



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

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Develop and Teach Graduate Course on Rail Terminal Design and Operations

By

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Develop and Teach Graduate Course on Rail Terminal Design and Operations

Introduction

The new CEE 598 RTD Railway Terminal Design & Operations course introduces students to the role of terminals in the freight railway transportation system, the functions required at different types of terminals, and the considerations and best practices for the design of terminal infrastructure to support these roles and functions. These topics are either not covered in the UIUC rail curriculum or introduced at a basic level with a brief overview. Design of mainline track and signal infrastructure is only one facet of the suite of challenges facing railway engineers; the proper design of terminal facilities to collect, sort, and deliver freight is also of critical importance to the function of an efficient freight rail transportation system. Studies have shown that mainline and network congestion is often rooted in terminal operations. Understanding these terminal operations requirements and the design of terminal infrastructure necessary to support these operations is critical to making informed railway capital investment and operating decisions.

The objective of this course is to prepare students for the challenges facing civil engineers engaged in the planning, design, construction and operation of railway terminal facilities, and to improve the ability of each student to consider the “big picture” objectives and challenges posed by the role of railway transportation in the movement of freight. Students will be encouraged to develop and/or refine their ability to critically evaluate multiple terminal layout, design and operations alternatives, grow communication skills and the ability to converse about terminal design and operations concepts and challenges, and leave the class with a strong foundation in the fundamental infrastructure required to support efficient freight transportation by rail. Students will also participate in a class project to perform develop a classification yard layout and operating plan.

Description of Activities

This project planned and developed the course material for CEE 598 RTD, and taught it as a full-semester course open to graduate students at UIUC in Fall 2014. Students enrolled in the class participated in lecture-discussion sessions, twice a week for 1-1/2 hours, throughout the semester.

Students spent additional time outside the lectures coordinating the class semester design project. During the course of the semester, the CEE 598 RTD students worked as a class to complete a major terminal planning study. The main components of the planning study included a track layout, control system design and operating plan for each of several project alternatives for a proposed classification yard and intermodal facility.

Through the class project, students are exposed to the matrix style of project team organization employed by design consultants (figure 1). Each student is assigned responsibility for a specific component of the study for a certain alternative. Successful completion of the project requires the student to collaborate with both their peers working on the same alternative and those working on the same task for the other alternatives. Students in the top row of Figure 1 were assigned to be the lead for each project alternative while students in italics were assigned to be leads of each design task assignment.

| Assignment | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 |
|-----------------------------------|----------------------|--------------------------|-----------------------|-------------------|
| Alt. Lead/ Hump Layout | <i>Jesus Serrano</i> | Matt Csenge | Andrew Scheppe | Sam Chadwick |
| Hump Layout | Dan Rivi | Matheus Lima | Yue Zhou | Gio DiDomenico |
| Hump Traffic | Arka Ghosh | Moyu Ren | <i>Mei-Cheng Shih</i> | Anmol Shrivastava |
| Hump Profile/Control | Binni Zhao | <i>Josue Bastos</i> | Marcelo Suarez | Po-Yin Liao |
| Intermodal Layout | Manu Martin | <i>Garrett Fullerton</i> | Mikkel Clausen | Chen-Yu Lin |
| Intermodal Site/Traffic | Hsiao-Hsuan Liu | Jing Yi | <i>Ivan Atanassov</i> | -- |

Figure 1: Class semester design project team matrix

The class design project uses three lecture periods as project meetings where the instructor functions as the project owner and students assume the role of consultants presenting their designs for review. Lecture number 15 was used as a group project “design charrette” where the project groups were given an opportunity to work on yard layouts during the first half of the class. During the second half of the lecture period, each group presented their project concept with critiques provided by the instructors and other students in the class. Lecture number 25 was used as a group project progress meeting and design review. The various groups presented the work they had completed on the facility operating plan and on the various site layouts. Feedback on all facets of the project was provided by the instructor. The final class of the semester, lecture number 29, was used to present the final operating plans and site layouts for the semester design project.

Outcomes

The Fall 2014 course syllabus and schedule for CEE 598 RTD developed through this project are attached to the end of the report.

