that we must add the immeasurable but still predictable benefits of the three-week College Faculty Overview Session and of providing sets of the instructional materials to schools and other agencies through the College Curriculum Program. If we assume that each of the 60 schools now in possession of the course materials trains only 10 students, another 600 users will have been reached. It is expected that planned follow-up evaluations will yield a much higher total.

When this information is in the hands of such a large audience of potential users, it is expected that numerous improvements will be made in the safety of existing and planned highways throughout the nation. Since the attitude that seems to prevail now in this country is to "sue for all you can get" if involved in any sort of an accident, it is not uncommon for single highway-related accident settlements to exceed $1 million. If only one such accident and subsequent lawsuit against a public agency can be prevented, the taxpaying public will have been well compensated for the expense of this project.

ACKNOWLEDGMENT

Success of any project of this magnitude must by necessity be attributed to the ideas and dedicated efforts of many individuals. I served as contract manager for FHWA during the final year of the project and would like to express may appreciation to all who have contributed so generously, especially to Howard L. Anderson, formerly associate administrator of the FHWA Office of Highway Safety, who conceived the idea and gave full support to the program; to Donald S. Berry, Ronald Pfefer, and Joseph L. Schofer of Northwestern University, who served as principal investigators during the project; and to James L. Foley, Jr., of the FHWA Office of Highway Safety for his continued advice and guidance. Special recognition must certainly be given to Roger L. Dean, who served as contract manager for FHWA and whose dedication to the project helped ensure its quality and integrity, and to John Nitzel for his part in conducting the course as well as in finalizing the course materials. Technical advice given by many from within FHWA and the National Highway Traffic Safety Administration is appreciated, especially that from David Merritt, Harry Strate, Robert Winans, Webster Collins, James Iverson, William Blessing, Richard Richter, Rudolph Umbs, Seppo Sillan, and Douglas Syverson. Most important, the improvements initiated by the instructors from Northwestern University and the criticisms and suggestions offered by the participants themselves added greatly to the success of the project.

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Railroad Engineering Education at the Undergraduate Level

RICHARD G. McGINNIS

At one time, courses in railroad engineering could be found in almost any civil engineering curriculum. Today, the opposite is true. As a result of the decrease in recruiting by the railroads during the 1950s and 1960s, emphasis in engineering education shifted away from railroads to other specialties. Because of the current growing interest in revitalizing the U.S. railway system, a few universities have begun to offer railroad engineering courses. During the decade of the 1980s, it is estimated that one-half of the railroad industry's current workforce and about two-thirds of top and middle management personnel will retire. The need for replacement personnel coupled with the increasing sophistication of railroad engineering activities has led to a growing need for highly trained engineers. To be most productive these engineers should have some education related specifically to railroads. Bucknell University has responded to this need by developing two courses and other educational activities oriented toward the railroads. The railroad education program at Bucknell has four objectives: (a) to stimulate student interest in the railroad industry, (b) to improve the student's understanding of the railroad industry and dispel common misconceptions, (c) to teach the fundamentals of railroad engineering, and (d) to discuss new concepts in railroad engineering and management. So far, response to the program from both the students and the railroad industry has been good. The university plans to continue improving the program as resources permit.

At one time, courses in railroad engineering could be found in almost any civil engineering curriculum in this country. Today, the opposite is true. In the 1950s and 1960s there was a decrease in recruiting on college campuses by the railroads; the result was that the emphasis in engineering education shifted from railroads to other specialties. With the exception of a few isolated courses and programs, the colleges and universities in the United States are no longer preparing engineering graduates specifically for entry into the railroad industry. This trend is in marked contrast, for example, to the 53 accredited undergraduate programs in aeronautical or aerospace engineering that were documented in the 47th Annual Report of the Engineer's Council for Professional Development (Sept. 30, 1979).

As the emphasis in engineering education shifted away from railroads to other specialties, the normal basis for the continuing evolution of courses and programs disappeared. Faculty interest shifted; courses were discontinued; no new textbooks were written. In the 1960s and early 1970s, the educational community was virtually isolated from the railroad industry.

With the current growing interest in revitalizing the U.S. railway system, a few universities have started to offer courses and conduct research in railroad-related areas. Although some progress has been made, it is difficult and expensive. As a result of the almost complete break in continuity of faculty and course development, the colleges and universities face a most difficult challenge.

NEED FOR RAILROAD EDUCATION

During the decade of the 1980s, it is estimated that one-half of the railroad industry's current workforce will retire and that between two-thirds and three-fourths of the top and middle railroad management personnel will have to be replaced (1). Although railroads have not had much difficulty in hiring the quantity of personnel they need, they have had some trouble in filling certain engineering positions. An associated problem experienced by some railroads is high attrition among young engineers during their first few years with the company.

