# International Civil Engineering Capstone Projects - Benefits, Challenges and Lessons Learned

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All engineering students at Seattle University are required to complete a nine month long, team based, externally sponsored senior design project. In the past decade civil engineering design teams have completed eight projects for clients outside the USA. This paper describes the projects, provides details of recruitment, implementation, and partnerships with organizations. It discusses the benefits to students, project challenges and the overall lessons learned.

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## *Introduction*

ABET[1] criterion 3h requires that all engineering graduates demonstrate the program outcome of a “broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.” Capstone projects are an ideal venue to demonstrate this outcome.

Seattle University (SU) has a well-established capstone program that has been in existence for nearly three decades. All engineering students work in teams on a nine month long, externally sponsored, capstone project under the supervision of a liaison engineer from the sponsoring organization and a faculty advisor.

Of the 141 civil and environmental projects completed within the department, eight were for international clients. Table 1 summarizes the projects, the year of completion and the sponsor. This paper describes project details, recruitment, implementation, benefits to students, challenges posed, and overall lessons learned.

## *Project Descriptions, Recruitment and Partnerships*

International capstone projects were proposed by various constituents as described below.

### Tibet and Haiti Projects

Long time supporter of SU’s senior design program, Herrera Environmental Consultants (HEC), proposed the Tibet pedestrian bridges and the Haiti flood control project. HEC is a local civil engineering company that is actively involved in humanitarian efforts around the world.

HEC partnered with a non-governmental organization (NGO) to construct pedestrian bridges in remote areas of Tibet. The 03-04 capstone design team designed an approximately 75-m span cable suspended pedestrian bridge in the village of Shoda. Prior to this bridge, children were forced to stay in school the entire week because they had to walk three hours to find a safe river crossing from their homes to the nearest school.

Table 1. International Civil Engineering Projects Completed at Seattle University

| Design of | Location (Yrs) | Sponsor |
|---|---|---|
| Pedestrian Bridge | Tibet (03-04) (04-05) | Herrera Environmental |
| Coffee Wastewater Treatment System | Nicaragua (07-08) (13-14) | Tetra Tech Kennedy Jenks |
| Community Foundation for Safe water | Zambia (08-09) | Seattle University |
| Diversion Channel for Flood Control | Haiti (09-10) | Herrera Environmental |
| Orphanage, Community and Learning Centers | Ethiopia (10-11) | Engineers Without Borders |
| Community Center | Colombia (10-11) | Tetra Tech |

In the 04-05 Tibet project, a student team designed a suspended bridge which serves the villages of Gyibu and Jayng so that they were no longer isolated from markets, healthcare facilities and schools by a 65m wide deep gorge. Before the project, the closest crossing was down the river valley two to three miles from the villages.

Both teams were mentored by a civil/structural engineering faculty member and a HEC engineer who had visited the site and had performed topographic surveys.

In the Haiti project, a farming community along Riviére des Moustique was adversely affected by flooding due to frequent hurricanes/ tropical storms, sediment accumulation and poor drainage in lower parts of the floodplain. In 2007 a European non-governmental organization partnered with HEC to develop a comprehensive flood control plan for the region. The design team completed the design work for a small portion of the master plan. The team designed the diversion channel, inlet and outlet structures and prepared construction ready drawings.

The student team was mentored by two engineers from HEC, a civil engineering faculty member and a NGO representative with 30-years of development experience in Haiti and an engineering degree from an American university.

### Nicaragua Projects

The Nicaragua coffee projects were proposed to the department by a Chemistry department faculty member who had worked with the local farmers for more than ten years on improving the quality, consistency and sustainability of coffee. Through her work, she had developed a close partnership with Catholic Relief Services/Nicaragua, Central Cooperative Services Multiples "Aromas Café" (CECOSEMAC) and University of Central America, Managua.

Wastewater produced during coffee processing is acidic, high in Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Total Nitrogen and Phosphorous. The processed water in most cases is directly released into local streams, adversely impacting the water quality and posing health hazards. The student team designed a wastewater treatment system for a new coffee *"beneficio"* or wet processing mill, for use by farmers in the town of La Suana in 07-08 and in San Antonio 13-14.

Local civil engineering companies provided financial funding and sponsor liaisons for the projects. A civil engineering faculty member and the chemistry faculty member served as advisors.

### Ethiopia and Zambia Projects

The Ethiopia orphanage and Zambia Community Fountain projects were initiated through the Engineers Without Borders (EWB) Student Chapter.