A total of 25 lectures of entirely new content were developed on the following topics:

- Railway as a freight transportation system
- Freight rail traffic
- Network operations and terminal types and functions
- Terminal process: originating and terminating a train
- Manifest train planning, connections and transit time
- Classification, blocking and sorting
- Yard studies
- Curve and turnout geometry
- Ladder tracks and basic yard geometry
- Yard layout in MicroStation
- Freight car rollability
- Flat yard design
- Hump classification yard layout (Part 1)
- Hump classification yard layout (Part 2)
- Retarders and hump yard speed control
- Hump yard profile design
- Railcar supply and distribution
- Intermodal facility lift equipment and pavement design
- Intermodal facility layout
- Bulk terminal facilities
- Bulk terminal spur and loop layouts
- Railcar maintenance and repair facilities
- Automotive and other specialized facilities
- Locomotive assignment, servicing and maintenance
- Crew scheduling and accommodations

Class sessions are designed to be interactive with blackboard lecturing supplemented by video clips and hands-on activities at the front of class. As an example, students are taught classification, blocking and sorting schemes by constructing a yard with wooden railway track and sorting railcars as a team.

The course includes ten individual assignments to help students understand the application of course concepts:

- Freight traffic
- Terminal scavenger hunt
- Train planning (Part 1)
- Train planning (Part 2)
- Blocking and classification
- Railcar rollability
- Hump yard crest design (Part 1)
- Hump yard crest design (Part 2)

- Intermodal facility capacity
- Locomotive assignment

The above tasks are supplemented by two larger “design studio” assignments completed with MicroStation CAD software. The MicroStation assignments allow students to develop their understanding of track geometry and how various turnouts, curves and tangents are arranged into a yard design that will operate efficiently. The two design studio assignments, a 12-track classification yard and a unit train loop unloading facility, are based on real-world projects and design criteria. Both assignments required the students to construct a yard/terminal design to fit given operational requirements and site constraints using the design principles introduced during the course.

As described above, the students also completed a semester design project in one large project team broken down by project alternative and design task. In addition to presenting their work at several points during the semester, the project team submitted a final report including detailed alternative site layouts and operating plans.

The course included a midterm test and comprehensive cumulative final exam.

The new CEE 598 RTD course was first taught in Fall 2014 with 23 students (22 graduate and one undergraduate) enrolled and three more students auditing the class. It is anticipated that the course will be taught again in Fall 2017.

Conclusions/Recommendations

During the initial offering of CEE 598 RTD, the student design submittals exceeded expectations. Overall the course was ranked as “excellent” by the students enrolled. Anecdotal evidence from course reviews indicates that the students enjoyed the interactive and multimedia aspects of the course lecture periods. The course reviews also indicated that students place a high value on the additional design content, particularly the exposure to MicroStation and the unique aspects of terminal design. This design software experience is one factor that can distinguish students enrolled in the course from their peers when applying for internships and permanent positions in the rail and general transportation design industry.

Publications/Examples

A NURail UTC Research Brief was developed for this project. It is attached to the end of this document.

Primary Contact

Principal Investigator

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CEE 598 RTD - Fall 2014
Railway Terminal Design & Operations
Mondays and Wednesdays • 11:00 am - 12:20 pm • 2310 NCEL

Course Syllabus

Instructor Information

Christopher P.L. Barkan, Ph.D

Professor and Director - Rail Transportation and Engineering Center (RailTEC)

Department of Civil and Environmental Engineering

University of Illinois at Urbana-Champaign

Office: 1245 Newmark Civil Engineering Laboratory, MC-250
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Office hours: Feel free to email me and set up an appointment.

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 handouts will be posted on Compass after the class period in which they were given. All reading assignments will be posted on Compass 2G.

Classes: Mondays and Wednesdays, from 11:00 am – 12:20 PM, Newmark Civil Engineering Laboratory, Room 2310. Occasional make-up classes will be scheduled at times mutually agreed upon by the instructor and students.

Credit: 4 graduate hours.

Prerequisite: CEE 408 or CEE 409 or CEE 411 or permission of instructor. Students that have not taken CEE 409 or 411 or equivalent courses dealing with basic railway curve and turnout geometry may wish to complete additional background reading in order to perform well on the assignments and exams.

