Civil Engineers in Public-Private Partnerships and as Master Planners for Infrastructure Development

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ABSTRACT: Public-private partnerships (PPP) have been actively implemented around the world since the 1980s, including projects in both developed and developing countries. Among the reasons for the growing use of this project delivery system are the deterioration of the basic infrastructure systems, the lack of public funding, and the interest of private investors for discovering attractive investment opportunities. Because of public-private partnerships as a project delivery system, civil engineers have been exposed to knowledge areas such as finance, risk analysis, public policy, and conflict resolution, which traditionally have not been taught in civil engineering curricula. Therefore, civil engineers now have opportunities to play a major role in PPP projects as master planners of infrastructure development. This paper analyzes the basic skills that a civil engineer must have in order to be an active participant in the development and implementation of PPP projects. We gathered input from industry practitioners in order to understand their role in these transactions and to inquire about the essential skills that civil engineers ought to have to facilitate successful PPPs. Finally, we describe the opportunities for civil engineers within the different phases of PPP. As a result, a new set of skills are proposed for civil engineers who would be involved in PPP projects.

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New infrastructure projects are required for satisfying and improving the basic needs of growing populations in developed and developing countries. These new projects have to consider new factors such as sustainability, life cycle analysis, risk, public agreement, and delivery schemes (European Commission 2003; Dahl et al. 2005; ASCE 2006). A public-private partnership (PPP) is a project delivery method that has been widely applied since satisfactory achievements were reached during the last 30 years (Cartlidge 2006). PPPs bring private and public sectors together in long-term contracts to produce a required infrastructure including but not limited to roads, airports, water systems, sewer systems, water and wastewater treatment plants, buildings, institutional buildings, health care centers, and recreation facilities.

Recently, the National Surface Transportation Policy and Revenue Study Commission issued a report called "Transportation for Tomorrow" (NSTPRSC 2007). This report addresses the current crisis in the transportation infrastructure across the United States. According to this report, the lack of funding for transportation infrastructure is estimated around $150 million per year for the next twenty years. This crisis has also been mentioned by the ASCE. In 2005, the budget to adequately address all infrastructure needs in the United States would be around $1.6 trillion for the next five years. In addition, there is not enough funding to cover the current needs (Reid 2008). This financial gap supports the fact that current funding levels would not be adequate to maintain the operational performance and physical conditions of U.S. highways, and would not be adequate to meet the level of investments required. As a consequence there are two principal sources of funding: tax increases or participation of the private sector through public-private partnership projects. Furthermore, this vision of the U.S. infrastructure, stated in "Transportation for Tomorrow" (NSTPRSC 2007), will require different delivery approaches and wider participation of civil engineers.

As PPPs have become a more common and effective delivery scheme, several procurement modes have evolved and generated a wide spectrum of relationships between the public and private sectors (Abdel-Aziz and Russell 2001). These types of procurement vary according to the degree of involvement by the public sector (Cartlidge 2006). From the traditional design/build, where the owner contracts a private partner to design and build a facility, to build, own, and operate (BOO), where governments transfer ownership and responsibility to a concessionaire in order to build, own, and operate a new facility for a long period of time. Between these two models, other types of PPPs such as turnkey, private finance initiative, and build, operate, and transfer (BOT) have been used. All of these PPPs share some basic characteristics: private partners contribute with money, expertise, or other resources to the partnership; partners (public and private) work together toward common goals; partners share the risk; and partners share decision-making and management responsibilities (Abdel-Aziz and Russell 2001).

PPPs aim to improve the performance at some project stages, such as financing, operation, or maintenance, that have been traditionally under direct responsibility of the government or owner. Each type of PPP has specific features, project applications, advantages, and disadvantages. For instance, BOO requires applying life cycle and sustainability concepts during the bid phase that are not generally applied when a design/build delivery method is used due to the long-term commitment of the private partner in the operation of the facility. As a consequence, civil engineers, in either the public or private sector, are now required to take on activities for which they had not previously been accountable. Hence, civil engineers require a different set of skills that have not been traditionally included as core skills within existing curricula.

