An Analysis of Constructability Strategies in Project Delivery: Making Infrastructure Construction Sustainable in Copán Ruinas, Honduras

By

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This report, “An Analysis of Constructability Strategies in Project Delivery: Making Infrastructure Construction Sustainable in Copán Ruinas, Honduras,” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN CIVIL ENGINEERING.

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Preface

This report is submitted as the completion of a master's degree in Civil Engineering from the Master's International Program in Civil and Environmental Engineering at Michigan Technological University. It is based on both literary research and field work done in Honduras while the author served as a Peace Corps Volunteer in the municipality of Copán Ruinas in western Honduras from February 2004 through March 2006.

This report discusses various infrastructure construction projects but focuses mainly on the initiation, design, construction, and maintenance of rural, gravity-fed potable water systems. It addresses the challenges encountered in international settings and some strategies which can be implemented to improve sustainability.

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Abstract

Many organizations are addressing water and sanitation infrastructure needs in Honduras and other developing countries. Infrastructure development is a process which involves many participants and many phases. Because international projects face more logistical challenges, projects often are not built to the level of quality expected in industrialized nations. Projects are also initiated in a top-down fashion, not allowing communities to participate in the decision-making process. This can result in a low quality project that may not meet the needs of the community and is not sustainable. Community initiated projects which utilize local knowledge can be maintained by the community and achieve sustainability.

While working with the Peace Corps as a water and sanitation volunteer in Honduras, I was involved in infrastructure development projects from initiation to community turnover. Working with the municipal government in Copán Ruinas, Honduras, I was able to collaborate with different organizations and analyze the approaches taken and their effectiveness.

This report analyzes many of the challenges that must be overcome to achieve sustainability in infrastructure development projects in Honduras. Comparing project delivery approaches used in industrialized nations and those used in Honduras, many similarities can be drawn. This report discusses how strategies common to known delivery approaches can improve project efficiency in international development work and improve the chances for project sustainability.

Acknowledgements

I dedicate this report to my parents who have always supported me throughout my travels no matter how far away I am, and to my brother, Kurt, who has always led the way for me. Without you, I never would have had the opportunities or strength to do it. Thank you for your visits, your correspondence, and your love.

I would also like to thank my advisors, Jim Mihelcic and Linda Phillips. You have both been invaluable resources as I struggled to bring my research and experiences together. Linda, you carried me and this report through its toughest moments. Thank you. Jim, you make the Masters International program the amazing program it is. You have encouraged me and many others not only to succeed in our careers but to be responsible citizens and steer engineering toward a more sustainable future. And thank you for finding my car, I owe you one. I would also like to thank Ciro Sandoval and Amlan Mukherjee, my graduate committee, for their efforts and ideas.

Finally, thank you to my friends, colleagues, and the communities, both at home and in Honduras for your support and for making me understand how important my work was. I would especially like to thank Jodi for accompanying me to Central America for the last two years, for supporting me, and being my best friend through the best and toughest times.

1.0 Introduction

1.1 Background

Throughout the developing world people suffer due to inadequate or failing infrastructure. Infrastructure, which includes roads, dams, water supply, sanitation, irrigation, houses, schools and bridges, is the physical foundation on which development efforts and improved living standards are established (World Bank, 1984). The World Bank's report on the construction industry in developing countries states that the construction industry is an essential contributor to the process of development, influencing nearly every sector of the economy. Improving the capacity and capabilities of the construction industry in developing countries is a critical step to improving infrastructure development that is often overlooked.

In Latin America alone, 125 million people lack access to safe water and 200 million people are without adequate sanitation. Surveys of the rural poor indicate that lack of access to infrastructure services is the major obstacle to improving their lives (Estache et al., 2003). Without roads, accessibility, drinking water, or sanitation it is extremely difficult for these millions of people to maintain their family's health, much less to participate in local economies in order to rise out of poverty. This has been understood for years and countless resources and efforts have been devoted to improve infrastructure. How is it that, despite this effort, the world's poorest still live without basic necessities?

An estimate by the United States Department of Commerce in 1998 claimed that $400 billion is spent annually on civil infrastructure systems in the developing world and this figure is growing at 20%-40% annually (Pennoni, 1998). As shown in Figure 1, the 1990s saw a rapid growth in private involvement in infrastructure development as markets opened across borders. Unfortunately, these investment flows, at least in the private sector, peaked in 1997 and had dropped by more than half as of 2003 (Harris, 2003).

This private sector trend is indicative of the challenges and frustrations frequently encountered during construction and infrastructure projects in the developing world. These declines have been sparked by high profile cancellations and renegotiations of projects which, in turn, reduced investor appetite for these activities (Trigunarsyah, 2004). Cases like these emphasize the high level of risk involved in international construction.

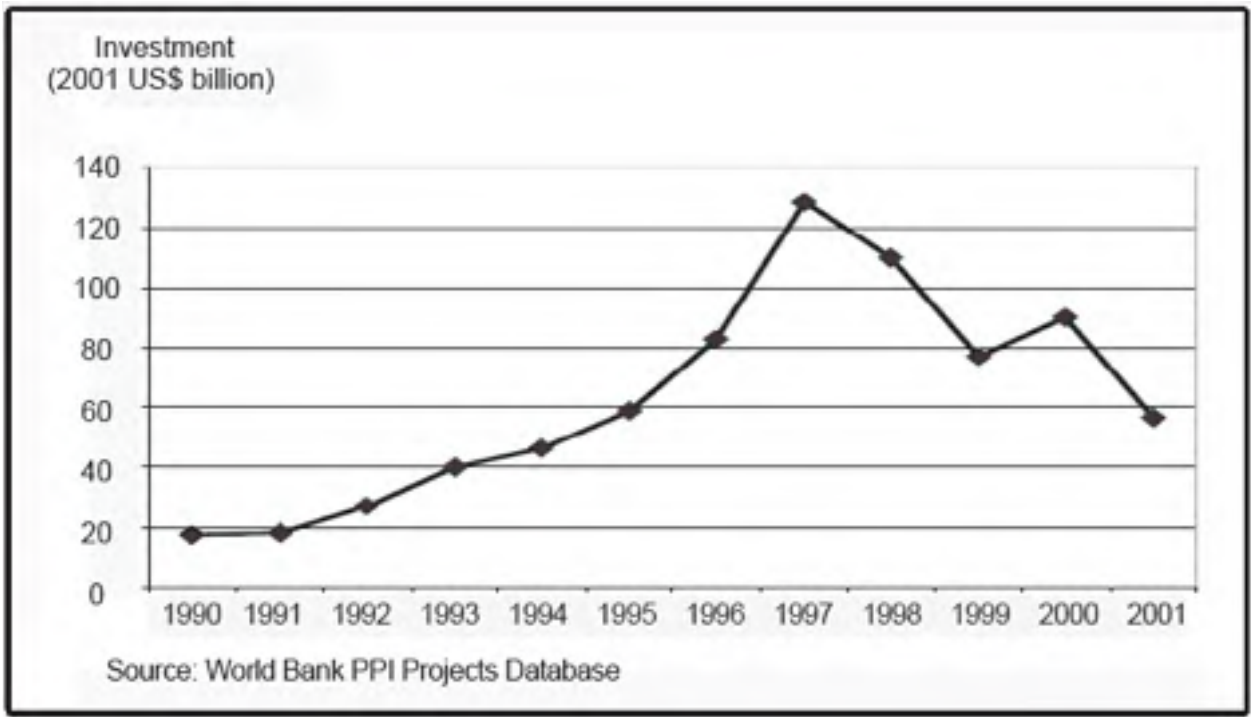

Figure 1: Private Investment Trends for Infrastructure Projects in Developing Nations

(Source: Harris, 2003)

These problems are not only encountered in high profile cases, but arise from a number of characteristics inherent to international construction on any scale. For example, cultural differences and challenges presented by accessibility in remote areas will always exist as obstacles but other challenges that can be avoided deserve closer examination.

1.2 Experience

Working as a water and sanitation engineer for the Peace Corps in Honduras has provided me a unique opportunity to work on projects of infrastructure construction in a developing country. The term 'international construction' is generally used to describe projects which involve large firms working on large projects for profit. The projects in which I was involved are generally called 'international development work.' International construction and international development work in scope but face many of the same challenges. The projects in which I worked were not large in scale or budget, but tailored to the demands and needs of the local community. They varied from gravity-fed water systems to roads and storm water management to small bridges. Each project was unique in its scope. Some lasted months while

others were completed in a matter of days. I had a unique opportunity to be involved from the project initiation through the design, construction, and finally to the project turn-over. I worked closely with the communities and the donor agencies, each acting in their capacity as project owners. In most projects I had closer contact with the community than any other participant and acted as the bridge between the contractor and owners.

At the beginning of my service I had yet to develop an understanding of local building practices or the structure of the municipal government. For two years I did my best to learn what was expected of me in my position as a project manager and soon realized that my role needed to be redefined in order to facilitate each different project. I adapted each project delivery individually, while still working within a rigid, bureaucratic system. I encountered many challenges. Understanding and surpassing them was a daily struggle. In general, the challenges I faced were caused by one of the following characteristics common to construction in developing countries:

1) Working within a traditional, bureaucratic project delivery system.
2) Constructability, due to the gap between the designer and the contractor.

Both of these issues contribute directly to the negative results in the international construction industry that I mentioned earlier. This paper will look closely at these two influential characteristics.

1.3 Focus

Infrastructure throughout the developing world consistently falls into disrepair. The projects are not built to the same level of quality expected in industrialized nations and in many instances the local communities do not have the capacity or desire to maintain the project (Breslin, 2003). This occurs because projects are initiated from the top, down, paying little attention to the needs and capacity of the community. Policy-makers decide what is best for the beneficiaries and what projects will be implemented (Ahrens, 2005). Instead of making important decisions for communities, agencies should respond to the needs presented by these communities. Local communities must be active in the decision-making process throughout the entire project development and construction so their feeling of ownership carries on to aid operation and maintenance. To facilitate this, agencies involved must participate in each step of

the project process, providing continuity for the benefit of the designer, contractor, and the community.

As defined by the Construction Specifications Institute (CSI), project delivery is the contractual relationships between the owner, designer, contractor(s), and the management services utilized to design and construct a project (CSI, 2005). Project delivery is the framework used to take a project from its initiation stage to completion. The most common delivery systems used today in the developed world are design-bid-build, design-build and construction management (Arditi et al., 2002). In the developing world, engineers have only recently been introduced to different project delivery systems. Before this, the contractors acted as master builders coordinating everything from start to finish. This master builder system leaves no gaps between participants and uses a simple contractual agreement. Unfortunately, the system can no longer be implemented effectively as modern construction has become too complex.

Now that donor agencies and governments assume the owner's role in financing projects, designers are hired to design, and the management of construction is left to local contractors or supervisors with little or no experience in management. The relationships between these participants should be defined by through contractual agreements, but contracts are vague and responsibilities unclearly defined. This creates a fragmented project delivery in which risk is not clearly assigned.

Many development agencies and local governments have implemented traditional, rigid, top-down approaches to deliver projects. These bureaucratic approaches are often aimed at preventing corruption common in these situations. Such approaches are becoming a thing of the past in more modern, industrialized nations. Three main project delivery approaches are used commonly in the United States: design-bid-build, construction management, and design-build. Variations of the approaches have been implemented in order to provide the flexibility needed to adapt to the demands of very diverse projects. Project delivery systems have aimed to bridge gaps between designers, contractors and owners, allowing input and exchange by all participants throughout the span of a project. Project delivery structure in developing countries has not evolved past its bureaucratic origins. These traditional bureaucracies are a hurdle the construction industry must surpass in order to implement teaming strategies (Songer et al., 2000).

The construction industry is a fragmented industry in which the owner, contractor, and designer have differing and often conflicting objectives. This fragmentation is particularly

prevalent in traditional project delivery systems (Arditi et al., 2002). With minimal contact between participants a project will suffer from a lack of constructability practices. The Construction Industry Institute (1986) defines constructability as "the optimum use of construction knowledge and experience in planning, engineering, procurement, and field operations to achieve overall objectives." Jergeas and Van der Put (2001) describe constructability as the “integration of construction knowledge and experience into each phase of the project delivery process.” In effective project delivery approaches the contractors are involved from the beginning stages of a project. Their input and expertise is invaluable in the elaboration of plans and schedules that will be the cheapest and most efficient to build. At the other end of a project, the technical support of a designer during construction allows contractors to better understand the design and construction plans. Involvement at the construction site also provides the designer an opportunity to learn about local innovations in construction for future designs. Independent studies confirmed that integrating construction knowledge into design processes greatly improves the chances of achieving a better quality project, completed in a safe manner, on schedule, and for the least cost (Arditi et al., 2002). Constructability practices have a high potential in international construction because local innovation greatly influences the construction process and the gap between the contractor and designer is often rigidly defined.

