
The *Tren Urbano* UPR/MIT Professional Development Program

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ABSTRACT

This paper describes an innovative professional development program conducted jointly by the University of Puerto Rico (UPR) and the Massachusetts Institute of Technology (MIT) focusing on a major infrastructure project—*Tren Urbano*—which is a heavy rail system under construction in San Juan. This program is unusual in several respects. First it is funded as an integral and essential part of the infrastructure project itself. Second it has been sustained over a six-year period from the earliest stages of planning through the current state of construction. Furthermore the program is expected to continue through the start of revenue service in 2002. Finally the interdisciplinary, but tightly focused nature of the program provides a valuable opportunity for young professionals to see the important roles that different disciplines play in such major infrastructure projects. After a brief description of the *Tren Urbano* project itself, the paper explains the key elements of the program, provides an evaluation and discusses the necessary ingredients for replication elsewhere.

I. INTRODUCTION

In 1993 the Commonwealth of Puerto Rico made a decision to embark on a major infrastructure project, the development of a heavy rail transit system for metropolitan San Juan, referred to as *Tren Urbano*. From this initial decision a strategic objective was to develop a cadre of young Puerto Rican professional experts in all aspects of major infrastructure projects capable of assuming the leadership roles in future expansions of *Tren Urbano* as well as in similar major infrastructure projects.

A joint program of research and education was developed to achieve this objective, which included the University of Puerto Rico, the Massachusetts Institute of Technology and the Commonwealth of Puerto Rico itself. This paper briefly describes the *Tren Urbano* project and the professional development program. It then critically assesses the effectiveness of the program and identifies the critical ingredients for the development of similar programs.

II. SAN JUAN AND THE *TREN URBANO* PROJECT

The San Juan Metropolitan Region, with a population of 1.3 million living in a 1036 square km area, comprises 37% of the population of Puerto Rico as well as 63% of the island-wide employment. Population and employment densities of the region are among the highest in the U.S. mainland, and Puerto Rico. The region also has the dubious distinction of having the highest concentration of vehicles per mile of paved road in the world, a figure of 146 which is three times the figure in the U.S. overall. Furthermore, half the region's highways are heavily congested during the rush hours, and the existing public transport system is inadequate with buses and *públicos* (vans operated largely by individual owners without subsidy) having to compete with autos on congested roads.

For all these reasons, San Juan is an ideal candidate for the introduction of a high quality heavy rail transit, and in 1993 the Commonwealth of Puerto Rico embarked on the first phase of building a rail system, *Tren Urbano*. Phase I of *Tren Urbano* is the largest infrastructure project in the history of Puerto Rico with an approximate construction cost of \$1.6 billion for the 17.2 km segment, which will include 16 stations.

After an intensive planning and environmental review process, the procurement process was completed in 1997, and construction is now well underway with initial revenue service scheduled for 2002.

III. THE *TREN URBANO* PROFESSIONAL DEVELOPMENT PROGRAM

From the outset of the *Tren Urbano* project, it was recognized that if the initial phase were successful it would be the first piece of a larger regional rail system. Since there was no substantial expertise in Puerto Rico in the planning, design, construction and operation of urban rail systems, it was recognized that Phase I of the project would have to rely heavily on professional expertise from the U.S. mainland (as well as other parts of the world). However, it was essential during this first phase to develop a large number of Puerto Ricans as knowledgeable professionals who could go on to take leadership roles in the later expansion phases of *Tren Urbano* as well

as in other major infrastructure projects on the island. This resulted in the *Tren Urbano* Professional Development Program, which has the following principal objectives:

1. To develop local professionals in transit system planning, design, construction and operation, whose expertise can become a valuable high-technology service with a ready export market in Latin America.
2. To strengthen the educational and research programs in the most important infrastructure-related disciplines at the University of Puerto Rico.
3. To establish a model for cross-disciplinary cooperation among UPR faculty in engineering, architecture, and planning, working together with experts from government and industry to apply an integrated systems approach to the development of a major urban infrastructure project.
4. To develop a collaborative relationship between the University of Puerto Rico and the Massachusetts Institute of Technology through this educational program which can serve as a model for other programs involving joint efforts between educational institutions.

