OFFSHORING OF ENGINEERING SERVICES IN THE CONSTRUCTION INDUSTRY

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Prepared for the Workshop on the Offshoring of Engineering:
Facts, Myths, Unknowns, and Implications
National Academy of Engineering
October 24-25, 2006

ABSTRACT

The construction industry is a large contributor to the United States (US) and world economy. Participants in the industry are responsible for designing and constructing the built environment including infrastructure, housing, offices and other facilities. It is a very diverse industry with many project types and many engineering disciplines working together including civil, electrical, mechanical, chemical, and architectural. Employment within the industry is currently strong supported by a strong US and global construction market.

Offshoring of engineering services within the construction industry is not new. US companies have had offshore offices in low income countries for many years to perform design and construction management services. But, with the increase in information technology and the drive to reduce engineering costs on projects, there is a recent trend toward the increase in offshoring within the industry. In particular, many large capital projects performed by US companies are being designed with some level of engineering work performed in low cost engineering centers. To date, the large scale offshoring of design services for smaller projects is limited with a relatively small amount of CAD drafting, 3D modeling and engineering detailing performed by offshore technicians, architects and engineers.

While offshoring is having an impact on the US construction industry and the structure of the jobs within the industry, the impact remains limited at this time. The US remains a net exporter of design services within the construction industry and employment within engineering remains strong. But, the construction industry is prone to economic cycles which could have a significant impact on this situation in the future. It is prudent to consider actions which could be implemented to minimize potential negative impacts of offshoring within the construction industry. US companies will continue to use lower cost labor in other countries which can make US companies globally competitive and aid in making more facility projects more economically viable. Some measures that should be considered include supporting the continued development of more globally focused engineers; supporting the growth in the export of engineering services from the US; ensuring that national security and intellectual property are appropriately protected when offshoring design services; and continuing to encourage our youth to pursue productive careers within engineering in the construction industry.

INTRODUCTION

The Construction Industry is a large and diversified industry which focuses on the design, delivery and renovation of facilities such as large petrochemical plants, bridges, buildings, tunnels, roads, ports, and residential units. These facilities play a significant role in housing the population and providing the core infrastructure within the country. Engineers from multiple disciplines perform many different tasks in this diversified industry including facility programming; design of engineered systems; construction engineering and management; and facility management.

The Global Construction Industry is a $3.9 trillion per year global industry[1]. The US has the largest construction market of any country with a current annual value of approximately $1.22 trillion of construction performed in the United States[2]. This accounts for 9.2% of the Gross Domestic Product of the US. US companies also perform over $34 billion per year of international work[3].

The US construction market has recently been in a significant growth period. Figure 1 shows the annual construction spending from 1993 to 2005. The average annual growth rate during this period was 7.3%. Construction spending growth in the US market has increased by 12% from 2003 to 2004, and 11% from 2004 to 2005. This rate has slowed slighted in 2006, but it is currently at 8.5%[2].

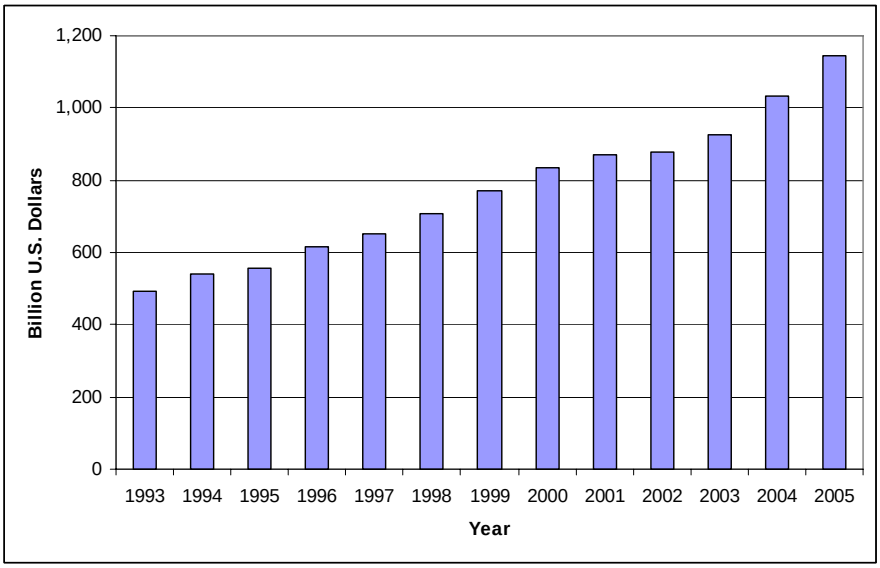

Figure 1: Construction Spending (1993 – 2005) [Data from U.S. Census Bureau[2]]

The global construction market has also been growing. There is a significant need for infrastructure and housing within developing nations such as China and India, along with continued investments in high income countries. Data regarding the overall size of the global industry is more limited and more unreliable, but Engineering News Record (ENR) data

collected from multiple sources shows that the global construction market grew from $3.4 trillion in 1999[4] to $3.9 trillion in 2004[1] for a total growth of 14.7% over a 5 year period.

The US share of international work (work performed by a company that is not headquartered in the country where the constructed facility is located) has been declining. In 2005, US construction companies listed within the ENR Top 225 International Contractors performed $34.8 billion of international work or 18.4% of international work performed by the largest 225 international contractors[3]. This percentage of work is down from 36.5% in 1985, although it has remained relatively stable for the past 10 years.

One of the most significant challenges within the US construction industry has been the supply of workers within the industry, both field employees and professional employees. Fewer people are interested in working in the construction trades which has caused challenges for the consistent delivery of quality facilities. There are significant efforts to recruit new design professionals into the industry, but these efforts face many challenges including a negative perception of the construction industry and low salaries relative to other industries. This limitation in the recruitment of new design professionals, combined with an aging population of experienced engineers who are retiring, is currently placing a strain on the industry for locating employees to design and manage the construction of facilities.

This paper focuses on offshoring of design and construction management services in the construction industry. There is not a universal definition for offshoring[5] and the definition used is important. The American Society of Civil Engineering (ASCE) defined offshoring within the construction industry as 'the practice of acquiring architectural / engineering services from sources outside of the United States.'[6] But, some level of design services have historically been performed for international construction projects in international locations. For example, if a power plant is being constructed by a US contractor in India, some design work has historically been performed in India, and some design work may have also been performed in the country of the large equipment suppliers. Therefore, the following definition is proposed for offshoring of design services in the construction industry:

> *Offshoring of design services in the construction industry is the relocation of work that is typically performed in one country to design professionals in the same company in another country or to another company in another country to achieve lower wage rates.*

Sometimes offshoring is performed through offshore outsourcing, where a company hires an external company to perform the service in another country. Other times the services are performed by company employees who are located in an office within another country. Large international construction companies have worked in many international locations. Through this process, they have set up offshore offices to perform services on these international projects. Many of these services would not typically be performed in the US, and they should not fall within the definition of offshoring when we consider the potential shift in work from US to offshore locations. But, more recently, companies have been either setting up offices, using existing offices, or hiring companies to perform design services that would have previously been performed in the US office. These services would fall into the proposed definition of offshored services.