1.4 Objectives

Many international construction projects are not sustainable. New approaches must be implemented and new strategies in constructability adopted in order to increase sustainability. Accordingly, the objectives of this report are to:

- Provide a clear understanding of the challenges and shortfalls encountered in construction projects in developing countries;
- Describe the project delivery approaches commonly used in infrastructure construction projects in developing countries;
- Compare these delivery approaches with the well-researched and studied approaches used in industrialized nations; and
- Cite constructability practices using three case studies and explain how these can be incorporated into the project delivery systems in developing countries.

2.0 Honduras

Figure 2: Map of Honduras (Source: CIA, 2005)

2.1 Geography

Honduras is situated in the heart of Central America, bordered by the Caribbean Sea to the north and east, Guatemala to the west and Nicaragua and El Salvador to the south (Figure 2). Its total land area is just over 112,000 sq. km., mostly mountainous in its interior with narrow coastal plains. The climate ranges from subtropical in the lowlands to temperate in the mountains (CIA, 2005). Most of the country receives steady rainfall beginning in June lasting until November. The wet season ends earlier in the drier, south and lingers longer in the north and the east. The dry, hot season spans the months of March until May. In these times water resources are scarce and many people, especially in rural areas, have limited access to water. The country is also burdened by an expanding urban population, rapid deforestation, clearing of land for agriculture, and frequent flooding due to hurricanes, much of which could be mitigated by proper

land use and controlled development (CIA, 2005).

I served with the Peace Corps in western Honduras in Copán Ruinas, a village of about 7,000 residents. Copán Ruinas is situated in a valley near the Guatemala border at approximately 600 meters above sea level surrounded by mountains which reach over one thousand meters. Not very high in elevation, the climate is subtropical with temperatures reaching over 100 degrees in the hottest months and cooling to the 50's at its coldest. The dry season begins in late February and lasts into May. The climate and water availability change from valley to valley. Adjacent valleys often have different forests, soils types.

Deforestation is a large problem because of slash and burn techniques and unsustainable population growth. Wood from the surrounding forests is used for cooking and for building materials. The environment on which the rural people in Copán depend is being degraded quickly.

2.2 Demographics

The population of Honduras is estimated at 7 million (CIA, 2005). They live primarily in the western half of the country leaving the vast eastern region, called La Moskitia or the Mosquito Coast, largely unpopulated. The population is growing at a rate of 2.16%. This number would be over 3% but is decreased significantly due to infant mortality and a high migration rate (CIA, 2005). Just over half of the country (54%) still lives in rural areas (CIDA, 2003), but the country is experiencing unsustainable urban growth.

Ninety percent of the population is described as Mestizo, a mix of Amerindian and European. Seven percent are indigenous Ameridian, primarily the Lenca in the southwest near El Salvador and the Maya Chorti in the west along the border of Guatemala, especially near Copán Ruinas. The remaining three percent are mostly of African descent, largely the Garifuna people who live on the north coast (CIA, 2005).

2.3 History and Government

Honduras gained its independence from Spain in 1821. The current government is a democratic Constitutional republic. The capitol, Tegucigalpa, is host to the government's executive, legislative, and judicial branches.

The 20th century saw much influence from the big fruit companies. The export of fruit, mainly bananas, remains a mainstay of the Honduran economy (MSN Encarta, 2005). In 1982, a democratic government rose to power after two and a half decades of mostly military rule (CIA, 2005). Recent history is marked most heavily by involvement in El Salvador's civil war in which Honduras, siding with the U.S. proved haven for anti-Sandinista contras in the 1980's and more recently by Hurricane Mitch, which caused 5,600 deaths and $2 billion in damage in 1998 (CIA, 2005).

The local history of Copán Ruinas is very unique as it has been home to the indigenous Maya for thousands of years. Because of the temples and other structures in the ruins, this area was believed to be the center of culture and trade when the civilization was at its peak around 800 A.D. The civilization collapsed soon after its peak. It is commonly believed that the collapse was caused by overpopulation and poor land management.

The community of Copán Ruinas remained a small, quiet, remote village in the western corner until the late 1980's when an interest arose in some ancient ruins located just outside of town. These ruins are one of the main tourist attractions in all of Central America. Tourism and the town grew slowly, but have boomed in the last five years with the construction of new highways, local infrastructure, and the tourism industry.

2.4 Economy

Although it is rich in natural resources, Honduras is one of the poorest countries in the western hemisphere. Unemployment levels are estimated at nearly 30%, inflation rates hover around 10%, and the wealth is very unevenly distributed among the population (CIA, 2005). These statistics show that Honduras is behind when compared to the average rates of unemployment and inflation in Latin America shown in Figure 3. Over 62% of the population lives below poverty (IMF, 2005). Due to poor systems of infrastructure and access to available commercial markets, many rural communities remain on the fringe of the economy, living well below the poverty level. Some of the main industries are coffee, bananas, timber, clothing and tourism. The United States is the main export partner, leaving the country's economy dependent on that of the United States.

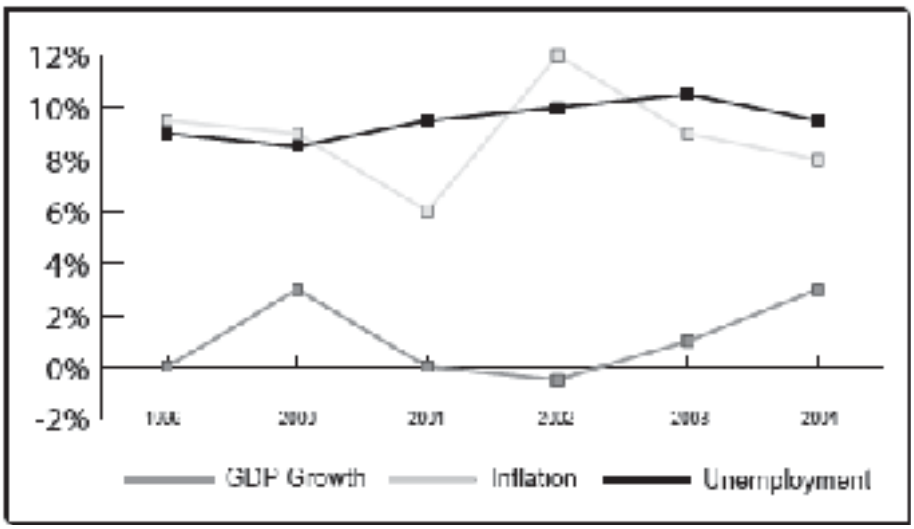

Figure 3: Latin America: Rates of Unemployment, Inflation, and GDP Growth (Source: IMF, 2005)

Due to the economic boom from tourism, the village of Copan Ruinas is much wealthier than most villages in Honduras, but the municipality of Copan Ruinas is actually one of the poorest in the country. Most people do not realize this on their quick tour of the ruins and this quaint village. Ten years ago, tourism was nearly nonexistent and Copan Ruinas was a small village. The road into town was unpaved and the villagers were completely dependent upon a neighboring community for commerce. Now the road which leads to town is a paved highway. It has become the main corridor between Guatemala City and San Pedro Sula. The city has grown fast, but efforts are being made to retain the feel of a small pueblo. It is that look and that feel that draw many people, and their money, to the city. The number of hotels and restaurants has grown faster than tourism. The city is now looking for ways to increase the number of travelers that come into town and the number of days they stay, spending money.

Today the Mayan people play a smaller role. In Copán Ruinas nearly everyone is mestizo. Few claim any Mayan heritage at all; quite ironic for a city that has made its name and money from Mayan culture. Many rural villages in the municipality are predominantly Mayan and among the poorest in the department of Copán.

2.5 Drinking Water and Other Infrastructure

The first major public works happened some 1,500 years ago in Honduras. Mayan cities

were built with aqueducts and storm water drainage systems that function still today. It took until 1883 for the country to build its first modern aqueduct. It was built in San Pedro Sula using tubes which were already in place on an existing railroad. A more elaborate system was built soon after in 1890 in the capitol, Tegucigalpa. The system was financed (at a 1% annual interest rate) and designed by private groups from the United States. At its completion in 1891 the aqueduct delivered 63 liters of water per person each day and functioned perfectly until 1894 when the project ran out of money for maintenance and fell into ruin (COSUDE, 2005).

Currently, only about 81% of the population has access to an improved water supply system (IMF, 2005). This figure drops in rural areas and also includes existing systems with contaminated water. As a result, the incidence of water-borne diseases is high, and women spend much of their time fetching drinking water from long distances and washing clothes in local streams. The systems which are in use today still fall into ruin each year- just like the capital's first system back in 1894. Since improvements in water supplies contribute directly to reductions in the diarrhea morbidity among children (Esrey et al., 1985), the construction and repair of potable water systems in Honduras is an urgent need throughout the country. Constructing and rebuilding systems however is not enough; these efforts must be accompanied by training and organization so that communities are prepared to maintain systems after the development agencies leave.

Honduras has about 14,000 kilometers of highways, less than 3,000 kilometers of which are paved (CIA, 2005). Access for many rural areas is challenging especially during the long rainy season. Communities which are accessible only by larger four-wheel drive vehicles in the dry months and are only accessible by foot or on horseback during these rainy months. Bridges only exist on major highways, isolating communities from vehicle access during heavily rains.

In the municipality of Copan Ruinas, outside of the city, very few villages have access to potable water and even fewer have electricity. Roads are not paved and only reach about half of the villages when they are not destroyed by rains. I spent time in these villages and was amazed how different life is. A couple kilometers from the city most people are subsistence farmers and do not participate in the cash economy. For these rural villagers things are getting tougher as land is used up and water sources become contaminated or dry up.

2.6 Project Entities

Even though I lived in the city, the main emphasis of my work was in these rural communities, designing and managing the construction of water and road projects. I worked with government and non-government agencies to address the needs of these rural communities. The next sections will provide a background of these agencies and the beneficiaries who they worked for.

2.6.1 Beneficiaries

The beneficiaries, who this report will refer to, are the local community members living in the municipality of Copán Ruinas. The beneficiaries of public works projects, such as road repair and storm sewer, are the residents of neighborhoods in Copán. The majority of my work however, was in constructing rural aqueducts. The beneficiaries of these projects were the rural community members who lived with much less than those in urban areas.

Within the municipality of Copán Ruinas lives Honduras' largest indigenous Maya Chortí population. Nearly half of the villages in Copán are considered Maya Chortí. According to a Project Honduras report, in 2003 50% of all Maya Chortí children died before the age of 7 (2006). This rate is over ten times the national infant mortality rate. The Maya Chortí are a population that have not been included in development until recently.

Large amounts of money have been pledged and efforts are being made to bring drinking water to the rural communities of Copán Ruinas, but this is not the end. Due to population pressures water shortages are predicted to get even worse (UNICEF, 2003). The hardest hit will be the world's poorest populations such as the Maya Chorti. The present demand for water will increase and the local communities must be ready and capable of addressing these needs. Water projects today must address these communities' future challenges, not just their present demands.

2.6.2 Government and Non-Government Development Agencies

A top-down approach to infrastructure development has been practiced for many years in Honduras. The federal government decided where resources would be targeted and what projects would be executed. In recent years non-governmental agencies are working at the local level to execute projects and governmental agencies have begun to follow. Even though agencies are locally-based and decisions are made in their local offices, projects are still executed from the top, down. They are implemented to appease the deadlines and quotas given

by donors and central offices. Another trend has also begun in which smaller agencies and local governments have started working at the local level involving communities in the decision-making process and responding to their needs.

Grass roots approaches are gaining acceptance in the international development community. Grassroots developing works closely with local community members to identify needs. A project which is initiated locally will ideally empower a community to maintain the project and benefit from it.

International infrastructure projects receive their funding and technical support from outside agencies. These agencies are either government or non-government agencies (NGOs). Government organizations receive their funding from a government; in this case it is usually a foreign government donor. NGO's are financed and administered from private sources. Although many exceptions exist, both agencies usually work through a local government institution in order to implement the project. The labor force is usually local unless a project requires an expertise not found locally. In past experience I noticed that NGOs are freed of political constraints and have freedom to work where they choose and in the manner of their choice, whereas government agencies have traditionally worked in top-down, bureaucratic styles. The Honduran government has been trying to decentralize, a process which will give more power and funding to local government. This process may change the style in which projects are executed on the local level.

Between government agencies and NGOs there are a variety of projects executed at any given time on the municipal level in Honduras. Communication between agencies has been poor, preventing cooperation and coordination of projects. A lack of communication results because decision-making takes place at the federal level without local input or consulting local agencies.

An increase in decision-making on the local end and coordination of projects among institutions, local government, donors, NGOs and communities can streamline the implementation of local projects (Davis and Brikke, 1995). Municipal governments have organized agencies and projects by devoting staff to oversee and arrange projects. This gives power to local officials and allows various agencies a part in local government. This approach can also be an effectively addresses issues of education, health, community organization, water resources, economics, environment, sanitation, and accessibility on the municipal and local level providing a balanced approach to development.

2.8 Peace Corps Honduras Water and Sanitation Project

The Peace Corps has been active in Honduras since 1962, and currently the program is one of the largest in the world. In 2005, there were 220 Peace Corps Volunteers working in the poorest parts of Honduras, 55 in the water and sanitation program. The program is committed to increase access to water and sanitation services throughout Honduras. As in other countries, the Honduras program has a broad approach which including technical assistance in design and construction, training of local staff to administer and operate, and training of a local plumber to maintain the systems. The Peace Corps does not supply funding directly to build infrastructure but volunteers can solicit funds through donor institutions.

