HCM method. Assume a two-phase system, L = 3.5 seconds per phase, no conflicting pedestrians, and the volume data given below. Round the cycle length to the nearest whole number.

Phase	*Lane Group*	*Saturation Flow Rate (veh/hr)*	*Peak Hour Volume (veh/hr)*	*PHF*
1	Eastbound	1900	850	0.85
	Westbound	1900	795	0.85
2	Northbound	1800	500	0.90
	Southbound	1800	475	0.90

13. Given the data from the previous question, calculate the v/c ratio for each lane group and the LOS (level of service) of the entire intersection.

Questions 14 and 15 refer to the following information:

A certain region is divided into five zones. The number of trips produced by and attracted to each of the zones is given in Table 1 below, and the current friction factors between zones are given in Table 2 below. Use the gravity model to answer the following questions about the trip distribution. Assume all K factors = 1.

Table 1: Productions and Attractions

Zone	*Trips Produced*	*Trips Attracted*
1	830	2050
2	2400	890
3	1000	1280
4	2210	830
5	760	2150

Table 2: Friction Factors Between Zones (F_{ij})

Zone	*1*	*2*	*3*	*4*	*5*
1	0.1	0.2	0.2	0.1	0.1
2	0.2	0.1	0.3	0.2	0.1
3	0.2	0.3	0.1	0.2	0.2
4	0.1	0.2	0.2	0.1	0.3
5	0.1	0.1	0.2	0.3	0.1

14. A new highway has been proposed to connect Zone 1 and Zone 4. If the travel time between Zones 1 and 4 on the new highway will be 5 minutes, how many of the trips produced in Zone 1 *will be* attracted to Zone 4?

    Assume that $F_{1j} = \frac{1}{T_{1j}}$.

15. Explain how you would predict traffic volume on the new highway based on the given data and network information.

Experimental Class: Lecture Topics and In-Class Exercises/Discussions

Lecture Topics

- Transportation overview
  - Organizations and careers in transportation
  - Characteristics of humans (drivers, pedestrians, bicyclists), vehicles, and roadways that affect transportation operations
- Transportation networks
  - Networks and route systems
  - Functional classification of roads
  - Transportation planning
  - Traffic engineering studies
  - Travel demand forecasting
  - Traffic flow
- Road segments
  - Capacity and LOS analysis of highway segments (two-lane and freeway)
- Intersections
  - Intersection control
  - Signalization
  - Capacity of lane groups / approaches
  - LOS analysis of signalized intersections
- Safety
  - Determining crash rates and statistics
  - Identifying safety problems and possible solutions

Exercises/Discussions

- Objective: Identify organizations and careers involved in the design, construction and maintenance of transportation systems.
  1. Each student receives a sheet containing several organizations or terms and descriptions. In groups of three, match organizations/terms with descriptions. Use your answers to fill in the blanks on the next few slides in the lecture. Example: NHTSA (National Highway Traffic Safety Administration) is "responsible for reducing deaths, injuries, and economic losses resulting from motor vehicle crashes."
  2. Form groups of students with same specialty within civil engineering or a group of non-majors. In groups, make a list of types of work (engineering) you might do relevant to transportation. Example: structural engineers may design bridges.
- Objective: Explain how characteristics of people and vehicles affect transportation operations.
  1. A city engineer plans to install a stop sign at a 4-way intersection. The speed limit on the approach is 40 mph, and the approach is on a +5% grade. What affects the minimum distance from which the driver must be able to see the stop sign in order to stop? (class discussion)
  2. Calculate the distance traveled by the vehicle in the example before braking using a perception-reaction time of 2.5 seconds.

3. Calculate the braking distance for the vehicle in the example.
4. Calculate the total stopping distance required for the example and compare your answer with a person beside you.
5. What if instead of a STOP sign we had a sign requiring a change in speed, such as a speed limit sign? From what distance should the driver be able to read the sign in order to slow down to 25 mph at the sign?
6. What do you need to know to determine the maximum safe speed for traveling around a curve? (class discussion)
7. For a curve with radius of 400 ft and superelevation rate of 8%, calculate the maximum safe curve speed (in small groups).

- Objective: Determine the functional classification of a road.
  1. In small groups, list at least five modes of transportation. Which do you think is the most-used mode for moving freight between cities? Which is the most-used for moving passengers between cities?
  2. In small groups, identify the arterials, collectors, and local roads in an example town.
- Objective: Collect and analyze traffic data, including volumes and speeds.
  1. Given a traffic count report, determine: Average Daily Traffic (ADT) for the count period, Peak Hour Volume (PHV), and Peak Hour Factor (PHF).
  2. Determine the AADT for the location in the previous exercise.
  3. Given turning movement volume data, determine the peak hour time, volume, and PHF.
  4. Graph the cumulative percentage of observations v. midpoint of the speed ranges. Compare your graph to your neighbor's and determine: 85th percentile speed, median speed, and pace in 10-mph interval**.**
- Objective: Apply the travel demand forecasting process to a basic planning scenario.
  1. Given a situation description, (1) identify at least two possible project objectives; and (2) identify evaluation criteria for those objectives. Situation: Route 12 in Fitchburg and Leominster, MA, is a two-lane urban arterial. It has relatively high traffic volumes and many signalized intersections, and traffic becomes congested during peak periods. The existing right-of-way is not enough to widen the roadway to four lanes without encroaching on residential and commercial properties.
  2. Use a sample page from *Trip Generation* to estimate the number of trip ends generated by a single-family housing development containing 10 units (1) on an average weekday and (2) during a peak hour between 4-6 p.m. on an average weekday.
  3. For a given gravity model example, how many total trips are attracted to TAZ 2?
  4. Given a simple network map, find the shortest path from TAZ 1 to TAZ 2 in terms of time.
- Objective: Use traffic flow models to illustrate the interrelationships among volume, speed and capacity.
  1. (Problem 6-1 in G&H): Observers stationed at two sections XX and YY, 500 ft apart on a highway, record the arrival times of four vehicles as shown in the table. If the total time

of observation at XX was 15 sec, determine (a) the time mean speed, (b) the space mean speed, and (c) the flow at section XX.

2. If you were given a density and an average time headway for a section of road, how would you calculate the flow?
3. Given density and mean speed data, calculate a and b (linear regression coefficients) to fit the data to the Greenshields model.
4. What is the maximum flow according to the model (Greenshields)?
5. Vehicles are approaching a signal-controlled intersection at a density of 72 veh/mi. When the signal turns red, what happens to (a) the flow, (b) the speed, and (c) the density of the traffic? (class discussion)

- Objective: Identify data needed to determine the level of service of a basic highway or freeway segment; describe or perform a level-of-service analysis.
  1. List types of data that might be needed to determine the LOS of a two-lane highway (class discussion).
  2. Given: a 5-mile segment of a Class I 2-lane highway in rolling terrain. V = 900 veh/h (2-way, with 50-50 split), PHF = 0.9, 10% trucks, 4% RVs, 60% no-passing zones, posted speed limit = 60mph, 11-ft lanes, 5-ft shoulders, 10 access points per mile. Calculate v_p.
  3. Calculate PTSF for the same segment.
  4. Calculate ATS for the same segment. Assume that the BFFS is the posted speed limit of 60 mph.
  5. On a printout of the HCS2000 input screen for two-lane highways, fill in the data for the example problem.
- Objective: Choose an appropriate control type for an intersection.
  1. Why are intersections important? (class discussion)
  2. For your assigned intersection, what information would you need to determine if a Yield, 2-way Stop, or multiway Stop sign were warranted?
  3. Given a handout of traffic data, compare the data on the handout to Warrant 1. Does this location meet this warrant?
  4. In lab groups, determine the required intersection sight distance for yield control at your assigned intersection.
  5. In lab groups, determine the required intersection sight distance for stop control at your assigned intersection.
- Objective: Develop a signal timing plan for a signalized intersection.
  1. In lab groups, choose a (preliminary) phasing system for your assigned intersection.
  2. In lab groups, look through the equations in Table 10.4 and determine which of the adjustment factors will affect the saturation flow rate for your assigned intersection.
  3. Assume the saturation flow rate for all approaches is 1500 vph per lane. For your assigned intersection, calculate demand hourly volumes (v) and (v/s) for each lane group, and $\sum_i (v/s)_{ci}$ for the intersection (in lab groups).

4. For an example intersection, assume a speed limit = 30mph and G = 0 on all approaches, and calculate the minimum yellow interval for each phase.
5. In lab groups, make a list of information needed to do the following (steps 7-11) for your assigned intersection: find the effective green time for each phase, the minimum yellow intervals, and the actual green times; check that pedestrians have enough time to cross during the green and adjust actual green times if necessary; and summarize the signal timing plan.

- Objective: Determine the capacity of lane groups at a signalized intersection.
  1. Using the information in G&H Figure 10.30 (an input worksheet), complete the top half of a "volume adjustment and saturation flow rate worksheet."
  2. In small groups, for a given example, calculate capacity and v/c for each lane group (one lane group per group of students). Report your v/c values to the rest of the class. Then calculate X_c for the intersection.
- Objective: Identify data needed to determine the level of service of a signalized intersection; describe or perform a level-of-service analysis.
  1. Given example data, determine the uniform delay for each lane group.
  2. For the same example, determine the incremental delay for each lane group.
  3. For the same example, find the total control delay for each lane group.
  4. For the same example, find the intersection delay and LOS.
  5. In lab groups, complete the HCS2000 input screen for a capacity (operations) analysis of your assigned intersection for Lab 2.
- Objective: Use data to assess safety at an existing roadway segment or intersection.
  1. In lab groups, from the Worcester DPW accident data for 2002, determine how many crashes occurred at your intersection. Then calculate the RMEV for your intersection (using 2004 ADTs and 2002 accident data).
  2. Given example crash data for a two-lane undivided rural road segment, list some possible road-related causes of the crashes (class discussion).
  3. List some possible improvements to reduce the crash rate of the example road segment (class discussion).
  4. Given three alternatives for safety improvement of the example road segment, which alternative by itself is the most effective?
  5. What is the current crash cost for the example road segment, based on NHTSA's accident costs?
  6. In small groups, calculate the benefit-cost ratio for an alternative (one per student group). Is the alternative cost-effective?

LAB EXERCISE 1: DATA COLLECTION
CE3050 - Introduction to Transportation Engineering

Introduction – Traffic engineers are responsible for making sure traffic moves smoothly, efficiently and safety through the network. Obtaining accurate information about traffic characteristics is one important aspect of a traffic engineer's job. In this lab you will be collecting some of the traffic data commonly used by traffic engineers.

