

CVEEN 5520/ 6520 (formerly 5840/6840): SAFETY ISSUES IN TRANSPORTATION

Department of Civil and Environmental Engineering, University of Utah

Spring Semester 2001: January 8-April 30

Instructor: Wayne D. Cottrell, Ph.D., P.E.
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Course Hours: Monday and Wednesday 3:00-4:15 P.M.
Room: 617 William Browning Mineral Science Building (WBB)
Office: 117 Energy and Minerals Research Office (EMRO) Building
Office Hours: Monday, Wednesday 10:30-11:45 AM
Tuesday, Thursday 12:30-2:00 PM (and by appointment)

Course Description

The *University of Utah General Catalog 2000-2002* offers the following description: "Safety as it relates to geometrical design, roadside safety, safety management systems, safety analysis, traffic control devices, work zone safety, risk management, education and enforcement, and railroad safety." This ambitious course description indicates an emphasis on the safety aspects of ground transportation. One of the unfortunate by-products of transportation is the numerous injuries and losses of life that are incurred each year. The majority of these are highway-related, so the course emphasizes motor vehicle travel. The purpose of this course is to encourage the student to consider the safety implications of both existing and new transportation projects, and to appreciate the numbers of injuries and fatalities experienced on transportation facilities.

Goal

The goal of this course is to prepare the student for research, applications, programming, and implementation in transportation safety. The student who successfully completes this course might begin as an information provider to the transportation safety management process, either as a consultant, an engineer with a government agency, or a researcher. As the student gains experience, he or she may move into either a decision-making, project management, or advanced study role. The fundamentals of transportation safety analysis, as learned in this course, should continue to form the basis for the student's contributions.

Modules

To reach the goal, this course is divided into three modules:

1. Transportation system safety overview and crash data (Lessons 1-7)
2. Crash data analysis (Lessons 8-15)
3. Motor vehicle crash factors and countermeasures (Lessons 16-27)

Module three is divided into three submodules, as follows:

- 3.1 Skid resistance analysis and design (Lessons 19-22)
- 3.2 Crash cushion design and analysis (Lessons 23-24)
- 3.3 Alcohol-related safety issues and measures (Lessons 25-26)

In short, Modules 1 and 2 emphasize the description and analysis of transportation safety problems, while Module 3 emphasizes designing for and mitigating transportation

safety concerns. In addition to these topics, the student will either discuss or perform research in such topics as rollovers, air bag safety, road safety audits, rail-highway grade crossings, and funding for transportation safety programs. The number of lessons spent on each module may be subject to change depending on the pace of the class, and on external factors, such as inclement weather, that might affect the schedule. The course's topics will be presented as separate pieces, with occasional (but not nearly enough) reference to how the pieces are integrated into an overall transportation safety management system. The student, particularly the graduate student, is challenged to begin making the connections.

Objectives

Upon completion of this course's three modules, both the undergraduate and the graduate student should be able to:

Module 1:

- ?? Describe the duties of a Federal Highway Administration, State Division office Safety Engineer,
- ?? Enumerate some of the activities of traffic safety engineers at the Utah Department of Transportation,
- ?? Understand the distribution of fatalities by mode of transportation in the U.S.,
- ?? List some of the major U.S. transportation safety organizations,
- ?? Recognize the difference between an "accident" and a "crash,"
- ?? Describe the human, machine and environmental components involved in crashes,
- ?? Understand the difference between a "hazard" and a "cause."
- ?? Relate some of the programs and funding amounts available for transportation safety in the Transportation Equity Act for the 21st Century,
- ?? Recount the data elements collected in a typical crash report,
- ?? Define the various levels of crash severity,
- ?? List and understand the numerous crash types,
- ?? Differentiate between the vehicle types provided in a crash database,
- ?? Demonstrate an understanding of the importance of location information to a crash database,
- ?? Indicate an understanding of how the various environmental conditions listed in a crash database are important,
- ?? Diagram or describe the various points of impact in a crash,
- ?? Explain the various time-related items in a crash database and why such information is significant,
- ?? Enumerate the driver and passenger information that is important to the traffic safety engineer or analyst,
- ?? Distinguish between the different types of in-vehicle restraints used by motorists,
- ?? List and describe some of the typical pedestrian and bicyclist actions prior to a motor vehicle-related crash,
- ?? Construct a collision diagram,
- ?? Explain the symbols used in a collision diagram,
- ?? Discuss the purpose of a condition diagram,
- ?? List and describe some of the prominent crash data resources (i.e., crash databases),

