AC 2012-4046: CONSTRUCTION IMPACTS: A WEAKNESS IN CONSTRUCTION EDUCATION

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Students Lacking in Understanding of Construction Impacts

A weakness in construction education

Introduction: Current educational curricula across the US generally lack an in-depth emphasis on impacts caused by construction projects, and hence graduates are unprepared to deal with real life issues confronting them when working on such projects. For the preparation of this paper, the author examined two public projects – one very large[1], and another a smaller project[6] that imposed huge costs in mitigating these impacts.

Although the focus of this paper is on the largest transportation project constructed in the heart of a major US city, the Central Artery/Tunnel (CA/T) project popularly known as the "Big Dig", the approaches discussed here are equally applicable to infrastructure construction projects of almost any size.

On the Central Artery/Tunnel Project (Big Dig), almost one third of the total cost of $15B was expended on the mitigation program. The paper examines the nature of those costs and how construction managers could have reduced the costs by dealing more effectively with political, social, cultural and technical demands. Similar experience on a much smaller project demonstrates a great need for our construction educational curriculum to incorporate this aspect of construction into our estimating, scheduling and decision making process.

Brief History: The project was conceived almost fifty years ago. The old interstate I-93 (Central Artery) that traveled through the Boston downtown was constructed as an elevated highway in the early 1960s. Two immediate outcomes of that construction were that the City became bifurcated from its water front communities, and the elevated roadway became inadequate to carry the traffic volume of the time. The highway was designed for a capacity of 75,000 vehicles per day, but soon the traffic volume climbed to over 200,000 vehicles per day creating big traffic tie ups that would last for hours on daily basis. The historic North End – a predominantly Italian American community on the waterfront was completely cut off from the rest of the city.

Planning for an underground highway started in the early 1980s and the construction began in 1991. There were three distinct parts to the project: completing theI-90 from the city to the Logan International Airport; taking down the elevated highway (I-93) and putting it underground; and building a bridge over the Charles River as part of the I-93. All in all, the project was completed at a cost of $14.7 billion in 2003. The initial estimates were in the range of $2.5B - $4.5. The Massachusetts Transportation Department had contracted with the joint venture of Bechtel/Parsons, Brinckerhoff (B/PB) for providing construction management services including design and construction phases. [1]

Biggest Challenge during Construction: Although the project had to go through an exhaustive environmental review process that took several years to complete, nobody had envisioned the totality of the public process that would demand mitigation of construction impacts ranging from traffic re-routing to environmental and economic losses. Addressing those impacts confounded the earlier estimates for the completion of the project. Almost 1/3rd of the project cost can be attributed to mitigation.[4]

The major requirement by the City of Boston in granting various permits to the state and hence to the project, was that the city would not be shut down at any time during construction. The city had to stay open for businesses, vehicular and pedestrian traffic at all times. As the project design began to progress, and initial construction started to show visible signs of activity, the public process also began to intensify. Business wanted the construction to be done at nighttime and the residential neighborhoods wanted construction to be done during day time so the residents could have a good night's sleep.

The project managers found out that there were no textbook solutions to these unique issues. Mostly engineers or project managers who had worked on large construction projects had never encountered activist citizenry that although supported the project but was not ready to accept the impacts that would disrupt their normal lives or their businesses. It became clear that a comprehensive mitigation plan would have to be developed that would be flexible enough to be modified or upgraded as a particular situation arose.

Quarry Hills Recreational Complex: Similarly, on a smaller project called the Quarry Hills Recreational Complex with an estimated cost of $50 million, mitigation of impacts resulted in almost 20% of the project estimated cost. This project covering an area of 540 acres consisted of filling in old granite quarries, capping of adjacent landfill and creating a recreational complex of golf courses, ball parks and tennis courts on top of the famous Blue Hills in the City of Quincy and the Town of Milton. The site is located approximately seven (7) miles south of Boston on Interstate 93. The site provides spectacular views of Boston Harbor and the Boston Skyline.

For the designers and managers of this project, there were two major challenges: one, transporting 13 million tons of excavated material from the Big Dig to the site, and the second involved the protection of the residential neighborhoods, and a car dealership near the project site from construction related impacts.

