National University Rail Center - NURail
US DOT OST-R Tier 1 University Transportation Center

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Railway Transportation Engineering (CEE 408) Course Updates and Online Conversion

By

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Railway Transportation Engineering (CEE 408) Course Updates and Online Conversion

Introduction

Course CEE 408 "Railway Transportation Engineering" is a cornerstone of the railway engineering education program developed by the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign (UIUC). Although lectures in this course have been continually improved and presented and data has been updated each year, many elements of the course date to its initial offering in 1999. This project developed new and revised course materials to expand coverage of key concepts that influence the economics and efficiency of railway transportation. The class was restructured to introduce the railway infrastructure, vehicle, motive power and control subsystems in a manner that highlights the key economic drivers behind industry decisions and their impact on the overall efficiency of the railway system in North America. In revising the course content, the class was transitioned to being offered both in the classroom and online commencing in Fall 2013.

Description of Activities

CEE 408 is a full-semester course that is open to graduate students and upper-level undergraduate students at UIUC. Although most students enrolled in the course are in the civil/transportation engineering program at UIUC, students from other departments and campus units with an interest in railway transportation frequently enroll in the course. Upon completion of this project, it was also offered online to non-degree students and students enrolled in the UIUC online M.S. program in civil engineering. When previously taught, CEE 408 covered four major topic areas in the following order:

- Industry overview and passenger operations
- Economics and efficiency
- Track structure
- Railcars
- Train resistance and performance
- Operations

Although this order of lecture topics makes sense from the perspective of building the railway system “from the ground up”, it was often confusing to students. Without knowledge of the size and shape of railcars, it is difficult to explain why the track structure components are sized and designed for specific

loads. Without knowledge of economics and operations, it is difficult to explain key drivers of railcar design and locomotive selection/assignment. The class schedule also pushed large assignments on developing train resistance and performance calculators to the very end of the semester when students are very busy.

This project completely redeveloped and reorganized the order of the lectures to follow a "top down" approach. The new order of lecture topics is as follows:

- Industry overview
- Economics, efficiency and operations
- Railcars
- Train resistance and performance
- Track structure
- Passenger and high-speed rail

The new order of lectures provides students with a sound introduction to the main concepts behind efficiency and economic railway operations. This naturally follows into the design of railcars for safe, efficient and economical operations. With railcars introduced, the lectures on train resistance and performance can be moved earlier in the semester so students have more time to work on assignments related to this topic. Finally, with the rationale for the properties of railcars well defined, the course can move on to the track structure designed to support and guide them in trains. Finally, the course concludes with an introduction to passenger and high-speed rail. This is a good topic to end on because many students are highly interested in these aspects of railway transportation.

Outcomes

The revised course syllabus and schedule developed for CEE 408 through this project are attached to the end of the report.

The course consists of 26 lectures and nearly all of them were modified, expanded or otherwise improved through this project. Many lectures were altered to include worked examples and additional engineering content related to railcar design, track structure and train performance. Three lectures of nearly entirely new content were developed on the following topics:

- Competition, mergers and economic regulation
- Optimization of railcar design for lading density and structural design of railcars
- Highway-rail grade crossings

This project also redeveloped 11 assignments for the course with five of them being brand new:

- Railcar capacity and route tonnage
- Rail and highway efficiency (new assignment)
- Commodity market value
- Fixed and variable costs
- Pricing and competition
- Railcar design (new assignment)
- Railcar structure (new assignment)
- Air brakes
- Train power, resistance, acceleration

- Track (new assignment)
- Grade crossings (new assignment)

The two term tests and final exams were also modified to fit the new course structure.

The redeveloped version of CEE 408 was first taught in Fall 2013 and again during subsequent fall semesters. Enrollment in the course for each of these four years is listed below:

- Fall 2013: 40 students (including 4 online)
- Fall 2014: 49 students (including 1 online)
- Fall 2015: 37 students (including 4 online)
- Fall 2016: 27 students (including 1 online)

Conclusions/Recommendations

From the instructor perspective, revising the order of CEE 408 lecture topics was a complete success. Given the small class size, and that no students were enrolled in both the "new" and "old" versions of the course, it is difficult to definitively quantify if student comprehension of course concepts improved following the redevelopment of the course.

A key lesson learned from this project is that examining an established course from a fresh perspective can improve and reenergize the conduct of the course. New lecture material can reignite instructor enthusiasm for lecture topics that have grown routine, stale or out-of-date. Careful ordering of lecture materials can aid instructor delivery and student comprehension of important course concepts.