THE NATURE OF ENGINEERING SERVICES IN THE CONSTRUCTION INDUSTRY

The construction industry can be subdivided into several categories. For the analysis of offshoring, it is helpful to separate the industry into two market scope sectors: 1) the Engineering, Procurement and Construction (EPC) sector, and 2) the Architectural, Engineering and Construction (AEC) sector. Companies that perform work in the EPC sector focus on large industrial or infrastructure facilities. Most companies within this sector tend to be large and employ many engineers and engineering technicians working on the design and construction of large projects such as power plants, refineries, industrial facilities, offshore platforms, etc.

Companies which service the AEC sector are much more diversified. Engineers within this sector focus on the design and construction of buildings and residential facilities. The AEC sector of the construction industry is very fragmented and is serviced by a large number of small companies. There are a number of companies that perform work in both the EPC and AEC sectors, but they frequently separate the different work activities into different divisions within the company.

This paper addresses the offshoring of engineering services performed within both sectors of the construction industry. The residential construction portion of the AEC sector (approximately 55% of the US construction work put in place[7]) is excluded due to the small company size typical of many residential design and construction companies, even though several residential developers are large and construct many residential units each year.

The construction industry is a very decentralized industry. Within the US construction market, there are almost 2.8 million construction firms employing over 7 million people[8]. A vast majority of the companies within the industry tend to be small with almost 2 out of 3 firms having less than 5 employees[9]. The largest US contractor by revenue in 2005 (Bechtel) had a total revenue of $14.6 billion with $7.2 billion in international markets[10]. Therefore, approximately 0.6% of the US market revenue flows through the company. The contractor with the largest share of the US domestic market was Centex with $12.6 billion in US revenue[10] (approximately 1% of the US market). If you combine the revenue of all top 400 largest contractors, their 2005 domestic revenue is $200 billion[10] (19% of the US market). This is very different than many other industries which are controlled by a small number of larger companies. It is also important to recognize that a very large percentage of the revenue for the top 400 contractors is subcontracted to specialty firms. Therefore, the industry is very diversified with many different companies contributing to the facility construction process.

Design work which includes architectural and engineering services is one portion of the overall revenue in the construction industry. ENR ranks the top 500 design firms in the US each year. The top 500 design firms generated $59.25 billion in design revenue in 2005 which was an increase of 11.8% from 2004[11].

Engineering work is related to all phases of the delivery of a capital facility. The primary phases for delivering and operating a facility have been defined by Sanvido et al.[12] as Manage, Plan, Design, Construct, and Operate a facility. Engineers play a role to varying levels in each of

these phases, from the initial inception of the facility concept through the operation and renovation of the completed facility.

There are several important characteristics related to typical projects within the construction industry which influence the potential for using offshore engineers to perform engineering services. Engineers typically perform work on large, uniquely designed projects. It is rare that an owner will wish to use the same design for multiple buildings or facilities. Even if they do, the design must be modified to accommodate site conditions and projects must comply with building codes in the location of the project. The local knowledge necessary to design the facility to meet local codes and to consider local conditions, e.g., geotechnical, weather, and cultural, are significant and provide an advantage to local design firms. The location of the project will vary, but some degree of onsite construction must always occur. Therefore, there is always a need for engineering support in the location of the physical project. Another important factor is that the owner typically maintains active involvement in the design of the facility which requires frequent interaction with the owner or their representatives. Finally, many owners do not want the detailed design information for their facility widely distributed to international locations, so security of data is an important issue on many projects. These factors can make it more challenging to manage engineering teams from various locations, and therefore more difficult to execute a project with offshore engineering labor.

DATA COLLECTION METHODOLOGY

To analyze the current status of offshore outsourcing within the construction industry, three different data collection tasks were performed. The data presented in this paper includes data taken from multiple data sources including the Bureau of Labor Statistics, the US Census Bureau, the Bureau of Economic Analysis, the National Science Foundation, and Engineering News Record.

Data is also presented from two different surveys performed at Penn State. The first survey was completed in 2004 and was sponsored by the Construction Industry Institute (CII). This survey was developed with significant industry input from a research team (CII Project Team 211) with 16 industry and 4 academic members. Throughout this paper, this survey will be referred to as the 'CII Survey'. Following the survey, over 20 detailed interviews were conducted with survey participants to gain additional insight into their global sourcing strategies and challenges.

A second survey was distributed in July 2006 to the top US design firms listed in the Engineering News Record Top 225 Global Design Firms. There were 82 US firms listed in the 2006 list of top global design firms. A survey was distributed to the director of engineering or design for these firms. Nine responses were received with a response rate of 11%. Therefore, no statistical data will be presented from the survey. The survey did identify current perceptions from several large design firms within the industry which are incorporated into the recommendations and comments throughout the paper. The response to this survey illustrates the challenges of collecting accurate data related to offshoring within the construction industry.

The referenced data sources are limited when aiming to draw accurate conclusions regarding offshoring. There is no single source of data that can be referenced to identify the specific information regarding the current status or trends for offshoring within the construction industry. For example, there is no reliable data source which provides the breakdown of domestic and foreign employees performing engineering and architectural services within companies in the construction industry. There is a need to identify and develop methods to improve the collection of accurate data regarding the offshoring of engineering and architectural services jobs within the construction industry.

ENGINEERING EMPLOYMENT AND EDUCATION

Demand for Engineers in the Construction Industry

The primary engineering discipline that works within the construction industry is civil engineering but many other engineering disciplines also work within the construction industry including electrical, mechanical, industrial, environmental, and architectural[13]. For the remainder of this analysis, the civil engineering discipline will be analyzed since it is most representative of the engineering disciplines working in the construction industry. The unemployment rate for civil engineers within the US market is only 2.2%[14]. Out of a total of 1.4 million engineers in the marketplace in 2004, 237,000 were civil engineers. This is the largest single percentage of any of the engineering disciplines (16.4%)[15], although if you combine electrical engineering and computer science, they are larger. While there are many civil engineers in the workforce, the average starting salary for these graduates is one of the lowest within the engineering disciplines with a median salary for graduating students of $43,679 for a BS degree, $48,050 for an MS, and $59,625 for a Ph.D. (May 2004 data)[15]. The overall median salary for practicing civil engineers in May 2004 was $64,230 which is the next to lowest of all engineering disciplines. The Department of Labor is projecting a need for an additional 39,000 civil engineers by 2014 which is a 16.5% increase[16]. This is one of the largest projected increases of all engineering disciplines (only environment and biomedical are higher and they are much smaller disciplines by quantity).