Your assignment is to collect and analyze volume data for a roadway and an intersection in the WPI neighborhood. You will be assigned to a group (4 to 5 people) and specific locations. To see the list of lab partner assignments and location assignments check the MyWPI webpage under "Assignments." Each group must perform:

- One 24-hour automatic volume count at your assigned road segment on a weekday, using either the Jamar TraxPro or the NuMetrics Hi-Star; and
- One two-hour turning-movement volume count at your assigned intersection, including the AM or PM peak hour, on a weekday. Be sure to count the number of pedestrians crossing each approach as well as the vehicular traffic.

Once the data are collected, each group must use the appropriate software to produce reports and graphs as described later in this document.

The assignment is due at the beginning of class on Wednesday, October 1.

Location -- Each group will be assigned a road section and intersection. Your road section will be specified as a particular street between two intersections (e.g., Highland Avenue between West Street and Park Avenue). The particular location along the street where you perform the volume counts does not matter, so find a suitable place anywhere on the road section. Please be *careful* crossing the street and working near traffic, especially late in the day when visibility is not good. When setting up the automatic traffic counters, anyone who enters the street should be wearing a reflective vest.

Equipment -- You will need to check out several pieces of equipment from the TA. (She will have a list of all the equipment needed.) You will be responsible for the equipment during your assigned period, and you will not receive a grade for the course until the equipment is returned. If you lose or damage the equipment, your group will be held financially responsible, so please be careful with it.

Equipment for this lab includes:

- automatic traffic counters and associated equipment,
- electronic count boards for recording turning movement volumes, and
- software for downloading and analyzing the counter and count board data (TraxPRO or HDM and PETRA).

Automatic Traffic Volume Count – WPI owns two automatic traffic data recorders. Both types record data that can be downloaded to a computer. Instructions for using the automatic volume counters will be handed out in class and are also located on the MyWPI webpage. You will need to set up and remove the counters as a group or at least in pairs.

Turning Movement Volume Counts -- This type of count records all of the traffic movements at an intersection (e.g., right turns, pedestrians crossing, straight through the intersection, etc.). You will use an electronic count board to record the data. The count board has a manual that explains how to use it. You can do these counts with only one person or take turns collecting data, as your group chooses. Allow time before each count to set up the count board for recording data.

Report -- Your report should have the following parts:

Title Page

Include the names of the team members, location of the study, date(s) the data were collected, assignment due date, and the class number and name.

Data and Analysis

- Automatic Volume Count
    - Print out a report and graph of the automatic volume count data by hour.
    - Report the total 24-hour volume, peak hour time and volume, and PHF.
    - Estimate the AADT of your road segment based on your volume data. Use the monthly adjustment factor from MassHighway's seasonal adjustment factors worksheet.
    - Check the online traffic volume data from MassHighway. Find the count nearest to your count (if your street is listed make sure the MassHighway count is near yours and if your street is not listed find one close by). Do you think your prediction of the AADT is reasonable given the MassHighway data? Using your data and the MassHighway data, forecast what the traffic volume on your street will be in five years.
- Turning Movement Count
    - Draw a neat sketch of your intersection showing all approaches, lanes and shoulders, and any channelization devices (e.g., islands, stripes, etc.).
    - Print out a report and diagram of the turning movement volumes for each 15-minute period. Report the peak 15-minute period and PHF for each approach (considering vehicular traffic only).
    - Identify the peak hour for the vehicular traffic at the intersection during your data collection period.

- Report the pedestrian volumes crossing each approach during the vehicular peak hour.

Summary

- What are some sources of error (at least three) in each type of count you performed?
- How might a traffic engineer use the data you collected? List at least three ways.
- Do you have any suggestions for improving this lab in future classes? Explain.

LAB EXERCISE 2: INTERSECTION SIGNALIZATION STUDY

CE3050 - Introduction to Transportation Engineering

Introduction – In Lab Exercise 1, you and your classmates collected data about intersections and adjacent road segments. In this exercise, you will use those data to complete a preliminary study of the signalization of an intersection.

You will complete this exercise in the same group as Exercise 1, for the same intersection. Each group will be given traffic and accident data for their intersection and will complete:

- A signal warrant analysis,
- A preliminary signal timing plan, and
- A level-of-service planning analysis.

The assignment is due at the beginning of class on Wednesday, October 15.

Equipment – The only equipment required for this lab is the HCS2000 software, which can be installed from the WPI network and should be available in the Kaven Hall computer labs.

Signal Warrant Analysis – Analyze the data to see which signal warrants are met at this intersection.

Signal Timing Plan – If a signal were installed, a timing plan would be needed. Develop a pre-timed signal timing plan for the current volumes at the intersection. Use the HCM method for cycle length and a target X_c of 0.85.

LOS Planning Analysis – Use the HCS2000 software to perform a planning analysis of the intersection LOS. First, find the capacity of each approach based on your signal timing plan. Determine what the LOS would be using the current volumes; then predict the LOS in ten years, assuming 2% annual traffic growth.

Report -- Your report should have the following parts:

Title Page

Include the names of the team members, location of the study, assignment due date, and the class number and name.

Analyses

- Signal Warrant Analysis
  - How many warrants are met? List them and show why they are met.
  - Is a signal justified?
  - Is a signal required?

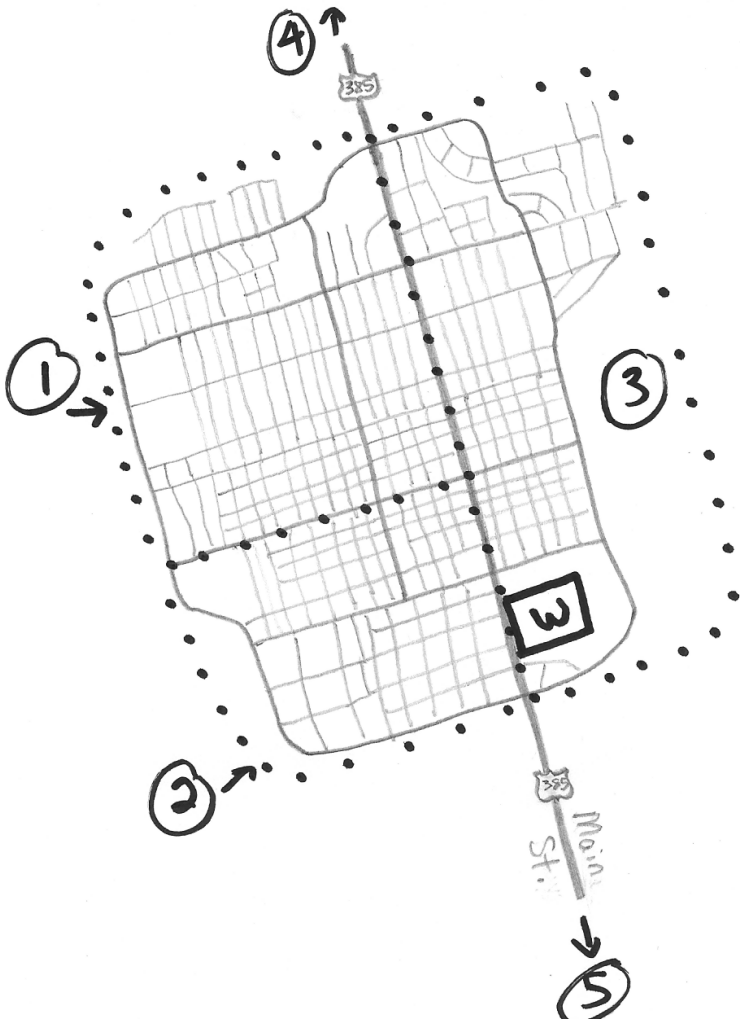
- Signal Timing Plan
    - Present your signal timing plan as discussed in class.
    - Include neat calculations to support your plan.
- LOS Planning Analysis
    - Report the capacity of each approach based on your signal timing plan.
    - Print out the HCS2000 report for each of the two LOS analyses (current and future volumes).
    - Will your signal timing plan be appropriate in ten years? If not, how should it be changed?

Summary

- If it is economically feasible, should a traffic signal be installed at this intersection? Why or why not?
- Would you suggest a pretimed or actuated signal? Why?
- Is the expected LOS for current and future volumes acceptable? How could it be improved?

Exam 1 – CE 3050, A03/A04

WalMart wants to build a 150,000 SF WalMart Superstore at 100 Main Street in Andrews, TX (population 9,652). As the town's traffic engineer, you have been asked to predict the impact of the proposed store on the traffic flow in the town. The sketch below shows the town, the TAZs used in the model (three zones represented by dotted lines and two external zones), and the proposed location of the WalMart store (represented by a rectangle marked "W").



(15 pts) 1. Identify the functional classification of Main Street and explain (briefly) your choice. Will the location of the WalMart store be suited to the primary function of the road?

(18 pts) 2. Given the traffic count data below, find the peak hour volume, estimated AADT, and 85th percentile speed. Use a monthly adjustment factor of 0.97.

Traffic Volume Count
Andrews, TX
Main Street (Route 385)
N of the loop
4/17/03 - 4/18/03

Start Time (Fri, 4/18)	NB	SB	Total
12:00 AM	200	100	300
1:00	80	40	120
2:00	20	30	50
3:00	30	20	50
4:00	20	30	50
5:00	80	100	180
6:00	100	300	400
7:00	500	900	1400
8:00	600	1000	1600
9:00	550	850	1400
10:00	300	400	700
11:00	500	300	800
12:00 PM	600	500	1100
1:00	550	480	1030
2:00	400	500	900
3:00	450	400	850
4:00	600	350	950
5:00	1070	500	1570
6:00	900	600	1500
7:00	850	700	1550
8:00	600	800	1400
9:00	400	600	1000
10:00	300	300	600
11:00	300	200	500
Total	10000	10000	20000

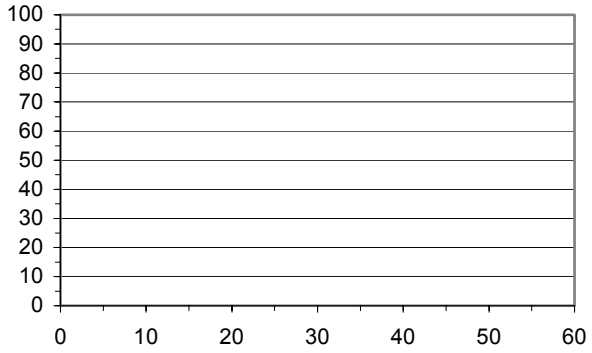
Peak hour volume: _____

AADT: _____

85th percentile speed: _____

Peak Hour Speeds

Speed (mph)	% of Vehicles
0-9	0
10-19	2
20-29	35
30-39	62
40-49	1
50-59	0



(18 pts) 3. Use one iteration of the gravity model to predict the trip distribution that will result from the addition of the WalMart store. (The trip distribution matrix is partially completed below; fill in the blank values.) Is one iteration sufficient?