The Peace Corps has addressed the fragile and lacking water and sanitation infrastructure with the following goals:

1. Rehabilitate, expand or construct potable water systems
2. Construct new latrines
3. Establish and train water committees to administer, operate, and maintain their water systems, protect and manage watersheds, and encourage the responsible use of water and sanitation systems
4. Train local plumbers to operate and maintain water systems
5. Facilitate health education courses, encouraging understanding of water and sanitation and its relationship to the community's health
6. Facilitate environmental education courses to encourage watershed management and proper solid waste disposal

Peace Corps volunteers provide technical assistance by designing and managing the construction of water and sanitation infrastructure, focusing their efforts on strengthening communities' abilities to manage their own systems. With this focus, the Peace Corps hopes to balance the overall effort made by development agencies which are focused on financing and construction. In this role, volunteers serve as liaisons between various agencies and the local communities. It is vital to establish this communication and relationship so the community can play a leadership role. In development, leadership must come from within the community. Peace Corps aims to energize this leadership and promote it among development agencies (Fussell, 2004).

3.0 International Development Work

According to the IMF (2005), nearly 20% of the population in Honduras lacks access to potable water, 25% lack any form of sanitary facility, and over 35% lack electricity, and only 20% of the countries' roads are paved. Both governmental and non-governmental agencies are working to improve this infrastructure which is a barrier to the nations' poor. As the population increases so must the resources needed to improve and maintain the infrastructure in Honduras and the rest of the developing world.

3.1 Goals of Infrastructure Development

According to the United States Agency for International Development (USAID), official development agencies spent over 5 billion dollars in Latin American countries in 2005 in an effort to alleviate poverty and its effects (USAID, 2006). Ideally, 100% of the resources devoted to this cause (minus a small percentage for administrative costs) should be realized in infrastructure and training. However, in practice resources are often mishandled, administrative costs are high, quality of construction is low, and communities are not trained adequately to operate and maintain the project which they now own. Development agencies are aware of these problems and work to prevent them with the goal of providing infrastructure projects in the developing world that are affordable, efficient, and most importantly, sustainable.

Infrastructure development presents numerous challenges. Projects are time consuming, costly, and not always sustainable. For example, the World Health Organization (WHO) estimates as many as 60% of the water systems in Honduras and the rest of the developing world are not operational (Davis and Brikke, 1995). Infrastructure systems are not maintained properly and are not built to last. The prime objective of any infrastructure project should be sustainability. Sustainability is a central focus among development agencies in Honduras, but it is still a lofty goal. Until sustainability is achieved, the resources spent in Honduras and other developing countries on civil infrastructure will not reach its goal of alleviating poverty.

A sustainable development project is one that can be maintained by a local community for its expected life. This requires a design which focuses on sustainability, quality construction, and a capable, organized community to manage the project. These are all challenging goals to achieve in a project, only achievable by overcoming a serious of barriers.

3.2 Barriers to Successful Project Implementation

Many challenges in construction projects throughout the world are presented by different personalities, financial limitations, time and scheduling, technical barriers, and various surprises of Mother Nature. Development work faces issues that are unique to the developing world. These problems may be present in industrialized nations but due to inherent characteristics of developing countries, these issues are exacerbated and pose even larger challenges in development work.

3.2.1 Funding

The Honduran government has limited funding for infrastructure development. The absolute amounts available for infrastructure development are small; this, as in most developing countries, is partly due to low incomes and a non-tax paying culture (Danert et al., 2003). In industrialized nations, governments pay large sums to develop infrastructure to maintain a strong economy.

Funds for development work are donated by foreign governments and private donors. The funds are handled by local organizations which are either private or a branch of the government. Private donors contribute funds through organizations such Rotary International or faith-based groups which provide resources with which local institutions implement projects. Organizations such as World Vision or Save the Children have local offices and staff in-country to execute projects. These offices receive and raise funds based on how effectively they execute projects and convey this to their private donors.

Building infrastructure is very expensive. Lacking a strong economy, Honduras is dependent on outside sources for funding. This limits the availability of funds and makes it very difficult for local governments and organizations to build and maintain the infrastructure needed to improve the local economy. Honduras must rely on these organizations for funding until their economy and government can provide it themselves.

3.2.2 Construction

Construction is a risk-driven, multi-dimensional process. It is a series of interdependent steps, each requiring specific technical knowledge and participants working together. In the developing world, construction employs techniques, materials and expertise that make perfect use of available resources and expertise, while others compromise the integrity of the final

product. Material delays, misunderstandings, and discrepancies in design are a few common problems that prevent projects from being completed successfully, on time. Every party in the project must work together in a coordinated effort because tasks are interdependent. If one person fails, so may the entire project.

The following are some of the most common problems encountered during the construction process in rural development work:

1. *Material Procurement*

Material procurement in developing countries requires significant pre-planning due to road conditions, scarcity of transportation, and inconsistency of suppliers. Many sites are remote and are accessed by small 4-wheel drive vehicles, horse, and in some cases only by foot. Roads are also often washed out and thus prevent any vehicles from passing.

Photo 1: Large quantities of materials are transported to remote sites.

For example, gravel, sand and aggregate are taken from local river beds. Often rivers swell, access to the river beds becomes impossible, and aggregate cannot be obtained. Local materials should be ordered early to prevent delays

Non-local materials such as piping, cement, and accessories should be purchased early and stored on site where it can be monitored by local officials. Material costs fluctuate greatly in developing countries because they lack policies to prevent price hikes due to shortages, gas rates or inflation (Jaselskis and Talukhaba, 1998). In order to avoid these price hikes and shortages, materials are ordered weeks in advance and stored securely in the community.

2. *Material Storage*

Storage sites can also pose problems due to security, weather-proof construction, and proximity to the work site. Most rural structures are made of adobe or stick and mud. During the rainy season, moisture-sensitive materials such as cement may be ruined. Most sites are not

secure and theft is often a problem. Storage location is important as community members must carry the cement, wood, rebar, and accessories to the site which, in water projects may span miles. When materials are forgotten or miscalculated, design changes made, or repairs required, additional materials may be needed.

3. *Material Quality*

In developing countries, material costs are high in comparison to labor and are generally of inferior quality to those available in industrialized countries. Designers need to compensate for this lower quality in their designs. Design calculations cannot assume the typical 3000 psi concrete design strength because it cannot be attained in practice. A trial using locally manufactured cement in Bangladesh proved this point where no test results met 28-day strength tests (Koehn and Ahmmed, 2001). Inferior quality materials may not be noticed until they arrive at site, and thus are reordered or installed as-is compromising work quality. Local contractors are accustomed to stretching materials to save money.

Photo 2: Aggregate is carried by mules and concrete is hand-mixed on site.

4. *Labor*

Many labor problems are also unique to infrastructure development. The labor force is generally poor and unskilled. Aside from the contractor, the labor force consists of community members with little or no construction experience or education. This produces a number of challenges:

- High levels of unemployment and low levels of education lend to a surplus of willing but poorly skilled 'contractors' looking for income opportunities (Danert et al., 2003).
- Poor organization of community members during planning, which cannot be correct by contractors.
- Discontinuities and fluctuations in the construction market do not permit contractors to

maintain permanent supervisory staff. This is also a problem in industrialized nations, but it is much more volatile in the developing world. (Jaselskis and Talukhaba, 1998)

- Expensive materials are stolen by 'free' community labor or underpaid qualified laborers.
- Lack of equipment, such as mixers, yields low quality. For example, concrete is mixed in small, inconsistent batches and most large structures cannot be poured in a single stage.

3.2.3 Planning and Design

There is a large separation of knowledge and responsibility between the design and construction phases. This causes major problems in both the design and construction. Designers do not have practical construction experience so local knowledge and construction techniques are not taken into account during the design, causing unreasonable expectations and inadequate specifications. The skill levels and knowledge of the contractors vary greatly. Designers also complain that they have to overcompensate for the expected lack of expertise in operations and maintenance (Davis and Brikke, 1995), but this is exactly what is needed to design for sustainability.

3.2.4 Corruption

High levels of poverty and financial shortcomings for many professionals lead to need and greed throughout the developing world. Some individuals look to supplement their incomes whether it is for necessity or greed. This creates an environment of corruption where there is little trust between participants. In the absence of trust, rigid rules and procedures introduce bureaucracies, aimed at preventing corruption. Yet in the complexity of bureaucratic procedures corrupt practices can be hidden (Danert et al., 2003). In today's international construction industry these traditional, rigid, top-down approaches are the norm.

3.3 A Better Future for Infrastructure Development

Project sustainability depends on the participants involved and the implementation practices they employ. Development agencies strive to reach the ultimate goal of sustainability, but improvement is needed. Projects require dedication and competence on behalf of the contractor, engineer, development agency, and community owners.

Participants do not share common goals. This has created trends which commonly hinder

development work. Designers work independently of the community, sending technicians to collect field data. Removed from the community, designers do not work in their best interest. Contractors also may not work in the best interest of the community, cutting corners to finish a project faster and cheaper. To prevent this projects are supervised by the development agency, but they also benefits from shortcuts. The development agency's efforts to involve the community in decision-making processes, training, and follow-up are time-consuming and are not financially rewarded. They are not held accountable for construction quality or project sustainability, but only need to make the project look successful on paper to satisfy their funding agency and solicit future funds.

To improve project sustainability, these trends must change. These trends stem from a lack of trust and cooperation between participants. When participants work closely and are involved from the beginning of the project, goals are united and participants work as a team. Sustainability needs to be addressed as early as project initiation and focused on throughout the design and construction. This emphasis increases participant interaction, community involvement, and leads to future success in operation and maintenance.

4.0 Project Delivery

Project delivery is the contractual relationships between the owner, the designer, the contractor, and management service used in a project. These relationships create the framework in which a project progresses from an idea to completed facility (CSI, 2005). Different project deliveries have been developed to effectively address the unique demands in each project caused by cost, extent, and time constraints. The benefits and limitations of each delivery system need to be understood when choosing a delivery system. This decision will determine the relationships between participants and how they will work together to complete a project.

Construction projects in industrialized nations experience problems similar to those in international development work. The following section defines the three most common project delivery systems used in industrialized nations. Later this report will compare these three common project delivery systems with project delivery in international development. In this context, it will be possible to analyze strategies common to certain project delivery systems and

discuss whether they are viable in international development work.

4.1 Design-Bid-Build Project Delivery Systems

Design-bid-build project delivery is characterized by distinct design and construction phases. The owner has separate contracts with the designer and contractor. As shown in Figure 4, the owner first contracts a designer, then, usually after the design is completed will award a contract for construction. The contractor is hired either through a bidding process or by a process of pre-selection and negotiation (CSI, 2005). This approach is designed to provide complete design prior to bidding and to achieve a low price through contractor competition.

As mentioned earlier, construction is a fragmented industry and the owner, contractor, and designer may have differing and sometimes conflicting objectives. These conflicts are prevalent in the design-bid-build system where the participants do not work closely together and often have conflicting interests (Arditi et al., 2002). In design-bid-build projects the designer, contractor, and owner all want to minimize costs. Cost savings however, can come at the expense of the other participants, and may lead to litigation.

Most participants in construction are very familiar with their roles within a design-bid-build delivery system. This is the most common system used in industrialized nations. It is also the required system in most government contracts as it effectively achieves low price and fair competition, upholding the best interests of tax payers (CSI, 2005). Early completion of the design eases planning and facilitates scheduling. The timing also allows the owner to work closely with the designer during the design phase.

Like all delivery systems, design-bid-build has its pros and cons. It can be used in any size of project, aims to minimize costs, but is not the fastest way to execute a project. Its popularity is due to its familiarity and low-price guarantee. Unless industry trends change unexpectedly, the design-bid-build system will be here for a long time.