Since Fall 2013, where appropriate, the revised lecture materials have been updated annually with the latest industry data. Since the overall order of lectures appears to be successful, no major changes have been made. Additional homework assignments and questions have been developed so that the same assignment materials are not used every academic year.

Publications/Examples

Not applicable.

Primary Contact

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CEE 408 - Fall 2013
Railroad Transportation Engineering
Mondays and Fridays • 3:00 - 4:20 PM • NCEL 2312

Course Syllabus

Instructor Information

Christopher P.L. Barkan, Ph.D
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Teaching Assistant (TA)

Alexander Lovett
Graduate Research Assistant - RailTEC
Email: alovett2@illinois.edu
Telephone: 217-244-6063 (office)

Alexander will be holding office hours at the following times and locations:
• TBD (NCEL TBD)
• TBD (NCEL TBD)
• Other times by appointment (make appointment via email)

Course Web Site (Compass 2G): <https://compass2g.illinois.edu>
Set your Web browser to accept pop-up windows from compass2g.illinois.edu. PDFs of all PPT handouts will be posted on Compass after the class period in which they were given. All reading assignments and course PPTs (PDF format) will be posted on Compass 2G.

Classes: Mondays and Fridays, from 3:00–4:20 PM, Newmark Civil Engineering Laboratory, Room 2312. Occasional make-up classes will be scheduled at times mutually agreed upon by the instructor and students.

Credit: 3 or 4 undergraduate or graduate hours. Graduate students enrolled for 4 credit hours will be required to undertake additional work, as described below.

Prerequisite: CEE 310. Students that have not taken CEE 310 or equivalent may wish to complete additional background reading in order to perform well on the exams and to be in a position to participate fully in class discussions.

Course Description

Rail transportation requires infrastructure, vehicles, motive power and energy to move goods and people. Each of these interacts to affect efficiency, service quality, energy requirements, economics and environmental impact of railroad transport. Railroad technology spawned a transportation revolution that continues to substantially influence national and global markets. This course includes an introduction to the fundamental economics of transportation that shape the role of the railroad mode in freight and passenger transportation. This is followed by consideration of railroad rolling stock design, running gear and other mechanical components, train braking system design, function and dynamics, and locomotive design, operation and function. Quantitative analysis of train resistance and consequent power and train energy requirements including effects of aerodynamics, grade and curvature are covered with consideration of train speed, power and acceleration. Next is an introduction to railroad track system design, components, roadbeds and maintenance required to support the movement of railway vehicles. The course concludes with a discussion of passenger rail transportation, high-speed rail and the technical and operational challenges of increasing the speed and frequency of passenger ral service on existing freight corridors. There will be field trips to railroad facilities to observe infrastructure, equipment and operation.

Course Vision

To provide students a complete picture of the railway transportation mode and its role in the overall freight and passenger transportation system. By giving students a knowledge of the economics, efficiencies, operations and infrastructure requirements of railway transportation they will be prepared to consider a proper balance between all modes and develop more effective solutions for the challenges facing civil engineers engaged in planning, design, construction and operation of transportation systems.

Course Instructor's Mission

Encourage students to develop and/or refine their ability to critically evaluate transportation modes, encourage growth in communication skills, form lasting friendships amongst the class, and leave the class with a strong

foundation in fundamental transportation economics that drive civil engineering projects. Encourage students to consider careers in railway engineering through increased exposure to the railway mode and the possible job opportunities.

Course Objectives

This course will provide you with a foundational knowledge the economics, efficiencies, operations and infrastructure requirements of the railway transportation system and how these characteristics shape the role of the railway mode in the overall freight and passenger transportation system. The railcar portion of the class will allow the students to understand the optimization of the railcar structure and systems and how this leads to the shape and size of railcars and their subsequent space and clearance requirements. The train resistance, power and acceleration portion of the class will provide the student with the tools required to perform basic train performance simulations to determine the running time over a particular railway route. An introduction to basic track design concepts is designed to provide students who may be designing other civil engineering projects that interface with the railway mode in the future basic design tools and an understanding of the requirements and standards for railway infrastructure. Finally, the passenger rail portion of the class will allow you to become conversant in the issues, technical challenges and operational obstacles required to implement high-speed rail in North America and higher-speed rail on existing freight corridors.