The trip generation and friction factor values are given in the tables below. Assume all K factors = 1. The ITE average attraction rate for a "superstore" is 3.82 trips per 1000 SF during the peak hour, and 38 trips per 1000 SF during an average weekday.

Trips Produced and Attracted (per day)

TAZ	*P's*	*A's*
1	5000	1700
2	4500	1700
3	3000	1300
4	9000	8500
5	8700	11,500
WalMart	0	

Friction Factors Between TAZ's

	1	*2*	*3*	*4*	*5*	*W*
1	0.5	1	1	0.7	0.7	1
2	1	0.5	1	0.7	0.7	1
3	1	1	0.5	0.7	0.7	1
4	0.7	0.7	0.7	0	1	0.5
5	0.5	0.5	0.5	1	0	0.5
W	1	1	1	1	1	0

Trip Distribution Matrix

	1	*2*	*3*	*4*	*5*	*W*
1	180	361	276	1263	1709	1213
2	325	162	248	1137	1538	1089
3						
4	607	607	464	0	5867	1454
5	540	540	413	5398	0	1810
W	0	0	0	0	0	0

(18 pts) 4. List three measures that you might use to assess the effects of the proposed store on traffic flow on individual streets in the town.

(6 pts) 5. If the traffic on Main Street can be described by the Greenshields model, what is the maximum flow attainable under current conditions? Assume a free flow speed of 40 mph and jam density of 250 vehicles per mile.

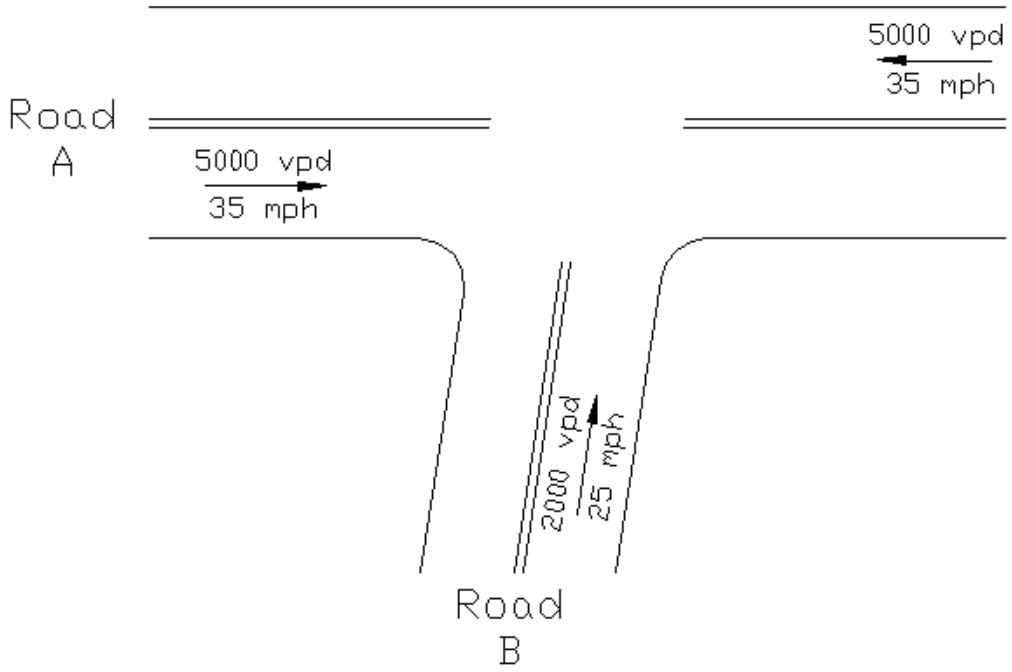
(12 pts) 6. A number of tractor-trailer trucks will be arriving and departing from the WalMart store to deliver and pick up goods. A typical truck is 8.5 feet wide and 55 feet long and can weigh 80,000 pounds. Describe two ways these trucks might affect traffic flow on Main Street.

(6 pts) 7. Would you recommend that the store be built at this location, based solely on traffic considerations (questions 1-6)? Why or why not?

(6 pts) 8. If road improvements are needed, from what agency (besides WalMart) is the town likely to receive funding?

Exam 2 – CE 3050, A03/A04

Questions 1 – 3 refer to the intersection shown below.



Summary of Crashes at the Intersection of Roads A & B:

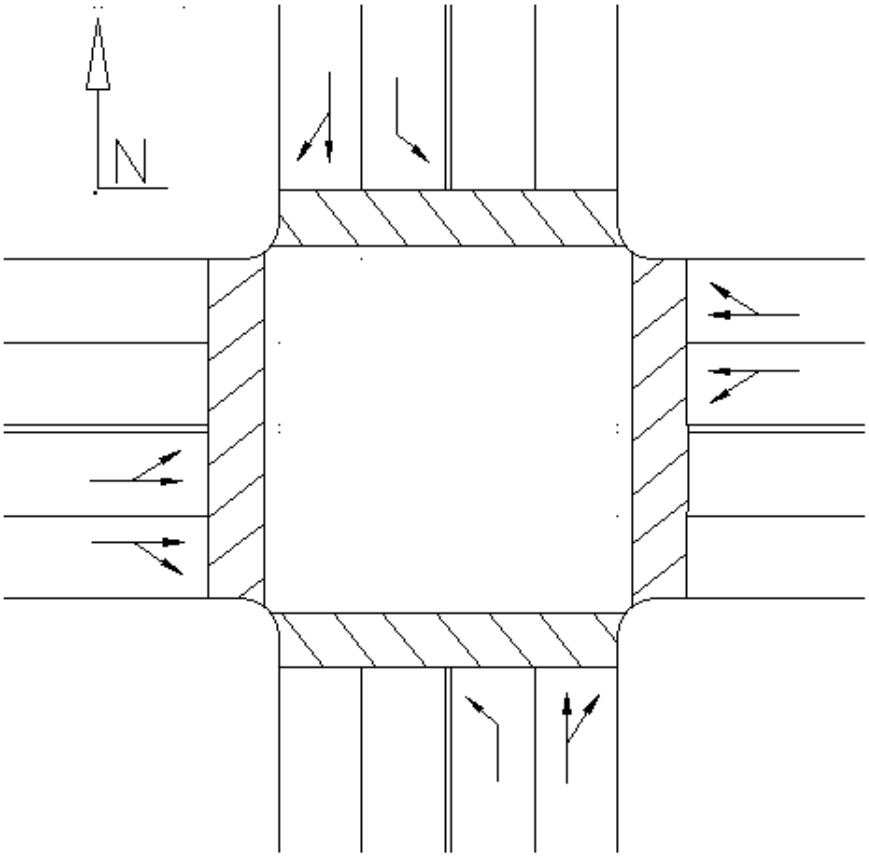
Year	*# Fatal Crashes*	*# Injury Crashes*	*# PDO Crashes*	*Total # Crashes*
2002	0	5	12	17
2003	1	4	14	19
Average	0.5	4.5	13	18

(12 pts) 1. If the average crash rate for intersections in this state is 2-5 crashes (including 0-0.2 fatal crashes) per million entering vehicles, is this a problem location?

(12 pts) 2. A driver traveling toward the intersection on Road B pauses 155 feet away from the intersection and observes that he can see clearly for 75 feet along Road A in each direction. Which of the following traffic control methods are ***not*** appropriate for the intersection: yield control or one-way stop control? (Show why.)

(16 pts) 3. Determine the ***LOS*** of a one-mile section of Road A. Road A is a Class II two-lane highway in level terrain with 60% no-passing zones. The peak hour volume is 574 vehicles/hour in each direction with a PHF of 0.82; this includes 10% trucks ($E_T = 1$) and no RVs.

Questions 4-8 refer to the intersection shown below.



Phase	*g/C*	*Lane Group*	*s*	*v*	*c*
1	0.4	NB Thru/Right	1800	440	
		SB Thru/Right	1800	543	
2	0.3	NB Left	1850	301	
		SB Left	1850	357	
3	0.3	EB Left/Thru/Right	3000	884	
		WB Left/Thru/Right	3000	879	

Note: Lost time and Yellow time are both 4 seconds per phase.

(12 pts) 4. Calculate the ***capacity*** of each lane group and record your answer in the table above.

(12 pts) 5. If the desired X_c is 0.9, how long should the ***cycle length*** be according to the HCM method?

(12 pts) 6. What would the ***capacity*** of the southbound thru/right lane group become if a bus stop was added on the southbound approach, with 10 buses stopping per hour?

(16 pts) 7. Describe how you would use the information given and your answers to questions 4 and 5 to complete a LOS operations analysis of the intersection. (Show equations and identify tables you would use.)

(8 pts) 8. A summary of the LOS analysis results is shown below.

Lane Group	*Lane Group LOS*	*Approach LOS*	*Intersection LOS*
NB T/R	C	C	D
NB L	B		
SB T/R	C	C	
SB L	B		
EB L/T/R	E	E	
WB L/T/R	E		

An analysis of related crash data also shows that a high number of angle crashes occurred in the last two years.

What changes (at least two) would you consider making to the signal timing and/or intersection geometry? Explain briefly.

BONUS: *(+4 points)*
According to Prof. Ray, what four elements are needed for a good MQP?

CE3050 Exit Survey – A2003/04

At the beginning of this course, your instructor identified twelve learning objectives (listed below) on which the course would focus. Please complete the table below by indicating the following:

(1) Which objectives, if any, do you think were particularly difficult to master? (mark with a "Y" or other obvious indication)

(2) Rate your achievement of each objective, from 1 to 4. (1 = minimal understanding; 4 = complete understanding.)

(3) For each objective, indicate how well your achievement was assessed by the homework, exams and/or lab exercises. Since you have not yet been tested on objectives 7-12, rate these on homework or lab assessment only. (1 = bad assessment; 4 = excellent assessment.)

Learning Objectives: Be able to…	**Particularly difficult?**	**Your achievement** (1 to 4)	**Exam/lab assessment** (1 to 4)
1. Identify organizations and careers involved in the design, construction and maintenance of transportation systems.			
2. Explain how characteristics of people and vehicles affect transportation operations.			
3. Determine the functional classification of a road.			
4. Collect and analyze traffic data.			
5. Apply the travel demand forecasting process to a basic planning scenario.			
6. Use traffic flow models to understand the relationships among volume, speed and capacity.			
7. Identify data needed to determine the level of service of a basic highway or freeway segment; describe or perform a level-of-service analysis.			
8. Choose an appropriate control type for an intersection.			
9. Develop a signal timing plan for a signalized intersection.			
10. Determine the capacity of lane groups at a signalized intersection.			
11. Identify data needed to determine the level of service of a signalized intersection; describe or perform a level-of-service analysis.			
12. Use data to assess safety at an existing roadway segment or intersection.			