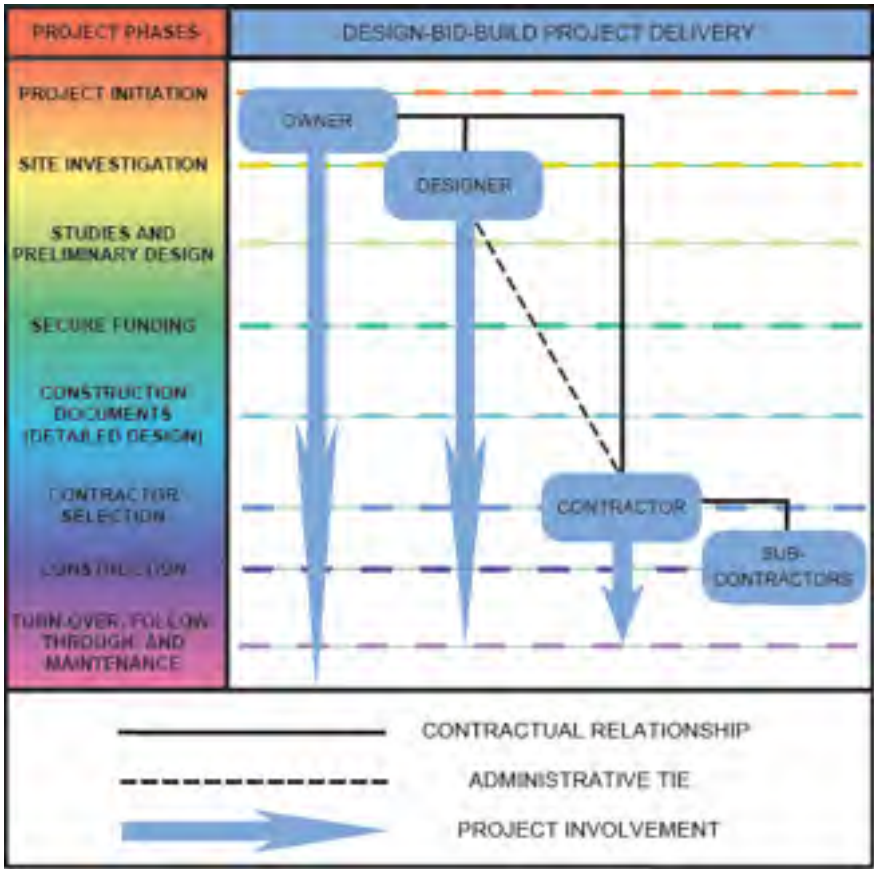

Figure 4: Contractual Relationships between Participants and Project Involvement throughout Design-Bid-Build Project Delivery

4.2 Design-Build

Design-build approaches are characterized by a single contract between the owner and a design-build entity, as shown in Figure 5. In this system, the design-build entity is responsible for both the design and the construction. Although design-bid-build approaches are still the norm, some firms have shifted to design-build. Design-build approaches are beneficial because the contractor is involved in design, fast-track scheduling is possible, and firms have more control over their product as most services are provided in-house.

Acting as a single entity driven by profit, the design-build firm may have a conflict of interest with the owner. A design-build firm may cut costs at the owner's expense. There is no independent agent to check for quality design and construction as in the construction phase of design-bid-build when the owner, contractor, and designer work together. The design-build

system can be adapted and owners can hire an administrative professional with construction experience to act in their interests (CSI, 2005).

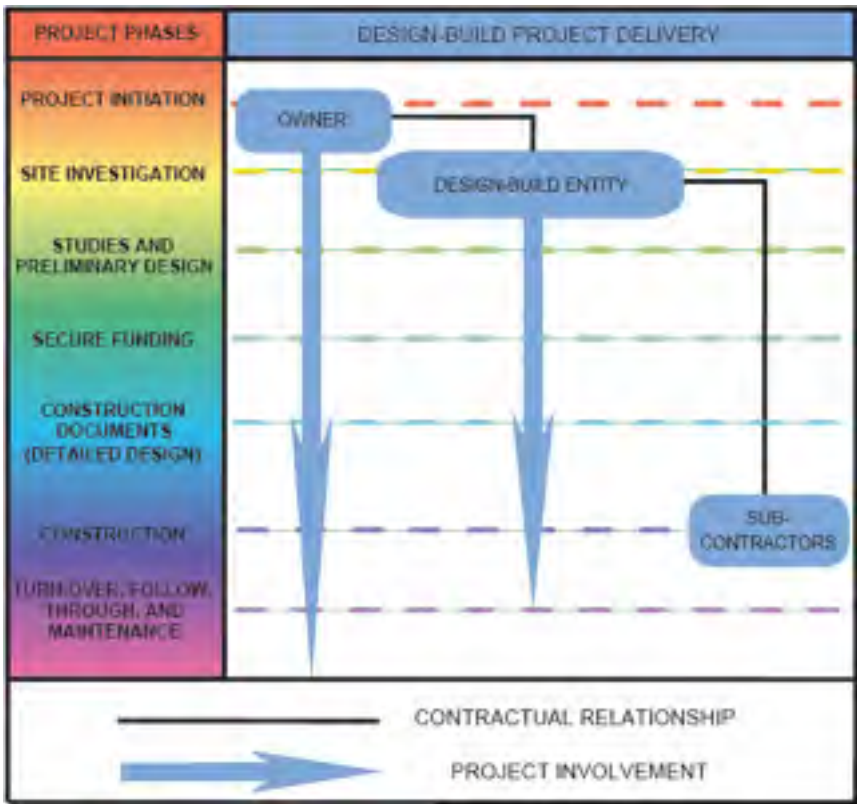

Figure 5: Contractual Relationships between Participants and their Involvement throughout Design-Build Project Delivery

An ideal design-build approach reduces constructability problems and allows changes to be implemented easily as the interface between the contractor and the designer is more frequent than in the design-bid-build. The long-term partnership between the contractor and designer throughout the project minimizes constructability problems because the designer understands what the partnering constructor requires of the design (Arditi et al., 2002). The single point of accountability also lessens confusion for both the owner and the design-build firm. Without competitive competition however, this project delivery is more expensive than other systems. This design-build is chosen when the scope of a project is within the capacity of a trusted design-build firm and the extra up-front cost is not a problem.

4.3 Construction Management

The construction management project delivery system introduces professional management throughout the project acting as an agent of the owner. As illustrated in Figure 6, the owner has separate contracts with the contractor, designer, and construction manager. The role construction manager as an agent of the owner does not bear any financial risk. The construction manager works closely with the designer and contractor during the design and construction phases in the best interest of the owner. The construction management entity has expertise in construction and allows the owner to execute complex projects which require extensive coordination between project participants (CSI, 2005).

The construction manager's expertise and involvement improves efficiency of even the most complex projects by minimizing rework, change orders, and cost overruns. The construction manager advises the owner in the design and construction stage allowing the owner to have influence throughout the project. This involvement facilitates constructability, integrating construction knowledge during the design phase. The construction manager oversees design implementation during construction, often diminishing the designer's role in construction, but the involvement of the designer in construction differs in each project. In expensive, complex projects the extra cost of hiring a construction manager is offset by avoiding general contracting fees, savings in cost management, and the reduction of cost overruns.

There is no delivery approach that is best in every situation. These three systems are the basic frameworks used in most projects. From each of these frameworks many variations and hybrids have evolved and been implemented. Projects may be adapted in any way that may aid in the project delivery and utilize the strengths of all project participants. The best project delivery system will address each of the project's unique needs and characteristics.

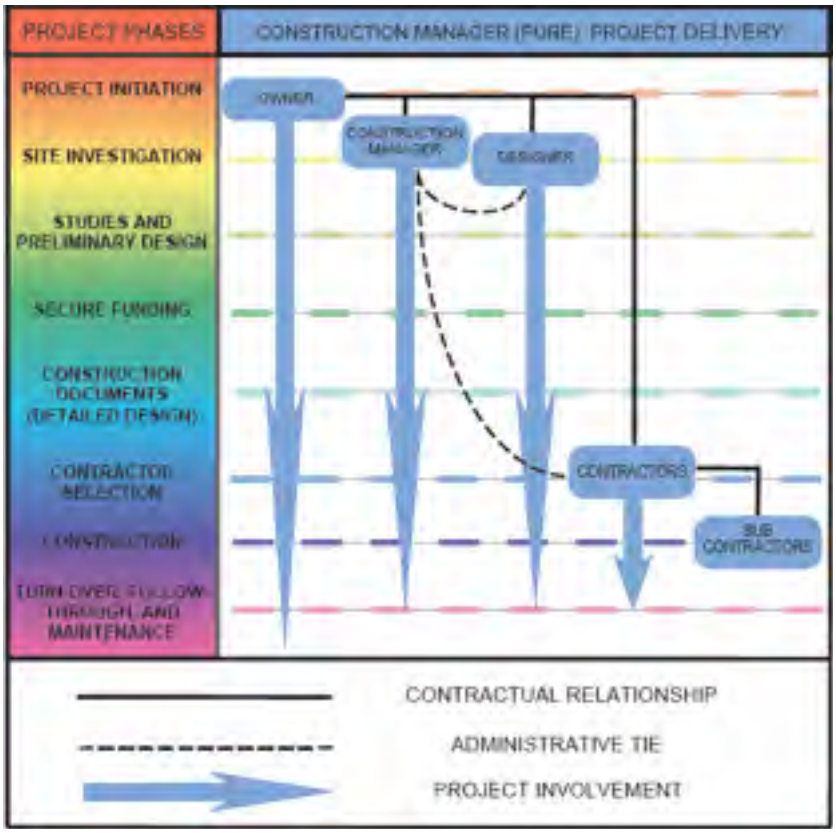

Figure 6: Contractual Relationships among Participants and their Involvement throughout Construction Management (Pure) Project Delivery

5.0 Organizational Structure of International Development Work

Infrastructure projects in industrialized nations are owned by the government, a business, or a private entity. The owner will provide the funding for the project, the initial idea, and set the project in motion. Infrastructure projects in developing countries have a much different organization. The owner's role is shared and executed by different participants. This changes the entire structure of a project and the relationships within it. Although very unique, the project delivery in international development work has many similarities with the three basic project deliveries used in industrialized nations. In order to identify these similarities, this section first examines the structure of projects in international development work.

5.1 The Participants Involved in International Development Work

Better terminology is needed to address communities not as mere users or beneficiaries or clients. Terms such as "partners," "co-owners" or even "community owners" deserve consideration in developing participatory models and community management (McCommon et al., 1990). In this context, a community can best be defined as a group of individuals with a shared interest and a network of social relationships that develop around the creation and then maintenance of a common property resource. To insure success, development projects must be collectively cared for, viewed as a public asset, and thus managed for the common good (Ratner and Gutiérrez, 2004).

The role of the owner is not included in the following list of project participants. Due to the nature of development work, there is no clear owner. In these projects, the role of the owner is played by the beneficiaries, the development agency and the funding agency.

Beneficiaries or Community Owners- In development projects, the beneficiaries are usually communities, rural or urban, usually poor and under-developed, for whom the project will serve. Like owners in industrialized nations, the beneficiaries are usually responsible for the project initiation and should be involved throughout the project until turn-over.

Development Agency- The development agency sets the project in motion. This agency will perform a site investigation, provide or contract a designer, manage construction, and award the contract for construction. The development agency secures and handles money for the project. For some projects they will also provide funding. In Honduras, the development agencies are usually municipal or federal governments, or an NGO. Often, multiple development agencies are involved and share responsibilities.

Designer- The designer's role varies in each international development project. The designer often works inside the development agency, but may also be contracted by the development agency to do the design work and estimate construction costs.

Funding Agency- The funding agency provides financial resources for the project. This entity has a contract with the development agency, delegating the management of the design and

construction. The development agency can also be the funding agency. For example, a local municipality may pay for a project and coordinate the construction effort.

Contractor- After the design phase of the project, the development agency awards a construction contract to a contractor. In most projects this is when contractor involvement begins in the project. The contractor is usually a local builder with experience in local construction techniques particular to the project.

5.2 Project Phases

Before a project is initiated, it is merely an idea. A series of phases will guide a project from initiation to project completion. These phases are:

1. Project Initiation
2. Site Investigation
3. Studies and Preliminary Design
4. Securing Funding
5. Construction Documents (Detailed Design)
6. Contractor Selection
7. Construction
8. Turnover, Follow-Through, and Maintenance

5.2.1 Project Initiation

Government, business, private group or individual owners in industrialized nations provide the ideas and funding for their projects, setting their projects in motion. Infrastructure projects in the developing world follow a different path. The community owners do not provide the funding for the project. Projects are done in poor, rural, communities, or in urban communities with a diverse socioeconomic background. Whether communities are able to help with funding or not, greater success is achieved when these communities initiate their projects.

It is common for projects to be initiated from outside of these communities. Development agencies or funding agencies propose projects, they have funding, and they take it to the community. This does not involve the community as early in the decision-making processes. As shown later in Figure 7, this approach may not involve the community until the

construction phase of the project. Some projects even engage the communities as late as turn-over. Projects which are not initiated from within the community are not as sustainable as community solicited projects. By initiating a project a community shows that they are ready and willing to engage in the long-term commitment which will be required of them.

5.2.2 Site Investigation

After a community solicits assistance to initiate a project, an engineer or technician from the development agency performs a feasibility study. This first visit is a way for the development agency to determine if the project is viable. Development agencies approach projects as developers do in industrialized nations. Physical factors are assessed to accurately predict a project's viability. Factors include travel time and distance to the site, project size, estimated cost, and number of beneficiaries. It is also common to assess interest of local government as municipal support will help insure project success.

The viability of a project is very important to a development agency. Although profits do not drive development work, NGOs and government agencies have a lot to lose or gain depending on the efficiency in which a project is completed. Future funding depends on their current project's success. Development agencies want to invest their efforts in projects that can be completed on time and within budget. Difficult, labor-intensive projects in remote areas are very risky and avoided by development agencies. Unfortunately the most remote communities are often the most in need of assistance so a disproportionate number of projects are executed in the most visible and viable communities in developing countries.