- ?? Express some of the concerns associated with crash data,
- ?? Indicate how the engineer prepares for crash data analysis,
- ?? Compute values for exposure-based crash rates, and
- ?? Calculate values for other crash rates, using bases such as population and registered drivers.

Module 2:

- ?? Compute measures of central tendency and dispersion for a set of data,
- ?? Determine the probability value associated with a given problem,
- ?? Describe and calculate conditional probabilities,
- ?? Apply the axioms of probability to various problems,
- ?? Understand and apply Bayes' Theorem,
- ?? Define discrete and continuous random variables,
- ?? Define and apply probability distribution functions, including probability mass functions, cumulative mass functions, probability density functions, and cumulative distribution functions,
- ?? Compute the expected value of a given probability distribution,
- ?? Explain and use the Poisson distribution in traffic safety problems,
- ?? Define the terms commonly used in statistical inference,
- ?? Calculate point and interval estimates for various problems,
- ?? List and discuss the various crash rate analysis methods,
- ?? Use expected value analysis, the classical statistical method, and the rate quality control methods to perform assessments of crash rates,
- ?? Demonstrate an understanding of how regression analysis is performed,
- ?? Apply regression analysis to crashes at intersections,
- ?? Apply previously developed intersection crash prediction equations,
- ?? Define a before-after comparison study,
- ?? Use the normal approximation and modified binomial tests to conduct before-after studies,
- ?? Indicate an understanding of the criticisms of before-after studies,
- ?? Describe the empirical Bayes approach to before-after analysis, and
- ?? Use the empirical Bayes approach to estimate the number of crashes before or after a safety improvement.

Module 3:

- ?? Describe the primary factors involved in motor vehicle crashes,
- ?? Discuss the human factors involved in motor vehicle crashes,
- ?? Discuss the road and environmental factors involved in motor vehicle crashes, including demand, design, weather, control, and surface-related items,
- ?? List and discuss countermeasure to the human, road and environmental factors, including highway design, traffic control, driver-related, and motor vehicle technology measures.
- ?? Review the relative effectiveness of various countermeasures in terms of both crashes forestalled and benefit-cost ratio,
- ?? Evaluate countermeasures in terms of before-after analysis and crashes reduced,
- ?? List the most effective motor vehicle crash countermeasures,

- ?? Define skid resistance,
- ?? Interpret the vehicle motion processes involved in turning, braking and skidding,
- ?? Recount the assumptions of a point-mass model,
- ?? Define friction, coefficient of friction, friction factor, and friction force,
- ?? Describe the longitudinal and radial forces involved in braking and cornering,
- ?? List the design considerations for braking, cornering, and skid avoidance,
- ?? Determine the forces and friction coefficients involved at the impending moment of skidding,
- ?? Demonstrate an understanding of the relationship between the skidding coefficient and the permissible friction factor,
- ?? Define wheel slip,
- ?? Compute the maximum friction factors for both tangential and radial motion,
- ?? Apply the equation of tangential motion to vehicle braking,
- ?? Apply the equation of radial motion to vehicle braking,
- ?? Determine the stopping performance of a vehicle moving tangentially,
- ?? Determine the cornering performance of a vehicle moving radially,
- ?? Calculate the skid distance of a vehicle in a situation that involves skidding,
- ?? Compute design values for radial and tangential friction,
- ?? List the various skid resistance measurement methods,
- ?? Interpret the usage and results of the locked-wheel trailer method,
- ?? List some types of impact attenuators,
- ?? Discuss the parameters and purpose of crash cushion testing,
- ?? Illustrate the crash cushion design process,
- ?? Assess an impact using the impact severity analysis method,
- ?? Understand and apply tolerances to the measurement of impact severity,
- ?? Indicate an understanding of the extent of the alcohol-related motor vehicle crash problem in the U.S.,
- ?? List and discuss some drunk driving countermeasures,
- ?? Briefly expand upon some of the state laws used in drunk driving prevention,
- ?? Outline the structure of a drunk driving safety program, and
- ?? Discuss the effectiveness of various anti-drunk driving strategies.