Extra Questions for IDEA Short Form "Student Reactions"

19. Which of the following was most helpful to you in understanding the course material?
    a. reading assignments
    b. lectures
    c. lecture notes/slides on MyWPI
    d. homework
    e. lab exercises

20. What is your area of concentration within CEE?
    a. CPM, Geotechnical, or Structural
    b. Environmental
    c. Transportation
    d. Undecided or Other (within CEE)
    e. Not a CEE major (ME, MA, etc.)

For each of the following statements, indicate if you disagree or agree with the statement. (1 = strongly disagree, to 5 = strongly agree)

21. This course was boring.
22. The material covered in this course will be useful to me in my career.
23. This course was challenging.
24. Transportation engineering is a rewarding career.
25. Traffic engineers have an easy job.
26. Traffic engineering requires a significant amount of specialized knowledge.
27. I am interested in working in the field of transportation engineering.
28. I read the reading assignments on a regular basis.

Possible topics for comments:

What did you particularly like or dislike about this class?

Can you suggest anything that the instructor might do to improve this course?

Any comments on teaching methods (lectures, lab exercises, etc.)?

The IDEA Short Form Report for **WEIR, JA**

Civil Engineering 3050 (MTWU 03:00), Fall 2003-2004
WORCESTER POLYTECHNIC INSTITUTE

Number Enrolled: 37
Number Responding: 35
94.6 % Responding

Your results are considered reliable; re-rating by the same students would be unlikely to produce a report resulting in different conclusion. The percentage of enrollees who provided ratings is high; results can be considered representative of the class as a whole.

Sections and Purposes of the Report

Page	Section	Purpose
2	I. Overall Measures of Teaching Effectiveness	Provides **global assessment** of teaching effectiveness. Use with pages 3 and 4 for administrative use in making personnel recommendations.
3	II. Student Ratings of Progress on Relevant Objectives	Provides student **self-report of learning** on objectives identified as relevant (*Important* or *Essential*) by the instructor
4	III. Course Description/Context	Primarily to **assist in interpreting** the results by considering the context in which the course was taught
4	IV. Statistical Detail	Primarily to provide details which may help you or your consultants to **understand or interpret** the report accurately

Definitions

Raw Score: Results obtained by using students' numerical ratings, all of which are based on a scale of 1 (low) to 5 (high).

Adjusted Score: Ratings have been statistically adjusted to take into account factors that affect ratings but are not under the instructor's control: student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

T Score: A statistically derived score that makes it easy to compare various measures. Unlike raw scores which have different averages and standard deviations (variabilities), T Scores all have an average of 50 and a standard deviation of 10. This means that 40% of all T Scores will be in the range of 45-55, while less than 2% will be below 30 or above 70.

Understanding the Graphs

Most results are presented on graphs. Unadjusted T Scores are shown by the symbol ×; adjusted T Scores are shown by the symbol ◆. In most cases, we use a line on both sides of a symbol to indicate that ratings have a "margin of error"; the line represents ± one standard error of measurement, a statistical indication of the reliability of the measure.

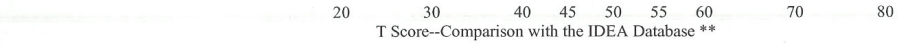
A Few Words of Caution

1. Normative information was updated using classes rated during the 1998-99, 1999-2000, and 2000-2001 academic years. **Exercise caution when comparing T Scores with those for classes processed prior to December 1, 2001.** The new norms have slightly higher item averages. Therefore, T Scores for a given average will be somewhat lower than those for past years. If results are being summarized with classes processed prior to December 1, 2001, review both T Scores and raw scores to determine if differences are due to a more competitive normative group or if the item averages have actually changed.
2. The process for adjusting scores was updated on October 7, 2002. Use caution when comparing adjusted scores with classes processed prior to that date.
3. Student ratings can make a useful contribution to the appraisal of teaching effectiveness and to the development of improvement strategies. However, they have distinct limitations that need to be acknowledged before appropriate use can be made of them. Please read ***Overview of Student Ratings: Value and Limitations***. (www.idea.ksu.edu)

Section I. Overall Measures of Teaching Effectiveness

This section compares your results with those for other instructors and courses in the national database on four OVERALL MEASURES OF TEACHING EFFECTIVENESS. **The primary value of this information is to aid in making administrative recommendations; if this is the only use you will make of the report, you need to consult only these results along with page 3 and the context provided by Section III, page 4.** Please remember that most of the classes included in the database have been taught in a reasonably successful manner; therefore, a rating which is "below average" does not necessarily mean that the quality of instruction was unacceptable. Additional sources of evidence should always be used to review teaching effectiveness.

Overall Measure of Effectiveness	T Score Unadj. / **Adj.**	2% of all classes	28% of all classes	40% of all classes (Avg. range)	28% of all classes	2% of all classes	Your Average * (5-Point Scale) Raw	Adjusted	IDEA Average
1. Progress on Relevant (Essential and Important) Objectives	49 / **46**						NA_1	NA_1	NA_1
2. Improved Student Attitude	46 / **39**						3.6	3.2	3.9
3. Overall Excellence of Teacher	38 / **36**						3.4	3.3	4.2
4. Overall Excellence of Course	44 / **38**						3.6	3.2	3.9



T Score--Comparison with the IDEA Database **

⊢×⊣ Unadjusted T Score ± one standard error of measurement
⊢◆⊣ Adjusted T Score ± one standard error of measurement: adjusted for student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

You may wish to assign these ratings to categories like those that have been used historically with the IDEA system. Simply assign T Scores to categories as follows: **Low** (lowest 10%)=T Score below 37; **Low Average** (next 20%)=T Score 37-44; **Average** (middle 40%)=T Score 45-55; **High Average** (next 20%)=T Score 56-63; and **High** (highest 10%)=T Score above 63.

1. Progress on Relevant (Essential and Important) Objectives. Because student learning is the central purpose of teaching, and because you chose the objectives considered by this measure, this is probably the most vital measure of effectiveness. A double weight is given to student ratings of progress on objectives you chose as ***Essential***, and a single weight to those chosen as ***Important***; objectives identified as being of ***Minor or No Importance*** were ignored in developing this measure.

2. Improved Student Attitude. The graph shows the average response of students to item 16, "As a result of taking this course, I have more positive feelings toward this field of study." This rating is most meaningful for courses that are taken by many non-majors. Most teachers hope that such students will develop a respect and appreciation for the discipline even if they choose to take no additional courses in it. The IDEA national average for this item is 3.9.

3. Overall Excellence of Teacher. This shows the average response to item 17, "Overall, I rate this instructor an excellent teacher." Overall impressions of a teacher affect student attitudes, effort, and learning. The IDEA national average for this item is 4.2.

4. Overall Excellence of Course. This shows the average response to item 18, "Overall, I rate this course as excellent." This evaluation is likely determined by a number of factors (e.g., teaching style, student satisfaction with course outcomes, and characteristics such as organization, selection of readings and/or other influences). The IDEA national average for this item is 3.9.

NA_1: Based on a combination of ratings where an average on a 5-point scale is not comparable.

* Statistically, adjustments can exceed 5.0 on the 5-point scale. If this occurs, "Your Average," reported in the table above, will be rounded to 5.0. However, the T Score reported will reflect the actual adjusted score, which may exceed 5.0. Therefore, identical adjusted scores of 5.0 may have different adjusted T Scores.

** Normative information (T Scores) was updated on December 1, 2001. See page 1 for "A Few Words of Caution."

Section II. Student Ratings of Progress on Relevant Objectives

This graph shows student progress ratings on the objectives you chose as ***Essential*** (Part A) and those you chose as ***Important*** (Part B). To the degree that students make progress on the objectives you stress, your teaching has been effective.

Part A. Essential Objectives	T Score Unadj. / **Adj.**	2% of all classes	28% of all classes	40% of all classes (Avg. range)	28% of all classes	2% of all classes	Your Average * (5-Point Scale) Raw	Adjusted	IDEA Average
1. Factual knowledge	50 / **47**						4.0	3.8	4.0
2. Principles and theories	49 / **47**						3.9	3.8	3.9
Part B. Important Objectives									
4. Professional skills, viewpoints	48 / **45**						3.9	3.8	4.0
9. Use of resources to answer questions	45 / **45**						3.5	3.5	3.7

20 30 40 45 50 55 60 70 80

T Score--Comparison with the IDEA Database where the Objective was Selected as "Essential" or "Important" **

⊢×⊣ Unadjusted T Score ± one standard error of measurement
⊢◆⊣ Adjusted T Score ± one standard error of measurement: adjusted for student work habits (item #13); student desire to take the course regardless of who taught it (item #15); and instructor reported class size.

Similar to Section I, you may wish to assign ratings to categories. Simply assign T Scores to categories as follows: **Low** (lowest 10%)=T Score below 37; **Low Average** (next 20%)=T Score 37-44; **Average** (middle 40%)=T Score 45-55; **High Average** (next 20%)=T Score 56-63; and **High** (highest 10%)=T Score above 63.

These graphs are intended to help you identify a focus for improving your instructional effectiveness. If student progress ratings on ***Important*** or ***Essential*** objectives are disappointing, you are encouraged to discuss improvement strategies with your department head, the campus faculty development specialist, or a colleague. Such strategies could focus on matters such as teaching methods/styles, class activities and assignments, the text and other readings, assessment/feedback, and the need for course pre-requisites. You might also consider using the IDEA Diagnostic Form the next time you solicit student ratings, since it is designed to help identify specific teaching methods to use in improvement efforts.

Note: Students in your class also rated their progress on the objectives that you classified as being of ***Minor or No Importance.*** These ratings are considered irrelevant in judging your teaching effectiveness. However, a review of student ratings on these objectives, found in **Section IV** (Statistical Detail), may provide you with insights about some "unintended" or "additional" effects of your instruction.

* Statistically, adjustments can exceed 5.0 on the 5-point scale. If this occurs, "Your Average," reported in the table above, will be rounded to 5.0. However, the T Score reported will reflect the actual adjusted score, which may exceed 5.0. Therefore, identical adjusted scores of 5.0 may have different adjusted T Scores.