The project also created an interesting but challenging partnerships between a private developer, two municipalities and the state government through its highway department.

The mitigation package included the following:

- Construction of a new ramp from the Interstate 93 exclusively for trucks hauling the excavated materials from the Big Dig to the site.

- Creating a noise/dirt mitigation plan for the residential communities that included periodic spray washing of exteriors of homes.
- Monitoring noise and dust levels in compliance with state environmental regulations.
- Construction of two truck wheel wash stations in order to wash the wheels of trucks leaving the site in order to prevent tracking of mud on city streets.

The above steps were specifically taken to deal with the unique nature of the construction impacts of this project. There were, of course, many standard mitigation measures such as using hay bales for erosion control, implemented at the site.

Need for Training of Engineers & Constructors: Since studying or analyzing the impacts of construction transcends traditional boundaries of engineering disciplines and of social sciences, engineers and constructors need preparation and training in the area of mitigation of construction impacts. Reviewing current curricula of civil engineering or construction engineering/management, one would find scant information that can deal with this subject that is multi-dimensional in its scope. The following is presented as a model for inclusion in a course related to heavy construction or large infrastructure projects. Although dealing with construction impacts is required on publically funded project, the process is equally rigorous on privately funded projects.

The material related to construction impacts and the development of a mitigation plan for construction engineering/construction management students may be divided as follows:

- Freshman Year – Introduction to Construction Impacts
- Junior Year – Development of a Mitigation Plan
- Senior Year – Capstone project must incorporate implementation strategies for mitigating construction impacts.

These topics could be embedded into courses such as Heavy Highway Construction, Public Infrastructure Project Management or a new course that could be created to combine various aspects of project management including analysis of construction impacts, strategies for minimizing impacts, negotiation skills etc. The course could also be called Contemporary Project Management in the 21st Century.

Curriculum Development: Any course that is developed to address the above aspects of design and construction must start with an Impacts Analysis & Mitigation Plan development: Following steps are laid out as guidance:

1. **Locational Information:** The first step in analyzing construction impacts is to determine the magnitude of the project and its location. The Big Dig project because of its location in the center of a major US city required a thorough assessment of its abutters along the alignment. That included businesses, residences, public lands, transportation facilities, commercial enterprises, and financial institutions such as the Federal Reserve Bank of

Boston. Constructing this mega project required an extensive program to mitigate its impact on city residents, businesses, and visitors). It has been said that the constructing the Central Artery/Tunnel (CA/T) project over two decades was like doing open-heart surgery on a patient who continued to work and play tennis every day. [2]

2. **Identification of Stakeholders:** Next step will be to identify all stakeholders such as proponents, funders, opponents, abutters, interest groups, neighborhood groups, citizens advisory groups, environmental advocates etc. This list should be as comprehensive as possible. On the Big Dig, the list included almost 200 entities.[4]

3. **Determination of Areas for Mitigation:** After Identifying the stakeholders, the most important task then is to delineate areas for mitigation. That's the most challenging phase in the life of a construction project. Every stakeholder whether a private or a public entity would attempt to derive the maximum benefit for their constituency. This may involve extensive negotiations with various entities and that could have a big impact on the overall cost and project schedule. To cite the example of the Big Dig, negotiations concerning one element of the project, the Charles River Crossing, almost took two years to resolve. Some environmental groups wanted a tunnel constructed under the river rather than a bridge for I-93. Even after the mitigation agreement was signed between the transportation and environmental agencies, a law suit was filed against that decision. Students of today must be trained in developing skills that will help them in dealing with these situations which are becoming more and more common on construction projects. Even the most ardent supporters of a project expect the project managers to minimize if not totally eliminate construction impacts.

4. **Mitigation Plan Development:** As the discussions with the stakeholders are proceeding and draft agreements are being hammered out, mitigation plan development should start immediately to refine the various elements of a mitigation plan, keeping in mind cost and schedule impacts. In some cases the cost of mitigating a certain impact may be much more cost effective than have prolonged negotiations. Again, it must be emphasized that our students must be trained in carrying out negotiations and be able to communicate effectively with adversarial stakeholders.