There are numerous efforts to improve the public-private partnership approach, but these have been traditionally focused on the successful characteristics and on procurement rather than on practitioners' skills and knowledge (Tiong 1996; Miller et al. 2000; Zhang and Kumaraswamy 2001; European Commission 2003; Zhang 2005; Russell et al. 2006; Zhang 2006; Abdel-Aziz 2007). It is necessary to analyze how civil engineers can actively participate in PPPs as master planners and leaders in these transactions. Previous efforts in this domain include the works realized by El-Haram and Agapiou (2002) and RISC (2003), both in the United Kingdom. The vision for civil engineering during the next twenty years, suggested by The American Society of Civil Engineering (ASCE 2006) and the Civil Engineering Body of Knowledge for the 21st Century (BOK; ASCE 2008a), have established the need of a new generation of civil engineers and they suggest that new trends, issues, and pressures are underlining the future role that civil engineers would play in order to guarantee a sustainable world and enhance the global quality of life. We link these two documents with the potential role(s) that civil engineers would have as master planners of infrastructure development throughout PPPs.

ASCE (2006) and Galloway (2007) have stated that the future demands new areas of knowledge for civil engineers that have not usually been taught. "Study of globalization, world cultures, languages, communication, leadership, public policy and ethics must constitute a core component of overall engineering education" (Galloway 2007). All these efforts are mainly focused in civil engineers' skills and knowledge, but they have not considered specific requirements for civil engineers as PPP practitioners and master planners of infrastructure development. We argue that civil engineers have a prominent role in the conception, evaluation, and development of

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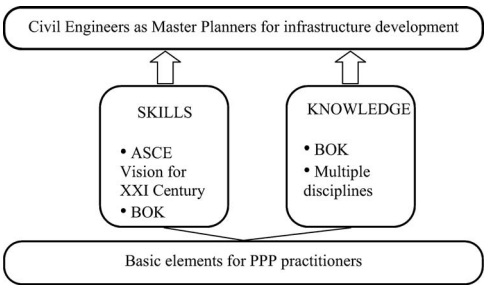

Figure 1. Interaction between skills and knowledge for PPP practitioners

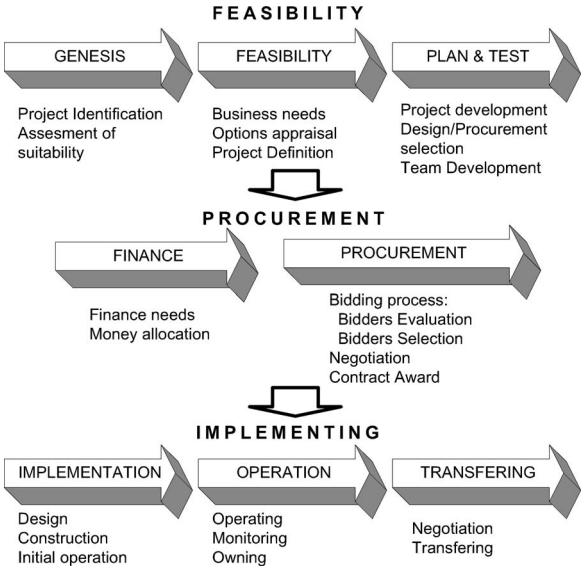

Figure 2. PPP project cycle (Adapted from El-Haram 2002 and Pakkala 2002)

PPPs based on three major arguments: (1) PPPs are mostly utilized to develop civil infrastructure systems, which have historically been designed and constructed by civil engineers; (2) civil engineers can provide better assessment and life cycle perspectives for the development of new infrastructure systems due to the technical complexity associated with these projects; and (3) civil engineers can enhance the operation, maintenance, and innovation of civil infrastructure because they are participants in the design process.