Course Description

In this course, students learn details of the design and operations planning, management and optimization of the terminal facilities required for the railway network to function as an efficient freight transportation system. Focus is on design of classification yards, intermodal facilities and bulk terminals, and how these facilities are organized into a network to provide different types of freight transportation service. Course includes a classification yard semester design project and field trip to observe a railway terminal facility.

Course Vision

To prepare students for the challenges facing civil engineers engaged in the planning, design, construction and operation of railway terminal facilities, and to improve the ability of each student to consider the “big picture” objectives and challenges posed by the role of railway transportation in the movement of freight.

This course is being developed with the support of the National University Rail (NURail) Center, the first USDOT- RITA University Transportation Center with a focus on rail transportation research, education, technology transfer and workforce development.

Course Instructor’s Mission

Encourage students to develop and/or refine their ability to critically evaluate multiple terminal layout, design and operations alternatives, encourage growth in communication skills and the ability to converse about terminal design and operations concepts and challenges, form lasting friendships amongst the class, and leave the class with a strong foundation in the fundamental infrastructure required to support efficient freight transportation by rail.

Course Objectives

The primary focus of most courses in railway engineering is on infrastructure, geometry and economic justification of mainline projects to benefit passenger and line-haul freight rail operations. However, the typical railcar spends the majority of its time off the mainline, either in intermediate classification yards or specialized terminal facilities where freight is transloaded to and from rail customers or connecting modes of transportation. These facilities represent significant capital investments for the railways and, given the amount of time that railcars and trains spend in them, poor design of terminal facilities can lead to inefficiencies that quickly degrade the provided level of freight transportation service. This course will introduce students to the role of terminals in the freight railway transportation system, the functions required at different types of terminals, and the considerations and best practices for the design of terminal infrastructure to support these roles and functions.

Specific lecture topics include:

- The railway as a freight transportation system
- Network operations, terminal functions and types of terminals
- Originating and terminating a train
- Train planning, connections and transit time
- Classification, blocking and sorting
- Curve and turnout geometry (review)
- Ladder tracks and basic yard geometry and layout
- Freight car rollability
- Flat yard design
- Hump classification yard layout
- Retarders and hump yard speed control systems
- Major retarder hump and mini-hump profile design
- Mechanical, electrical and signal design considerations
- Yard studies
- Intermodal facility lift equipment and pavement design
- Intermodal facility layout
- Bulk terminal facility loading and unloading equipment
- Bulk terminal facility layout, spurs and loops
- Automotive and other specialized facilities
- Locomotive assignment
- Locomotive servicing and maintenance facility layout and design
- Railcar supply and distribution
- Railcar maintenance and repair facility layout and design
- Crew accommodations
- Yard automation and future trends

Required and Suggested Reading:

- Droege, Freight Terminals and Trains (1925)
- Wong et al, FRA Railroad Classification Yard Technology Manual (1981)
- Hay, W. W., Railroad Engineering, Wiley and Sons (1982)
- Sussman, Transportation Systems (2000)
- Armstrong, The Railroad; What it is, what it does (5th Edition)
- AREMA Manual of Railway Engineering, Chapter 14, Yards and Terminals
- 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 a major railway classification yard terminal facility. 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: "CEE598RTD_LastName_HomeworkNumber".

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.

Semester Design Project

The group semester design project will incorporate a major portion of the effort you expend on this class. Teams will be selected by the instructor, with the goal of evenly matching the teams based on class standing, experience in railroad engineering, and prior knowledge of the subject matter. The design project deliverables will include two class presentations and a final design technical memo.

Examinations

There will be two closed book exams in this course:

- The first exam will be held Monday, October 27th during class
- The final exam is scheduled for Wednesday, December 17, 8:00 am

Course Grading (4 Credit Hours)

| | |
|----------------------|-----|
| Homework Assignments | 10% |
| Design Assignments | 10% |
| Design Project | 25% |
| Mid-Term Exam | 20% |
| Final Exam | 25% |
| Class Participation | 10% |

Note: Plusses and minuses will be given.