In addition to the statistics, it is clear from discussing with industry executives that one of the most significant challenges that they face is the staffing of projects which requires the recruitment and retention of engineers. Throughout the construction industry, there is currently a high demand for design and construction professionals in engineering and architecture in the US market. There is also an aging engineering workforce and there is a gap in experienced engineers in many of the large EPC companies. This current situation is allowing EPC companies within this sector to use offshoring for their engineering work with little impact on the size of their existing workforce in the US.

In addition to engineers, the other primary professional design participant that can not be ignored when discussing offshore outsourcing in the construction industry, particularly in the AEC sector, is the architect. The Bureau of Labor Statistics[17] reported that there were approximately 129,000 architects in the US in 2004. Many architects are professionally

registered design practitioners. They had a reported median salary of approximately $60,300 (May 2004). There is an average projected growth of 17.3% by 2014 (or 22,000 architects).

It is also important to note the size of the overall construction workforce. When discussing overall employment within the construction industry (not just engineering employment), in 2004 5.2% of the overall workforce in the US was working in construction supervision or for the construction trades[16]. This does not include other manufacturing jobs that are related to the construction industry through the supply of building materials and equipment.

Supply of the Engineering Workforce

In the US, there were 7,827 Bachelor degrees awarded in civil engineering (CE) in 2004. There has been a decrease of over 25% from the largest number of CE graduates which was 10,678 in 1981 (see Figure 2). This is similar to the trend in declining engineering degrees for all engineering disciplines. The number of total Bachelor's degrees awarded in all engineering disciplines in 2001 was 59,258 which is 23.6 % less than the high of 77,572 in 1985[18]. But, it is interesting to note that while the engineering graduates within all disciplines have been declining since 1985 with only a slight increase between 1993 and 1995, engineering degrees in civil engineering had a resurgence in the mid 1990s, but they have since significantly declined from their peak in 1996.

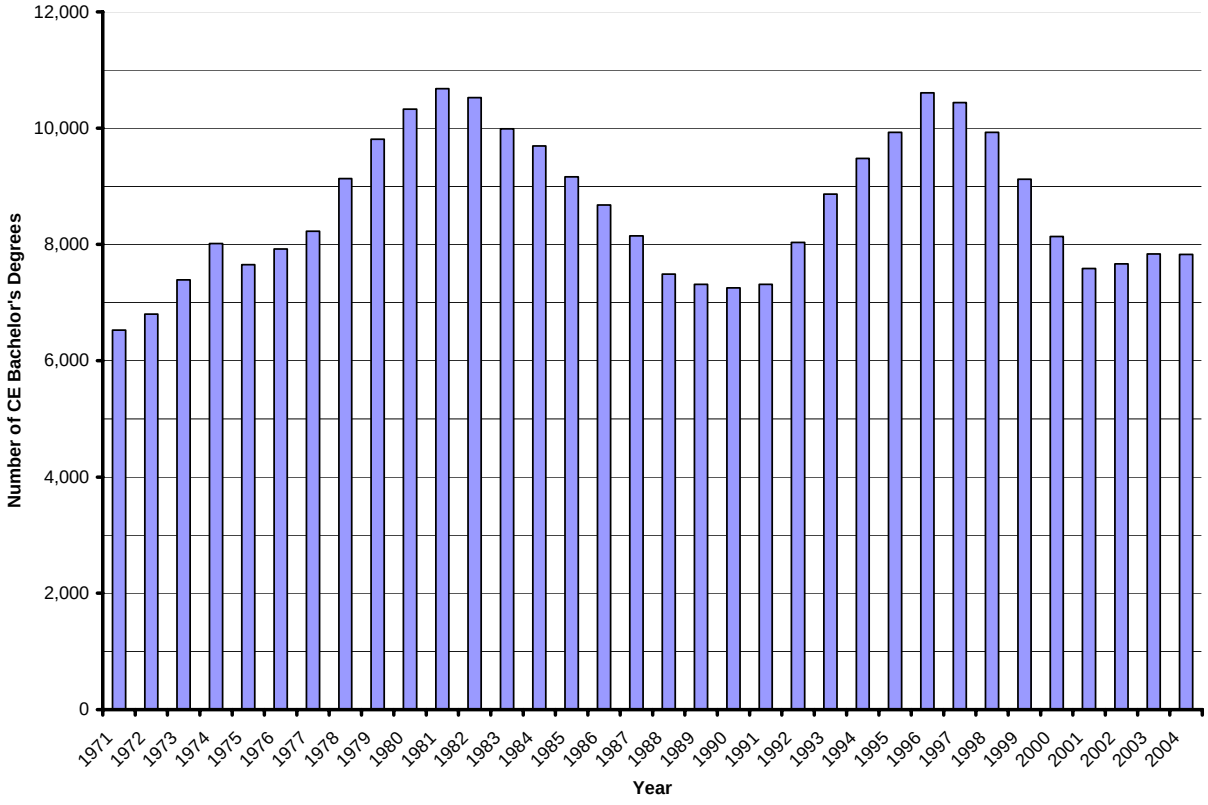

Figure 2: Civil Engineering Bachelor's Degrees from 1971 to 2004

In a recent study performed at Duke University, the number of degrees (Bachelors and Subbaccalaureate) awarded for engineering, computer science and information technology in 2003-2004 was estimated to be 644,106, in China; 222,335 in the US; and 215,000 in India[19]. There are a significant number of engineers graduating from universities in several lower wage countries, and many of them are within the civil engineering field. While there is a current debate regarding the total number of engineers in lower wage countries, it is clear that there are lower cost engineers available in other countries. For example, several of the largest universities that are graduating civil engineering graduates in China include Tsinghua University with 811; Central South University with 593; and Wuhan University with 219[19].

US Companies are currently able to identify and employ engineers in other countries (e.g., India, China and Eastern Europe) for a lower wage rate. Wages vary based on region and demand, but figures developed by Hira[20] have shown that a typical engineer in the US would receive an annual salary of $70,000 while an engineer in China and India would receive $15,120 and $13,580 respectively. This clearly illustrates the wage disparity between engineers in different countries. Base on interviews with engineering directors in several companies, the wages that are required to hire qualified engineers in some locations is increasing significantly, e.g., Mumbai, India.