5.2.3 Studies and Preliminary Design

In this stage of a project, field data is recorded and compiled to create preliminary design documents, which include drawings, design calculations, material lists, and specifications. This work is responsibility of the development agency. The development agency either employs its own engineer or contracts an outside engineer to collect field data, determine the most feasible approach, and make the preliminary design documents. These documents will be compiled in a proposal and used to secure funding. The studies and preliminary design take an idea and make it workable plan.

An accurate preliminary design allows potential contractors and funding agencies to better understand the project and determine their possible involvement. The uncertainty of

construction makes it impossible to develop a perfect preliminary design, but by properly utilizing pre-existing designs, employing modern equipment to collect field data, and involving construction personnel in this stage, the preliminary design will prevent discrepancies that can surface later during construction. Changes are always required, but accuracy in the studies and preliminary design will reduce the time and budget of a project.

5.2.4 Securing Funding

The proposal, a summary of the project, is used by the development agency to solicit funds. It will include information about the community, accessibility, a summary of the design, material lists, drawings, and estimated costs. This provides a funding agency enough information to make a decision about their involvement. If an agency gets involved and finances the project, it will depend on the development agency to manage the funds.

Securing funding is the pivotal point of any project. When funding is received, project participants can be organized and plans made to execute the project.

5.2.5 Construction Documents (Detailed Design)

Construction documents are based on the preliminary design documents. These documents include detailed specifications and drawings, construction plans, and contracts. Additional data is gathered through site visits to create a detailed design. This design, which includes material lists and specifications, is used by contractors during the bidding process. Construction agreements and contracts are created to define the contractor's responsibilities and describe the scope of the work. These documents also explain the responsibilities of the development agency and what assistance the contractor can expect. These documents clearly assign responsibilities to the contractor and the development agency to avoid disputes during construction. Once signed, the contract legally links the client and contractor, allocating risk to each party. The contracts used in rural water system construction in Honduras are standard forms that the development agency selects and adapts to particular projects.

5.2.6 Contractor Selection

Most international development work may be simple, but without qualified skilled labor, projects can suffer from poor workmanship and management. Since rural communities lack the specialized skills required for these projects, a contractor is hired by the development agency to

assume responsibility for the construction. The contractor rarely enters the project until immediately before the construction process. The contractor is usually hired by the development agency based on previous work experience or by lowest bid, but in many international settings 'cronyism' still holds sway over more effective and fair selection methods, especially when the government is involved, where status and credit among constituents is important (Midgley, 1999). In this case, a contractor is selected by the development agency and a price is negotiated. Contractor selection in Copán Ruinas followed no standard guidelines to assure fairness and quality work.

Contractor selection can be done in a single-stage or a two-stage process. In a single-stage process contractors are given the opportunity to bid for the contract. They base their estimated cost on the design documentation which the development agency provides for them. The contract is awarded to the contractor with the lowest bid. Local contractors may be accustomed negotiating, not competing for projects. When foreign participants and development agencies are involved, local contractors may try to inflate their price. The bid competition in single-stage contractor selection is an effective way to avoid this.

A two-stage process includes a prequalification stage before the bid evaluation and selection. The two-stage selection process aims to streamline the decision-making time and improve work quality. In international construction projects, three to four bidders are often pre-qualified. Once these bidders have submitted their bids, their prices are weighed against their experiences, qualifications of personnel, quality of service provided, quality management, current workloads, strategic alliances, and resources (Love et al., 2004). This process is also common in international development work. The process can take more time, but it provides the designer and owner with the best contractor to match their needs.

5.2.7 Construction

The construction phase includes the actual construction and the planning which leads up to it. These planning efforts save time and money. Studies show that planning greatly reduces the schedule and budget of projects. **S**trategies, which take place in the planning stage, can reduce the project schedule by 35% at no extra cost. Most prevalent are material procurement strategies, aimed to save time by never lacking materials (Songer et al., 2005). Materials, both local and non-local can be acquired before construction begins if they can be stored securely.

Materials can be acquired during construction, but common problems in transportation and supply can cause delays.

During planning, the development agency, contractor, designer, community and funding agency must establish clarity of roles and responsibilities. When an issue or task arises, it must be clear who is responsible. This is especially important when multiple development agencies are involved. If disputes arise, the project will suffer and the partnership between participants may not be possible for future projects. Construction planning is the responsibility of the contractor and the development agency, but it is important to include the community owners in this decision-making process.

A project's success is dependent on the construction planning efforts (Love et al., 2004). This includes the material planning as well as the organization of labor. A good relationship must exist between the contractor, the development agency and labor force. In the developing world, most contractors lack management training so it is important for the development agency to play a role in helping the contractor establish management procedures. Coordination and planning among the management and labor is critical to a project's success.

Before the construction of rural water projects begin, it is necessary to establish and begin training an administrative water board. This should be done after funding is received and before the construction, while enthusiasm for the project is high and community members are ready to engage in a long-term commitment. Through the water board, labor is organized and a tariff system is established to assure that the community can afford future maintenance costs. A project's sustainability depends on this organization. Water systems require maintenance and often fail after a few years in service. A well-organized and motivated water board can sustain a project more than twenty years.

5.2.8 Turnover, Follow-Through, and Maintenance

Success of an infrastructure project is measured by sustainability and whether its benefits continue after project turnover. This is especially true for rural drinking water systems. Project sustainability depends largely on the community's ability to operate and maintain the system. During construction it is imperative that community members are trained and practice technical construction aspects such as pipe fitting and concrete work. The construction process provides an excellent opportunity to learn these skills. The construction phase also provides the

administrative water board an opportunity to meet and make decisions regarding labor and scheduling. The development agency and the contractor must initiate both.

At completion, the community becomes sole owner of the project. They are responsible for system operation and maintenance. A good development agency will continue to work with and check on the community to make sure that daily operations are carried out correctly and problems successfully resolved. The goal is to prepare the community for any situation that may arise, but communities will usually need help regarding issues that were not fully understood earlier in the project.

Davis and Brikke (1995) wrote that water supply projects should not be regarded as an end in themselves but as "initiators of a range of benefits which continue long after projects have been handed over." A project which lasts for twenty years is ten times as effective as a project that lasts two years. The difference is whether a community responsibly assumes ownership of a project. It is imperative that development agencies focus on project turn-over and sustainability from the moment a project is initiated.

5.3 Project Delivery

The project delivery which guides a project through each of the stages above is unique to development work. The ownership role in these projects involves a funding agency, development agency and community owners which are usually distinct entities. This multiple 'owner' involvement makes the project delivery structure unique but still comparable to the project delivery systems established in industrialized nations. As illustrated in Figure 7, projects can be initiated by development agencies or funding agencies. This is a 'top-down' style of project delivery. Projects can also be initiated from within community.

The top-down approach does not involve the community until the very end of the project. In some projects the community merely agrees verbally to accept the project and does little more than receive the project. Figure 7 shows that the community is linked to the development agency by an administrative tie. This relationship is not contractual. It requires no effort from the community nor promises an obligation to the community on behalf of the development agency. The community-initiated approach shown in Figure 8 shows how the community is involved from the beginning of the project to project completion. Community initiated and driven projects are focused on community needs and capabilities in maintenance.

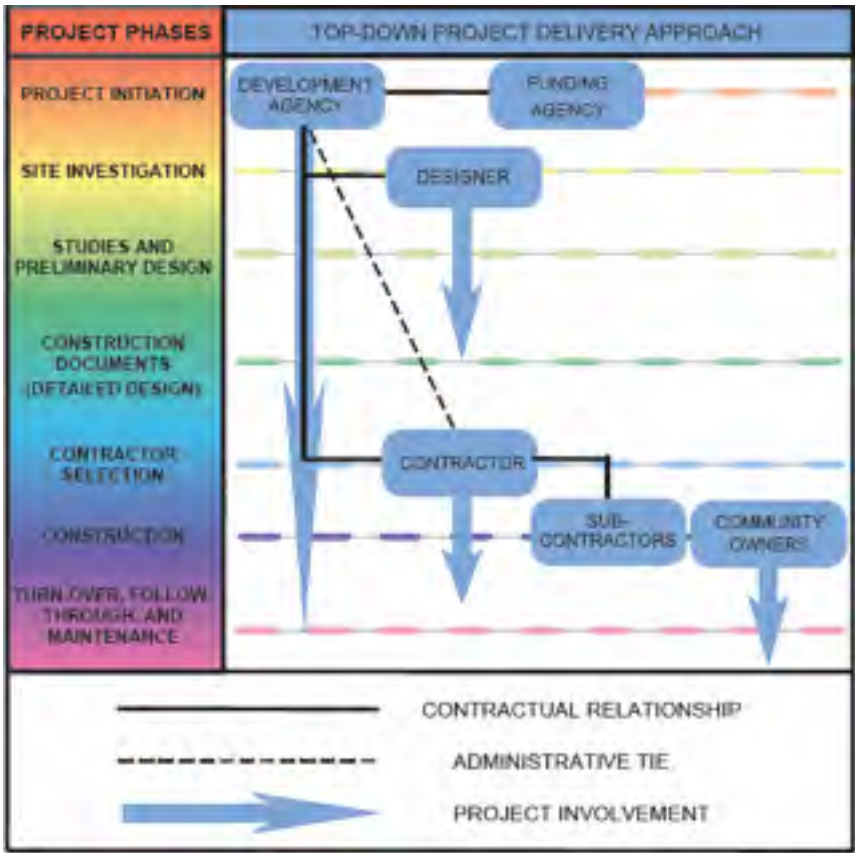

Figure 7: Relationships and Participant Involvement in Top-Down Project Delivery in International Development Work

In most development work projects the development agency is involved throughout the project. The development agency manages construction and oversees the design and construction phases of the project, acting in the best interest of the community owners. In this way the development agency provides a service similar to a construction manager. The contractual relationships in this approach are similar to those in construction management project deliveries.

As described earlier, the development agency either employs its own engineer or contracts an outside engineer to design work. When a development agency seeks an outside engineer, there is a contractual agreement between the development agency and the designer, as shown in Figure 7. Here the designer may not be involved during the construction, just the early design phases.

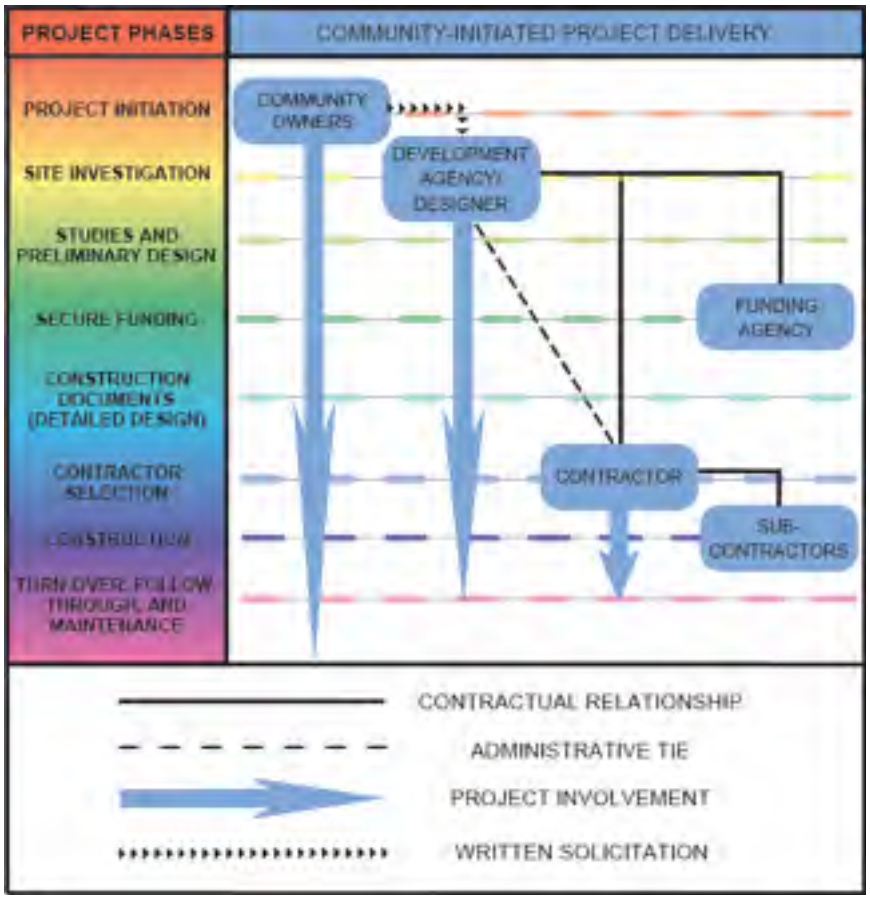

Figure 8: Relationships and Participant Involvement in Community-Initiated Project Delivery in International Development Work

When the development agency has an engineer on staff, a project has project management and design expertise throughout the entire project. This 'development agency/designer' approach is a variation of construction management project delivery called owner/designer/CM. In this delivery system the owner, designer and construction manager work as one entity as shown in Figure 9. This provides good continuity in the project, but the development agency does not usually have the construction expertise to lend during the design that a construction manager would have in an industrialized nation. Incorporating construction personnel early in this project delivery could make this project delivery effective in international development work.