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 10% 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 11:00 AM 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 598 RTD – Fall 2014
Railway Terminal Design & Operations
Mondays and Wednesdays • 11:00 AM - 12:20 PM • NCEL 2310

Course Schedule and Reading List

Instructors

| | |
|--|---|
| <p style="text-align: center;">Christopher P.L. Barkan, Ph.D Telephone: 217-244-6338 (office), Fax: 217-333-9464 e-mail: cbarkan@illinois.edu Office: 1245 NCEL Office hours: Feel free to set up an appointment via email.</p> | <p style="text-align: center;">C. Tyler Dick, P.E. Telephone: 217-300-2166 (office), Fax: 217-333-9464 e-mail: ctdick@illinois.edu Office: 1241 NCEL Office hours: Feel free to set up an appointment via email.</p> |
|--|---|

| Class | Class Date | Lecture Topic | Reading Assignment | Assignment |
|-------|---------------------------|--|--|--|
| 1 | Monday August 25 | Course Overview Railway as a Freight Transportation System | | Assignment 1 – Freight Traffic |
| 2 | Wednesday August 27 | Freight Rail Traffic | Read Assigned Article for September 3rd | |
| -- | Monday September 1 | NO CLASS - LABOR DAY | | |
| 3 | Wednesday September 3 | Network Operations Terminal Types and Functions | | Assignment 2 – Terminal Scavenger Hunt |
| 4 | Monday September 8 | Terminal Process – Originating and Terminating a Train | | |
| 5 | Wednesday September 10 | Manifest Train Planning, Connections and Transit Time | | Assignment 3 & 4 – Train Planning |
| 6 | Monday September 15 | Classification, Blocking and Sorting | | |
| 7 | Wednesday September 17 | Yard Studies | | Assignment 5 – Blocking and Classification |
| 8 | Monday September 22 | Curve and Turnout Geometry Design Project Introduction | | |
| 9 | Wednesday September 24 | Ladder Tracks and Basic Yard Geometry | | |

| | | | |
|----|--------------------------|---|---|
| 10 | Monday September 29 | Yard Layout in MicroStation (rescheduled around AREMA Conference) | |
| 11 | Wednesday October 1 | Freight Car Rollability | Assignment 6 – Railcar Rollability |
| 12 | Monday October 6 | Flat Yard Design | Design Assignment A – Flat Yard MicroStation Design |
| 13 | Wednesday October 8 | Hump Classification Yard Layout | |
| 14 | Monday October 13 | Hump Classification Yard Layout (part 2) | |
| 15 | Wednesday October 15 | Group Project Design Charette | |
| 16 | Monday October 20 | Retarders and Hump Yard Speed Control | |
| 17 | Wednesday October 22 | Hump Yard Profile Design | Assignment 7 & 8 – Hump Yard Crest Design |
| 18 | Monday October 27 | MID-TERM EXAM (Lectures 1 – 16) | |
| 19 | Wednesday October 29 | Railcar Supply and Distribution | |
| 20 | Monday November 3 | Intermodal Facility Lift Equipment Pavement Design | |
| 21 | Wednesday November 5 | Intermodal Facility Layout | Assignment 9 – Intermodal Facility Capacity |
| 22 | Monday November 10 | Bulk Terminal Facilities | |
| 23 | Wednesday November 12 | Bulk Terminal Spur and Loop Layouts | Design Assignment B – Bulk Terminal MicroStation Design |

| | | | |
|----|---|---|--|
| 24 | Monday November 17 | Railcar Maintenance and Repair Facilities | |
| 25 | Wednesday November 19 | Group Project Progress Meeting & Design Review | |
| -- | Monday November 24 | NO CLASS THANKSGIVING BREAK | |
| -- | Wednesday November 26 | NO CLASS THANKSGIVING BREAK | |
| 26 | Monday December 1 | Automotive and Other Specialized Facilities | |
| 27 | Wednesday December 3 | Locomotive Assignment, Servicing and Maintenance | Assignment 10 – Locomotive Assignment (in-class) |
| 28 | Monday December 8 | Crew Scheduling and Accommodations | |
| 29 | Wednesday December 10 | Group Project Final Design Review | |
| -- | **Wednesday December 17 8:00AM** | FINAL EXAM (Cumulative) | |

Note: Additional reading assignments may be added by the instructors during the semester.

New Semester Course in Railway Terminal Design & Operations

C. Tyler Dick P.E., University of Illinois at Urbana-Champaign

The new Railway Terminal Design & Operations course (CEE 598 RTD) at the University of Illinois at Urbana-Champaign (UIUC) introduces students to the role of terminals in the freight railway transportation system, the functions required at different types of terminals, and best practices for design of terminal infrastructure to support these roles and functions.