CURRENT STATUS OF OFFSHORING IN THE CONSTRUCTION INDUSTRY

There is limited data available to quantify the current value of work that is performed in lower wage offshore locations within the construction industry. At this time, there is no single source of data available in the public domain that documents either the dollar value of offshore engineering work performed or quantity of engineering time spent by engineers in lower wage engineering locations. Therefore, the best data sources available at this time are surveys and interviews with industry practitioners. There are obvious limitations to these data collection techniques including potential inaccurate self reporting, limitations in response rate, and reliance on perception instead of quantitative data. With these limitations defined, the survey and interview data can provide insight into the current status and future trends in offshoring within the construction industry.

To date, the offshoring of engineering services to lower wage engineering locations has primarily been focused within the EPC sector. The large EPC contractors, along with owners who hire these contractors, were the focus of the CII Survey. This survey, administered in July of 2004, had a total response of 46 people. These respondents represented a total of 32 companies with 20 construction companies and 13 large facility owners[21].

Some large construction companies have been very active in international markets and have been performing offshoring of engineering work for more than 15 years[22]. Relative to several other service industries, the construction industry has been slow to adopt offshoring, but the larger companies, along with several niche markets in the industry have started to perform offshore outsourcing tasks with some large scale operations. Some examples of niche markets are the development of 3D models during the design process, converting 2D sketches to CAD

models, and the development of engineering shop drawings for trade contractors, e.g., mechanical and steel subcontractors.

The US is a net exporter of construction, architectural and engineering services. According to data compiled by the US Bureau of Economic Analysis (BEA)[23], the United States has a trade surplus in 'Construction, Architecture and Engineering services' (CAE Services). This surplus was US $2,991 million in 2004[1] (see Figure 3). The annual values vary widely due to specific large projects which may be performed in different years. It is interesting to note that the US still maintains a trade surplus in CAE Services with low income countries that are known for providing low cost engineering services to the EPC and AEC sectors of the construction industry. Of particular note is India which is the location of many offshoring centers used by EPC companies. In 2004, the US exported $107 million of CAE services to India and imported $42 million in services. This trade value does not include direct company employees located in India, but does include contracted services by Indian companies. Therefore, the value does not accurately reflect all architectural and engineering offshoring, only contracted offshoring work. For the large EPC companies, many of the offshore offices are sole ventures and would not be included in the import data. But, it is clear that there is not a tremendous volume of CAE Services performed under contracts with companies in low income countries and the US is maintaining a net surplus of services in the construction industry.

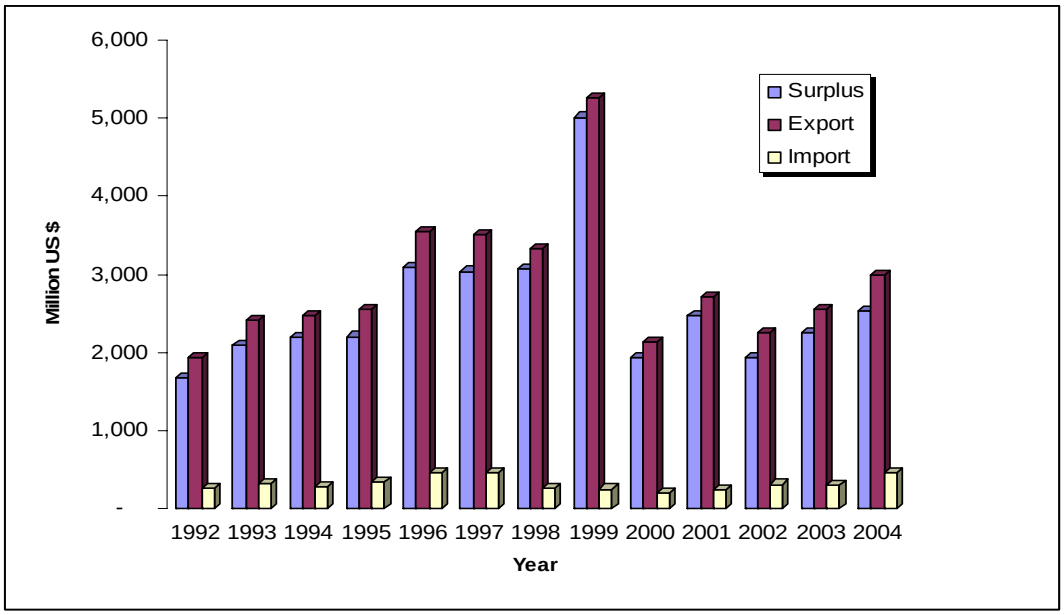

Figure 3: Trade Surplus for Construction, Architectural and Engineering Services (1992-2004) [Data from US Bureau of Economic Analysis[23]]

[1] The export value in the BEA data does not include merchandise exports or outlays abroad for wages, services, materials or other expenses. The import value is a total value.

Offshoring in the EPC Sector:

Offshoring within the EPC sector of the construction industry is not new. One survey respondent to the CII study stated that "the use of low cost engineering centers has emerged as a common practice among many large Engineering, Procurement and Construction (EPC) companies. This has primarily been driven by the realization that a large portion of the detailed engineering design work can be treated as a commodity."

Many of the capital facility projects performed within the EPC sector are large and require many engineering hours of work. Much of the work is related to detailed engineering, including the sizing and routing of piping; design and location of electrical conduit and wire; and the detailing of structural elements. This type of repetitive detailed engineering work makes offshoring within the EPC industry more attractive than in some other design practices since it is easier to systematize this work and less direct communication is required between the designers.

Of the companies that participated in the CII survey, 74% of the companies had international offices that were participating in a multi-office execution strategy for the delivery of projects. Many of these companies had offices in low cost engineering locations. Locations of international offices used for offshoring as reported in the CII Survey include India, China, Czech Republic, Russia, Romania, Poland, Mexico, and Taiwan. Some of these offices were specifically developed for the purpose of providing low cost engineering services on company projects. Other offices were developed for servicing specific design tasks focused on domestic construction projects. Large projects within low wage countries often contain some provision for local design work and it is sometimes necessary to use engineers within the local environment for code verification and other engineering work which requires a detailed understanding of the local environment. It is also important to note that many companies had other international engineering offices in high wage countries that they use for the development of global virtual teams including England, Finland, and the United Arab Emirates.