In addition to the objectives listed above, the graduate student should be able to explain formulas, synthesize and integrate information from the three modules, apply the techniques and concepts learned to real-life situations, appraise methodologies, and be prepared to expand his or her knowledge into areas not specifically covered in this course. For example, each graduate student will be required to prepare an essay on a topic that will not necessarily be discussed in depth during the lessons.

Course Outcomes: Tailored ABET Criteria

Items a-k below represent the ABET criteria for undergraduate degree program outcomes that have been specially tailored to the Department's civil and environmental engineering program. Immediately beneath each item, in italics, is a statement regarding how or if CVEEN 5840/6840 intends to meet the given criterion.

"By the time they graduate, students are expected to have:"

- a. an ability to apply knowledge of mathematics (including differential equations), probability and statistics, science (including calculus-based physics and general chemistry), and engineering problems.

Knowledge of mathematics, including advanced algebra, physics, and probability and statistics are required of the student. The student will apply these tools in homework exercises and on examinations. The applications will be to transportation safety problems. Applications in sciences such as chemistry will not be emphasized in this course.

- b. an ability to design and conduct experiments, as well as to analyze and interpret data in more than one of the recognized major civil engineering areas.

The design and conduct of experiments will not be emphasized in this course. The analysis and interpretation of data, however, is essential to the effectiveness of transportation safety engineering. The student will be regularly required to perform computations with transportation data and discuss the results.

- c. an ability to design a sustainable and buildable civil engineering system, component, or process that meets desired needs and considers life-cycle cost issues.

Transportation safety analysis presents a design component that incorporates both safety factors and benefit-cost analysis. Design, however, is from the perspective of negotiability and rideability, rather than sustainability. Cost issues, in relation to safety, are controversial, because of the difficulty of placing values on disabilities and fatalities. These issues will be discussed during the course.

- d. an ability to function on multi-disciplinary teams.

Transportation safety analysis involves transportation engineering, automotive design, psychology, medicine, and other fields. From the outset of the course, the students are made aware of the interdisciplinary issues involved in transportation safety analysis, and of the different arenas from which the major players come.

- e. an ability to identify, formulate and solve civil engineering problems in at least four of the following areas: structural, geotechnical, transportation, environmental, and water resources.

The students will receive instruction, training and practice in solving transportation safety problems.

- f. an understanding of civic, professional and ethical responsibility, especially as it relates to health and safety, and the importance of professional licensure.

As a result of completing this course, the student should gain an enhanced awareness of the transportation engineer's responsibility toward the safety of transport systems. Topics such as societal benefits and public concerns will be discussed in various contexts.

- g. an ability to communicate effectively using written, graphical, and verbal skills.

Skills in these areas will be required of all students in this course. The homework assignments feature a mixture of writing, plotting and computational exercises. The undergraduate students will be required to turn in weekly half-page papers summarizing the preceding week's lessons. The graduate students are required to prepare an essay documenting their work on a selected topic. Participation in in-class discussions will be expected from all students; a portion of the students' grades will be based on their participation.

- h. the broad education necessary to understand the ethical, economic, environmental, social and political impact of engineering solutions in a global and societal context.

The safety impacts of transportation policies, programs and projects will be discussed in class and examined in a number of exercises. One submodule of the course will feature a review of drunk driving problems, countermeasures and programs. A video presentation will be designed to broaden the students' awareness of the societal issues involved.

- i. a recognition of the need for and the ability to engage in life-long learning and continuing engineering education as a necessary part of professional practice.

Although the importance of this criterion is acknowledged, it will not be explicitly emphasized in this course.

- j. a knowledge of contemporary issues that are affecting our infrastructure and environment.

Many of the topics in this course will be discussed in the context of transportation safety in the state of Utah. One lesson will be devoted to a discussion of current issues in transportation safety. Guest speakers from both the Federal Highway Administration and the Utah Department of Transportation are scheduled to offer the students a variety of perspectives.