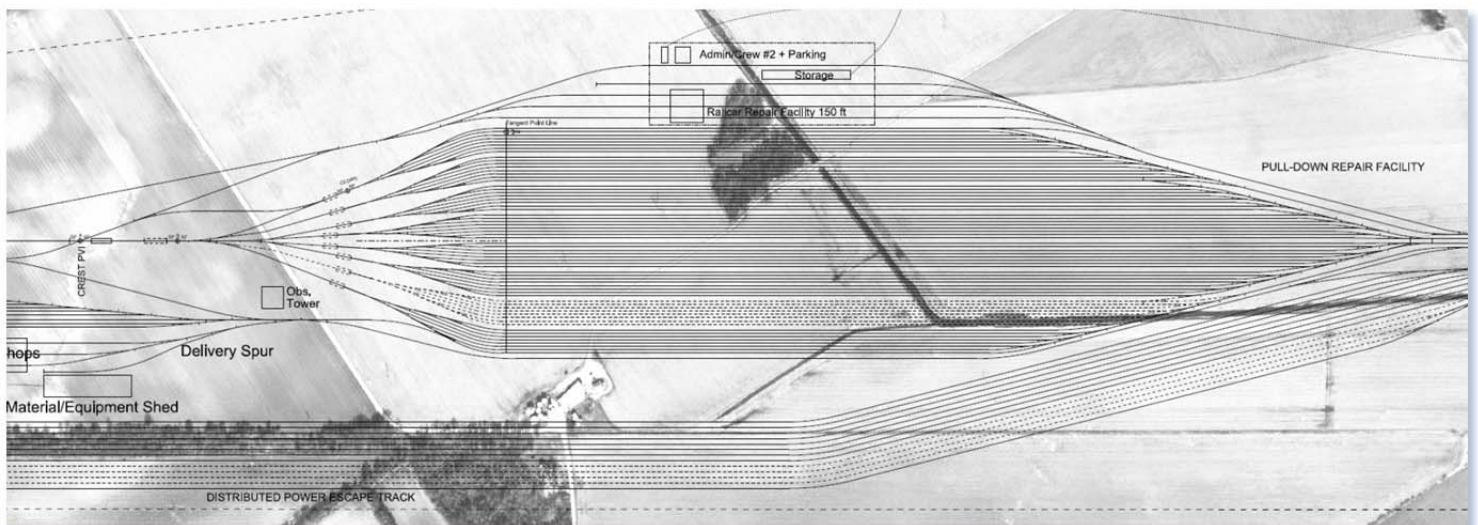
Course Rationale

The primary focus of railway engineering courses at UIUC is on infrastructure, geometry and economic justification of mainline projects to benefit passenger and line-haul freight rail operations. However, the typical railcar spends the majority of its time off the mainline, either in intermediate classification yards or specialized terminal facilities where freight is transloaded to and from rail customers or connecting modes of transportation. These facilities represent significant capital investments for the railways and, given the amount of time that railcars and trains spend in them, poor design of terminal facilities can lead to inefficiencies that quickly degrade the provided level of freight transportation service.

In the new Railway Terminal Design & Operations course (CEE 598 RTD) developed as a NURail education project, students learn details of the design, operations planning, management and optimization of the terminal facilities required for the railway network to function as an efficient freight transportation system. The focus is on design of classification yards, intermodal facilities and bulk terminals, and how these facilities are organized into a network to provide different types of freight transportation service by rail.

Lecture Topics

The lecture material developed for the course centers around three major topic areas. The first of these areas is the railway as a freight transportation system. Lectures in this portion of the course cover network operations, terminal functions, the train origination process, train planning, connections and transit time, and classification and blocking. These topics provide students with an understanding of how railcars are moved across the freight railway network and the terminal activities that are required to support these movements. This knowledge is essential for students to understand the fundamental terminal engineering and design considerations introduced in subsequent



sections of the course. As part of this background, students are also introduced to railway operations concepts such as empty railcar distribution and locomotive and crew assignment.