Required and Suggested Reading:

- Armstrong, The Railroad; What it is, what it does (5th Edition)
- Hay, W. W., Railroad Engineering, Wiley and Sons (1982)
- Locklin, Economics of Transportation (1972)
- Other selected textbooks, magazines, and manuals (see course schedule and reading list)

You are not required to purchase any of the above textbooks or reference materials. All relevant chapters will be provided on Compass 2G.

Class Sessions

Class sessions will include lectures, discussions of the readings and small group activities. There will also be a field trip for this class to the Monticello Railway Museum in Monticello, IL on Saturday, September 14th Field trips are not required, but If you are unable to attend one of these field trips, please notify the instructor immediately. Finally, please bring calculators and writing materials to all class meetings, as there may be problems that we will be working through individually or as a group.

Assignments

Course assignments will help you achieve the objectives of the course that were described earlier. Unless otherwise specified, all written assignments must be submitted on paper in hard-copy form **AND** via Compass 2G. The filename

for your assignments should be as follows:
"CEE_408_LastName_HomeworkNumber".
Compass 2G submissions should be submitted prior to the class period in which they are due.

Assigned Reading and Discussion

To prepare for the classroom discussions and enhance your understanding of the subject, you will be required to complete the reading assignments prior to the beginning of each class period for which the reading is listed. Reading assignments are listed in the course schedule and PDFs of all reading assignments can be found on Compass2G in the "Reading Assignments" folder.

Examinations

There will be three closed book exams in this course:

- The first exam will be held Monday, October 7 during class
- The second exam will be held Monday, November 11 during class
- The final exam is scheduled for Thursday, December 19, 1:30 pm

Course Grading (3 Credit Hours)

Term Exam #1	22%
Term Exam #2	22%
Final Exam	22%
Homework Assignments	22%
Class Participation*	12%

Note: Plusses and minuses will be given.
*Modified for online students

Course Grading (4 Credit Hours)

In addition to what is listed above, students signed up for 4 credit hours will have an additional 33% added to their grade based on performance in an additional seminar discussion section held each week and W.W. Hay Railroad Engineering Seminar Series attendance.

Four-hour students are expected to attend the W.W. Hay Railroad Engineering Seminar on Fridays at Noon during the Fall semester. Watch for announcements of upcoming seminars via email, the Compass 2G site and in class. Attendance will be taken; please notify the instructors if you have a recurring conflict that prevents attendance.

When there is no Hay seminar scheduled, the extra session will meet on Fridays, 12:00-1:30 PM in TBD NCEL for a discussion of a previously selected paper of interest. All 4-hour students are expected to have read the paper in advance of the extra section and participate in the discussion. Each week, two students will be selected on a rotating basis to prepare a 10-minute presentation to summarize the paper, identify key points for discussion and facilitate the discussion among the 4-hour students. Although the instructors will observe and

participate in the discussion, it is expected that the discussion will be led by the particular students preparing the summary presentation that week. Credit will be given for the quality of the summary presentation and resulting discussion in the leadership role, and also for participation in the discussion hen other students are facilitating.

COURSE POLICIES

This course will follow all policies in the *Student Code* (http://www.admin.uiuc.edu/policy/code/index.html). In addition to University Policies, we expect you all to show respect to your instructors and your classmates at all times, both in the classroom and on our field trips. During field trips, you will be required to **strictly** follow individual railway safety procedures that will be discussed in greater depth prior to field trips. If you are unable or unwilling to abide by these procedures, you will not be allowed to attend the field trips. No exceptions.

Class Discussion and Participation

You are encouraged to actively participate in class, and class participation constitutes 12% of your course grade. If you have questions about this policy, or would like interim feedback on your participation in class, please feel free to contact the instructor throughout the semester.

Attendance

Attendance in class is critical to your success as discussions and presentation of lecture material will provide insights and knowledge that cannot be gained from the assigned reading and lecture materials alone.

Accommodations

If you require special accommodations, you should notify the instructor as soon as possible. In particular, you should contact the instructor if a disability might interfere with the successful completion of a course requirement. All accommodations will follow the procedures as stated in Article 1-110 of the *Student Code* (http://www.admin.uiuc.edu/policy/code/article_1/a1_1-110.html).

Academic Integrity

This course will follow Articles 1-401 through 1-406 of the *Student Code* (beginning at http://www.admin.uiuc.edu/policy/code/article_1/a1_1-401.html). This rule defines infractions of academic integrity, which include but are not limited to cheating, fabrication, and plagiarism. You are responsible for following these guidelines. If you have any questions about whether something would be an infraction, please consult with the instructor before proceeding.