** Normative information (T Scores) was updated on December 1, 2001. See page 1 for "A Few Words of Caution."

Section III. Course Description/Context

This section describes several aspects of your course. This description summarizes information you supplied when you administered the IDEA form. Information on this page provides the context in which the class was taught, which should guide the interpretation of the ratings. The IDEA Center will conduct additional research on these data to determine more precisely how they can improve interpretation of the report.

Course Description:

Primary Instructional Type: *Lecture*
Secondary Instructional Type: *Field Experience*
Team Taught: *No*
Distance Learning: *No*
Principal Type of Student: *Upperclassmen, majors*

Instructor's Ratings of Special Circumstances:

Positive Impact on Learning: *Previous experience teaching course, Desire to teach course, Control over course management decisions, Student effort, Technical/instructional support*
Neither Positive nor Negative Impact: *Physical facilities and/or equipment, Changes in teaching approach, Adequacy of students' background/preparation*
Negative Impact on Learning:

Instructor's Ratings of Course Requirements:

Much Required: *Mathematical/quantitative work*
Some Required: *Computer applications, Group work, Critical thinking*
None (or little) Required: *Writing, Oral communication, Creative/artistic/design endeavor*

Section IV. Statistical Detail: Item Frequencies, Averages, and Standard Deviations

Items 1-12: Progress on Objectives

Key: 1=Low 2=Low Average 3=Average 4=High Average 5=High

	1	2	3	4	5	Omit	Avg.	s.d.
1.	**0**	**1**	**6**	**20**	**8**	**0**	**4.0**	**0.7**
2.	**0**	**1**	**8**	**19**	**7**	**0**	**3.9**	**0.7**
3.	0	1	7	22	5	0	3.9	0.7
4.	**0**	**1**	**9**	**16**	**8**	**1**	**3.9**	**0.8**
5.	0	1	10	19	5	0	3.8	0.7
6.	7	13	11	4	0	0	2.3	0.9
7.	13	6	11	4	1	0	2.3	1.2
8.	9	11	11	4	0	0	2.3	1.0
9.	**1**	**2**	**16**	**12**	**4**	**0**	**3.5**	**0.9**
10.	7	7	16	5	0	0	2.5	1.0
11.	3	10	17	4	1	0	2.7	0.9
12.	3	8	15	9	0	0	2.9	0.9

Bold items were selected as ***Essential*** or ***Important***.

Items 13-18: Self-Ratings

Key: 1=Definitely False 2=More False Than True 3=In Between 4=More True Than False 5=Definitely True

	1	2	3	4	5	Omit	Avg.	s.d.
13.	1	2	11	15	5	1	3.6	0.9
14.	2	3	8	15	5	2	3.5	1.1
15.	1	3	7	13	10	1	3.8	1.1
16.	1	3	8	17	5	1	3.6	0.9
17.	0	6	11	13	4	1	3.4	0.9
18.	0	6	6	19	3	1	3.6	0.9

Items 19-28: Extra Questions

	1	2	3	4	5	Omit	Avg.	s.d.
19.	0	5	12	16	1	1	3.4	0.8
20.	17	5	5	5	2	1	2.1	1.3
21.	2	9	13	6	3	2	3.0	1.0
22.	6	2	16	7	3	1	3.0	1.2
23.	1	7	18	8	0	1	3.0	0.8
24.	1	4	14	13	2	1	3.3	0.9
25.	3	10	16	3	2	1	2.7	1.0
26.	1	3	7	17	6	1	3.7	1.0
27.	7	3	17	5	2	1	2.8	1.1
28.	8	13	6	4	2	2	2.4	1.2

File: WPI2925.SFR
Class ID: 975812
November 04, 2003

Student Comments (Control Class)

"While I liked the course and did find it challenging, I often found myself day-dreaming during class and never felt compelled to listen in lecture. I would suggest that lecture be more engaging and require the participation of students. Besides that, I felt the class was taught well and the lecture notes provided on myWPI proved extremely helpful for review of material. On a side note, this form of course evaluation sucks, go back to the old form. I believe it better allowed students to express their likes and dislikes in each course." – undecided / other CEE

"I enjoyed the fact that the professor put everything on the Web. I also liked the fact that all the tests were open-book. I disliked almost getting killed setting up the equipment for the traffic count lab (maybe future groups study less busy streets). The only other thing is to maybe have the students choose their lab groups; everyone in my group had conflicting schedules and it made it hard to do the labs together." – environmental

"Make computer programs more available. Warn about safety issues when doing traffic counting on Salisbury St." – CPM / geotechnical / structural*

"The two labs in this course were excellent. They clearly provided a direct link to the material being presented in class. The HW, as with most courses at WPI, were key in understanding the material from class. The lecture slides were not helpful – the notes provided online (used by the prof in class) were far more useful. This professor CLEARLY has a deep understanding of course material. HOWEVER, the prof needs to be more assertive in class. Often times she spoke to the board. She would at times, also, fail to explain where variables were derived from. She's smart, but she needs to learn how to teach. (She was good, otherwise.)" – transportation*

"Write darker on the board, it was hard to see the notes." – environmental

"Spend a class period going over software used for labs. Speak louder in class. Have the class earlier in the day." – transportation*

"The class was not what I expected. Since it is transportation engineering, I was expecting some exposure to transit studies, which is what I am more interested rather than auto traffic. But I guess there was not enough time for that, and it was not the objective, perhaps another course? With all due respect, the instructor must speak up; volume is too low." – undecided / other CEE*

"It would be helpful if there was more instruction with the software needed for the labs. The examples done in lecture were very helpful." – non-CEE

"I liked the hwks for the most part – gave good background for the exam. Liked your notes online – if I missed something I could check them. Make the exams worth less of the final grade – even down to 25% each – exams are stressful and your entire grade rests

heavily on them. Make sure groups get along – my partners were dysfunctional but I couldn't do much about it." – CPM / geotechnical / structural

"It would be helpful to take one or two classes and do a tutorial on the HCS2000 software. I feel that would be rewarding and helpful." – CPM / geotechnical / structural

"I think that this course could have been more useful and fun had we seen more real world application examples. I think that traffic engineering could be an interesting field, but I don't feel that I understand what specifically an engineer in this field would do." – undecided / other CEE

"Homework assignments were extremely helpful." – CPM / geotechnical / structural

"I really liked the proper use of MyWPI. There was a great opportunity to get all the information provided. The instructor was a little boaring. Didn't as much teach the class as talk to herself about the problems. There could have been something to make the class more interesting. A field trip / videos would have been helpful. The HW assignments were good. Not every day was a plus, and 20% of the final grade is a good % for HW. Also it was good to have extra credit. Good class, the TA is hot." – transportation

"Method of teaching was frustrating – I often felt like I was learning more from notes online and book despite going to class everyday. Labs and such could have been really fun (overall material is interesting, just presentation is so dry and full of calculations), but weren't. Prof seems excited and interested in topics, but couldn't really share her enthusiasm." – environmental

"Use board more. Explain what HW is about." – undecided / other CEE

"Like myWPI lecture notes online, HW was very useful." – CPM / geotechnical / structural

"I didn't like that we only have 2 exams that are worth 60% of the grade. Maybe in future you could give some quizzes then exams." – CPM / geotechnical / structural

*Interested in working in the field of transportation engineering.

Total: 17 civils (CPM, structural, geotech), 5 environmental, 5 transportation, 5 other CEE, 2 non-CEE, 1 omit

WEIR, J.A.

WORCESTER POLYTECHNIC INSTITUTE

Fall 2004–2005

Civil Engineering 3050 (MTWUF 3:00)

IDEA Short Form Repo

To learn more, see the Interpretive Guide: www.idea.ksu.edu/shortguide.pdf

There were **42** students enrolled in the course and **24** students responded. Your results are considered **fairly reliable**. The **57**% response rate indicates that results **may not be representative** of the class as a whole.

Summary Evaluation of Teaching Effectiveness

Teaching effectiveness is assessed in two ways: **A. Progress on Relevant Objectives**, a weighted average of student ratings of the progress they reported on objective selected as "Important" or "Essential" (double weighted) and **B. Overall Ratings**, the average student agreement with statements that the teacher and the course were excellent. The **SUMMARY EVALUATION** is the average of these two measures. Individual institutions may prefer to combine these measures in some other manner to arrive at a summary judgment.

Converted Averages are standardized scores that take into account the fact that the average ratings for items on the IDEA form are not equal; students report more progress on some objectives than on others. Converted scores all have the same average (50) and the same variability (a standard deviation of 10); about 40% of them w be between 45 and 55. Because measures are not perfectly reliable, it is best to regard the "true score" as lying within plus or minus 3 of the reported score.

For comparative purposes, use converted averages. Your converted averages are compared with those from all classes in the IDEA database. If enough classes are available, comparisons are also made with classes in the same broad *discipline* as this class and/or with all classes that used IDEA at your *institution*. The *Interpretive Guide* offers some suggestions for using comparative results; **some institutions may prefer to establish their own "standards" based on raw or adjusted scores rather than on comparative standing.**

Both unadjusted (raw) and adjusted averages are reported. The latter makes classes more comparable by considering factors that influence student ratings, yet are beyond the instructor's control. Scores are adjusted to take into account student work habits (item 13), student desire to take the course regardless of who taught it (item 15), and instructor reported class size.

Your Average Scores

	Your Average (5-point scale)	
	Raw	Adj.
A. Progress on Relevant Objectives [1] **Four** objectives were selected as relevant (Important or Essential –see page 2)	3.9	3.8
Overall Ratings		
B. Excellent Teacher	3.9	3.8
C. Excellent Course	3.5	3.2
D. Average of B & C	3.7	3.5
Summary Evaluation (Average of A & D) [1]	**3.8**	**3.7**

[1] If you are comparing Progress on Relevant Objectives from one instructor to another, use the converted average.

Your Converted Average When Compared to All Classes in the IDEA Database

Comparison Category	A. Progress on Relevant Objectives		Overall Ratings: B. Excellent Teacher		Overall Ratings: C. Excellent Course		Overall Ratings: D. Average of B & C		Summary Evaluation (Average of A & D)	
	Raw	Adj.	Raw	Adj.	Raw	Adj.	Raw	Adj.	Raw	Adj.
Much Higher Highest 10% (63 or higher)										
Higher Next 20% (56–62)										
Similar Middle 40% (45–55)	50	47	46				45		48	
Lower Next 20% (38–44)				44	43			41		44
Much Lower Lowest 10% (37 or lower)						37				

Your Converted Average When Compared to Your:

Discipline (IDEA Data)	53	51	50	49	47	43	49	46	51	49
Institution	52	53	46	46	43	44	45	45	49	49

IDEA Discipline used for comparison:
Engineering

Student Ratings of Learning on Relevant (Important and Essential) Objectives

Average unadjusted (raw) and adjusted progress ratings are shown below for those objectives you identified as "Important" or "Essential." **Progress on Relevant Objectives** (also shown on page 1) is a weighted average of student ratings of the progress they reported on objectives selected as "Important" or "Essential" (double weighted). The percent of students rating each as "1" or "2" (either "no" or "slight" progress) and as "4" or "5" ("substantial" or "exceptional" progress) is also reported. These results should help you identify objectives where improvement efforts might best be focused.