Figure 1 describes the combination of recommended skills and knowledge for civil engineers and the vision of civil engineering and the BOK. New areas of knowledge are necessary and different skills are required in order to have civil engineers involved as master planners for the development and implementation of PPPs (Abdel-Aziz 2007; Levitt 2007). For instance, PPPs often require independent engineers to review the management plans, capital reinvestment strategies, condition at handover, and monitor performance, representing both the public owner and the financial investors. This requires a broader skill set than traditional civil engineers are taught. Therefore, an adapted set of skills and knowledge for civil engineers as master planners of PPPs has to be considered.

In order to explain the different roles that a civil engineer can have in PPPs, we analyze the intersection between skills and knowledge at different phases or stages within these projects. The analysis is performed for each of the different phases in order to determine the role of civil engineers. Additionally, some types of PPPs are considered in order to determine the basic skills and knowledge for PPP practitioners. Then the results of several interviews conducted with industry practitioners involved in PPPs are described and a comparison between "theory and practicality" is shown in order to illustrate the "adapted" set of skills for civil engineers involved as master planners in PPP. This new set of skills and knowledge has been conceived within the framework "Vision of Civil Engineering" stated by ASCE (2006). It is expected that some of these skills and knowledge areas can be developed through elective courses at the undergraduate level or within the MS/30 hours framework suggested by the ASCE policy statement 465 (ASCE 2008b).

Phases of Public-Private Partnerships

A PPP project cycle involves several phases which are common for the majority of these partnerships (Figure 2). These phases can be grouped in three large divisions: feasibility, procurement, and implementing/operating (HDR 2005; European Commission 2003). Each of these phases consists of many stages and two principal parties are involved: the client (public owner) and the service provider (private sector) (El-Haram and Agapiou 2002). The first phase embraces these steps: genesis, feasibility, plan and test. The second phase covers finance, and selecting and contracting a partner. Financing, when required, is a major aspect that is likely to be used in the U.S. market; this is an extremely complex subject that engineers would do well to learn about. The third phase joins the executing activities to deliver a project: design, build, operate, and maintain. The third phase can also include operation, ownership, and transfer (if applicable).

Before the feasibility phase, typically a team from the private sector and a team from the public sector are assembled to study the project (HDR 2005; El-Haram and Agapiou 2002). Zhang (2005) suggested that these two groups will be responsible for the success or failure of a PPP project. Genesis is the preliminary stage of the first phase and answers this fundamental question: What is driving the public or the private sector for PPP projects? Both sectors are driven by specific needs. In the public sector, these needs are linked with population growth, better quality of life, and

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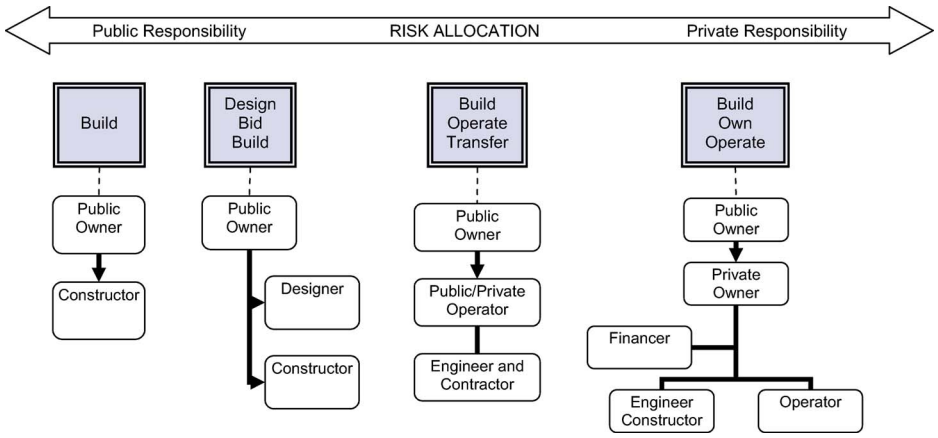

Figure 3. Relationship between public sector responsibility and type of PPPs (Adapted form Cartlidge 2006 and HDR 2005)

infrastructure restoration. On the other hand, the private sector looks for an economic benefit and a reasonable risk allocation between the parties. So, during this phase, general needs have to be identified and potential solutions can be defined as well (HDR 2005).