Many engineering graduates do not even consider the railroad industry as a possible career. Some of these graduates have the false impression that the U.S. railroads have met the same fate as the passenger trains and that most, if not all, railroads are bankrupt or near bankruptcy. Others are repelled by the industry's image of conservatism, inflexibility, and antiquity. Some look toward other industries for jobs after hearing horror stories from recent graduates who are working as track supervisors and performing endless hours of work without relief or overtime compensation. Students must be properly informed about the railroad industry if they are to make suitable employment decisions.

Since the railroads have existed for two decades without university curriculum offerings in the railroad area, one might question the need for any special railroad engineering courses. However, changes are taking place in the industry today that will make it increasingly difficult for the railroads to keep pace with technological advances if they are forced to rely solely on the various means of on-the-job training that they have used over the years.

Many sectors of the railroad industry are rapidly increasing the sophistication of their operations. Within the engineering departments, advances are occurring that will, within the next decade, drastically change the day-to-day operations of the engineer. Many of these changes are predicated on the expected increased use of the computer for cost accounting, capital planning, and manpower and equipment management. Railroad engineers will soon be able to make decisions based on reliable data rather than on merely years of experience. Some railroads have already implemented computer-based management information systems that are used for maintenance-of-way (MOW) planning, maintenance equipment management, maintenance personnel management, and budgeting. Others are using the newly available information on maintenance costs and operating statistics to perform value engineering studies on the various components of the track structure.

The design, implementation, and operation of these new engineering computer models require a specialized education that can be obtained from railroad engineering courses at the college level. In the future, deregulation of the railroad industry and fiscal and energy constraints will only serve to heighten the demands on engineers for more-sophisticated solutions to the engineering problems of the railroads.

It is the belief at Bucknell University that the major need for railroad education is at the undergraduate level rather than at the graduate level. This feeling has been confirmed by numerous persons in the railroad industry and is a finding of the recent study of the educational needs in the railroad industry conducted by the University of Tennessee (1). It is also encouraging that the University of Tennessee study has recommended that federal assistance be provided to aid railroad education in four possible forms: (a) short courses, (b) curriculum enrichment, (c) university research, and (d) fellowships. This paper is concerned primarily with the second form--curriculum enrichment.

UNDERGRADUATE RAILROAD ENGINEERING EDUCATION AT BUCKNELL UNIVERSITY

Since the fall of 1976, Bucknell University has been developing educational activities related to the railroad industry. Initial interest came from the College of Engineering, in which courses have been initiated in the departments of both civil engineering and mechanical engineering. More recently, the Department of Management has shown an interest in incorporating railroad material into its curriculum.

During the development of the railroad program, Bucknell has maintained close contact with the railroad industry, which includes operating railroads, railroad suppliers, railroad consultants, the Association of American Railroads (AAR), the American Railway Engineering Association, and the Federal Railroad Administration (FRA). These organizations have been very supportive of Bucknell's program development and have given valuable direction.

The philosophy of railroad education at Bucknell is best described by a list of the program's objectives:

1. To stimulate student interest in the railroad industry,
2. To improve the student's understanding of the railroad industry and dispel common misconceptions,
3. To teach the fundamentals of railroad engineering, and
4. To discuss new concepts in railroad engineering and management.

The program is not intended to be a mechanism for recruiting personnel for the railroad industry. Although it is anticipated that some students may elect to pursue careers related to railroads, the main purpose is to give them a clear understanding of the railroad industry and its role in providing transportation services.

Stimulating Student Interest

Stimulating student interest in a subject is always an important ingredient in effective teaching. In the case of railroad engineering, it is difficult to get the students to consider the subject matter seriously because this requires convincing them that the railroad industry is a viable career option. Once the students realize that railroad engineering involves more than building model-train layouts, the romanticism of railroads is usually enough to sustain the students' enthusiasm through the course work.

One way to stimulate interest is to incorporate railroad examples into other engineering courses so that students are frequently encouraged to think about railroads. For example, at Bucknell, freshmen in an introductory engineering design course have used simulation to model a classification yard, sophomores in the required civil engineering computer course have written FORTRAN programs to compute train resistance, and juniors have designed rail sidings in their transportation engineering course and have analyzed various rail-related problems in their engineering economy course.