The program, which is described below, is now in its sixth year and has already served 94 UPR students and 62 MIT students.

IV. KEY PARTNERS

The *Tren Urbano* UPR-MIT Professional Development Program is sponsored by the Department of Transportation and Public Works (DTOP) of the Commonwealth of Puerto Rico, and the Puerto Rico Highway and Transportation Authority (PRHTA) and involves the following three entities: 1) *Tren Urbano* Office, 2) the University of Puerto Rico (UPR), and 3) the Massachusetts Institute of Technology (MIT). The role of each is outlined below:

A. *Tren Urbano* Office

The *Tren Urbano* project is a living laboratory for the development of young professionals with a focus on urban rail transit. It provides the context for the Professional Development Program and is the forum for study, research and professional practice for the university-based engineering, architecture, and planning students. All program components, to be described shortly, have evolved in tandem with the progress of the project—beginning with planning, environmental analysis, and design; moving on to construction; and eventually culminating in operations and maintenance of the newly-constructed transit system.

The *Tren Urbano* Office, through its General Management Architectural and Engineering Consultant (GMAEC),* manages a subcontract with each university, coordinates program activities with the universities, plans and implements work internships, serves as liaison for students, and evaluates the program.

* The General Management Architectural and Engineering Consultant (GMAEC) is composed of four prime consulting firms: Frederic R. Harris, Inc.; Daniel Mann Johnson and Mendenhall, Inc.; Barrett and Hale; and Eduardo Molinari y Asociados. This consortium has been under contract to the Puerto Rico Highway and Transportation Authority since August 1994 to perform environmental studies, preliminary engineering for Phase I, technology transfer, community participation support, technical services and procurement administration and support.

B. Universities

The two universities—UPR and MIT—recruit and select the students; plan and implement short courses; guide student research; provide faculty advisors to students; provide financial assistance to the students for conducting research, plan and implement site visits to other transit systems; and evaluate the program.

1) University of Puerto Rico (UPR): From 1993 to January 1999, the Civil Infrastructure Research Center at the UPR-Mayaguez planned and executed all program-related activities. In January 1999, the program became part of the Transportation Technology Transfer Center, also at the UPR-Mayaguez. Three schools participate in the program: 1) the School of Engineering located at the Mayaguez Campus, 2) the Graduate School of Planning, and 3) the School of Architecture, the latter two located at the Rio Piedras Campus. Designated professors from the three schools advise the students on their research projects and participate in all activities. To date a dozen UPR faculty have actively participated in the program, representing six departments and schools across the two campuses. Heavy faculty participation ensures academic rigor in the activities. The professors also use this special experience in classroom teaching, in developing new courses and in improving existing ones.

2) Massachusetts Institute of Technology (MIT): MIT also provides professional support for the *Tren Urbano* project overall and plays a major role in technology transfer activities by working very closely with the University of Puerto Rico. Specifically, several research staff use a significant portion of their time on site in San Juan providing technical assistance on various aspects of the project. In addition, a number of MIT faculty from the Schools of Engineering, and Urban Planning and Architecture are actively involved both in interacting with their counterparts at UPR, and in directing research by MIT students in support of the overall *Tren Urbano* project.

The MIT component of the collaboration is based in the Center for Transportation Studies, and many of the faculty and students in the program are associated with this Center. Students and faculty from the Departments of Civil and Environmental Engineering and Urban Studies and Planning are also an integral part of the program. To date, eight MIT faculty members have actively participated in this program.

V. PROGRAM ELEMENTS

The program consists of six key program elements, which are focused on giving students a well-rounded academic and practical foundation, as depicted below (table 1) and described briefly in the sections that follow.

A. MIT Summer Short Course on Public Transportation in Boston

Each summer, a specially tailored ten-day short course is provided at MIT giving the UPR students the opportunity to learn about the evolution of the public transportation system in Boston, and to see how this system has shaped the development of the Boston metropolitan area.