The feasibility stage must determine if the selected PPP is feasible both financially and technically. The overall objectives must be identified in this period as well. Some of the questions that need to be addressed are: How will the project be funded? What are the criteria to evaluate the net benefits of the projects? What constraints might hinder completion of the project? Among the available solutions, which solution is the best? Are there other approaches that might be even better? The final stage of this phase is to plan and test. As master planners, civil engineers should have an active participation in this stage, mainly in the evaluation of the different alternatives and the identification of major risks. Within this stage, a delivery methodology would be implemented as well as a financial plan, including a preliminary budget and schedule. Additionally, political climate, site analysis, stakeholder's attitude (feedback), environmental regulations, and market demands must be analyzed.

In the procurement phase, the best-value private partner is selected. This phase can also be subdivided in many stages according to the level of detail required by the parties. The procurement phase is time-consuming and has been considered a key to success by practitioners and researchers (Miller et al. 2000; Abdel-Aziz and Russell 2001; Zhang and Kumaraswamy 2001; Cartlidge 2006). For example, Jefferies (2006) addressed the procurement phase as the key success factor for the SuperDome facility in Australia. Also, during this phase, the scope of the PPP or performance requirements must be clearly defined (Zhang 2005) and the sharing of risks and rewards for both sectors have to be established. Abdel-Aziz and Russell (2001) stated that PPP procurements have three dimensions that have to be entirely discussed in order to avoid pitfalls during the implementation phase. These dimensions are: (1) rights (possession, revenues); (2) obligations (operation, financing, reward scheme, specifications); and (3) liabilities (taxes, risk, liabilities). This phase may also include a prequalification stage.

The implementation phase is the more visible stage (HDR 2005) and embraces all the actions associated with the physical completion of the project, from engineering design to the construction of the infrastructure. When the implementation phase is completed, the private partners have to operate the infrastructure according to the performance standards defined by the specifications and contractual documents. The final stage of implementation, transferring, may not be required in all PPPs. In this stage, the private sector transfers the control of all the assets to the local government after finishing the operational period

Types of Public-Private Partnerships

The stages of a PPP, as a project delivery system, may differ based on the degree of involvement by the government and the degree of involvement by the private sector. Typically finance, design, build, own, operate, and transfer are the principal stages of PPPs (Jefferies 2006; UGAO 1999). Figure 3 shows the different types of PPPs and how these fit according to the owner's responsibility and the duration of the partnerships. These stages can be grouped in different ways to generate the different types of PPPs.

Build, operate, and transfer, for example, is one of the most common approaches for PPPs (Abdel-Aziz 2007). This is an agreement between the public and private sector in which the private sector builds a facility and operates it for a specific time varying from short-term to very long-term

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Table 1. Current Characteristics in PPP Projects and Expected Features for Future Projects

Phase	Current	Expected
Feasibility	Optimization towards the reduction of the very first cost (construction phase)	Optimization towards the life cycle cost (economic, environmental, and social equity)
	Lower capital cost	Sustainability: lower life cycle cost
	Poor involvement of practitioners in public policy or politics	Active participation in public policy and politics
	Short-term alliances	Long-term and repetitive partnerships
Feasibility and procurement	Poor risk management, focusing in construction phase	Complete risk analysis and management for all project's phases
Procurement	Delivery scheme design/bid/build. One final design solution which mostly do not consider constructability.	More integrated procurement delivery scheme
		Several engineers in the design (several options)
		Constructability analysis performed
	Best price bids (total initial cost)	Best value bids (NPV economic analysis)
	Public and private sector in different directions	Public and private sector in win-win relationships, real partnerships
	Short and little price procurement phase	Longer, detailed, and higher cost procurement phase
Implementing	High-quality behind schedule and vice versa	Higher quality ahead of schedule (on time)
	No supply chain	A global supply chain required
Across all phases	Several parties with different vision (division of the construction industry)	All the parties chasing the same goal
	No stakeholders involvement and even no inputs	Stakeholders inputs strongly required
	Basic communication requirements	Extended communication enforced
Personnel	No requirements to PPP practitioners	Civil engineers must be PPP leaders