An Ethiopian immigrant living in Seattle had purchased a property in Ethiopia with the purpose of developing an orphanage complex which would host dormitories and learning centers for the orphans as well as a community center for various activities and training sessions for the villagers.

The design team developed architectural/structural designs and cost estimates of a typical dormitory for 50 children, a learning center for 25 children, and a community center that could accommodate 300 people.

Three Ethiopian engineers practicing in the US and the owner brought aboard the Civil Engineering Department of Addis Ababa University (AAU) as partners. The three entities along with a faculty advisor served as resources to the team throughout the project.

In Zambia lack of municipal water distribution system in the small town of Chirundu forced residents to collect water from the crocodile-infested Zambezi river. The student team designed a mechanical pumping system and a community fountain to provide a safe place to collect water. The team also designed a water treatment system to remove pathogens from water intended for potable use. This project was supervised by a civil engineering faculty member.

### Colombia Project

The Colombia community project was proposed by a faculty member from our department who is also a member of the board of directors of Poder Joven Foundation (PJF) in Colombia. PJF planned to build a community center to host their educational programs with underprivileged children, offer job training for adults and to conduct community meetings. The capstone team carried out the architectural and structural design of a three story reinforced-concrete building. The design had to be simple enough so that it could be completed by unskilled labor and could be completed in phases as funds become available.

## *Student Team Formation*

The goal is for all teams to succeed. Therefore the teams were formed by the instructor based on an interest survey done in the spring quarter of the junior year. Communication strengths and personality traits of students were taken into account to have well balanced teams. Each team had three to four students.

## *Benefits and Challenges*

International senior design projects provide the students with experiential learning in global, societal, economic issues. The students are exposed to other cultures, customs, and the ability to work with lay clients. Furthermore, studies have shown that service oriented projects help to retain women in engineering[2].

The project challenges vary from project to project. depending on the sub-discipline within civil engineering. But some challenges are common to all.

**Site visit**

An initial site visit is a critical aspect for most, especially non structural, civil engineering projects. It helps the designer visualize how the end product fits into the existing environment. However, the cost of student travel and travel advisories against some of the countries posed concerns.

In the Nicaragua projects, the student teams and the faculty members traveled to the site to conduct field reconnaissance, observe a coffee processing mill and to sample and analyze coffee wastewater. The field reconnaissance helped the team to better decide where the water treatment facilities could be located, a task that otherwise would have been difficult. The cost of travel was shared by the university and the students.

In the case of the Haiti flood control project, the faculty advisor travelled to the site in January 2010 to carry out a field reconnaissance and to meet with the NGO representative. The students could not join because of cost, a travel advisory and because the travel was scheduled when the school was in session. The faculty advisor's travel cost was covered by the university. The faculty advisor took plenty of photographs of the site and performed soil and water tests to help the students develop their design.

Because the Ethiopia project involved structural design of buildings and there was contact with the local university for data collection, the department decided that a site visit was not critical. Pictures of the site provided by the client showed no steep slopes at or near the site so there was no concern in regards to the topography or site stability issues. In addition, soil tests performed by a graduate student at AAU were sufficient for the team to carry out the structural design for the orphanage.

The Colombia, Tibet and Zambia teams did not visit the sites. For the Tibet project, the pictures and the topographic map provided by the sponsor were adequate to design the superstructure. The Zambia project would have benefitted by a site visit.

**Local Contacts in Other Countries**

For international projects to be successful it is imperative to have local contacts, both professional and personal, willing to work with the team throughout the academic year.

Site visit to Nicaragua by the team and faculty members helped to strengthen the connections with the farmers and helped the team during the year. The Haiti-based NGO representative provided invaluable advice to the team regarding appropriate construction methods in the region. The Ethiopian orphanage team collaborated with AAU to obtain geotechnical data. The team specified the locations and number of test pits to be dug, the types of lab tests to be performed and the data to be collected. These test results were used to design the foundations. In addition, a licensed civil engineer and an architect from the EWB chapter professionals, who had previously designed similar facilities in other African countries, served as a resource to the team. They reviewed the preliminary design and provided feedback.

**Building Materials, Construction Practices, Local Codes and Standards**

For design to be implemented successfully teams have to be aware of local design codes and standards, culture, material availability and construction practices.