Publicizing the course offerings in the railroad area is important since none of these courses is required. Bulletin boards that display color photographs of railroad operations have been useful, but the most effective stimulus has been the positive

feedback about the courses from former students. Interest in railroad engineering is further developed by having qualified personnel from the industry talk to the student chapters of the engineering professional societies.

Understanding the Railroad Industry

Before beginning with the fundamentals of railroad engineering, it is necessary for the student to understand fully how the railroads fit into the overall transportation picture. This involves looking at the modal characteristics that make railroads extremely efficient for certain types of traffic and inefficient for other types. The role of government in railroad regulation is an important area to cover to give the student a good idea of the environment within which the railroads must operate. Work rules and railroad unions and their impact on the operations of the railroads are discussed. Finally, the history of the railroads and the reasons why the industry is today in a financial condition that is less than optimum are reviewed and the current problems that confront the industry as well as future circumstances that will affect its prosperity are discussed. In summary, an attempt is made to give the students an understanding of the railroad industry's strengths, weaknesses, and potential future.

Another aim of the activities at Bucknell is to provide as much opportunity for direct contact with the railroads as possible. In the formal courses, field trips are arranged to visit various railroads and suppliers to inspect such facilities as a classification yard, a piggyback terminal, a major locomotive repair area, a rail-car manufacturing plant, a rail-fabrication mill, a tie-treatment plant, automated trace renewal, and the track-laying system of the National Railroad Passenger Corporation (Amtrak) in the Northeast Corridor. Bucknell is fortunate in that all these facilities are within easy driving distance and class sizes are small enough to make these trips feasible. The importance of field trips in the educational process cannot be overemphasized.

In addition to the field trips, speakers from the railroad industry are invited to the campus to meet the railroad classes. The speakers have ranged from recent graduates who are working for a railroad to the chief executive officer of a major railroad. The presentations are usually informal and allow maximum interaction between the speaker and the students. Although some of the topics have been technical, most have been aimed at providing information about opportunities for young college graduates in the railroad industry.

Excellent opportunities exist in the industry for talented young people; however, not all would be happy working for a railroad. The management philosophies of some railroads regarding employee relations are not what some graduates desire in a job. Many railroad jobs are rugged; they require strong dedication from the employee. In order to acquaint the student with the nature of the work in the railroad industry, contacts have been made with various railroads to place students in summer jobs. To date, six railroads have hired Bucknell students for summer employment. After working for two or three months with a railroad, the student has a much clearer understanding of railroad work conditions.

In addition to the above activities, Bucknell's unique voluntary noncredit January intersession program has been used to a limited extent to allow students to gain valuable hands-on knowledge of railroad operations and regulations. Each year, two or three Bucknell students spend January working in Washington, D.C., for FRA. The students have worked on various projects for the agency in either the Office of Research and Development or the Office of Policy and Program Development. A pilot program to have a student work with a railroad in January was initiated in 1978; however, the record snowfalls and cold temperatures during that month made it impossible for the sponsoring railroad to find the personnel necessary to work with the student. Any future attempts at such a program will be made with railroads that operate in warmer climates in January.

Teaching Fundamentals of Railroad Engineering

Currently, Bucknell has two formal courses in railroad engineering: one in civil engineering and the other in mechanical engineering. These courses are directed toward upper-level undergraduate students but are open to graduate students with the provision that additional work be done.

The railroad mechanical engineering course covers two main topics: (a) the train as an energy system and (b) freight-car and passenger-car force analysis and design. In the first part of the course the energy aspects of train operations are examined. The factors that affect power requirements, such as the various types of resistance (e.g., rolling, track, bearing, air, curve, and grade), are studied in relation to the tractive-force capabilities of locomotives and the subsequent acceleration and velocity characteristics of the train. Diesel and gas-turbine power-plant performances are examined and compared with the performances of the heat engine and electrical machinery. Thermal efficiency and tractive effort of various throttle settings are studied for diesel-electric locomotives. Comparisons of fuel consumption per ton-mile (or passenger-mile) are made for different power plants under various operating conditions, such as changes in velocity, grade, curves, and acceleration.

In the section of the course on rail-car analysis and design, the forces that act on the car and its various components are examined under static and dynamic conditions. Results of the AAR and FRA track train dynamics research program are used here. In the analysis and design of components (e.g., wheels, bearings, couplers, and cars), material strength and safety factors are discussed in relation to static and dynamic loading requirements.

The lectures in the course are supplemented by guest speakers and field trips. In addition to assigned readings, the students are given design problems and laboratory projects throughout the semester.

The railroad civil engineering course covers four main areas in addition to the introductory material on the nature of the railroad industry: (a) train operations, (b) geometric design, (c) track structure, and (d) MOW operations.