The UPR students begin the summer course in San Juan, with an introduction to the *Tren Urbano* Project during two intensive days of presentations and field visits. The urban development of the San Juan Metropolitan Region, the changes in travel demand and in

transport system characteristics, particularly post-World War II, including the wide-spread suburbanization and the exponential growth in the use of the automobile, set the stage for discussion of the planning, construction and operation of the *Tren Urbano* system. The two-day introduction concludes with a look at the long-term considerations of system expansion, island-wide transportation, joint development, and land use.

The UPR students then travel to Boston to meet their MIT colleagues. The MIT course includes field trips to study first hand transit design, construction, operations and maintenance. Students supplement the formal field trips with personal exploration of the city by transit. They participate in social activities and undertake a course project that mixes students from both institutions and across disciplines. The project requires field observation of the best and worst aspects of the Boston transit system, and concludes with recommendations on how to achieve the best system in San Juan. The student teams present course projects on the final day.

The instruction at MIT presents both engineering and broader policy and planning considerations relevant to public transportation. The sequence of planning, design, construction, operations and maintenance is followed in structuring the presentations, which are made by faculty from Civil and Environmental Engineering, Urban Studies and Planning, and the Center for Transportation Studies. Local professionals, transportation officials and community activists all add to the breadth of topics conveyed in the course.

Case studies of specific transit lines are used to organize the presentation of course material, and to focus the field trips. For example, the Southwest Corridor (MBTA Orange line) is presented to illustrate a design process with active community participation, and how the resulting line has achieved public support, personal security and even substantial volunteer maintenance of the parkland that was built as part of the transit project.

The specifics of Boston transportation projects are also placed in the context of land-use and development; local, state, and federal policies and politics; economics; and environmental considerations.

In summary, the summer course at MIT provides an intense introduction to the central issues of public transportation through presentations by experts and the direct experiences of the students. It also serves to spark students' curiosity about particular topics that will become the focus of their research for the coming year.

B. UPR Short Course on Tren Urbano and Transportation in San Juan

The UPR and the *Tren Urbano* Office jointly design and sponsor a ten-day course aimed at providing a first-hand experience of the San Juan Metropolitan Region and the *Tren Urbano* Project, as well as fostering the interaction of students and faculty with project staff.

The MIT students experience, with their UPR counterparts, life in metropolitan San Juan, learning first-hand about the problems of the city and the role that *Tren Urbano* will play in their solution. In this ten-day shared experience, held annually in January, the students are exposed to a number of distinguished professionals who give talks and lead discussions on topics ranging from aspects of Puerto Rican culture to technical details about the *Tren Urbano* project.

Faculty from the Schools of Engineering, Architecture, and the Graduate School of Planning, as well as Federal, Puerto Rico, and

local officials and professionals from the companies involved in the design and construction of *Tren Urbano* describe all aspects of the development of this complex project. The discussions are conducted at the Río Piedras Campus of the UPR and at the *Tren Urbano* Office, which integrates the work of government agencies, the GMAEC, and other firms involved in the project.

As parts of the activities, representatives from the major contractors provide status reports on the design and construction of the project. The participants learn first-hand about the progress of the civil and system contracts including issues such as scheduling, construction management and procurement, as well as transportation issues such as fare integration, operation and maintenance, and integration of *públicos* and buses with *Tren Urbano*.

Representatives from the government of Puerto Rico, including the Secretary of Transportation and Public Works, present the overall vision for the project and the program, stressing both the opportunities and the responsibilities of the Puerto Rican students in the program to contribute to the success of *Tren Urbano*. Federal Transit Administration officials also participate in the program, putting both the project and the program in the broader national context. It is noteworthy that this program is frequently cited by Federal Transit Administration and the U.S. Department of Transportation as one of the most promising professional development initiatives.

Both UPR and MIT students present their research-in-progress and receive feedback from the other students, faculty and *Tren Urbano* Office staff on how to proceed with their research. These oral and poster presentations are of great importance to the program because the students learn a lot from them. Not only are they demonstrating their technical know-how, but they are also "selling" their ideas to an authoritative and sometimes intimidating audience.