The Nicaragua project had a number of constraints: the farm lacked electricity and therefore the design alternatives could not include pumps or aeration; the design had to be compatible with sustainable and organic standards as required by the local farmer's cooperative, CECOSEMAC, and by the Nicaragua Fair Trade program; the final effluent to be discharged to surface waters had to meet or exceed local standards of the Ministerio Del Ambiente y Los Recursos Naturales de Nicaragua (MARENA) which was equivalent to the US-Environmental Protection Agency (US-EPA). The team had to use locally available materials, such as, concrete, plastic liner, gravel, PVC pipe, and wood.

In the Haiti flood control project the team analyzed rainfall data that had been collected by the sponsoring NGO during hurricanes Hannah and Ike and used this information to update a U.S. Army Corps of Engineers hydraulic models for the site that had previously been developed by HEC. The discharge and hydraulic information developed from these models guided the design of the flood control channel. The team researched appropriate construction and channel lining technology available in Haiti. In consultation with the NGO sponsor, they specified locally available clay, gravel and sand for levees at the channel inlet and outlet and specified concrete lined gabion baskets and Reno mattresses for the diversion channel lining.

Early in the Ethiopian orphanage project, the students researched the climate, local architecture and local construction materials. AAU provided information on local construction practices for the team's structural design and standard material cost information for the cost analysis. The team learned that it was common practice to use reinforced concrete framing with infill masonry. They also found that roof trusses are made of timber (Eucalyptus) for spans of up to 8 m and steel for longer spans. Common roofing material consisted of corrugated steel sheets. The students based the design on the Ethiopian Building Code Standards of 1995.

**Proficiency in Foreign Language**

Foreign language proficiency is helpful in international projects for multiple reasons. In the Nicaragua project, the design drawings for the wastewater treatment process and the maintenance had to be in Spanish to be useful for the farmers. In the Haiti flood control project much of the survey data provided to the team was in French. Because none of the team members knew the language, the team had to proactively ask questions of the NGO sponsor to clarify the meaning of the data. In the Ethiopian orphanage project the students were able to complete the project without any knowledge of a foreign language as the codes and other documents were in English.

### Working with Lay Client

International projects usually involve lay clients who have a vision and/or are interested in the social benefit to the community. The students have to translate the client needs and constraints into functional requirements and measurable design parameters. They also face the challenge of explaining engineering terms and constraints to a lay client.

## *Lessons Learned*

The above projects provide good examples of the pedagogical potential of international projects. Lessons learned from these projects are summarized below.

- Working with a Seattle-based liaison who has a vested interest in the project was a critical element of success in the Tibet, Haiti, Ethiopia and Nicaragua projects. Conversely, the projects in Colombia and Zambia did not have knowledgeable Seattle-based liaisons. Both projects had liaisons stationed abroad, a member of PJF Foundation in Colombia and a retired faculty member living in Zambia. The lack of regular meetings and smooth information flow made the projects more challenging.
- The Tibet and Haiti projects had a reasonable lag time between the design phase and the construction phase. On the other hand, the site for the community center in Colombia was under negotiation during the summer prior to project initiation. However, by the end of the fall quarter a different site was purchased. Due to the lack of permitting requirements, construction progressed rapidly often ahead of the design. This became a frustrating and stressful experience to the team as they had to constantly check that the construction met design code requirements.
- Site visits are crucial for non-structural projects. The Haiti team took a while to understand the water-shed wide context of the project because of the lack of site visit. Conversely, despite the lack of a site visit, the Tibet and Ethiopia structural projects were successful because of the available field data and pictures of the site. The Nicaragua projects would have been difficult without a site visit. The Zambia project would have benefitted by a site visit.
- Students should be required to address social, health and safety issues because codes and regulations in developing countries may not address these adequately. Nevertheless, students should be required to respect and abide by the local codes and governmental framework without having the notion that the US codes are superior to others and should be applied in any country without any further questions.
- Universities should continue to follow up with project partners either during construction or monitoring phases. After the 03-04 Tibet project the team travelled to Tibet to take part in the construction of the bridge. This led to a second bridge project the next year. Similarly, the continued partnership in Nicaragua led to a project in 13-14.
- Prior to team placement, students should be polled if they would like to be placed on an international project. If the project involves travel, students should be given time to prepare for local living conditions, food, language and culture. Furthermore some students may feel more comfortable traveling to certain parts of the world than others. Issues related to travel cost, such as cost sharing between university and potential funding partners should be discussed early. Some students may thrive in an international project but may not have the finances needed for travel.
- Identifying students with the appropriate language skills will be valuable during travel, for interpreting and preparing documents.
- Projects that are expected to be built with unqualified labor and/or with insufficient mechanisms of quality control should be designed to be simple and conservative to accommodate construction tolerances.

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