	Importance Rating	Your Average (5–point scale)		Percent of Students Rating		Your Converted Average When Compared to Group Averages					
						IDEA Database		IDEA Discipline		Your Institution	
		Raw	Adj.	1 or 2	4 or 5	Raw	Adj.	Raw	Adj.	Raw	Adj.
1. Gaining factual knowledge (terminology, classifications, methods, trends)	**Essential**	**4.1**	**4.0**	**4.5%**	**90.9%**	**52 Similar**	**49 Similar**	**54 Similar**	**53 Similar**	**52 Similar**	**54 Similar**
2. Learning fundamental principles, generalizations, or theories	**Essential**	**3.9**	**3.7**	**13.6%**	**68.2%**	**48 Similar**	**45 Similar**	**51 Similar**	**48 Similar**	**49 Similar**	**49 Similar**
3. Learning to *apply* course material (to improve thinking, problem solving, and decisions)	Minor/None										
4. Developing specific skills, competencies, and points of view needed by professionals in the field most closely related to this course	Important	4.0	3.9	9.1%	86.4%	49 Similar	48 Similar	53 Similar	51 Similar	55 Similar	57 Higher
5. Acquiring skills in working with others as a member of a team	Minor/None										
6. Developing creative capacities (writing, inventing, designing, performing in art, music, drama, etc.)	Minor/None										
7. Gaining a broader understanding and appreciation of intellectual/cultural activity (music, science, literature, etc.)	Minor/None										
8. Developing skill in expressing myself orally or in writing	Minor/None										
9. Learning how to find and use resources for answering questions or solving problems	Important	3.6	3.6	13.6%	59.1%	48 Similar	48 Similar	54 Similar	53 Similar	56 Higher	56 Higher
10. Developing a clearer understanding of, and commitment to, personal values	Minor/None										
11. Learning to *analyze* and *critically evaluate* ideas, arguments, and points of view	Minor/None										
12. Acquiring an interest in learning more by asking my own questions and seeking answers	Minor/None										
Progress on Relevant Objectives		**3.9**	**3.8**			**50**	**47**	**53**	**51**	**52**	**53**

Much Higher = Highest 10% of classes (63 or higher)
Higher = Next 20% (56–62)
Similar = Middle 40% (45–55)
Lower = Next 20% (38–44)
Much Lower = Lowest 10% (37 or lower)

Description of Students

The two items describing your students relate to their academic motivation and work habits and are key factors in developing adjusted ratings.

Student Description	Your Average (5–point scale)	Your Converted Average When Compared to Group Averages					
		IDEA Database		IDEA Discipline		Your Institution	
13. As a rule, I put forth more effort than other students on academic work.	3.8	55	Similar	54	Similar	54	Similar
15. I really wanted to take this course regardless of who taught it.	3.6	55	Similar	55	Similar	45	Similar

Much Higher = Highest 10% of classes (63 or higher)
Higher = Next 20% (56–62)
Similar = Middle 40% (45–55)
Lower = Next 20% (38–44)
Much Lower = Lowest 10% (37 or lower)

Statistical Detail

The details on this page are of interest primarily to those who want to confirm scores reported on pages 1 and 2 or who want to determine if responses to some items were distributed in an unusual manner.

Converted Averages are reported only for relevant learning objectives (Important or Essential –see page 2) and other items for which comparisons were provided.

	Number Responding								Converted Avg.		Comparison Group Average		
	1	2	3	4	5	Omit	Avg.	s.d.	Raw	Adj.	IDEA	Discipline	Institution
1. Gaining factual knowledge (terminology, classifications,...	**0**	**1**	**1**	**15**	**5**	**2**	**4.1**	**0.7**	**52**	**49**	**4.0**	**3.9**	**4.0**
2. Learning fundamental principles, generalizations, or...	**0**	**3**	**4**	**8**	**7**	**2**	**3.9**	**1.0**	**48**	**45**	**3.9**	**3.8**	**3.9**
3. Learning to *apply* course material (to improve thinking, problem...	0	1	5	12	4	2	3.9	0.8	NA	NA	4.0	3.9	3.9
4. Developing specific skills, competencies, and points of...	**0**	**2**	**1**	**14**	**5**	**2**	**4.0**	**0.8**	**49**	**48**	**4.0**	**3.9**	**3.7**
5. Acquiring skills in working with others as a member of a team	0	1	8	8	5	2	3.8	0.9	NA	NA	3.9	3.4	3.0
6. Developing creative capacities (writing, inventing, designing,...	6	4	8	3	1	2	2.5	1.2	NA	NA	3.9	2.9	2.8
7. Gaining a broader understanding and appreciation of...	8	6	4	3	1	2	2.2	1.2	NA	NA	3.7	2.6	2.7
8. Developing skill in expressing myself orally or in writing	7	3	7	4	1	2	2.5	1.3	NA	NA	3.8	2.8	2.8
9. Learning how to find and use resources for answering...	**1**	**2**	**6**	**8**	**5**	**2**	**3.6**	**1.1**	**48**	**48**	**3.7**	**3.4**	**3.3**
10. Developing a clearer understanding of, and commitment to,...	6	2	4	10	0	2	2.8	1.3	NA	NA	3.8	3.0	NA
11. Learning to *analyze* and *critically evaluate* ideas, arguments,...	3	4	6	8	1	2	3.0	1.2	NA	NA	3.8	3.2	3.2
12. Acquiring an interest in learning more by asking my own...	1	2	7	11	1	2	3.4	0.9	NA	NA	3.8	3.5	3.3

Key: 1=No apparent progress 2=Slight progress 3=Moderate progress 4=Substantial progress 5=Exceptional progress Bold=Selected as Important or Essential

13. As a rule, I put forth more effort than other students on...	1	0	6	10	4	3	3.8	0.9	55	NA	3.6	3.7	3.7
14. My background prepared me well for this course's requirements.	1	2	8	9	1	3	3.3	0.9	NA	NA	NA	NA	NA
15. I really wanted to take this course regardless of who taught it.	1	2	5	9	4	3	3.6	1.1	55	NA	3.3	3.4	3.8
16. As a result of taking this course, I have more positive feelings...	1	3	2	9	6	3	3.8	1.2	48	43	3.9	3.7	3.8
17. Overall, I rate this instructor an excellent teacher.	0	1	5	10	5	3	3.9	0.8	46	44	4.2	3.9	4.1
18. Overall, I rate this course as excellent.	0	4	5	10	2	3	3.5	0.9	43	37	3.9	3.7	3.9

Key: 1 = Definitely False 2 = More False than True 3 = In Between 4 = More True than False 5 = Definitely True

Item 14 is an experimental item. Therefore, no comparative information is available.

Additional Questions:

	1	2	3	4	5	Omit	Avg.	s.d.
19.	0	1	2	8	1	12	3.8	0.8
20.	8	0	1	3	0	12	1.9	1.4
21.	2	3	4	2	1	12	2.8	1.2
22.	0	3	4	4	1	12	3.3	1.0
23.	0	2	6	3	1	12	3.3	0.9
24.	0	2	5	4	1	12	3.3	0.9
25.	2	7	3	0	0	12	2.1	0.7
26.	1	1	1	8	1	12	3.6	1.1
27.	4	3	3	1	1	12	2.3	1.3
28.	6	1	4	0	1	12	2.1	1.3

Notes

Dept code selected on FIF: 1408
Dept code used for discipline comparison: 1400

Additional responses to items 19-28 were recorded on some answer sheets as comments. The total response distribution was as follows:

	1	2	3	4	5	Avg
19	0	1	4	11	1	3.7
20	13	0	2	3	0	1.7
21	3	5	7	2	1	3.4
22	0	5	6	5	2	3.2
23	0	2	10	5	1	3.3
24	0	2	8	6	2	3.4
25	2	10	5	1	0	3.7
26	1	1	2	11	3	3.8
27	4	6	5	1	2	2.5
28	8	1	7	1	1	2.2

Student Comments (Experimental Class)

I particularly liked: "online notes, class discussion." Suggestions for improvement: "course overview." – transportation*

"Well organized and planned. Great introduction to the transportation field. However, I would have liked to have seen more topics than just traffic & highway engineering." – unknown concentration

I particularly liked: "notes." Suggestions for improvement: "more time on test." Comments on teaching methods: "Good!" – CPM / geotechnical / structural

"Labs were helpful – need more!!" – CPM / geotechnical / structural

"I liked how the lecture notes were available throughout the entire class on MyWPI. Suggestion: more field work. Teaching methods: maybe class time could be more upbeat and interesting with people getting involved in discussion." – undecided / other within CEE*

"Possibly to boost attendance, reward students with perfect attendance or very few absences." – undecided / other within CEE

"More homework problems – assign problems that are more similar to what we are tested on. Labs are great! Harder problems in lecture – easier or same level on exam (as of now it seems lecture = easy problems, exam = hard problems). Speak a little louder, make it interesting! Slides = GREAT! Class preparation = GREAT! Answering questions = GREAT!" – CPM / geotechnical / structural

"You are in pressure once you get the test. Do the HWs." – unknown concentration

"Hard to hear professor lecturing b/c she doesn't have a loud voice (needs to project better). In class exercises not useful." – CPM / geotechnical / structural

"I don't feel as if the final exam is a good indication of whether you know the class (not enough time)." – CPM / geotechnical / structural

"I liked the slides and HW solutions on MyWPI. No improvements. I enjoyed the [teaching] methods she used." - CPM / geotechnical / structural

*Interested in working in the field of transportation engineering.