In addition to the presentations, a number of field trips are included, giving students the opportunity to visit the Phase I alignment as well as the facilities of government agencies that will play a major role when the train starts operating. A highlight of the activity is a helicopter tour for all participants, following the alignment, an experience that really helps develop an understanding of the city and its future interaction with the train.

C. Research Experience

The program emphasizes the multidisciplinary nature of major infrastructure projects. Students learn the importance of considering all the aspects of a project, including engineering (civil, mechanical, industrial, and electrical), transportation planning, systems, architecture, social, urban planning, safety, and public participation. The students come to appreciate that a successful project requires a strong integrated team effort. Each student, under the guidance of one of the faculty involved in the program, chooses a research topic and conducts research throughout their one to two years' participation in the program. For the graduate students this research frequently becomes the basis of their theses. The undergraduates conduct research either for credit hours or for pay as part of their undergraduate program. They must submit a research report to fulfill a requirement of the program.

Research topics are selected to combine the particular interests of the student with important questions in the development of *Tren Urbano* and the enhancement of the overall urban transportation system in San Juan. The idea is that as the *Tren Urbano* project

progresses, the focus of the research agenda also shifts to keep it in tune with the project priorities. There is a delicate balance to be maintained in the research program. On one hand, it is essential that the research be highly relevant to the current and emerging decision-making domain for *Tren Urbano*. This is the only way to generate commitment and support from the organizations directly responsible for *Tren Urbano* and this program. Without the active involvement of these organizations the research would be fundamentally unsatisfying for all concerned. On the other hand, it is essential to have a clear distinction between the applied research appropriate to a university and the consulting work necessary to support the *Tren Urbano* project. Typically, graduate students will be involved in a single research project, which takes at least nine months to complete and has a strong learning component. Consultants must be experts from the start and be able to respond to short and firm deadlines as well as to adjust their priorities on short notice. It is necessary that these differences be clearly understood by all parties going into this type of program.

While the majority of MIT students involved in *Tren Urbano* are graduate students conducting thesis research, a number of undergraduates are also involved, typically working closely with a graduate student under the direction of a faculty member. This has been found to be a highly effective way to interest MIT undergraduates in particular areas of study and potential careers.

A final element of the research program is to develop joint advising for master's thesis students across the UPR and MIT faculty. This is now being tried on a pilot basis with two students, one each from MIT and UPR. We also intend to identify topics for joint research involving students from each institution.

D. Professional Practice—The Internship

During their second summer in the program, UPR students are assigned to a ten-week, full-time internship with *Tren Urbano* contractors and consultants, organized and coordinated by the GMAEC. The internship has two main objectives: (1) to provide students with a meaningful and professionally-relevant work experience, and (2) to provide a forum for professional development.

UPR students are given priority for internships; but in most years several MIT students with Spanish language skills also participate when their participation would benefit the project and when there are positions available.

The internship planning process begins in January/February when students apply for an internship. Simultaneously, contractors and consultants are required to develop job descriptions for the interns. These descriptions and the intern applications are the background documents for the interview session coordinated by GMAEC after which students and supervisors express ranked preferences for the available internship placements and the available students, respectively. Based on these preferences, the best placements are jointly determined.

Students spend ten weeks at their work sites and also participate in four bi-weekly lunch meetings. Two of these meetings are designed to enhance professional development, and the other two are evaluation sessions. The first lunch meeting consists of a resume-writing workshop, to which the interns bring their own resumes to review and revise based on a resume-writing presentation. The second professional development activity consists of a panel discussion by transit professionals on career experiences and opportunities in the transit industry. The evaluation sessions are conducted in both

written and oral forms at the mid-point and end of the internships. The summer internship culminates with an Intern/Supervisor Recognition Evening where interns are awarded certificates of participation and are recognized for their contributions to the project.