Late Submission Policy

You are expected to submit assignments at or before 3:00 PM on the due dates. If you are unable to submit an assignment by this time, please contact the instructor and an agreement will be reached that is fair to all parties involved.

CEE 408 – Fall 2013
Railroad Transportation Engineering
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Course Schedule and Reading List

Instructors

Christopher P.L. Barkan, Ph.D	C. Tyler Dick, P.E.
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Class	Class Date	Lecture Topic	Reading Assignment	Homework
1	Monday August 26	Course Overview Introduction to Rail Transportation	R-01 R-02	
2	Friday August 30	Introduction to Rail Transportation (continued) Rail Safety		Assignment 1 – Railcar Capacity and Route Tonnage
--	Monday September 2	***NO CLASS*** ***LABOR DAY***		
3	Friday September 6	Rail Transportation Efficiency	R-03 (Chapter 4)	Assignment 2 – Modal Efficiency
4	Monday September 9	Transportation Economics 1	R-04 R-05	
5	Friday September 13	Transportation Economics 2	R-06	Assignment 3 – Commodities and Markets
--	Saturday September 14	**FIELD TRIP** **Monticello Railroad Museum** **Work Day**		
6	Monday September 16	Transportation Economics 3 - Fungibility	R-07	
7	Friday September 20	Transportation Economics 4	R-08 (Chapter 3)	Assignment 4 – Fixed and Variable Railroad Costs
8	Monday September 23	Transportation Economics 5 – Pricing and Competition	R-09	

9	Friday September 27	Economic Regulation	R-10 R-11 R-12 (optional)	Assignment 5 – Railroad Pricing and Competition
10	Monday September 30	Rise, Fall and Renaissance	R-13	
11	Friday October 4	Freight Cars - Introduction	R-14 (Chapter 5) R-15	Assignment 6 – Railcar Design
12	Monday October 7	**EXAM #1** **(Lectures 1-10)**		
13	Friday October 11	Freight Cars: Coupling Systems	R-14 (Chapter 6) R-16 (Optional)	
14	Monday October 14	Freight Cars: Trucks, Wheels and Axles	R-17 R-18 (Optional)	Assignment 7 – Railcar Structure
15	Friday October 18	Brake Systems	R-19 R-20	
16	Monday October 21	Brake Systems (continued)	R-21 R-22 (Optional)	Assignment 8 – Air Brakes
17	Friday October 25	Train Resistance	R-23 (Chapters 6, 9) R-24	Assignment 9 – Train Resistance, Power and Acceleration
18	Monday October 28	Locomotives	R-23 (Chapter 7) R-25 R-26 (Optional)	
19	Friday November 1	Power and Acceleration	R-23 (Chapter 10) R-27	
20	Monday November 4	Track 1 - Basics	R-28 (pp 21-38)	
21	Friday November 8	Track 1 – Basics (continued)		
22	Monday November 11	**EXAM #2** **(Lectures 11-19)**		

23	Friday November 15	Track 2 - Maintenance	R-29 R-30	
24	Monday November 18	Track 3 – Special Trackwork	R-28 (pp 38-50) R-31	Assignment 10 - Track
25	Friday November 22	Track 4 – Track Geometry and Bridges	R-32	
--	Monday November 25	***NO CLASS*** ***THANKSGIVING BREAK***		
--	Friday November 29	***NO CLASS*** ***THANKSGIVING BREAK***		
26	Monday December 2	Passenger Rail Transportation	R-33 R-34	Assignment 11 – Grade Crossings
27	Friday December 6	Passenger Rail Transportation 2 – High-Speed Rail	R-35	
28	Monday December 9	Shared Passenger and Freight Rail Corridors	R-36	
--	****Thursday December 19 1:30 PM****	**EXAM #3 (Lectures 20-28)**		

Note: Additional reading assignments may be added by the instructors during the semester. Graduate students registered for 4-credit hours will be assigned additional weekly reading assignments.

CEE 408 – Fall 2013

Reading Assignments – Lectures 1-10 (Exam #1)

R-01 Martland, Carl 2002. Railroad Transportation, Section 6.40.2.5, Encyclopedia of Life Support Systems

R-02 Armstrong, J. 2008. The Railroad What it is, What it does: Introduction and Chapter 1

R-03 FRA-ICF 2009. Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors: Chapter 4.