- k. an understanding of and the ability to use the techniques, skills (including engineering economics), and tools necessary for professional civil engineering practice.

The students will be required to write, compute, discuss, graph and, in the case of the graduate students, present their work. Probability and statistics skills will be needed during the crash data analysis module. Skills in physics fundamentals will be needed for portions of the motor vehicle crash factors and

countermeasures module. The students will be at liberty to either use computers or perform manual calculations for nearly all of the mathematical problems. The importance of good quality technical writing in achieving professional success will be repeatedly emphasized. Plenty of opportunities for writing and for the assessment of writing skills will be available.

Assessment

The following assessment techniques will be used in this course:

Homework assignments (weekly). The homework assignments will require the students to apply the techniques and consider the concerns covered in both the lessons and in the assigned reading materials. The completion of these problems will involve skills in mathematical computation, usage of spreadsheet software, preparing written summaries of results, preparing short essays, and graphically displaying data.

Minute papers (weekly). Minute papers will be required of the undergraduate students. These will be weekly summaries of the preceding week's lessons. The purposes of these papers will include getting the students to: regularly come to class, pay attention in class, regularly complete a writing exercise, and reveal (to both themselves and to the instructor) subjects in which there is a lack of clarity.

Examinations (two). The first exam will cover the first two modules of the course (roughly the first half of the course), while the second exam will cover the third module, which consists of three submodules. The purpose of these exams will be to evaluate the students' understanding and mastery of the subject matter in a controlled environment. The format of the exams is under development.

Discussions (each lesson). A variety of questioning techniques will be used during the lesson to engage feedback from the students. The questions will be designed to incite discussion, get the students to think, get the students to participate, uncover unclear areas, and reveal a lack of preparation. The questioning techniques might include general questions, calling on students individually, getting the students to think first and then answer, and having pair or small-group discussions before requesting a response. Participation in the discussions will be graded, with a heavier portion of the graduate student's grade allocated to participation.

Essay (one). Each graduate student, instead of completing minute papers, will be required to complete an essay, to be due at the end of the term. Graduate students will be expected to display skills in analysis, synthesis and evaluation (the 4th, 5th and 6th levels of Bloom's taxonomy) in their work.

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Prerequisites: CVEEN 3520 “Transportation Engineering” (or equivalent); introductory probability and statistics, introductory physics.

Grading Systems

“Safety Issues in Transportation” is open to both undergraduate (5840) and graduate (6840) students. The grading systems are different for undergraduate and graduate students. As might be expected, graduate students will be held to higher standards than undergraduates. This expectation will be manifested in the greater amount of work required of graduate students on each homework assignment, longer or modified exams, a greater portion of the grade being based on participation in in-class discussions and exercises, and an essay. In contrast, undergraduate students will not have an essay, but will be required to turn in weekly “Minute Papers” summarizing the previous week’s lessons. An example Minute Paper will be handed out in class. Also, a somewhat lower weight will be placed on classroom participation, with the weighting offset by partially basing the grade on attendance. The grading systems are as follows:

Element	Undergraduates	Graduates
Homework (13 assignments)	35%	35%
Exam 1 (Modules 1 and 2)	20%	20%
Exam 2 (Modules 3, 3.1, 3.2 and 3.3)	20%	20%
Essay	--	15%
Class Participation and Attendance	10%	10%
Minute Papers	15%	--
TOTAL	100%	100%

Classroom and Course Rules

- ?? Homework assignment solutions will, in general, be posted on the wall outside of 117 EMRO by the afternoon of the day following the due date.
- ?? Late homework will be accepted until the solution is posted. Late turn-ins (i.e., after class has concluded) will be subjected to a 5% penalty.
- ?? Late homework will not be accepted once the solution is posted.
- ?? A request for a change in a score or grade must be submitted in writing.
- ?? If a student cannot take an exam during its scheduled time, the exam must be taken *before* the scheduled time. Arrangements are to be made with the instructor.
- ?? Minute papers are due at the beginning of class on Monday (except for the two weeks that include a Monday holiday, in which cases the paper is due on the Wednesday of that week). Late minute papers will not be accepted.
- ?? Courtesy: please do not carry on a non-course related conversation with a classmate while the instructor is speaking.