E. Tour of Operating Transit System

During Spring Break, the UPR students and faculty visit another city to study first-hand another rail-based transit system. This is a formal three-day activity including lectures, panels and visits to stations, the control center and maintenance facilities. The students have a strong background at this time so they absorb all the information provided to them and can contrast and compare the planned San Juan system and the Boston system with which they became familiar the previous summer. So far visits have been made to Caracas, Miami, New York City, and Medellin.

F. Work Opportunity with *Tren Urbano* Consultant or Contractor

After UPR students complete their internships and their academic studies, every effort is made to place them in an entry-level professional job with one of the companies working on the *Tren Urbano* project. Placement with these companies varies upon the availability of positions and the volume of the *Tren Urbano* work.

VI. PROGRAM FUNDING

The program was initially funded for a two-year period in 1994, with the expectation that it would be extended for at least a six-year period. Now in year six, the funding has been committed through the eighth year of the program when initial revenue service is scheduled to commence. To date the total cost base has been approximately ten million dollars, which includes the costs of the GMAEC to run the program and the costs of UPR and MIT faculty and student participation. In addition, PRHTA was successful in securing the support of the Puerto Rico Economic Development Administration for two years of the UPR portion of the program at a cost of \$750,000.

Cost elements that are funded by the program through the participating universities include student support, short course expenses, travel expenses, and faculty participation.

It is noteworthy that the total cost of this major professional development program represents less than one percent of the total Phase I *Tren Urbano* project cost. Furthermore, the professional development program was written into the procurement process as part of the GMAEC scope of work and thus was not a subject of separate negotiation. This means that both universities are subcontracted as part of the overall GMAEC contract with the PRHTA. This strengthens the relationship between the universities—in particular the students and faculty doing research under this program—and the GMAEC, and indeed the *Tren Urbano* Office staff, whose active involvement is essential to making this a successful program.

VII. OUTCOMES AND EVALUATION

Since 1994, 168 students and engineers have participated in the program-94 from the UPR, 62 from MIT, 11 engineers from the Puerto Rico Highway and Transportation Authority, and one

graduate student from the University of Texas at Austin. Sixty-eight students, almost all from UPR, have completed or are currently doing internships with Tren Urbano contractors and consultants. Of these, 30 have been hired upon completion of their studies, 8 are still studying, 21 are current interns, and for 9 there is no follow-up information. Former students are already in responsible positions with the City of San Juan, the PRHTA, and in private companies such as Booz Allen Hamilton, Frederic R. Harris, Inc., Barrett & Hale, and Siemens.

Many students indicate that the program has given depth and focus to their studies, and greatly enriched their learning experience. The program has motivated increased numbers of students to choose transportation as a major. Moreover, students are also choosing to pursue graduate studies. Some of these have gone to MIT, The University of Texas, Purdue University, Virginia Tech, Georgia Tech and University of Wisconsin.

The research program has produced a significant body of work. To date about 125 research projects have been undertaken in a variety of areas (see Appendix A). The project has made some use of the research but greater effort is required to further integrate student research into the project.

As interns, the students have made a significant contribution to the project, assisting in key tasks such as field and office engineering, scheduling, field surveys, quality control and assurance, geotechnical analysis, document control, and urban design. Supervisors are highly enthusiastic about the students and are frequently sorry to see the interns depart at the conclusion of the internship experience. The excellent track record with student interns has resulted in a continuous demand for interns during the academic year. Internships are offered all year long to students recruited from other local universities in a program that is related to, but separate from, the UPR-MIT Professional Development Program.

While detailed evaluations are conducted for each of the program elements every year, which uniformly show great enthusiasm for the individual elements as well as for the program overall, it is premature to evaluate the longer term impact of the program. Certainly the students and faculty at both UPR and MIT who have participated in the program are extremely enthusiastic advocates for it.

VIII. OUTLOOK FOR THE FUTURE AND CONTINUING NEED FOR CHANGES

The UPR/MIT collaboration continues to evolve. With the progression from planning and design to construction, and now towards operations and maintenance, there are continually new challenges and new faculty and fields of expertise participating. As a result, more students are now pursuing research topics related to operations and maintenance of transit systems, and to long-range planning for system extensions. Both of these areas provide long-term opportunities for student work to be of real benefit to the *Tren Urbano* project itself.