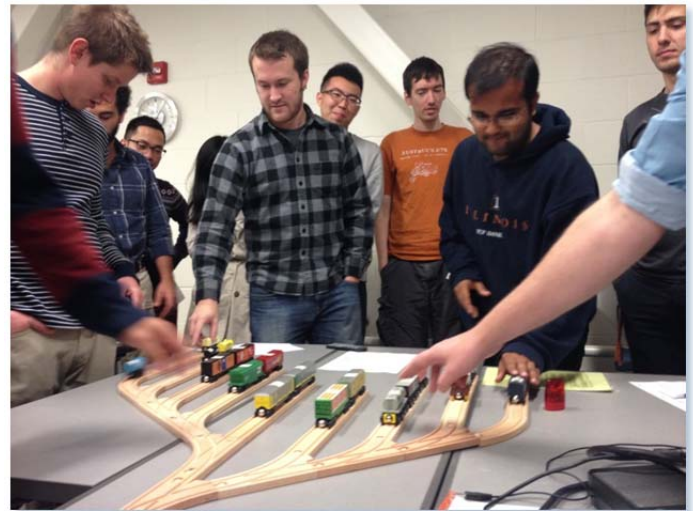
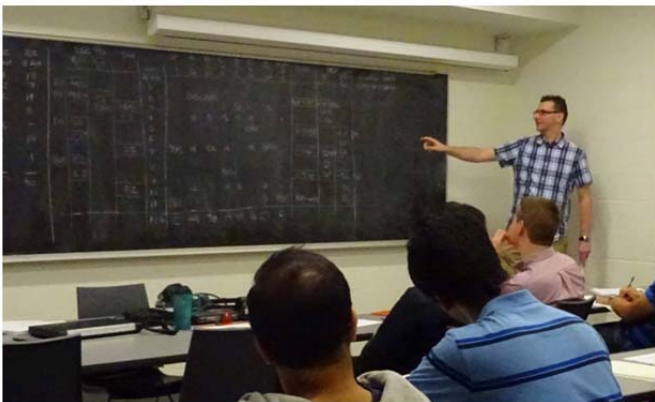
The second topic area focuses on the design of classification yards. Lectures introduce basic yard geometry, ladder tracks, flat yards and hump yards. Several lectures are dedicated to the physics and detailed design of the hump crest and retarder speed control system, a topic that several students likened to “the railroad version of fluid mechanics”.

The third topic area examines specialized terminal facilities, including intermodal facilities and bulk freight terminals. In addition to facility layout, lectures cover intermodal lift equipment and bulk loading and unloading mechanisms.

Class sessions are designed to be interactive with blackboard lecturing supplemented by video clips and hands-on activities at the front of class. As an example, students are taught classification, blocking and sorting schemes by constructing a yard with wooden railway track and sorting railcars as a team.

Assignments & Design Studio

The course includes ten individual assignments to help students understand the application of course concepts. These tasks are supplemented by two larger “design studio” assignments completed with MicroStation CAD software. The MicroStation assignments allow students to develop their understanding of track geometry and how various turnouts, curves and tangents are arranged into a yard design that will operate efficiently. The two design studio assignments, a 12-track classification yard and a unit train loop unloading facility, are based on real-world projects and design criteria.



Semester Class Design Project

During the course of the semester, the CEE 598 RTD students work as a class to complete a major terminal planning study. The main components of the planning study include a track layout, control system design and operating plan for each of several project alternatives.

Through the class project, students are exposed to the matrix style of project team organization employed by design consultants. Each student is assigned a specific component of the study for a certain alternative. Successful completion of the project requires the student to collaborate with both their peers working on the same alternative and those working on the same task for the other alternatives.

The class design project also involves a design charrette and two project review meetings where the instructor functions as the project owner and students assume the role of consultants presenting their designs for review.

Inaugural Course Offering

CEE 598 RTD was offered for the first time in Fall 2014 with 23 students enrolled on the UIUC campus. The initial design project, developed in conjunction with CSX Transportation, investigated four alternative layouts for a new hump classification yard near Terre Haute, IN and a new intermodal facility near Indianapolis, IN. The student design submittals exceeded expectations. Overall the course was ranked as “excellent” by the students enrolled, marking it as another NURail success.

The author acknowledges the support of Jeremiah Dirnberger, Manager – Network Modeling & Analytics CSX Transportation, in development of the course.