The CII survey aimed to determine the driving forces for companies establishing global engineering teams for the execution of projects. Table 1 provides the survey results from the EPC companies. There are several forces that are driving engineering firms within the construction industry toward the offshoring of engineering work. The top five factors identified in the CII study include 1) the need to reduce engineering service costs, 2) competitors, 3) global customers, 4) the need to locate services close to the project, and 5) the need to reduce engineering schedule. Of these factors, the need to reduce engineering service costs was ranked significantly higher than the other factors with an average score of 4.3 out of 5.

Table 1: Drivers for Global Virtual Teaming in the EPC Sector (EPC and Owner data)

Drivers of Offshoring	**Average Score** (1=low, 5=high)	**Ranking**
Need to reduce engineering service costs	4.3	1
Competitors	3.2	2
Global customers or local customers	3.2	3
Need to locate services close to the project location	3.1	4
Need to reduce engineering schedule	2.9	5
Goal to expand detailing work for the same cost	2.8	6
Country, client, or funding source requirements	2.8	7
Need to understand / comply with codes and standards	2.7	8
Company policy, e.g., global procurement of services	2.6	9
Need to balance engineer workload between multiple offices	2.5	10
Development in technology	2.4	11
Availability of engineers	2.4	12
Need to improve engineering quality	2.3	13
Need to maintain consistency of product / service	2.3	14
Changing education / demographics	2.1	15

There are several significant challenges facing companies within the EPC sector at this time. These challenges include the aging engineering workforce within many companies. The engineering workforce within the EPC sector companies is aging, and there is a gap in engineers with 10 to 25 years of experience. In a study by Gibson et al. [24], 69% of the workforce was 40 years of age or older. The study also concluded that the new supply of engineers would be "insufficient to replace departing engineers and to support the level of growth desired by some owners and nearly all contractor firms."

Offshoring in the AEC Sector

When discussing design offshoring within the AEC Sector, there are primarily two professional groups impacted. They are engineering and architectural professionals. From an architectural perspective, until just recently, there was a very limited amount of work on US projects that has been performed by using offshore architects or technicians. This is starting to change as companies are seeking opportunities to offshore lower skilled technician jobs to lower cost markets. An example of this type of service includes the transformation of hand drafted documents into 2D CAD or 3D CAD models. This task, traditionally performed by CAD technicians or young architects, is a very straightforward task which can be performed without extensive knowledge of the project. Other tasks include the development of intelligent building information models (BIM) for a project or the creation of design details after conceptual design is complete. There is little reliable data regarding the scope and scale of these services being performed offshore, but the current perception is that the amount of jobs currently performed offshore is relatively small. There are companies that are exceptions to this and have larger offices in lower income countries, but this is currently a limit number of companies.

The other primary professional services that can be provided offshore are engineering tasks on a building project. These tasks range from the engineering design work for the foundation, structure, mechanical system, electrical system, storm water management, lighting, and other technical systems. The design of these technical systems for a building requires both design and analysis expertise. Again, there is no reliable source of data regarding the size and scale of offshoring in these building engineering disciplines. There are companies that are offshoring work and from survey results, this number is growing. Some examples include steel detailing for fabrication, wood truss detailing, and mechanical ductwork detailing. Again, the current scope of the services being offshored in these areas is believed to be relatively limited, but companies that are offshoring the work are typically not very interested or willing to share detailed information about their initiatives.

Several reasons have been provided for the current limited offshoring in the AEC sector of the construction industry including:

- The size of the firms is small which make the economies of scale for offshoring less attractive when considering the initial investment;
- Some projects contain secure or sensitive information which the owner does not want to be distributed to non-US based service providers;
- Design professionals require a significant amount of interaction with the owner and other design professionals which is more challenging when offshoring a project;
- Local knowledge regarding the project conditions is important, e.g., soil conditions, local codes, standard construction practices, standard materials, and architectural norms within the country; and
- Current market conditions allow design professionals to obtain reasonable fees with their existing labor force which limits the incentive to reduce costs.

There are service providers in low wage countries that are organizing to focus on providing design services with offshore labor to architecture and engineering companies. To date, there are no large offshoring companies that have a significant impact in this area, such as Tata Group, Wipro and Infosys in information technology offshoring. As more foreign companies and domestic consulting companies start to provide and manage these services, it will become easier for architectural and engineering companies to implement offshoring on a smaller scale[25]. As this occurs, the primary issue will be how much work will companies be interested or willing to perform with offshore labor. Most architectural and engineering companies are small and it would be a significant undertaking for them to offshore a large amount of their business. Many architects and engineers are also very aware of their responsibility as a service provider to the facility owner along with their legal responsibility associated with the final design. Therefore, many may hesitate to perform offshoring due to the perceived loss of control over the design process and increased challenges in communication and oversight. It is much more likely that an increasing amount of detailed analysis and detailed modeling work may be performed with offshore labor. These are tasks that are traditionally performed by technicians and lower level engineers who are just starting their careers. These well defined tasks have consistent procedures that can be performed to ensure quality task performance with less oversight. It is interesting to note that these same tasks have increasingly been replaced by software tools that are automating these tasks. For example, the detailing of steel continues to get easier as new computer applications automate the sizing and detailing of the steel members

and connections, and new 3D modeling software makes it easier to develop detailed 3D information models for facilities.

DOES OFFSHORE OUTSOURCING REDUCE ENGINEERING COST?

In the previous section, the primary driver identified for offshoring was cost reduction. Therefore, one critical question when determining the future of offshoring within the construction industry is to identify if offshoring contributes to this goal of reducing engineering costs. There have been several indicators that suggest that offshoring, when properly executed, can reduce the overall engineering costs, at least for large facility projects and specific, well defined tasks on smaller projects.

The CII Survey contained questions regarding the perception of the survey respondents regarding cost, time and quality of projects performed with some offshore engineering work. Within a project, it is not only important to consider initial engineering design cost, but instead the total delivered facility cost. Therefore, the survey contained questions regarding both the engineering and construction cost, time and schedule. In the CII survey (see Table 2), contractors felt that offshoring the projects could provide a reduction of cost with the highest percentage of respondents projecting the cost savings to be more than 10%. This reduction was perceived to be obtained with no increase (and a potential decrease) in construction cost. There were considerable differences in the potential savings in time with the average response being the same amount of time. Most participants felt that they received the same or a slight reduction in engineering quality but that it resulted in the same or better construction quality.