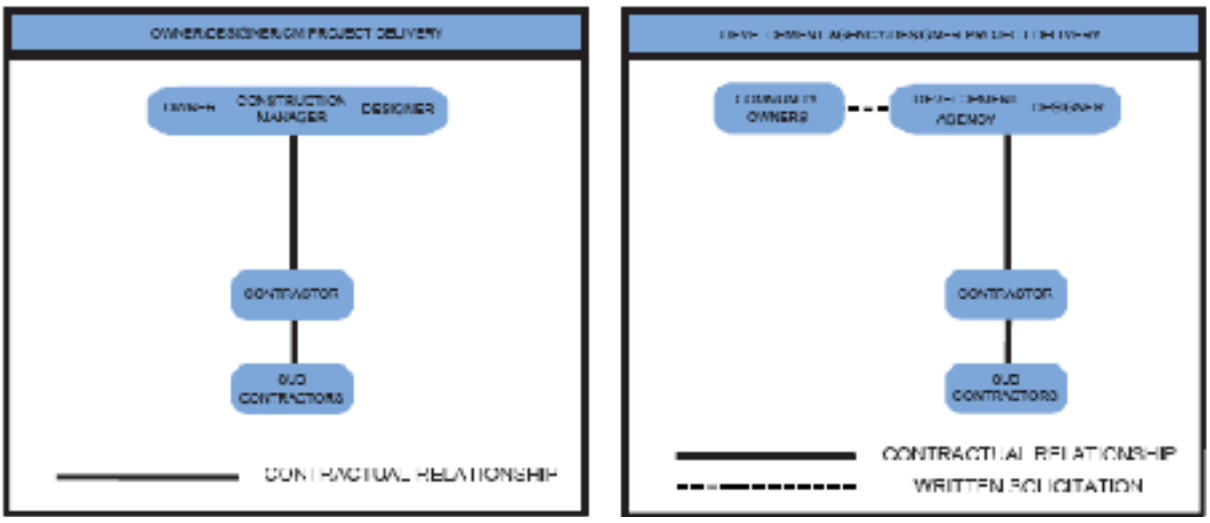

Figure 9: The Owner/Designer/CM Delivery System Compared to the Development Agency/Designer Approach Used in Development Work

An important characteristic of project delivery in international development work is the late involvement of the contractor after the design has been substantially completed and the specifications developed. In most approaches, the contractor has no influence in the design and is confined to a rigid role only within the construction phase as in design-bid-build. Designers are also divorced from the responsibility of construction, preventing any knowledge of local innovations and construction from improving the design and construction (Trigunarsyah, 2004).

A lack of construction knowledge in the design phase also creates problems in industrialized nations. To address this, constructability strategies are implemented, introducing more construction knowledge in early project phases. Understanding development work in the context of known project delivery systems, we can now analyze constructability strategies to determine their potential in international development work.

6.0 Modern Practices in Constructability

Through research and the implementation of different strategies, the construction industry in industrialized nations addresses the problems and challenges commonly encountered in infrastructure development. These strategies shape the way projects are executed, contributing to

better quality, efficiency, and ease of delivery. One of the main focuses of this effort has been in constructability. As mentioned earlier, the Construction Industry Institute (CII) defines constructability as "the optimum use of construction knowledge and experience in planning, engineering, procurement, and field operations to achieve overall objectives" (1986). Jergeas and Van der Put (2001) describe constructability as the “integration of construction knowledge and experience into each phase of the project delivery process.” Constructability aims to prevent problems caused by gaps between design and construction.

Problems arise from faulty drawings, incomplete specifications, and adversarial relationships between owners, designers and contractors. Problems result in poor quality, or even litigation. Poor quality in design or construction can require rework. Rework, “the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time,” typically accounts for 3-23% of contract values (Love et al., 2004). This is a significant cost and no one wants to assume the cost or the responsibility often leading a project into litigation.

Strategies can be implemented to avoid these problems. One of the most effective strategies used by design and construction firms is the implementation of constructability programs. A sound constructability program helps the designer and contractor work together in each stage of a project to avoid confusion or misunderstanding. Four effective strategies in constructability, their aims and challenges are shown in Figure 10. These strategies effectively introduce construction knowledge throughout a project, minimizing complications which can arise during construction.

Constructability is one element in a package which Jergeas and Revay (1999) call “integrated value management." The other elements of this package include strategic alliances or partnering, value engineering, and risk management. These strategies should be implemented together to maximize a project’s success. Constructability is interrelated with each of the other elements. If a constructability program is introduced successfully, the other elements are more effectively implemented. The following section focuses on successful constructability strategies that have been researched and implemented in industrialized nations. Later in this report, the effectiveness of these strategies in international infrastructure development work is discussed.

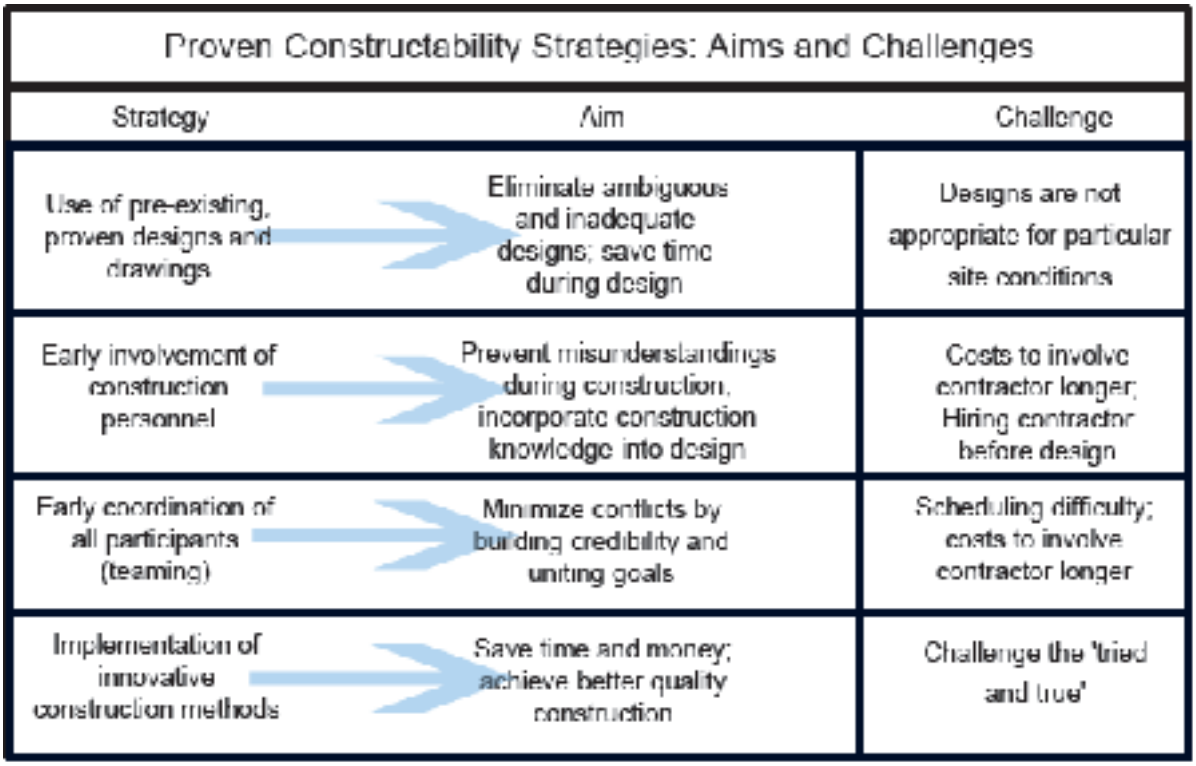

Figure 10: Strategies in Constructability, How they Can Benefit Projects, and What Prevents their Implementation

6.1 Project Delivery

In a survey of 134 of the top design firms in the United States, 66% of the respondents provided design-bid-build services, 34% provided design-build, and 18% provided construction management (Arditi et al., 2002). Design-bid-build services, which most commonly omit construction input during the design phase account for the majority off contracts. This supports a need to implement constructability practices because no construction personnel are involved early in the project within the design-bid-build project delivery system.

As discussed earlier, project delivery systems determine which constructability practices are viable for a project. All definitions of constructability focus on the issue that its benefits are best achieved through the integration of the construction knowledge and experience into each phase of the project delivery (CII, 2001). As shown in Figure 10, constructability programs are more effective early in a project. Analyzing the project delivery system, the earliest opportunity to implement constructability can be identified. Constructability is commonly implemented in construction but when it is implemented during design it is more effective. Certain

characteristics of project delivery systems provide better opportunities for constructability practices during the design.

Constructability is presumably less of a problem in the design-build and construction management delivery systems where designers and contractors are in constant communication (Jergeas and Van der Put, 2001). Due to its structure and limited interfacing between participants, the design-bid-build project delivery approach has higher instances of rework and disputes than in design-build delivery (Love et al., 2004). Many participants in the industry have abandoned the design-bid-build system or adapted it to bring construction personnel into the project from the beginning.

6.2 Planning, Design, and Documentation

Successful constructability strategies start from project onset and are integrated into each project phase. Constructability is most cost-effective if implemented in the design and planning phases. One study showed that 65% of process changes implemented for constructability purposes occur during the design and planning phases (Songer et al., 2005). These changes are effectively implemented by incorporating construction expertise in the design, planning and documentation. Constructability practices not only ease the construction, but they can shorten the schedule and reduce the budget as well.

Efforts made in early project phases are most effective at preventing problems in constructability. Figure 11 shows how changes are easier to implement in early stages of a project and cost less. Constructability practices implemented early will be the most cost-effective. Unfortunately the most common approach, design-bid-build, does not facilitate early incorporation of construction knowledge so constructability programs must be added at an extra cost to the owner.

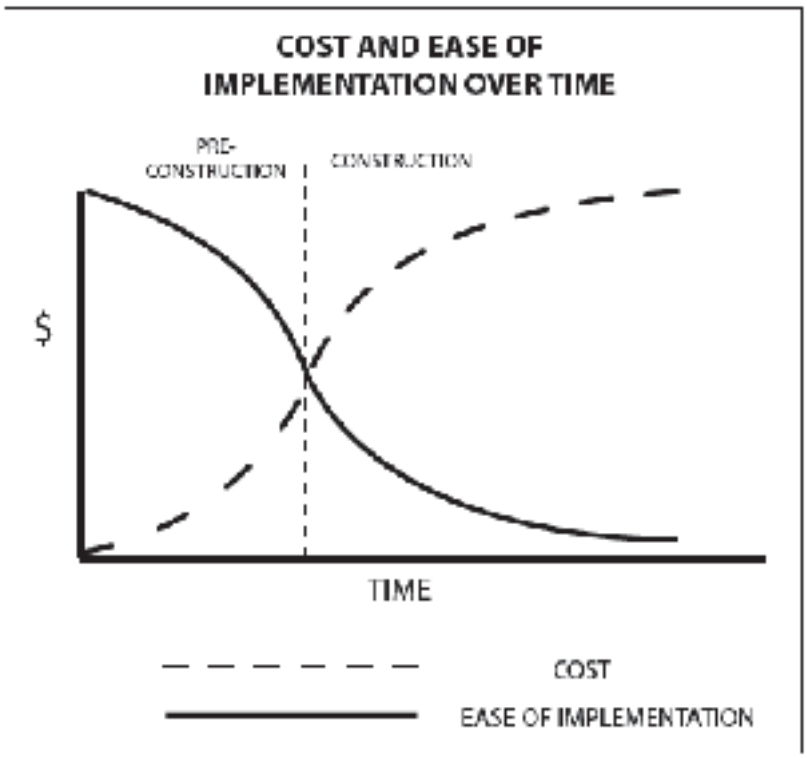

Figure 11: Changes Implemented Early in a Project Cost Less and Are Easier to Implement (Adapted from Haltenhoff, 1999)

In addition to using more construction knowledge in design it is best not to "reinvent the wheel." One strategy which minimizes these design and documentation problems is utilizing proven, preexisting designs and drawings (Songer et al., 2000). Preexisting designs are the liability of the designer. It is the designer's responsibility to revise the designs and make any modifications and adaptations that are needed for each project. Using preexisting designs makes construction documentation available earlier in the project and assists construction personnel if they are involved at this early stage. Using preexisting designs improves the consistency and quality of design and reduces the design time, a key focus of scheduling reductions.

6.3 Contractor Involvement in Design

As constructability practices strive to integrate construction knowledge into each phase of the construction process, perhaps the most obvious strategy is to involve the contractor in each

stage of the process. Independent studies confirmed that early contractor involvement and integration of construction knowledge into the design process improves the chances of achieving a better quality project, completed in a safe manner, on schedule, for the least cost (Arditi et al., 2002). Unfortunately the early involvement of construction personnel is expensive and difficult to implement within the most common project delivery approach, design-bid-build.