Construction Mitigation Examples:

Using the Big Dig Project as an example, it may be useful to understand how the mitigation program was developed in four specific areas. As stated earlier, a comprehensive mitigation program was developed in concert with the requirements of federal and state environmental review process.[3] The environmental review process began in the mid-1980s and was completed in 1991 when the actual construction of the project started.

Described below are four specific examples of construction mitigation implemented on the Big Dig project.

NOISE MITITGATION

The CA/T committed to minimizing noise impact during construction. This goal was especially difficult because of Boston's unique neighborhoods, which integrate residential, commercial, and industrial activities. With this mix, daytime businesses often prefer work to be done at night in contrast to residents, who prefer noisy activity to be done during the day. To find an achievable balance, the CA/T project staff worked closely with all abutters to develop appropriate construction schedules, work hour limitations on jack hammering, restriction on the use of backup alarms, and ongoing noise monitoring). In some cases, the CA/T had to construct noise walls and noise curtains. In the historic North End, many houses had to be retrofitted with acoustical windows to dampen the effect of construction noise. This approach to construction resulted in the most comprehensive noise specifications in the country, and they have been used as a model for other public works projects.

TRAFFIC FLOW

The elevated highway was finally dismantled in 2005 when the project was substantially complete, making way for businesses housing, and parkland development. During construction, however, the project maintained all six lanes of the elevated Interstate 93 roadway. To accomplish this goal, the project had to phase in the underground tunnel construction located directly below the exiting elevated structure with great engineering precision and coordination. The first phase of construction included construction of the new tunnel walls on either side of the current roadway system. Over time, the weight of the existing elevated structure was transferred to the new walls clearing the way for under artery tunnel excavation.

PEDESTRIAN AND BUSINESS ACCESS

In addition to keeping traffic moving, the CA/T Project constantly undertook mitigation measures to lessen the impact to pedestrian and business access. It incorporated standardize pedestrian walkway amenities into all contracts to ensure safe and efficient pedestrian flow. Contract specifications required the use of jersey barriers, standardized blue and gold plywood panels, lighting, and temporary surface pavement for all CA/T work. The walkways were augmented with street signs, business graphics, tourist information, landscaping, and art to maintain and enhance the pedestrian environment throughout an ever-changing construction project.

AIR QUALITY

Air quality impact was mitigated with an array of dust control measures, such as the use of truck covers and designated truck routes. CA/T contract specifications also called for contractors to suppress dust on the worksites, sweep the streets, and wash truck wheels to minimize potential impact.

Instructional Techniques: As we all understand that each project, small or large, has its own identity; students should be exposed to the real life projects. Instructors should identify projects in early stages which could be used as model projects with moderate complexity. Students could work in teams of two or three to start the analysis of potential impacts, and then proceed to the development of mitigation plans with cost estimates and schedules of implementation. This could be accomplished as part of a capstone project at the conclusion of which an external panel of judges could be asked to review student work. Flexibility should, however, be built into the process so that the instructor has leeway in requiring the necessary academic rigor.

Assessment of Quality of Student Work: Clear objectives should be laid out in the assessment process. At a minimum, the following student learning objectives should be targeted in measuring student work:

1. Develop project impacts
2. Analyze impacts in terms of the severity and timeline of the project
3. Develop mitigation costs
4. Develop impacts, negative as well as positive, on the schedule

Meeting Accreditation Requirements: Generally, the accreditation requirements are based on assessing program goals. The teaching faculty would establish criteria for the assessment of program goals based on clearly defined learning objectives. Enhancements can be made based on industry input, student surveys, employer surveys and faculty review process.

Conclusion:

Based on the foregoing discussion, it is quite evident that the project managers/construction managers lack a focused academic training in the area of developing mitigation plans for dealing with the impacts associated with construction projects. Since mitigation plans can have a profound impact on cost and schedule, it is vitally important that the graduating students have the necessary competencies to deal with the present day challenges in moving construction projects forward.

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