Table 2: Perceived Impact of Offshoring on Cost, Time and Quality by CII Respondents[21]

Performance Metric	***Impact on Metric***				
	More than 10% increase	*0 – 10% increase*	*Same*	*0 – 10% reduction*	*More than 10% reduction*
Engineering Cost	4%	2%	7%	39%	48%
Construction Cost	-	4%	75%	17%	4%
Engineering Time	2%	18%	48%	24%	8%
Overall Project Delivery Time	-	9%	59%	30%	2%
Engineering Quality	6%	11%	65%	18%	-
Construction Quality	2%	19%	72%	7%	-

Cost is one of the main concerns when performing the design. Architectural and engineering design services vary widely as a percentage of the cost of a project, but they are typically from 7 to 18% of the total capital cost of a project depending on project complexity and size. The cost of the design services are impacted by labor rates for the design professionals along with productivity of the workforce. For engineers, this wage rate in lower income countries can be significantly less, but there are other additional costs associated with offshoring including travel, added planning time, and information system costs.

A detailed case study by one large owner illustrated the potential savings on large capital facility projects based on the use of low cost engineering labor. The study analyzed 5 projects performed by the owner between the years of 1992 and 2001. The owner was able to reduce the engineering cost on the projects from an average cost of 16.9% for their typical facility to a design cost of only 10.2%. This is a total reduction in design service costs of 40% compared to their typical costs[26]. The project team stated that they did not notice any specific negative impacts to the construction costs on the projects, although the company did need to overcome many challenges in the execution of the projects with engineers from multiple locations.

This information is not provided to justify offshoring of engineering services or to convince a company to pursue offshoring, but instead to present the results of the findings related to the opinions along with some quantitative analysis of the impact of offshoring on the cost structure of large capital facility projects. Like many other industries, the construction industry is extremely cost conscious and therefore, it is important to consider the economic factors when

predicting the future trends. If design and construction firms can consistently reduce the overall engineering costs through offshoring without impacting quality, then these services will continue to shift toward countries that can maintain a supply of low cost engineers which is the current trend that is occurring within the industry.

There are benefits obtained by different construction industry participants through offshoring. The benefit to the facility owner may include a lower cost for engineering services on a project. During an interview, one executive stated that, "some projects become viable due to outsourcing, thereby creating more jobs once the project is complete." This can provide benefit to the owner, and potentially increase employment in the local economy.

There are also costs to offshoring for US citizens. One cost is the potential reduction in engineering and architectural jobs within the US market, and the potential downward pressure on their salaries. The second cost is the reduction in tax revenue to the US government for services that are subcontracted to offshore companies. But, it is important to note that if companies are obtaining more work due to a reduced design cost, than the overall potential tax revenue may increase instead of decrease. One thing is clear, if US companies start to lose contracts by having a higher cost structure for engineering, then they will also lose engineering and architectural jobs; have reduced company revenue; and fewer US products will tend to be incorporated into the designed projects.

THE FUTURE OF OFFSHORING IN THE CONSTRUCTION INDUSTRY

What does the future hold related to offshore outsourcing in the construction industry? This is a difficult topic to address since it is always difficult to predict the future, especially on a very limited quantity of data related to the inception and current status of offshoring. There is a clear and consistent perception from executives within the industry that the level of offshore outsourcing in the construction industry will increase. When asked about the future plans of their company, 92.5% of contractors in the CII Survey stated that they plan to increase their use of offshoring. Many interview subjects state that they feel that an increased level of offshoring in the industry is inevitable since there is a drive to reduce the costs of design services and there are a limited number of engineers within the US market to service the industry needs.

Some practitioners feel that the trend will be very detrimental to the quality of design services in the industry. As stated by one survey participant, 'Eventually, all owners will get what they want - low cost designs - high cost problems.' Many of the most significant engineering disasters have been caused by poor coordination, communication, and understanding of design responsibilities. The possibility for these problems increases with the formation of global virtual teams to perform the engineering work.

Other practitioners who have operational low cost engineering centers feel that they can develop quality engineered solutions and documentation at a lower cost within their design centers, provided the design teams are properly structured and managed. Some even use the lower cost structure to create more detailed designs than they would typical develop in the US since the design costs are lower and they can save costs in construction with added detailing and coordination.

Much of the quality debate associated with offshore outsourcing tends to revolve around the industry perspective and industry segment. For example, if you consider the industry as a service industry, then it is more difficult to provide good service to a client when separated by distance and cultural factors inherent in global engineering teams. But, if you view engineering services as more of a well defined task (or more similar to a commodity) then it is more likely that you would view a low cost engineer center to be a viable option for performing cost effective design services with little impact on quality. This is obviously all predicated on the perception that engineering services performed in low cost centers is of a lower quality which tends to be a fairly widely held belief by US practitioners, although there are exceptions where practitioners feel that any quality differential is generated from poor communication and management.

WHAT CAN BE DONE TO ADDRESS ISSUES FROM INCREASED OFFSHORING?

Since offshoring will continue to increase in the US construction industry, it is important to consider actions that can minimize the negative impacts of offshoring, while taking advantage of possible benefits. The following sections define possible actions that can be pursued.

Prepare Engineers for Global Team Responsibility

One very important activity is to ensure that the engineers being prepared to enter the construction industry, no matter which discipline, are prepared to develop a track toward a global design management role. This requires that students learn about global issues along with the managerial skills required to manage a global virtual team.

Recent changes in the assessment of education outcomes by the Accreditation Board for Engineering and Technology (ABET) have revised the focus on accreditation from input (or teaching) to outcomes (or learning)[27]. Since the implementation of the Engineering Criteria 2000 (EC 2000) by ABET, there has been an increase in the emphasis on professional skills[28]. There has also been an increase in international travel by students and participation in study abroad programs over the past 10 years[28]. It is critical that these activities continue to be supported and expanded.

Additional ongoing efforts seek to expand the eleven EC 2000 criteria with an additional 4 outcomes for students in civil engineering programs. These efforts are defined in the Body of Knowledge by the American Society of Civil Engineers[29]. The Body of Knowledge aims to define "the knowledge, skills and traits necessary to become a licensed professional engineer". This report proposes the addition of outcomes related to business, public policy, and the understanding of the role of the leader and leadership principles. These additional criteria would aid in expanding the breadth of knowledge of engineering graduates and better prepare them to participate in global engineering teams. These recommendations are consistent with recommendations developed by the National Academy of Engineering as defined in The Engineer of 2020[30].