In the train-operations section, students are exposed to the operational strategies of terminals and classification yards as well as to line-haul operations. Time-space diagrams are studied as well as railroad timetables and operating rulebooks. Various blocking and centralized traffic control strategies are discussed in relation to track capacity. The students are also introduced to train resistance, tractive effort, and locomotive power principles. In the near future these topics will probably be expanded into a separate course on railroad operations.

The civil engineers learn about basic geometric design in their required transportation engineering course, so emphasis in the railroad course is placed on transition spirals and turnout design. The students do several laboratory design projects in

this section on turnout, crossover, and siding design by using the Coordinate Geometry System (COGO) interactive computer graphics program to verify calculations and to produce drawings.

The functions and the design of the components of track structure--i.e., rails, crossties, ballast, and subgrade--are discussed individually and as a system. Much of the material for these topics is taken from current railroad publications and recent research reports, in particular from the Facility for Accelerated Service Testing (FAST) project.

Because of the importance to the civil engineer of MOW operations, it is necessary to give the student some background in this subject. Unfortunately, many of the day-to-day MOW operations are difficult to teach in a classroom and can be learned best in the field. Thus, in the lectures, topics related to the management of MOW operations such as MOW planning models, engineering data bases, and FRA track classification and safety standards are stressed. MOW tasks (surfacing, undercutting, stringlining, timbering, grinding, etc.) and MOW equipment are described to the students by using color slides and a few field trips to inspect actual MOW operations.

Introducing New Concepts

Within the last few years, large commitments have been made to railroad research by the federal government and the railroad industry. At Bucknell, it is felt that it is very important that students be made aware of the findings of this research, since there is some evidence that these results are being implemented at a fairly slow rate in certain sectors of the railroad industry.

Much of the exposure to these new concepts is accomplished by the professor in the classroom lectures. However, each student is required to study at least one topic in depth and to write a paper and to present a seminar on the subject. In addition to exposing the student to current research, this exercise enhances the student's oral and writing skills.

Whenever possible, students are encouraged to work on research projects that are under way in the department. The amount of sponsored research at Bucknell is modest since the education of undergraduate students is the university's primary objective. Consequently, Bucknell is selective in the type of research projects it seeks. The type of projects consistent with the general objectives of the university and the specific objectives of the railroad program are those that allow undergraduate students to learn more about the operations and problems of the railroad industry.

Students are encouraged to develop their own research topics related to railroads and may earn course credit for their efforts. In addition to individually sponsored student research, civil engineering students have the opportunity to increase their railroad education by selecting a railroad-related topic for their required senior design project. This project, which is equivalent to approximately 5 semester-h of effort, begins in the fall of the student's senior year with a feasibility study. The feasibility study is extended into a detailed design during the spring semester.

RESPONSE TO THE PROGRAM

Student response to the program has been good. At a school the size of Bucknell (total enrollment, 3200; engineering enrollment, 650), large numbers are not encouraged for any specialized area. Over the last three years, approximately 25 percent of the civil engineering students have elected to take the railroad civil engineering course. Class size has been about 10 students, which is an optimum size for class field trips and good classroom discussions. Enrollment in the railroad mechanical engineering course has been lower.

Student evaluation of the courses has been very good, which reflects, in part, the students' enthusiasm for the numerous field trips. In general, the students feel that the courses have given them a much better understanding of the railroad industry and have provided them with interesting material that they would otherwise never have seen.

The railroad industry's response has also been good. In addition to support in the form of guest speakers, teaching materials, and field trips, the railroads have provided opportunities for both summer and permanent employment. Currently, four railroads send recruiters to the campus and several others solicit student applications for employment. The overwhelming response from the railroads coupled with the generally high demand for engineering graduates has resulted in a demand for railroad engineers that far exceeds the supply that Bucknell can provide. Over the last several years, about 10-15 percent of the civil engineering graduates have accepted jobs in the railroad industry, and about two or three times as many students were offered employment by the railroads.

PROBLEMS IN DEVELOPING RAILROAD ENGINEERING COURSES

Developing the railroad engineering courses at Bucknell has not been an easy task. As was stated in the introduction, universities have been somewhat isolated from the railroad industry for two decades. Consequently, experts in railroad engineering are difficult to find in the academic community. The latest comprehensive textbook on railroad engineering is by Hay (2), which was copyrighted in 1953.