concessions (BCMMA 1999). When the operating period ends, the public sector will assume responsibility for the facility. Generally, the financing for these types of projects is provided by the private sector (Cartlidge 2006). BOT advantages for the public sector include the low cost of private operations, the ownership (the facility always belongs to the government), the smaller amount of money needed to deliver a project, and a shorter delivery time. The main disadvantage is replacing the private partner if it goes out of business (BCMMA 1999). The operate, build, and transfer model is similar to the BOT model except that the transfer to the public owner takes place at the time that construction is completed, rather than at the end of the operating period.

The participation of civil engineers as master planners depends upon the type of PPP. For instance, a BOT scheme shows that the role of civil engineers is not limited to design and build, which implies that civil engineers should have the ability to provide technical advice for the design team, considering the long-term implications of those decisions. In a long-term lease agreement, such as the Chicago Skyway, Indiana toll road, and Pocahontas Parkway, civil engineers should be aware of the technical challenges when forecasting demand or estimating maintenance routines that will occur fifty years from now.

Role of Civil Engineers in Public-Private Partnerships

To define the role that civil engineers should play as master planners in the development of PPPs, we compared the current and future (suggested) approaches to the delivery of PPPs. Table 1 summarizes the comparison between traditional PPP infrastructure projects (design, bid, build) and a suggested approach for the development of future infrastructure projects.

The characteristics of PPPs indicate an integrated approach to delivery of infrastructure projects, which is in accordance with ASCE's 2025 vision (ASCE 2006). Tech-

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niques to assess best value or sustainability denote the need for a life cycle analysis. Similarly, this approach suggests the involvement of engineering practitioners in public policy, which in turn requires civil engineers with strong and fluent communication skills to communicate with stakeholders, coworkers, media, politicians, and community leaders in order to establish a productive dialogue and to present the benefits and challenges associated with project development.

Once the differences between the current and expected delivery approaches have been assessed, it is possible to identify the skills and knowledge required by civil engineers in their role of master planners for infrastructure development. The analysis was conducted based on recent publications by the ASCE (i.e., Vision for Civil Engineers in 2025 and the Civil Engineering Body of Knowledge for the 21st Century); the future of construction engineering and management research (Levitt 2007); the skills for PFI managers of the Royal Institution of Chartered Surveyors (RISC 2003); and interviews with industry practitioners. These practitioners belong to construction companies, investment banking institutions, law firms, government, and consulting companies. A major challenge in this process is the difficulty to separate and differentiate skills and knowledge. For example, communication can be seen as a skill (effective communication), but there is also knowledge associated with this area that civil engineers must learn. Based on the interviews with PPP practitioners, the suggested skills and knowledge are grouped in three main categories: (1) technical, (2) general management, and (3) specific to PPPs.

The first category is related to the basic knowledge and skill that civil engineers as practitioners of PPPs must have, regardless of their area of expertise. Basic concepts such as risk, procurement, and delivery methods are required. The second group, general management, covers skills related to leadership, ethical behavior, and management. These skills are not only applicable to PPPs, civil engineers working in the public sector should also be familiar with these topics, especially with the alternatives for delivery systems. The last