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Tuesday, Thursday 12:30-2:00 PM (and by appointment)

Textbook: As there is no definitive transportation safety textbook, the required readings for the course will be distributed, in the form of copies from books, papers and reports, throughout the course.

Course Outline

No. ¹	Date	Topics	Reading ²	Assignment Due ³	
				Undergraduate	Graduate
1	Jan. 8	Guest speaker: Kerry Perrillo, FHWA	--		
2	Jan. 10	Guest speaker: Eric Cheng, UDOT	--		
--	Jan. 15	Holiday	--		
3	Jan. 17	Course Objectives & Requirements Transportation Safety Overview	(1) (2)	Minute Paper #1 Homework #1	Homework #1
4	Jan. 22	Crash Data Elements	(3), (4)	Minute Paper #2	
5	Jan. 24	Crash Data (continued) Collision Diagrams	(3), (4)	Homework #2	Homework #2
6	Jan. 29	Crash Data Resources & Concerns	(3), (4)	Minute Paper #3	
7	Jan. 31	Crash Data Analysis Considerations Crash Rates	(3), (5), (6)	Homework #3	Homework #3
8	Feb. 5	Review of Probability & Statistics: Descriptive Statistics Introduction to Probability	(7) (8)	Minute Paper #4	
9	Feb. 7	Review of Probability & Statistics: Conditional Probability Bayes' Theorem Random Variables	(8)	Homework #4	Homework #4
10	Feb. 12	Review of Probability & Statistics: Probability Distributions	(8)	Minute Paper #5	
11	Feb. 14	Review of Probability & Statistics: Poisson Distribution Estimation Crash Rate Analysis	(8) (9)	Homework #5	Homework #5

--	Feb. 19	Holiday			
12	Feb. 21	Crash Rate Analysis Methods Overview of Regression Analysis	(3), (5)	Minute Paper #6 Homework #6	Homework #6
13	Feb. 26	Intersection Crash Prediction Before-After Comparisons	(6)	Minute Paper #7	
14	Feb. 28	Criticisms of Before-After Studies Empirical Bayes Approach	(10)	Homework #7	Homework #7
15	Mar. 5	Empirical Bayes Method & Applications	(10)	Minute Paper #8	
--	Mar. 7	Exam 1 (Modules 1 and 2)			
--	Mar. 12	Spring Break			
--	Mar. 14	Spring Break (continued)			
16	Mar. 19	Causes of Motor Vehicle Crashes Video: National Driving Test	(3), (4), (11)	Minute Paper #9 Homework #8	Homework #8
17	Mar. 21	Motor Vehicle Crashes: Factors and Countermeasures	(3)		
18	Mar. 26	Motor Vehicle Crashes: Factors and Countermeasures Crash Reduction Measurement	(3)	Minute Paper #10 Homework #9	Homework #9
19	Mar. 28	Selecting Countermeasures Skid Resistance: Background	(5) (12)		
20	Apr. 2	Skid Resistance: Braking, Cornering and Friction Video: Winter Driving & Braking	(12)	Minute Paper #11 Homework #10	Homework #10
21	Apr. 4	Skid Resistance: Equations of Vehicle Motion	(12)		
22	Apr. 9	Design for Friction Skid Resistance Measurement	(12) (13)	Minute Paper #12 Homework #11	Homework #11
23	Apr. 11	Impact Attenuators Crash Cushion Design Concerns	(14) (15)		
24	Apr. 16	Crash Cushion Impact Severity	(14)	Minute Paper #13 Homework #12	Homework #12
25	Apr. 18	Alcohol-Related Safety: Concerns and Countermeasures Video: Drunk Driving	(16)		
26	Apr. 23	Alcohol-Related Safety: Programs and Effectiveness	(16)	Minute Paper #14 Homework #13	Homework #13
27	Apr. 25	Discussion of Major Safety-in- Transportation Issues			Essay
--	Apr. 30	Exam 2 (Module 3)			

Notes:

¹ Module 1: Lessons 1-7; Module 2: Lessons 8-15; Module 3: Lessons 16-27.