R-04 Atack, J. and Passel, P. 1994. A New Economic View of American History: Chap. 6 The Transportation Revolution and Domestic Commerce, pp 143-174.

R-05 Locklin, D.P. 1972. Economics of Transportation: Chapter 1, Economic Significance of Improved Transportation, pp 1-18.

R-06 Locklin, D.P. 1972. Economics of Transportation:
Ch. 3 - Freight Rates and Prices, pp 49-66.
Ch. 4 - Freight Rates and the Locations of Industries and Market Centers, pp 67-89.

R-07 Murray 2008. How Much Does It Cost. Trains, January 2008

R-08 Hay, W.W. 1982. Railroad Engineering: Chapters 1-3 (Chapter 3 only)

R-09 Locklin, D.P. 1972. Economics of Transportation: Chapter 7, pp 142-151 (through "Ruinous Competition) and pp 166-1

69 (beginning with, "Is the Assumption of Unused Capacity Valid")

R-10 Gallamore, Robert 1999. Regulation and Innovation: Lessons from the American railroad industry (Chap. 15 in Essays in Transportation Policy & Economics) pp 493-529.

R-11 Basic Provisions of the Staggers Rail Act of 1980 (2 pages)

R-12 (Optional) Various authors 2007 "Regulation" In: Middleton, W.D., G.M. Smerk & R.L. Diehll, eds., Encyclopedia of North American Railroads, pp 919-935

R-13 McClellan 2011 TRB 11-0001 Deen Lecture - Railroads and the New Normal

Reading Assignments – Lectures 11-19 (Exam #2)

R-14 Armstrong et al 2008 5th Ed. The Railroad, What it is, What it Does: Chapter 5 – The Railroad Car (17 pages) and Chapter 6 – The Train (22 pages)

R-15 Freight Car Basics:
Schneider, Paul. Freight car trucks and carbodies (3 pages)
Kinkaid, Jim 2000. Freight car weight and capacity (1 page)
McGonigal, Robert. Freight car markings (3 pages)

R-16 (Optional) Dawson, R.W. 1997. Coupling Systems. In, W.W. Kratville, ed. The Car and Locomotive Cyclopedia of American Practices, 6th edition. pp 641 - 702. (66 pages but relatively little text)

R-17A & B Armstrong, J.H. 1983. The remarkable three-piece freight-car truck, Parts 1 and 2. Trains (July & August). (11 pages total)

R-18 (Optional) Monsell, D. et al. 1997. Trucks, Wheels, Axles and Brakes. In, W.W. Kratville, ed. The Car and Locomotive Cyclopedia of American Practices, 6th edition. (132 pages total, but only the following specific page ranges)

- pp. 709-717 (up to but not including "Support Pad Hunting Control)
- pp. 735-739
- pp. 771-784
- pp. 793-794
- pp. 796-797
- pp. 811-814

R-19 NYAB Basic Air Brake Operation (15 pages)

R-20 Carlson 2004 Air Brakes 101 (14 pages)

R-21 ECP Brakes NPRM 4 Sept 2007 (extract) (Summary & Sections I - V only) (5 pages)

R-22 (Optional) CLC 1997 Section 8 Braking Systems (25 pages)

R-23 Hay Chaps 6,7,9,10 (88 pages)

R-24 Baker Fact or Friction (3 pages)

R-25 Marre & Pinkepank (15 pages)

R-26 (Optional) Armstrong et al 2008 The Railroad: Chap 4 Locomotive (44 pages)

R-27 Johnson Acceleration (9 pages)

Reading Assignments – Lectures 20-28 (Exam #3)

R-28 Armstrong et al 2008 5th Ed. The Railroad, What it is, What it Does - Chapter 3 - The Track: Alignment & Structure (30 pages)

R-29 Encyclopedia of North American Railroads, 2007. Maintenance of Way (MOW) and Equipment pp 639 – 661 (23 pages)

R-30 Burns and Franke 2005. Analyzing the blitz approach to m/w, Railway Track and Structures (6 pages)

R-31 Hay Chapter 27 (pp 621-639, 648-653)

R-32 AREMA 2003. Practical Guide to Railway Engineering: Chapter 6 – Railway Track Design

R-33 American Railways High-speed Railroading - The Economist, July 2010

R-34 The U.S. Emphasis on Passenger Rail and the Future of Freight - The Transport Politic, July 2010

R-35 Kuehn 2011 New Roadmap for HSR

R-36 Oliver Wyman 2009 Future North American Passenger Operations The Infrastructure Dilemma