Table 2. Technical Skills and Knowledge

	Description	
Category	Skills	Knowledge
Risk/uncertainty	Risk management. Define risk position. Identify, evaluate, and respond to risk. Critical thinking.	Risk identification, quantification, and analysis, data-based and knowledge-based types. Probability and statistics.
Public policy (ASCE 2006)	Involvement and understanding of current and local public policies. Analyze, compare, and contrast the economic, environmental, political, and societal impacts of engineering (ASCE 2008a).	Politics, history, and current politics. Public policy techniques. Economic, environment, and social equity. Value of money.
Sustainability (Levitt 2007)	Evaluate the sustainability of complex systems, whether proposed or existing.	Process engineering, green construction, value engineering. Life cost analysis methodologies. Constructability.
Continuous improvement/ innovation	Promote creativity and personal growth. Life-long learning. Self-assess learning processes and evaluate those processes in light of competing and complex real-world alternatives (ASCE 2008a).	Improvement and productivity analysis. Select and organize relevant techniques, skills, and modern engineering tools to solve a well-defined problem (ASCE 2008a).
History	Recommend engineering solutions based on historical impacts on society, environment, and the economics (ASCE 2008a). Understanding of the historical context.	History of the delivery schemes and the consequences. Case studies. Events and developments in the history of civil engineering and their impact on society (ASCE 2008a).

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category is focused on particular skills and knowledge required for civil engineers who want to successfully work with PPPs for infrastructure development. These skills and knowledge areas include public policy, risk analysis, project financing, and novel procurement methods.

The suggested technical skills and knowledge areas are shown in Table 2. Knowledge in areas of risk, sustainability, and public policy are required in order to develop basic skills in these domains. For instance, topics such as sustainability can be incorporated within the feasibility analysis of PPPs at early stages. Similarly, engineering history is a field that must be studied by civil engineers in order to recommend solutions based on the impact to society and development of similar projects in the past.

Table 3 describes general management skills and knowledge. Some of these areas are currently covered in the traditional project or construction management courses. However, it is important to mention that PPPs require a more comprehensive understanding of these subjects due to the complexity of the projects and the diversity of the stakeholders involved.

The last category refers to specific skills and knowledge for civil engineers involved as PPP practitioners (Table 4). PPPs require specific abilities that may not be present in other types of procurement methods. A more systemic approach is required because of the complex interrelationships between the decisions that need to be made by both the public and private sector during the procurement process. As an example, Table 4 shows that negotiation and procurement knowledge (Miller et al. 2000; Abdel-Aziz and Russell 2001; Zhang 2001; Cartlidge 2006; Jefferies 2006) is essential in order to define the best alternatives to resolve disputes when they arise during the contract execution. However, the dispute resolution techniques need to account for the possibility that foreign investors are stakeholders in the special purpose vehicle company that is usually created to manage PPPs. Hence, having international participants may require a more comprehensive set of alternatives and locations to solve claims between the public and private sector. This also implies that the traditional dispute resolution techniques might need to be expanded to account for the expectations of foreign investors, who would like to resolve those disputes in a neutral environment. Similarly, an understanding of uncertainty is an important skill for civil engineers involved with PPPs. Practitioners should have a deeper knowledge regarding uncertainty and risk assessment in order to evaluate a multistage project with significant uncertainty in terms of revenues, long-term costs, maintenance routines, demand behavior, macroeconomic conditions, etc. Finally, when public-private relationships are considered, the private sector should have a clear understanding of the client expectations. These expectations usually go beyond the traditional customer satisfaction due to the participation of additional stakeholders such as users, the public, politicians, media, and regulatory agencies.

Summary

The current deterioration of America's infrastructure and the scarce resources available to sustain the country's economic growth require the consideration of novel project delivery schemes. Public-private partnerships are a delivery methodology that brings technical and financial resources from the private sector to the public sector in order to maintain, renovate, and build critical infrastructure systems. Hence, civil engineers must have a more prominent role in the conception, development, and implementation of these infrastructure projects. To accomplish this objective, new skills and knowledge need to be acquired by civil engineers so they can become the master planners of infrastructure development. Also, civil engineers have a role in independent monitoring of performance-based PPPs. According to the interviews conducted with industry practitioners involved in PPPs, civil engineers can add value to these transactions but it is necessary for them to get involved not only with the technical decisions, but managerial and financial decisions as well. However, current civil engineering curricula do not provide the required skills and knowledge base to civil engineers who would be the master planners and implementers of infrastructure projects. Our research has proposed an extended set of skills and knowledge areas to civil engineers involved in PPP projects, with the goal of supplying essential tools for PPP practitioners from three different perspectives: technical, managerial, and delivery systems.