² The reading assignments will be from the following materials:

1. *TEA-21 -- Transportation Equity Act for the 21st Century: A Summary*. U.S. Department of Transportation, Washington, DC, 1998.
2. Horodniceanu, Michael and Edmund J. Cantilli, *Transportation System Safety*, Lexington Books, Lexington, MA, 1979. Chapter 2, "The Existing Safety Problem in Transportation," pp. 9-20.
3. Institute of Transportation Engineers, *Manual of Transportation Engineering Studies*, H. Douglas Robertson, Joseph E. Hummer, and Donna C. Nels on, editors. Prentice Hall, Englewood Cliffs, NJ, 1994. Chapter 11, "Traffic Accident Studies," pp. 191-218.
4. *Traffic Safety Facts 1998: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, DC, 1999.
5. Garber, Nicholas J. and Lester A. Hoel, *Traffic and Highway Engineering*, 2nd edition, PWS Publishing, Pacific Grove, CA, 1999. Chapter 5, "Highway Safety," pp. 133-175.
6. Roess, Roger P., William R. McShane, and Elena S. Prassas, *Traffic Engineering*, 2nd edition, Prentice Hall, Upper Saddle River, NJ, 1998. Chapter 8, "Accident Studies," pp. 181-205.
7. Devore, Jay L, *Probability and Statistics for Engineering and the Sciences*, 5th edition, Duxbury Thomson Learning, Pacific Grove, CA, 2000. Chapter 1, "Overview and Descriptive Statistics," pp. 11-51.
8. Ayyub, Bilal M. and Richard H. McCuen, *Probability, Statistics, & Reliability for Engineers*, CRC Press, Boca Raton, FL, 1997. Chapter 3, "Fundamentals of Probability," pp. 61-97.
9. Johnson, Richard A., *Miller & Freund's Probability and Statistics for Engineers*, 6th edition, Prentice Hall, Upper Saddle River, NJ, 2000. Chapter 6, "Inferences Concerning Means," pp. 221-233.
10. Hauer, Ezra, *Observational Before-After Studies in Road Safety*, Pergamon, Elsevier Science Ltd., Kidlington, Oxford, U.K., 1997. Chapter 11, "Back to the Starting Point: The Empirical Bayes Approach," pp. 171-211.
11. Evans, Leonard, *Traffic Safety and the Driver*, Van Nostrand Reinhold, New York, NY, 1991. Chapter 6, "Driver Behavior," pp. 133-161.
12. Lamm, Ruediger, Basil Psarianos, and Theodor Mailaender, *Highway Design and Traffic Safety Engineering Handbook*, McGraw-Hill, New York, NY, 1999. Chapter 10, "Safety Criteria III," pp. 10.10-10.54.
13. *Highway Safety Engineering Studies Procedural Guide*, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, November, 1981. Procedure 17, "Skid Resistance Study," pp. 224-234.
14. Lawrence, L.R. and J.H. Hatton, Jr., *Crash Cushions – Selection Criteria and Design*, Federal Highway Administration, Washington, DC, September, 1975.
15. NCHRP Report 350, *Recommended Procedures for Safety Performance Evaluation of Highway Features*. Prepared by H.E. Ross, Jr., D.L. Sicking, and R.A. Zimmer, Texas Transportation Institute, Texas A&M University System, College Station, TX, for the National Cooperative Highway

Research Program, Transportation Research Board, National Research Council, Washington, DC. National Academy Press, 1993.

16. Transportation Research Circular 487, *Combating Impaired Driving in an Era of Diminished Resources and Shifting Priorities*. Prepared by the Committee on Alcohol, Other Drugs, and Transportation, Transportation Research Board, National Research Council, Washington, DC, February 1999 (or a similar type of document).

³ Each assignment is listed next to its corresponding **due** date.

Reading materials will be provided at least one week before the "due" date.

The instructor reserves the right to modify the syllabus during the term according to the pace of the class, the scheduling of guest speakers, equipment-related problems, the acquisition of pertinent materials, and inclement weather.