Total: 13 civils (CPM, structural, geotech), 0 environmental, 2 transportation, 3 other CEE

APPENDIX C

Detailed Performance Data

Table C-1. Control Class Performance on Pre-test Questions.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*Q12*	*Q13*	*Q14*	*Q15*	*Total*	*%*
1	5	10	10	0	0	0	0	5	0	5	5	0	0	5	5	50	33%
2	0	0	0	0	5	0	0	0	0	5	10	0	0	0	0	20	13%
3	5	0	0	5	5	0	0	5	0	0	0	0	0	0	0	20	13%
4	5	0	5	0	0	10	10	0	0	0	5	0	0	0	0	35	23%
5	0	5	5	0	0	0	0	5	0	0	5	0	0	0	0	20	13%
6	5	5	0	5	0	0	0	10	0	0	5	0	0	0	0	30	20%
7	5	0	5	0	10	0	0	5	0	5	5	0	0	0	5	40	27%
8	5	5	10	10	0	0	0	5	0	10	5	0	0	5	5	60	40%
9	5	10	5	0	10	0	10	10	0	5	5	5	0	0	0	65	43%
10	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	7%
11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	10	10	5	0	0	0	0	10	0	5	10	0	0	0	0	50	33%
13	5	5	0	0	0	0	0	5	0	0	0	0	0	0	0	15	10%
14	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	7%
15	5	5	5	5	5	5	5	5	0	0	10	0	0	0	0	50	33%
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
17	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3%
18	5	0	10	10	5	5	0	5	0	5	10	0	0	5	0	60	40%
19	5	10	0	0	0	0	0	0	0	0	5	0	0	0	0	20	13%
20	5	0	5	5	0	10	5	5	0	10	10	0	0	0	5	60	40%
21	10	5	5	0	0	0	0	5	5	0	10	0	0	0	0	40	27%
22	0	5	0	0	0	0	0	5	0	0	10	0	0	0	0	20	13%
23	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3%
24	5	0	0	5	5	0	0	10	0	5	5	0	0	0	0	35	23%
25	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	15	10%
26	5	10	5	5	5	5	0	0	0	5	5	0	0	0	0	45	30%
27	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
28	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
29	5	0	5	0	0	5	5	10	0	0	10	5	0	0	0	45	30%
30	5	5	0	0	0	0	0	5	0	5	0	0	0	5	0	25	17%
31	5	5	0	0	0	0	0	5	0	0	5	0	0	0	0	20	13%
32	0	5	5	0	0	5	5	5	0	0	0	0	0	0	0	25	17%
33	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	3%
34	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
35	5	10	5	0	0	0	0	0	0	10	10	0	0	0	0	40	27%
36	5	10	5	5	5	0	0	5	0	0	5	5	5	0	5	55	37%
37	5	0	10	0	0	0	5	5	0	0	5	0	0	0	0	30	20%
Mean	4.4	4.2	3.2	1.7	1.7	1.4	1.4	4.1	0.2	2.3	4.7	0.5	0.2	0.6	0.8	31.1	21%
Std. Dev.	2.4	4.0	3.5	3.0	3.0	2.9	2.9	3.4	0.9	3.3	3.9	1.5	0.9	1.7	1.8	18.7	12%

Table C-2. Experimental Class Performance on Pre-test Questions.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*Q12*	*Q13*	*Q14*	*Q15*	*Total*	*%*
1	5	5	0	0	5	0	0	5	0	5	0	0	0	0	0	25	17%
2	10	0	5	5	5	0	0	5	0	5	5	0	0	5	5	50	33%
3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3%
4	10	5	10	10	10	10	5	10	0	10	10	10	0	5	10	115	77%
5	5	10	5	5	5	5	0	0	0	0	0	0	0	0	0	35	23%
6	5	5	10	0	0	0	5	10	0	5	10	0	0	0	0	50	33%
7	5	5	0	5	5	0	0	0	0	0	5	0	0	0	0	25	17%
8	5	5	0	0	0	0	0	5	0	5	5	0	0	0	0	25	17%
9	0	0	0	0	0	0	5	5	0	0	5	0	0	0	0	15	10%
10	5	5	0	0	0	0	0	10	0	5	0	0	0	0	0	25	17%
11	5	5	0	0	0	5	5	5	0	0	0	0	0	0	0	25	17%
12	5	5	0	0	0	5	5	5	0	0	5	0	0	5	5	40	27%
13	5	0	0	5	5	0	0	5	0	0	5	0	0	0	0	25	17%
14	5	0	0	5	5	5	0	0	0	0	0	0	0	0	5	25	17%
15	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	10	7%
16	5	5	5	0	0	0	0	5	0	5	5	0	0	0	0	30	20%
17	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	7%
18	0	0	0	5	5	0	0	0	0	0	5	0	0	0	0	15	10%
19	5	10	5	5	0	5	5	5	0	0	5	5	0	0	0	50	33%
20	0	0	5	0	0	0	0	5	0	5	5	0	0	5	5	30	20%
21	0	5	0	0	0	5	0	0	0	5	5	0	0	0	0	20	13%
22	0	5	0	0	0	0	0	5	0	5	5	0	0	0	0	20	13%
23	5	5	0	0	5	0	5	5	0	5	0	0	0	0	0	30	20%
24	0	0	0	0	0	5	0	5	0	0	5	0	0	0	0	15	10%
25	0	0	0	5	5	5	5	0	0	5	5	0	0	0	0	30	20%
26	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	10	7%
27	5	10	0	5	0	5	5	5	0	5	10	0	0	0	0	50	33%
28	5	0	0	0	0	0	0	5	0	0	0	0	0	0	0	10	7%
29	10	5	5	5	0	5	0	0	0	5	0	0	0	0	0	35	23%
30	10	5	0	5	0	0	0	10	0	5	10	0	0	0	5	50	33%
31	5	0	5	0	0	0	5	0	0	0	5	0	0	0	0	20	13%
32	0	5	0	0	0	0	10	0	0	5	0	0	0	0	0	20	13%
33	5	5	5	5	5	5	5	10	0	0	0	0	0	0	0	45	30%
34	5	5	0	0	0	0	0	5	0	0	5	0	0	0	0	20	13%
35	5	0	5	0	0	0	5	5	0	0	5	0	0	5	5	35	23%
36	5	5	5	0	0	0	0	0	0	0	5	0	0	0	0	20	13%
37	10	10	0	0	0	0	0	5	0	5	5	0	0	0	0	35	23%
38	5	10	5	5	0	5	5	10	5	5	10	0	5	5	0	75	50%
39	10	10	0	5	5	5	0	5	0	0	5	5	0	0	0	50	33%
40	5	5	0	0	0	0	0	5	0	0	0	0	0	0	0	15	10%
41	5	10	5	10	5	5	10	5	0	5	5	5	0	5	5	80	53%
Mean	4.5	4.3	2.0	2.2	1.7	2.1	2.2	4.1	0.1	2.4	3.8	0.6	0.1	0.9	1.1	32.1	21%
Std. Dev.	3.1	3.7	3.1	3.1	2.8	2.8	2.8	3.3	0.9	2.9	3.0	2.3	0.9	2.2	2.6	23.2	15%

Table C-3. Control Class Performance on Exam 1.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Total*
1	15	18	15	15	6	12	6	3	90
2	15	18	10	18	6	12	6	6	91
3	12	15	5.5	6	6	12	3	3	62.5
4	12	18	18	18	6	12	6	3	93
5	15	15	0	18	6	12	6	3	75
6	12	15	12	18	6	12	6	3	84
7	14	18	12	6	6	12	6	3	77
8	12	6	9	12	6	12	6	3	66
9	12	10	1	18	6	12	6	6	71
10	6	18	9	18	6	12	3	6	78
11	12	18	9	18	6	9	6	6	84
12	12	18	11	9	6	12	6	6	80
13	12	18	11	12	6	12	6	3	80
14	12	12	11	15	6	12	6	5	79
15	9	18	18	18	6	12	6	5	92
16	15	15	5	6	6	12	6	5	70
17	15	18	15	18	6	12	6	6	96
18	9	15	11.5	15	6	9	3	5	73.5
19	12	15	3	0	6	12	5	5	58
20	12	12	5	9	6	12	3	3	62
21	12	18	9	18	6	12	6	6	87
22	15	18	18	12	5	12	6	6	92
23	12	18	17	18	6	9	6	6	92
24	6	18	6	12	6	12	6	3	69
25	12	12	8	10	6	9	6	3	66
26	9	18	14	6	6	12	5	6	76
27	12	18	8	18	6	12	3	6	83
28	9	18	8	18	0	12	3	5	73
29	12	18	12	18	6	12	5	5	88
30	12	18	0	18	0	9	6	6	69
31	12	18	18	12	6	12	6	3	87
32	12	18	12	18	6	12	6	3	87
33	12	18	15	18	6	12	6	5	92
34	12	18	11	12	6	12	3	6	80
35	15	18	15	18	6	12	6	6	96
36	12	6	5	18	6	9	3	6	65
37	12	15	11	6	6	9	6	3	68
Possible	*15*	*18*	*18*	*18*	*6*	*12*	*6*	*6*	*99*
Mean %	80%	89%	57%	78%	94%	95%	88%	77%	80%
Std. Dev.	14%	18%	27%	28%	23%	10%	20%	22%	11%

Table C-4. Experimental Class Performance on Exam 1.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Total*
1	15	18	18	15	6	12	6	6	96
2	12	12	2	18	5	12	6	6	73
3	13	15	18	15	6	12	6	6	91
4	12	18	12	15	6	12	6	5	86
5	11	18	17	15	6	12	6	5	90
6	15	18	18	18	6	12	6	6	99
7	9	18	9	18	6	12	6	6	84
8	15	18	12	18	6	12	6	3	90
9	14	18	4	18	6	12	6	5	83
10	9	18	12	12	6	12	6	5	80
11	15	18	18	15	6	12	6	4	94
12	12	18	18	12	0	12	6	3	81
13	12	15	11	15	6	12	6	6	83
14	12	18	3	18	6	12	6	3	78
15	15	18	4	18	6	12	6	3	82
16	15	18	14	15	5	12	6	3	88
17	12	18	9	18	6	6	6	3	78
18	12	15	12	18	6	12	6	6	87
19	9	15	15	18	6	12	6	3	84
20	9	12	5	18	6	12	6	6	74
21	12	12	18	18	0	12	6	3	81
22	12	18	15	18	6	12	6	6	93
23	9	16	9	15	6	6	6	3	70
24	9	18	18	18	6	12	6	3	90
25	12	18	4	18	6	12	6	6	82
26	13	18	18	18	6	12	6	3	94
27	6	17	14	12	6	12	6	5	78
28	6	18	13	12	6	9	6	3	73
29	12	18	10	18	0	12	6	3	79
30	10	12	8	15	6	12	6	5	74
31	13	18	18	18	6	12	6	4	95
32	15	18	8	18	6	12	6	3	86
33	15	18	11	15	6	12	0	3	80
34	15	18	18	18	6	12	6	6	99
35	15	18	11	18	6	12	0	3	83
36	12	18	18	18	6	12	6	6	96
37	12	6	16	12	6	12	5	3	72
38	10	12	8	18	6	12	6	3	75
39	6	18	7	15	6	12	6	5	75
40	15	18	9	18	6	12	6	6	90
41	9	12	0	18	6	11	6	6	68
Possible	*15*	*18*	*18*	*18*	*6*	*12*	*6*	*6*	*99*
Mean %	79%	91%	65%	91%	92%	97%	95%	74%	85%
Std. Dev.	18%	15%	29%	12%	26%	11%	22%	22%	8%