In design-build and construction management approaches, construction knowledge is integrated throughout the project. This is achieved in design-build because the contractor works together with the designer and it is achieved in construction management by a construction manager who lends construction expertise to the designer throughout the design stage. Professionals working in the design-bid-build systems also recognize the importance of construction knowledge in the design phase, but no contractor is bound contractually to assist in design. In design-bid-build, contractors are usually hired after the design is finished. To incorporate construction knowledge into the design the design-bid-build system relies on teaming practices to involve contractors earlier in the process. These teaming practices do take considerable effort and extra costs to implement, but can eliminate many recurring problems in construction (Songer et al., 2005).

A project's success is dependent on the construction planning efforts which fall mainly on contractor and construction manager (Love et al., 2004). Early involvement of the contractor or construction manager encourages early planning consideration during the design phase and improves the efficiency of the project. Understanding this, other participants in the project accommodate the contractor or construction manager throughout the initial stages to assist in the construction planning efforts and the creation of construction-sensitive schedules (Jergeas and Van der Put, 2001).

6.4 Challenges of Constructability Implementation

A 1998 survey regarding constructability approaches found that only 10% of general contractors had formal constructability programs. The remaining 90% took no action toward the implementation of constructability programs (Arditi et al., 2003). Since the majority of projects are design-bid-build, this can be attributed to the separation of the general contractor from the design process. If the general contractor is not involved when constructability is most effective, why should it be their responsibility? Design-bid-build projects confront owner resistance due to

initial costs and schedule increases. Owners generally do not understand the long-term benefits of constructability so designers who include constructability fees when bidding for a project are less attractive to potential clients (Arditi et al., 2002).

Since the design-bid-build approach is most commonly used today, it is the norm to bring the contractor into the project only after the design has been substantially completed and the specifications have been developed (Jergeas and Revay, 1999). This separation has created a lack of mutual trust, respect, and credibility between project planners, designers, and constructors. Because owners do not fully understand the benefits of constructability programs they choose not to commit the extra funds and resources needed to implement them.

The constructability innovations introduced by construction personnel during the design may be met with adversity from owners and designers. As mentioned earlier, the construction industry is risk averse and challenging the 'tried and true' methods is not comforting, especially when large stakes are held in projects. Lacking knowledge of the latest construction methods and techniques, designers and owners prevent the contractors from implementing what could be time and money saving innovations in the field (Jergeas and Revay, 1999).

Risk is always involved when trying something new as changes require additional up-front costs. In industrialized nations, constructability strategies have effectively reduced rework, litigation, and schedule and cost overruns in projects. These results encourage participants to implement these changes, but improvements are needed to reduce the risk that these changes might fail. The potential benefits of applying constructability principles are not realized in practice because of shortcomings in the following three areas (Jergeas and Revay, 1999):

- Up-front involvement of construction personnel
- Achieving efficiency through a coordinated construction effort
- Use of innovative construction methods

As constructability practices become more common, the barriers toward their implementation become smaller. These same strategies can be modified and implemented in development work. Many of the significant barriers in large projects in industrialized nations are not encountered in the more flexible environment of development work. This report will analyze three case studies to find opportunities where these constructability practices can be implemented.

7.0 Three Case Studies

In each of the following three developing world case studies, the project delivery structure is examined as well as the different strategies incorporated to facilitate construction. I was involved as the supervising and/or designing engineer in each case study. In this role I was involved from the initial site investigation, through the design, to the construction completion. I will note variations in each case when help was received from other engineers or construction project managers. The development agencies, beneficiaries, funding agencies, and builders also played different roles in each project. How these roles affected the project, particularly the projects' constructability practices will be discussed.

The final case study, Hacienda San Lucas is a privately-owned project. I included it as a case study to examine the differences that exist in a privately-owned project and the additional challenges that this development work posed.

7.1 Case Study 1: Barrio Cementerio (urban neighborhood): Storm water culvert

Beneficiaries:	Community/Neighbors of Barrio Cementerio
Development Agency:	Proyecto el Norte (NGO), Municipality of Copán Ruinas
Funding Agency:	Municipality of Copán Ruinas and Barrio Cementerio
Designer:	Jaime Rivera, Proyecto el Norte; Kraig Lothe, Municipality of Copán Ruinas (Peace Corps)
Builder:	Isauro Reymundo, local contractor

The project delivery system used in this storm water culvert construction project is illustrated in Figure 12. This approach only involved the designer during the design phases and does not involve the contractor until after the design phase. The community initiated and helped fund the project but did not participate in the construction. As in most development work approaches, the development agency managed the project from initiation to turn-over.

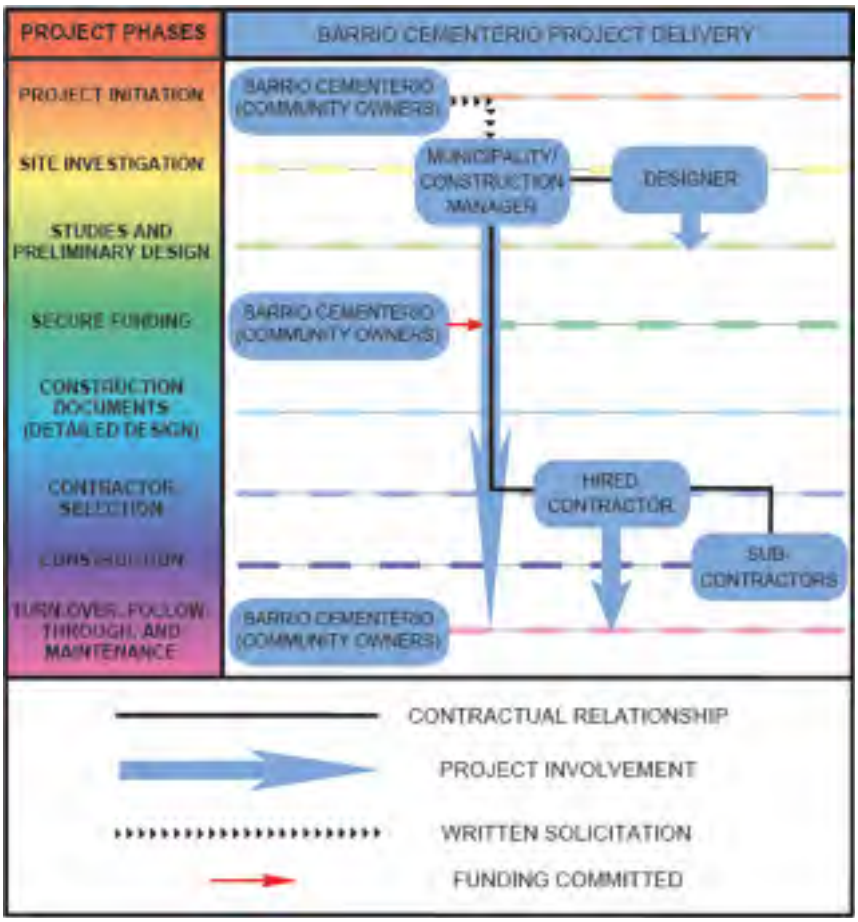

Figure 12: Project Delivery Diagram for Barrio Cementerio Shows Designer Contracted by the Development Agency, Late Contractor Involvement, and Community Involvement

Project Initiation

This storm sewer project was initiated by the neighborhood leaders in Barrio Cementerio. The neighborhood is organized through a *patronato* or representative to the city council. This representative, along with other members of the community submitted a written request for the project to the city council. Barrio Cementerio is a neighborhood of 25 houses which run along a small valley. An open sewer and storm water ravine pass between the houses. The area is unsanitary and the high water levels present a danger for the children in the neighborhood. After receiving the request, the municipality and the city council approved the project and a study was arranged.

Planning and Design

Proyecto el Norte, an NGO based in a larger city about 100 km away, was contracted to do the topographical studies and to design the project. As in past projects, I collaborated with them to complete the studies according to the demands of the community and the municipality.

Photo 3: Open sewer in Barrio Cementerio before the storm water culvert project

Proyecto el Norte's engineer submitted the design to the municipality which fulfilled the contract and thus, their technical assistance was finished. This is typical of most of the development projects in Copán Ruinas. After studying the design and revising the calculations for maximum flow rates and maximum vehicle loading, I made some minor changes to the project. I explained the project and the construction to the mayor who asked me to take on the project, acting as the construction project manager and supervising engineer. At that point, I was the only person involved in the design that continued to participate in the construction phase. Had I not been there, there would have been no continuity between the design and construction phases.

The estimated cost of the project was more than the municipality expected. Looking for a solution, the municipality called a meeting with the representatives of Barrio Cementerio. An agreement was made that the municipal government would provide over USD $10,000 to pay for materials, and the local community would pay approximately USD $3,500 in labor and some materials. This approach requires an effort on the part of the neighborhood, ensuring a vested interest in the project. Dividing the project cost among two participants eases the financial burden, but complicates payment structures and cost sharing later in the project.

Contractor Selection

The contractor selection/bidding process began soon after the agreement was reached

between the municipality and local community. Contractors were invited to come to the municipality where they were briefed on the project, given a copy of the drawings and specifications, and then interviewed informally on their experience in similar construction projects. After the bids were received, the mayor reviewed them and decided to seek one last bid from a contractor he believed to be the most qualified. The contractor submitted his bid which was higher than the other bids for the project. After some negotiation, the contractor lowered his bid but was still much higher than the lowest bid. Regardless, the contract was awarded to this contractor.

Construction

This was my first large construction site supervision project. I was unsure what to expect and what to prepare for. Months had been spent in design and planning and with the awarding of the contract, it was my responsibility to ensure the project was constructed according to design. Any changes had to have my approval. I was also responsible for the weekly contractor pay and daily supply of local and non-local materials.

The work site was prepared by channeling the waters, both storm and sewer through an existing pipe that ran through the project site. The excavation would be done incrementally ahead of the construction and the project was to be completed in 10-meter sections. The floor of the culvert would be poured first. The walls would be poured into forms and into the walls reinforcing steel would be anchored which would be used in the construction of the sewer's cover. The construction was to be finished in six weeks before early June, the start of the year's heaviest rains.

The first loads of local materials, including sand, gravel, and wooden forms were scheduled to be delivered using municipal transportation. A hardware store located next to the project site was contracted to supply cement and other non-local materials. This was an excellent opportunity to minimize problems with material transport. Meanwhile, teams of laborers excavated the site. Within three days, the first 10-meter section of the culvert was excavated and the forms were in place to pour the walls. Upon seeing the form work, the community questioned the culvert capacity and the project was halted.

I was called to the worksite early that same morning to talk to the community and hear their concerns. Apparently, in past years the water level had risen higher than the forms we had

in place. The community wanted the walls to be higher than the past water levels. Knowing the hydraulic calculations, I was sure that our design had the required capacity. Speaking with the community, I realized that the water only reached such high levels when debris and garbage obstructed the flow. I tried to explain this to a community of emotional people. Not only was their concern unnecessary, but to increase the size of the culvert would change the maximum loading calculations and costs of the project. I was confident of the calculations, but allowed an insignificant increase in the storm sewer's height as a compromise with the community. It was also evident that flow was obstructed below our construction site due to an existing culvert under the road. In addition to the small increase in height, we also planned to open the street to repair this obstruction. They were satisfied and the project continued. In the first year in operation the culvert never even approached half of its maximum capacity.

Photo 4: Formwork in question by the community where the new construction will meet the existing culvert.

Lack of materials caused delays during the project. The municipality had only one large truck for transporting materials. This same truck also ran the garbage route each day and delivered materials for numerous projects in the area. At one point in the project, the vehicle broke down leaving us without materials. Late in the project an early rain raised the level of the river preventing the removal of sand from the riverbanks causing another a delay in the project. Not expecting these problems, I did not prepare and have extra materials on hand. After this it was arranged to keep a back-up supply of local materials.

I spent time on site learning about local construction practices, reinforcing the details of the design, and insuring quality construction, especially in the concrete mixing and concrete cover over rebar. The contractor poured the floor slab as one slab continuing under the walls. The design called for different cross sectional areas, but time was saved using one, uniform cross section. The contractor also changed the type a rock used in the slab and the walls from river

Photo 5: Construction of the storm sewer culvert

rock to limestone. Limestone was more expensive, but it could be placed with fewer spaces, therefore using less concrete. The exchange between engineer and builder was very helpful and could have been more effective had it started during the design phase.

The project evolved into restructuring the area below this site, opening the culvert on both sides of the road, cleaning it, rerouting the flow, and constructing manholes on each side to allow future maintenance. Having an engineer involved in the construction process allowed for the project to continue and the scope of the project to change

Although there were setbacks and complications, the project was finished in just over six weeks and on budget. This was accomplished more by perseverance and luck than expertise. Most importantly I learned a great deal about managing a construction project in Honduras.

Turn-over

The nature of this project does not require a great deal of maintenance on the part of the community occasional cleaning and inspection of the manholes. Responsibility for inspection and cleaning was not addressed and this would be a suggestion for future collaborations with municipalities and communities. The

Photo 6: The new culvert turned a opened sewage drain into a path for bike through the community

community initiated the project, contributed financially, and took ownership of the project. Taking ownership is the key for any turn-over process. The project was done in response to community need and community action.