Finally, based on the ASCE's vision for civil engineering for the next 20 years, we argue for the need for reviewing and modifying the current civil engineering curriculum. Furthermore, the current status of PPPs and the necessity of infrastructure projects are demanding the development of new graduate programs that address delivery methods for infrastructure projects, particularly public-private partnerships. This new graduate program would be a sustainable way to provide skills and knowledge for civil engineers who will become the master planners for infrastructure development.

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Table 3. General Management Skills and Knowledge

Category	Description	
	Skills	Knowledge
Communication (ASCE 2006)	Communicate effectively with technical and nontechnical individuals.	Group communication, speech. Presentation techniques. Plan, compose, and integrate the verbal, written, virtual, and graphical communication. Virtual communication (ASCE 2008a).
Ethical behavior (ASCE 2006)	Justify a solution to an engineering problem based on professional and ethical standards and assess personal professional and ethical development (ASCE 2008a).	Client confidentiality, codes of ethics within and outside of engineering societies. Anticorruption and profession's responsibility. List the professional and ethical responsibilities of a civil engineer (ASCE 2008a).
Management	Executive control of design, planning, and finance, construction, and initial operation phases. Building relationships. Formulate and evaluate the effectiveness of a management plan.	Construction project management. Planning, monitoring, and control all aspects of projects. Supply chain management (ASCE 2008a).
Conflict resolution	Synthesize solutions from an engineering point of view.	Conflict-dispute resolution. Negotiation techniques. Strategic leadership (Fewings 2005).
Negotiation/ procurement	Define contract type. Promote discussion over alternatives.	Understanding of PPP procurement types. Virtual design construction. Negotiation techniques
Leadership	Make resources available. People motivation. Empowering employees. Formulate and articulate environmental, infrastructure, and other improvements. Decision making.	Motivation and empowering techniques. Decision making.
Teamwork	Provide meaning and purpose, enable others to take responsibilities. Team building. Building relationships, be an effective member of a team.	Group strategies. Team building. Problem solving.

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Table 4. PPP as a Delivery System

Category	Description	
	Skills	Knowledge
Public policy	Involvement and understanding of current and local public policies. Develop public policy recommendations, and create or adapt a system to a real-world situation on civil engineering work programs (ASCE 2008a).	Politics history and current politics. Economic, environmental, and social equity (ASCE 2006). Legislative and regulatory framework for private investment in public infrastructure.
Client understanding	New practitioners ought to completely understand the client's needs and requirements. Involve the client in the project team (Cartlidge 2006).	Total quality management, customer care. Virtual design construction.
Business development	Creation of new organization to accomplish complex projects. Requirements and time allocations to accomplish tasks, determine funding for projects. Legal and financial management (Abdel-Aziz 2007).	Topics applied in the private sector such as accounting, legal forms of ownership, organizational structure and design, income statements, balance sheets, decision economics, finance, marketing and sales, billable time, overhead, asset management and profit (ASCE 2008a).
Risk/uncertainty	Appraise a multicomponent system and evaluate its quantitative risk measure taking into account the occurrence probability of an adverse event and its potential consequences caused by failure (ASCE 2008a). Manage risk analysis and allocation.	Criteria (such as required safety factors) for the ill-defined design of an engineered system within an acceptable risk measure (ASCE 2008a). Long-term risk assessment preparation and application.
Negotiation/ procurement	Define contract type. Promote discussion over alternatives. Be able succeed and agreed on long and non easy negotiation. Rebidding (Ortiz and Buxbaum 2007).	Understanding of PPP procurement types. Virtual design construction. Negotiation techniques.
Teamwork	Evaluate the composition, organization, and performance of an intradisciplinary or multidisciplinary team. Provide meaning and purpose, enable others to take responsibilities.	Group strategies. Team building. Building relationships.
History	Synthesize cases and experiences to foster abilities to develop PPP projects.	Case studies within the PPP area. Post-learning project.

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