Table C-5. Control Class Performance on Exam 2.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Total*
1	10	12	16	12	11	12	12	8	93
2	12	6	12	2	11	9	14	8	74
3	4	0	12	12	10	6	12	4	60
4	12	6	15	12	9	10	12	8	84
5	8	12	6	12	11	10	0	8	67
6	12	0	13.5	12	5	3	12	8	65.5
7	12	6	16	12	11	12	12	8	89
8	2	6	13	12	11	6	10	8	68
9	8	4	13	12	8	0	10	8	63
10	8	6	11	12	10	9	10	8	74
11	0	8	15	12	7	12	0	8	62
12	0	12	14	12	11	12	10	0	71
13	0	0	10	12	3	12	12	8	57
14	0	8	12	12	1	0	14	8	55
15	12	6	16	12	12	10	16	8	92
16	0	0	12	12	10	12	12	8	66
17	6	6	15	12	11	9	12	4	75
18	12	12	13	12	11	0	12	8	80
19	8	0	12	4	12	10	16	8	70
20	2	8	11	12	11	0	16	8	68
21	8	4	15	12	11	12	16	8	86
22	12	8	13	6	11.5	10	12	8	80.5
23	6	10	15	12	12	12	12	8	87
24	8	8	14	12	11	10	14	8	85
25	0	0	9	12	2	0	0	8	31
26	8	8	15	12	9	10	16	8	86
27	8	10	12	12	9	0	12	8	71
28	0	2	12	0	11	0	12	8	45
29	11	0	12	12	9	11.5	8	0	63.5
30	0	2	4	12	2	10	0	8	38
31	12	12	14	12	11	10	12	8	91
32	0	8	13	12	10	7	4	8	62
33	0	4	13	12	11	12	16	8	76
34	8	2	13.5	6	11	12	12	4	68.5
35	0	6	14	12	11	12	12	8	75
36	0	2	13	0	4	0	0	0	19
37	12	8	15	12	11	11	12	8	89
Possible	*12*	*12*	*16*	*12*	*12*	*12*	*16*	*8*	*100*
Mean %	50%	48%	80%	88%	77%	66%	67%	88%	70%
Std. Dev.	40%	33%	16%	29%	26%	38%	30%	29%	17%

Table C-6. Experimental Class Performance on Exam 2.

Student	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Total*
1	0	0	11	12	12	12	16	8	71
2	0	0	15	12	10	0	4	8	49
3	6	0	14	12	10	0	0	8	50
4	7.5	4	13	12	7	0	0	8	51.5
5	0	10	15	12	9	0	12	4	62
6	12	12	14	12	10	12	12	8	92
7	2	0	15	12	11	0	14	8	62
8	0	0	14	12	11.5	12	16	8	73.5
9	12	0	14	12	10	0	15	0	63
10	10	11	15	12	0	12	14	8	82
11	12	12	15	12	11.5	12	16	8	98.5
12	0	2	14	12	10	0	14	8	60
13	0	0	14	12	11	12	16	8	73
14	0	0	0	12	9	0	14	8	43
15	0	0	12.5	12	4	0	12	8	48.5
16	6	10	13	12	12	11	14	8	86
17	0	0	15	8	10	1	15	8	57
18	12	8	15	12	12	12	16	8	95
19	12	8	14	0	11	0	15	8	68
20	12	0	13	12	11	12	1	0	61
21	11	0	16	9	10.5	1	15	8	70.5
22	0	12	14	11.5	11	11	16	8	83.5
23	4	0	12	12	6	0	0	4	38
24	0	0	14	12	11.5	12	0	8	57.5
25	0	0	14.5	12	10	0	14	8	58.5
26	0	0	15	12	10	0	12	8	57
27	0	0	15	12	10	3	14	8	62
28	0	0	15	12	9	0	8	8	52
29	2	12	15	12	11	0	14	8	74
30	12	10	0	9	12	12	12	8	75
31	8	0	15	12	12	12	16	8	83
32	0	0	3	2	5	0	0	0	10
33	4	8	14	12	5	0	16	8	67
34	8	0	15	12	11.5	11	10	8	75.5
35	11	0	7	12	9	0	14	8	61
36	8	1	15	12	12	11	16	8	83
37	8	4	15	12	11	11	4	8	73
38	11.5	0	2	12	12	0	14	4	55.5
39	10	0	15	12	11	0	16	8	72
40	0	0	15	12	11	0	14	8	60
41	0	0	7	12	0	0	12	8	39
Possible	*12*	*12*	*16*	*12*	*12*	*12*	*16*	*8*	*100*
Mean %	40%	28%	81%	92%	80%	42%	72%	89%	65%
Std. Dev.	42%	40%	25%	22%	22%	47%	35%	29%	17%

Table C-7. Control Class Performance (%) on Exams by Objective.

Student	*Objective #*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	50	100	100	100	83	88	100	100	92	100	83	83
2	100	100	100	100	56	100	75	50	92	46	92	100
3	50	100	80	83	31	50	75	0	83	75	67	33
4	50	100	80	100	100	100	94	50	75	92	83	100
5	50	100	100	83	0	100	38	100	92	92	33	67
6	50	100	80	83	67	100	84	0	42	63	83	100
7	50	100	93	100	67	50	100	50	92	100	83	100
8	50	100	80	33	50	75	81	50	92	75	75	17
9	100	100	80	56	6	100	81	33	67	50	75	67
10	100	100	40	100	50	100	69	50	83	88	75	67
11	100	75	80	100	50	100	94	67	58	100	33	0
12	100	100	80	100	61	63	88	100	92	100	42	0
13	50	100	80	100	61	75	63	0	25	100	83	0
14	83	100	80	67	61	88	75	67	8	50	92	0
15	83	100	60	100	100	100	100	50	100	92	100	100
16	83	100	100	83	28	50	75	0	83	100	83	0
17	100	100	100	100	83	100	94	50	92	88	67	50
18	83	75	60	83	64	88	81	100	92	50	83	100
19	83	100	80	83	17	25	75	0	100	58	100	67
20	50	100	80	67	28	63	69	67	92	50	100	17
21	100	100	80	100	50	100	94	33	92	100	100	67
22	100	100	100	100	100	71	81	67	96	67	83	100
23	100	75	80	100	94	100	94	83	100	100	83	50
24	50	100	40	100	33	75	88	67	92	92	92	67
25	50	75	80	67	44	67	56	0	17	50	33	0
26	100	100	60	100	78	50	94	67	75	92	100	67
27	100	100	80	100	44	100	75	83	75	50	83	67
28	83	100	60	100	44	75	75	17	92	0	83	0
29	83	100	80	100	67	100	75	0	75	98	33	92
30	100	75	80	100	0	75	25	17	17	92	33	0
31	50	100	80	100	100	75	88	100	92	92	83	100
32	50	100	80	100	67	100	81	67	83	79	50	0
33	83	100	80	100	83	100	81	33	92	100	100	0
34	100	100	80	100	61	75	84	17	92	75	67	67
35	100	100	100	100	83	100	88	50	92	100	83	0
36	100	75	80	33	28	100	81	17	33	0	0	0
37	50	75	80	83	61	50	94	67	92	96	83	100
Mean	77	95	80	89	57	82	80	48	77	77	74	50
Std. Dev.	22.3	9.8	14.5	18.0	27.3	20.4	15.6	32.7	25.5	26.4	24.2	40.4

Table C-8. Experimental Class Performance (%) on Exams by Objective.

Student	*Objective #*											
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	100	100	100	100	100	88	69	0	100	100	100	0
2	100	100	80	67	11	96	94	0	83	50	50	0
3	100	100	87	83	100	88	88	0	83	50	33	50
4	83	100	80	100	67	88	81	33	58	50	33	63
5	83	100	73	100	94	88	94	83	75	50	67	0
6	100	100	100	100	100	100	88	100	83	100	83	100
7	100	100	60	100	50	100	94	0	92	50	92	17
8	50	100	100	100	67	100	88	0	96	100	100	0
9	83	100	93	100	22	100	88	0	83	50	63	100
10	83	100	60	100	67	75	94	92	0	100	92	83
11	67	100	100	100	100	88	94	100	96	100	100	100
12	50	100	80	100	100	50	88	17	83	50	92	0
13	100	100	80	83	61	88	88	0	92	100	100	0
14	50	100	80	100	17	100	0	0	75	50	92	0
15	50	100	100	100	22	100	78	0	33	50	83	0
16	50	100	100	100	78	83	81	83	100	96	92	50
17	50	50	80	100	50	100	94	0	83	38	96	0
18	100	100	80	83	67	100	94	67	100	100	100	100
19	50	100	60	83	83	100	88	67	92	0	96	100
20	100	100	60	67	28	100	81	0	92	100	4	100
21	50	100	80	67	100	75	100	0	88	42	96	92
22	100	100	80	100	83	100	88	100	92	94	100	0
23	50	50	60	89	50	88	75	0	50	50	17	33
24	50	100	60	100	100	100	88	0	96	100	33	0
25	100	100	80	100	22	100	91	0	83	50	92	0
26	50	100	87	100	100	100	94	0	83	50	83	0
27	83	100	40	94	78	75	94	0	83	63	92	0
28	50	75	40	100	72	75	94	0	75	50	67	0
29	50	100	80	100	56	75	94	100	92	50	92	17
30	83	100	67	67	44	88	0	83	100	88	83	100
31	67	100	87	100	100	100	94	0	100	100	100	67
32	50	100	100	100	44	100	19	0	42	8	0	0
33	50	100	100	100	61	88	88	67	42	50	100	33
34	100	100	100	100	100	100	94	0	96	96	75	67
35	50	100	100	100	61	100	44	0	75	50	92	92
36	100	100	80	100	100	100	94	8	100	96	100	67
37	50	100	80	33	89	75	94	33	92	96	50	67
38	50	100	67	67	44	100	13	0	100	50	75	96
39	83	100	40	100	39	88	94	0	92	50	100	83
40	100	100	100	100	50	100	94	0	92	50	92	0
41	100	92	60	67	0	100	44	0	0	50	83	0
Mean	74	97	79	91	65	92	79	25	80	66	78	41
Std. Dev.	22.4	11.3	17.6	15.1	29.3	11.3	26.2	38.0	24.5	27.3	27.6	41.6