Starting with the fourth year of the program the Puerto Rican participants have been expanded to include young engineers working at the PRHTA with direct involvement in the *Tren Urbano* project. Their participation increased the attention given to the real-world obstacles that must be overcome to achieve success. This will be an important ingredient in the future of this program and is

a good illustration of the need to think continuously about areas for potential improvement.

An additional aspect of program evolution has been the more extensive participation of Puerto Rican students in the MIT portion of the program. A majority of the MIT undergraduates participating are from Puerto Rico. In the past three years, six UPR graduates who entered MIT for graduate studies have also joined the program.

A final significant change, which has occurred over the past year, has resulted from recognizing a weakness of the program in its first four years. Specifically, there was a feeling on the part of both the faculty at the universities and the *Tren Urbano* Office that much of the research being conducted under this program was not having the desired impact on the *Tren Urbano* project itself. There were several reasons for this. First much of the research results were written up in the form of Master's theses which are typically long and hard to access and digest for *Tren Urbano* staff, who are dealing with the daily pressures of this major project. To remedy this all research is now also summarized in 5-10 page research digests or executive summaries, which are widely distributed among interested *Tren Urbano* office staff.

Second, there was concern that some of the more important problems facing *Tren Urbano* were not being selected for student research, and conversely some student research was not as relevant as it could be. To deal with both these issues a *Tren Urbano* Steering Committee was established at the end of year four to bring closer alignment between the research agenda of the universities and the needs of the project, as well as to improve university-project staff communication overall. This committee, which consists of representatives of DTOP, PRHTA, the GMAEC, and both universities, meets approximately bi-monthly and has proven to be an effective mechanism for identifying and correcting incipient problems before they become significant.

IX. INGREDIENTS FOR SUCCESSFUL REPLICATION

The value of using major projects as a centerpiece for university-based teaching and research seems readily apparent to those of us who are intimately involved in this UPR/MIT collaboration. The students who have participated in the program, both from MIT and Puerto Rico, have already found immediate use of their experiences in employment and further academic studies. More importantly, they are primed with skills and knowledge for a lifetime of multi-disciplinary, collaborative work.

Turning to the possibility of replicating a *Tren Urbano*-type program elsewhere, there are a number of factors which would be vital:

1. There needs to be strong commitment to the program from the very top of the agencies involved. In the case of *Tren Urbano* these agencies are DTOP and PRHTA. This type of program would never get off the launching pad without top-level commitment and vision, which then must permeate these lead agencies.
2. There needs to be an appreciation that the participating universities can indeed provide value to the project itself. In practice this is likely to be true only if the universities have some faculty and staff with strong directly related experience to the project at hand. In the case of *Tren Urbano*, the presence of the staff at MIT of a previous State Secretary of

Transportation, who had been the prime mover in several major infrastructure projects, provided instant credibility in terms of developing and implementing major transportation infrastructure projects. Only with this sort of credibility will there be a perception in the lead agencies that the university will be able to deliver. Equally important is the availability of key university staff to spend extended time on-site.

3. There must be mutual trust, respect and openness among all parties. In the case of *Tren Urbano* this was possible due to the experience and knowledge that the leaders of DTOP and PRHTA had of both UPR and MIT and the direct personal relationships, which existed among some of the principals at the outset.
4. The project itself must have sufficient size and innovative content to justify this type and scale of program with extensive university involvement. *Tren Urbano* had both these critical ingredients as well.

X. SUMMARY & CONCLUSIONS

This paper presents the implementation of a professional development program based on the multidisciplinary nature of a major infrastructure project. The Tren Urbano Professional Development Program offers a unique opportunity for training and technology transfer. The program attempts the following: strengthen teaching and research programs in the university departments involved; expand the number of professionals in urban planning, architecture, and engineering interested in transportation; and develop local experts able to export their knowledge and experience in the form of integrated consulting services in infrastructure planning, design, and engineering. So far, the Tren Urbano Project team, the two universities, and the students have all benefited immensely from this collaborative endeavor.

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