Professional Society Leadership and Research

Professional societies have the opportunity to analyze offshoring and guide the changes that will be needed for the US to address increases in offshoring. Some professional societies are issuing policy statements to address the issue of offshoring. The American Society of Civil Engineering (ASCE) has approved a policy statement on Offshoring of Engineering Services[6]. The policy is a follows:

> *"The American Society of Civil Engineers (ASCE) believes that the offshoring of engineering services should be accomplished in a manner that protects the public health, safety and welfare. ASCE believes that A/E services must address the following criteria:*
>
> - *Appropriate homeland security requirements;*
> - *Licensing laws related to responsible charge;*
> - *Principles and/or requirements of Qualification-Based Selection using full disclosure of staffing and location; and*
> - *Fair trade agreement practices which apply."*

In January 2004, the National Society of Professional Engineers (NSPE) Board of Directors approved a position statement that aims to be much more restrictive in nature. The NSPE statement says that the "outsourcing of engineering should be done only when the talent cannot be found in the US. If outsourcing of engineering work is done, it should be done using the same rules, regulations, and laws that employers and employees are subject to in the US." Further, NSPE says that outsourcing should not jeopardize national security, and all parties should be aware of the location of the offshore work and the conditions under which it is being performed[31].

These policy statements clearly differ significantly in nature. There is a need for professional societies to perform an accurate analysis of the impact of offshoring and provide appropriate guidance for engineers and companies within the industry. This will require the collection of additional data in some industries, e.g., the construction industry, prior to issuing statements such as the NSPE statement. The professional societies have the opportunity to be leaders in the accurate delivery of information to their constituents regarding this topic and leading the development of recommended public policy.

Limit Trade Barriers

One thing is clear from interviews and surveys with executives within the US construction industry; no matter what opinion the executives have (some support increases in offshoring and others are against offshoring), the executives interviewed for this research felt that the US government should not intervene with trade barriers to impact the flow of trade in engineering services within the construction industry. Many feel that any intervention to limit

the use of offshore engineers would negatively impact their ability to compete on a global scale (for companies using lower cost engineering centers), or that restrictions would simply not work over the long term (for executives in companies that are not offshoring engineering services).

Retrain Workforce for Shifting Demand

With increases in offshoring, there will be a shift in demand for engineers, architects and technicians with particular skills within the industry. For example, some technicians are specifically focused on the development of 2D CAD or 3D models of existing paper based drawings or sketches. This type of work is easy for companies to offshore, and therefore the US employee must either gain additional skills or potentially lose employment. Companies and the government should consider potential programs that would support the retraining of technical employees to be productive in areas that are in higher demand within the US market. As offshore engineers gain expertise (move up the value chain), US engineers will need to continually outpace their lower cost counterparts in productivity or knowledge. It is important that engineers be provided proper guidance and retraining to stay ahead of engineers in lower wage countries.

Government Support for Exporting Engineering Services

For the long term competitiveness of the design professionals within the US market, it is important that the US firms remain competitive on a global scale. For this to occur, the US Government should facilitate the entry of engineering and architectural firms into foreign markets. The more work that US firms obtain in international markets, the more overall work that will be managed and executed by US employees, even if a portion of the design work for these projects are performed with an offshore workforce. While the US Government does support the export of architectural and construction services, it does not support these efforts to the same level as some foreign counterparts from other countries[32]. The continued expansion of markets and revenue for companies is critical to maintaining a thriving international and domestic construction industry.

Ensure Information Security as Needed

For national security, it is important that data related to our facilities is appropriately managed. This does not necessarily mean that work can not be performed in international locations, but additional security of information must be considered and assured when sensitive information is being used or developed. It is important that facility information related to the infrastructure systems and building projects in the US is not readily available to all people throughout the world.

Recruit and Retain More Engineers in the Construction Industry

Finally, it is important that we send an accurate message to future potential engineering and architectural college students. There are many factors which impact the decision for students to enter engineering as a profession in the construction industry including salary and the image of the industry. In addition to other factors, there are now students who are showing concern regarding entering engineering due to offshoring of jobs. Prospective students and their parents are watching the many negative messages distributed in the media regarding the potential future impact of offshoring on engineering jobs in the US, and these media stories make little distinction between the types of jobs being offshored. It is clear that offshoring will have long term impacts on the structure and way we perform engineering work in the construction industry, but it is also clear that there will be high domestic demand for well educated and motivated engineers. We should aggressively encourage our youth to enter engineering disciplines that support the construction industry, and universities must continue to work harder to retain students in engineering fields. More emphasis must be placed on career progression, career coaching, salary comparisons, and even intangible benefits of being able to see the results of your project efforts. The economics should make sense to prospective students, and the industry should identify methods to better support students and develop stronger talent pipelines.

CONCLUSIONS

It is clear that offshoring in the construction industry will have an impact, but the impact will not mirror the trends that are occurring in other service industries or within manufacturing industries. To date, a majority of offshore outsourcing has focused on large capital facility projects that require many engineering hours which are performed by large engineering companies in the US and other high income markets throughout the world. Most of the US companies performing this work are currently aggressively hiring new engineers in the US market, while many are also expanding their engineering workforce in lower income countries, and therefore, to date offshoring has not had a significant impact on employment of engineers within the US construction industry, although some lower level engineering technician and engineering work has been relocated offshore.

The fragmented nature of the AEC sector of the construction industry, combined with the sheer complexity of each unique project and the necessity to understand the owner's requirements, make offshoring on a large scale more difficult in the construction industry than in some other industries. Some companies have been focusing on the systematization of global virtual teaming processes to benefit from the use of offshore engineers, but many have not yet taken steps to significantly revise their standard business practices to cost effectively utilize lower cost engineers to provide services. A significant number of executives feel that the use of the lower cost engineers will impact engineering service quality and therefore reduce or remove any benefit from the reduced engineering labor cost.

Regarding employment, there is currently little impact of offshore outsourcing on the employment prospects for new college graduates or experienced engineers in the US engineering workforce within the construction industry. But, this does not mean that the situation will not

shift. The construction industry is dependent upon capital project spending of other industries, e.g., the oil industry, housing, transportation, private sector companies, etc. Therefore, construction spending in any particular segment within the broad industry is constantly shifting. If spending declines in market sectors with higher rates of offshoring, e.g., the power market, then employment by companies focused in these sectors could easily be impacted.

The United States is a net exporter of design services (architectural, engineering and construction services) in the construction industry. The ability for the US to export these services can provide significant benefit to other companies, primarily construction companies and suppliers to the construction industry. When US design firms perform the project design, they tend to use materials and equipment that are familiar to them which may more frequently be produced by US suppliers, and they will tend to support the use of US contractors when appropriate due to their working relationships with the US firms. This contributes to other sectors of the US economy.

Many large design firms believe that the use of low cost engineering centers provides an opportunity for them to remain cost competitive in the low margin environment typical of engineering projects in the construction industry. Some argue that the ability to use lower cost engineers in international locations such as India, Mexico, and Eastern Europe provides the advantage that they require to gain the engineering contracts. Without this cost advantage, the work may be procured by competitors in other countries, thereby impacting the US engineering community as well as the remainder of construction companies and suppliers within the US market.