The two greatest obstacles to developing railroad engineering courses at Bucknell were finding appropriate teaching aids and retraining faculty. Neither of the faculty members involved in the two railroad engineering courses had any specific experience in railroad engineering. Over a period of four years, these professors have developed the courses and their own backgrounds in railroad engineering through summer employment in the railroad industry and an extensive program of self-study. A sabbatical for one professor and released time from teaching responsibilities for the other professor along with travel funds for both to visit railroads and suppliers were contributed by the university. Since neither suitable textbooks nor lectures notes were available, teaching materials had to be developed topic by topic from whatever sources the professors could find. Current railroad periodicals and research reports were the most useful sources. These articles were supplemented by material from railroads and railroad suppliers and slides taken during visits to railroad properties.

At this time, it is safe to say that the courses are still in the development stage. Each year, additions are made to the lecture notes as more information becomes available. In the civil engineering area, sufficient material has been gathered to expand the original course into two--one in railroad operations and another in design and maintenance of track. However, without released time supported through external funds, this development will take several years.

CONCLUSIONS

The results of the four-year effort to introduce

railroad engineering into the undergraduate education program at Bucknell have been encouraging. It is felt that the future of the railroad industry is good and offers excellent opportunities for young college graduates. Bucknell plans to do as much as possible within limited fiscal constraints to continue the development of activities in the area of railroad education.

At this time, future plans are to increase Bucknell's involvement in sponsored research related to the railroad industry, to continue improvement and expansion of the current railroad engineering courses, and to extend the railroad offerings to the Department of Management.

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Cooperative Training Programs for Undergraduate Students

C.S. PAPACOSTAS

This paper describes the structure, operation, and accomplishments of a training program for undergraduate students undertaken cooperatively by the University of Hawaii and the Honolulu Department of Transportation Services with funding support from the Urban Mass Transportation Administration. The program consisted of a combination of activities that included practical student training, interactively conducted applied research, and a seminar series in public transportation. Recommendations are included that will, it is hoped, be useful to those contemplating similar efforts.

The derivation of mutual benefit from improved communication between universities and the transportation profession is a matter of increasing concern. The need for cooperation has been emphasized in relation to the utilization of the products of university research. In this case, the lack of involvement of the intended users throughout the research process has been identified as a critical barrier to technology transfer (1).

Recent conferences on engineering education have also recognized that the delivery of education and training programs stands to gain from a closer interaction between theory and practice. This is especially true in the case of undergraduate training in which the benefits of traditional university research are indirect and, according to a recurring theme advanced by employers, irrelevant to the demands of the entry-level positions sought by these students after graduation. University departments that emphasize undergraduate education are most sensitive to this need.

Efforts to increase the involvement of undergraduate students in the operational aspects of transportation and to enhance the interaction between the Civil Engineering Department of the University of Hawaii and the local professional community began in 1973 and led to the award by the Urban Mass Transportation Administration (UMTA) of an innovative research and training grant (provided by Section 11 of the Urban Mass Transportation Act of 1964, as amended) for the period beginning September 1, 1977, and ending August 30, 1978. Subsequently, a second grant was awarded for a study that was conducted from September 1, 1978, to June 30, 1980 (including a no-cost extension).

Although smaller in scope, these programs were similar to the program grants that were initiated later by UMTA. These programs can be described as a hybrid between traditional agency-administered work-study undertakings and typical university-based research projects. They were undertaken in cooperation with the Honolulu Department of Transportation Services (DTS) and consisted of a combination of activities that included practical student training, interactively conducted applied research, and a seminar series in public transportation that was attended by students and faculty, practicing professionals from the public and private sectors, elected officials, members of citizens' advisory groups, and the general public.

The purpose of this paper is to describe the operation and accomplishments of these cooperative programs and to offer recommendations that will, it is hoped, be useful to those who contemplate similar efforts.

EARLY EFFORTS

During the academic year 1973-1974, the civil engineering students enrolled in the junior-level introductory transportation course were assigned the task of participating in a DTS project by taking passenger counts and conducting on-board surveys on two peak-period express-bus routes. Faculty members assisted in the design of the survey questionnaire and assumed the responsibility of scheduling and overseeing the collection and analysis of data (2). Virtually all the juniors in the civil engineering program that year were thus exposed to patronage surveys and the information that can be derived from such surveys. A similar project, concerned with a survey of what proportion of bus patronage consisted of fare-paying adults, students, the elderly, and the handicapped, was conducted in 1978 (3).

A major consequence of the original project was the part-time employment of six students in the spring of 1974. Their work consisted of collecting ridership data on the countywide bus system. In the meantime, efforts to establish more-formal cooperative programs resulted in the hiring of five student