While offshoring is not currently causing a decline in engineering employment in the construction industry, it is very important to focus on fundamental changes that can be implemented now to address the clear trend towards increased offshoring that is occurring in the construction industry. Some recommendations for preparing for the future include the improvement of the breadth of education of engineering graduates; improving the support for US companies acquiring work overseas; ensuring that national security and intellectual property is appropriately protected when companies use offshore design professionals; providing guidance to engineers in the industry; and performing additional research to better understand offshoring. We must also continue to encourage our youth to pursue productive careers within engineering in the construction industry.

ACKNOWLEDGMENTS

The author would like to thank the National Academy of Engineering along with the Construction Industry Institute (CII) for their generous support of this research, along with a special thank you to Samuel Florman and George Tamaro of the NAE Committee of the Offshoring of Engineering and the CII Project Team 211 members. The author would also like to thank the many survey and interview participants who contributed to this research. Opinions, findings, conclusions, or recommendations expressed in this paper are those of the author and do not necessarily reflect the views of the sponsors or The Pennsylvania State University.

REFERENCES

1. Tulacz, G. J. (2005). "World construction spending nears $4 trillion for 2004." *Engineering News Record*, January 3.

2. US Census Bureau. (2006). "Construction spending - June 2006." Accessed: August 29, 2006.

3. Engineering News Record. (2006). "The top 225 international contractors: 2006 rankings by 2005 revenue." August 21-28.

4. Engineering News Record (ENR). (2000). "What the world spent on construction." *Engineering News Record*, December 4, 38-45.

5. Trefler, D. (2005). "Offshoring: threats and opportunities." Brookings Trade Forum 2005: The Offshoring of Services: Issues and Implications, Washington, DC, (Available at www.brookings.edu/es/commentary/journals/tradeforum/2005btf_trefler.pdf).

6. American Society of Civil Engineers. (2005). "Offshoring of engineering services." ASCE, (Available at www.asce.org/pressroom/news/policy_details.cfm?hdlid=507), Accessed: August 29, 2006.

7. US Census Bureau. (2006). "Construction spending - February 2006." April 03, 2006, Accessed: April 3,, 2006.

8. US Census Bureau. (2002). "2002 Survey of Business Owners." Accessed: August 25, 2006.

9. Bureau of Labor Statistics. (2006). "The 2006-07 career guide to industries: construction." U.S. Department of Labor, Washington, DC, (Available at www.bls.gov/oco/cg/print/cgs003.htm).

10. Engineering News Record. (2006). "The top 400 contractors: 2006 rankings by 2005 revenue." May 22.

11. Engineering News Record. (2006). "The top 500 design firms: 2006 rankings by 2005 revenue."

12. Sanvido, V. E., Khayyal, S. A., Guvenis, M. M., Norton, K. J., Hetrick, M. S., Muallem, M. A., Chung, E. K., Medeiros, D. J., Kumara, S. R. T., and Ham, I. (1990). "An integrated building process model." *Technical Report No. 1*, January, Computer Integrated Construction Research Program, University Park, PA.

13. Grigg, N. S. (2000). "Demographics and industry employment of civil engineering workforce." *Journal of Professional Issues in Engineering Education and Practice, ASCE*, 126(3), 116-124.

14. Rafferty, H. R. (2004). "Civil engineering: looking good this year." Diversity / Careers in Engineering & Information Technology.

15. Bureau of Labor Statistics. (2006). "Occupational outlook handbook 2006-2007 edition." U.S. Department of Labor, Washington, DC.

16. Hecker, D. (2005). "Occupational employment projections to 2014." Monthly Labor Review Online, (Available at www.bls.gov/opub/mlr/2005/11/art5full.pdf).

17. Bureau of Labor Statistics. (2006). "The 2006-07 career guide to industries: architect, except landscape and naval." U.S. Department of Labor, Washington, DC.

18. National Science Foundation Division of Science Resources Statistics. (2004). "Science and Engineering degrees: 1966-2001." *NSF 04-311*, March, Arlington, VA.

19. Gereffi, G., and Wadhwa, V. (2005). "Appendix: Duke outsourcing study: Emperical comparison of engineering graduates in the United State, China and India." December, Duke, School of Engineering.

20. Hira, R. (2003). "Global outsourcing of engineering jobs: recent trends and possible implications." Testimony of Ronil Hira to The Committee on Small Business United States House of Representatives, (Available at www.ieeeusa.org/policy/policy/2003/061803.html).

21. Messner, J. I., Chen, C., and Joseph, G. (2006). "Implementing Global Virtual Engineering Teams." *Research Report 211-11, Draft*, August, Construction Industry Institute, Austin, Texas.

22. Rubin, D. K., Reina, P., Powers, M. B., and Illia, T. (2004). "As cost pressures mount, offshoring is making the work go round." *Engineering News Record*, August 2.

23. Nephew, E., Koncz, J., Borga, M., and Mann, M. (2005). "U.S. International Services: Cross-border trade in 2004 and sales through affiliation 2003." Bureau of Economic Analysis, Washington, DC.

24. Gibson, G. E., Jr., Davis-Blake, A., Dickson, K. E., and Mentel, B. (2003). "Workforce demographics among project engineering professionals—crisis ahead?" *Journal of Management in Engineering, ASCE*, 19(4), 173-182.

25. Bryant, P. (2006). "Decline of the engineering class: effects of global outsourcing of engineering." *ASCE, Leadership and Management in Engineering*, 6(59), 59-71.

26. Messner, J. I., Hankins, L., and Krumins, A. (2006). "Planning a global virtual engineering team: a tool for success." *Research Summary 211-1, Draft*, August, Construction Industry Institute, Austin, Texas.

27. Engineering Accreditation Commission of Accreditation Board for Engineering and Technology. (2000). *Engineering criteria 2000, third edition*.

28. Lattuca, L. R., Terenzini, P. T., and Volkwein, J. F. (2006). "Engineering change: a study of the impact of EC2000." ABET, Inc., Baltimore, MD.

29. American Society of Civil Engineering. (2004). "Civil engineering body of knowledge for the 21st century: preparing the civil engineer for the future." American Society of Civil Engineers, Reston, VA.

30. National Academy of Engineering. (2004). *The engineer of 2020: visions of engineering in the new century*, The National Academies Press, Washington, DC.

31. Boykin, D. (2004). "Offshore outsourcing stirs national debate." *Engineering Times*, 26(3).

32. Vonier, T. (2006). "The export of professional design services by foreign architecture firms." AIA International eNews, (Available at www.aia.org/nwsltr_intl.cfm?pagename=intl_a_200607_vonier).