7.2 Case Study 2: 'Zona Chorti': six-community drinking water project

Beneficiaries:	Six rural communities
Development Agency:	SANAA (National Water Utilities Agency); Municipality
Funding Agency:	Rotary International; SANAA; Municipality
Designer:	Kraig Lothe, Municipality (Peace Corps)
Contractor:	Juan Antonio Medina; Elías Coto, local contractors

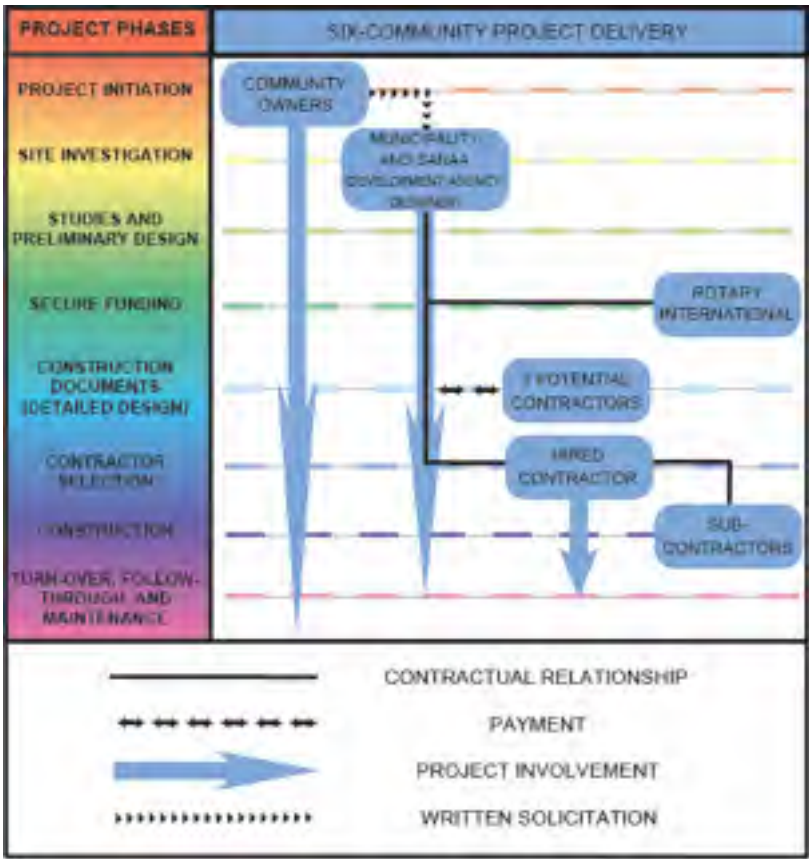

Figure 13: Project Delivery Diagram for Six-Community Water Project. Contractor Involved During Design.

This six-community drinking water project was a very large project and involved many different organizations. The project delivery approach used, shown in Figure 13, is a common approach used in development work. The development agencies manage the design and construction of the project. A very common approach to development, this delivery system deserves special attention and improvement.

Project Initiation

This large gravity-fed drinking water system was originally built for five communities, population approximately 1,500, six years prior to my involvement. It was built at a cost of USD $100,000 by SANAA, the federal government's agency for the development of drinking water and sewage systems. The SANAA engineer for the original system did not oversee the work and there were problems in the construction, design, and material management. He elaborated a design based only on technician field notes. After the construction, no follow-up was done and the communities were left to maintain the system alone. The 8-kilometer conduction line failed less than two years after it was built due to landslides and had been inoperable since that time. Even with flaws in the original system, it would have been impossible to design a system to withstand the land slides which erased large swaths of the mountainside. Because most of the structures and materials were in place, it was possible to reconstruct the system.

Leaders from the five original communities and one new community organized and submitted a letter requesting help in repairing the system. In response to their request, I planned an initial site investigation. With a dozen men from the communities, I visited the source, checked the dam, and then walked 6 kilometers along the mountainous conduction line to the first village in the project. Each repair was explained in detail to the community members, and they related the history of the previous construction and how each section fell into disrepair. This was especially important because these community members would be involved in the construction and they need to understand each job and have the opportunity to suggest improvements based on experience and local construction knowledge.

Design, Planning, and Contractor Selection

The project would need funding support as the system would require 4-inch piping, a single 6-meter section costing over USD $200. After contacting the regional SANAA engineer, Rotary Club representatives and the local mayor, I found that the project had sufficient support. This was an extensive project but with collaboration among the agencies and my involvement with other technicians throughout the process, it could be successful.

USD $20,000 worth of materials had been bought and delivered with the cost shared by SANAA and the municipal government. The area is remote and when transportation became available, as many materials as possible were sent to the site. When the materials arrived, the communities began replacing the broken pipes with no contractor or skilled labor in the field to help with the more technical tasks. When we learned the work was progressing without supervision, we called things to a halt. With the remoteness of the site and no regular access to transportation, it was impossible to provide constant supervision.

If the project moved on without proper supervision and organization, it would fail for the same reasons the original project did. A meeting was called of the community members, Rotary Club representative, the project coordinators from the SANAA, and me from the municipality. The focus of the meeting was to establish a central water board, plan for long-term maintenance of the project, and reiterate the need for qualified labor in the field.

Photo 7: Meeting with local water boards to plan construction and organize community leadership

The communities understood the need to take a different approach to the project but they feared that the reconstruction was moving in the same direction as the original project six years ago. Before the meeting, funds were secured through the Rotary Club's local liaison to pay an experienced contractor who would stay on site for the duration of the project and supervise the construction.

This redirection grabbed the attention of the community members and focused them in the right direction.

I returned to conduction line three more times with potential contractors, noting every repair and listing the required materials. The municipality paid each contractor a fair daily wage to accompany me. These contractors had very good ideas about the construction and, valuing their expertise, I added their suggestions to the plans. This improved the design and allowed us to find the contractor best suited for the job.

Orchestrating three different agencies plus six communities was very challenging. Before the contactor went to the site to resume the work, I called for another organizational meeting between all of the participants. The meeting focused on the sustainability of the system. We discussed the future maintenance and how important it was to take advantage of the construction period when community members would have the opportunity to learn the basics of plumbing and concrete work with the contractor. Each community designated a plumber who would play a larger role in the construction. We also stressed the need to implement a monthly tariff that would be paid by each household. This money would be used in the future to pay the plumber and purchase any materials that would be needed for future repairs. We did not impose any rules, but guided the community leaders so that they could make an informed decision regarding tariff requirements. Finally, we organized work teams and set a date to start the construction. The communities left the meeting very optimistic, committed to do what was necessary for the success of the project.

Construction

I visited the project once or twice per week during the construction period. Accompanying me often was a technician from SANAA who provided valuable expertise during the project's construction. He and I served as representatives for SANAA

Photo 8: Rehabilitated distribution chamber

and the municipality, respectively, and approval by both of us was required for changes. Modifications were made to the original design and were mostly initiated by the contractor whose experience and time at the site gave him insights that were not available to us during the initial studies. The construction continued steadily and with a high level of quality work. After 4 weeks the construction had spanned over 5 kilometers and approached the tank site of the first of the six communities. Once water arrived at this community the first phase of the project would be completed.

Photo 9: Pipes burst as we try to advance the water to the previous tank site

In the last 100 meters before the tank, the conduction line climbed vertically thirty meters. Contrary to the design data, the community members told us that the water would not have the pressure to reach the tank which was a previous problem. Trusting the design, we laid the piping up to the tank site to test the outcome. As the water filled the tubes and climbed up to the tank site, the pressure increased in the entire system, bursting at weak spots in the line. Immediately the water receded in the tubes. The community members walked over 4 kilometers to the point where tubes had broken to repair the problem and we attempted to turn the water on again. Two more times the tubes burst. After repairing and retrying for three days we did what the community had quietly mentioned to us from the beginning: pass the line lower, closer to the village.

After finishing the conduction line, only minor repairs were necessary to get water to the remaining four communities that were a part of the original project. The new community, which had hoped to be part of the project, participated throughout the reconstruction. Land owner issues near this community resurfaced with the conduction line and the resolution of the land dispute was not in favor of the original design. The entire project had to be rerouted. Working

under pressure I began a new design for the community which was still incomplete when we started construction on the system. This allowed me to spend time on site throughout the entire process, constantly revising the material list and construction specifications. It also allowed me, as a designer, to work intimately in the construction of this community's distribution system.

This six-community project was built to the satisfaction of all participants involved. Local knowledge about this system and local construction techniques were invaluable during the construction. There was no way to understand what was failing in the system without being on site, listening to the locals, and witnessing the work and failures.

Photo 10: Water taps are installed for every home in the six communities

Turn-over

Meetings with the central water board continued and the meetings became progressively community led. They established their own maintenance schedules and tariff systems. In the first six months after the construction, landslides and fallen trees cut the waterline three different times. Each time the communities took responsibility and repaired the line within two days. This is quite an accomplishment considering that the locals who repaired these failures had to walk over ten kilometers just to diagnose the problem, then return to get the necessary materials only to go back again carrying their tools, materials, and food with them.

7.3 Case Study 3: Hacienda San Lucas: privately-owned drinking water project

Owner:	Hacienda San Lucas
Design-Build Entity:	Non-local engineering and contracting service provider
Water System Designer:	Kraig Lothe
Facilities Manager:	Carlos Muco

The drinking water project at Hacienda San Lucas followed a unique organizational framework not common in development work. As shown in Figure 14, the project delivery is similar to design-build approaches used in industrialized nations. The project at Hacienda San Lucas was privately funded allowing this approach to be possible.

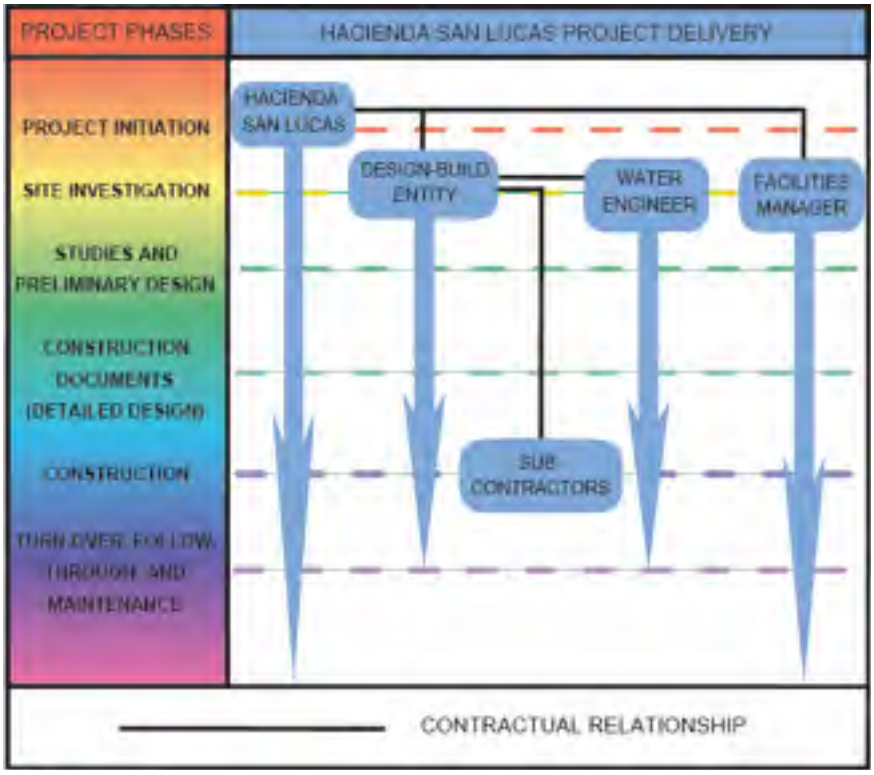

Figure 14: Project Delivery Used in Hacienda San Lucas. Design and Construction Provided through One Contract; Water Engineer is Sub-Contracted.

Project Initiation

Hacienda San Lucas is a locally owned and operated eco-resort. This 100-year old Hacienda is a popular destination for tourists and the owner decided to expand. The expansion required a larger and more reliable water supply.

This project was different from normal development projects as it was financed by a private owner and managed like a business. A design-build firm was hired to design and build the project. No competitive bidding was done for the contract. The firm was hired based on reputation and experience. The engineer did not work in water systems so the firm contracted me for the project. I was responsible for the initial studies through project completion, working with the design/build engineer and the Hacienda's construction personnel.

Photo 11: Water quantity is measured at the source

In this project, the owner was the funding agency and the beneficiary. This made the project very different from one involving a development agency and community owners. The decision-making process was very direct, roles were well defined, and responsibilities were clearly divided among the few participants involved.

Design and Planning

Accompanied by the Hacienda's in-house facilities manager, Carlos Muco, and two other permanent workers I executed topographical surveys from each of the springs to a proposed tank site. Carlos had been involved in water projects and plumbing at various local hotels and proved to be an excellent resource and partner throughout the entire project. He would oversee the daily site construction. During the study, recommendations and decisions about the system were shared between us. The two local workers who had built the previous system for the Hacienda had much to contribute about construction in the field. In the end I made the final decisions about the design and took full responsibility for it. With this

additional input the design was not only more feasible, but the construction team had a better understanding of the process and took ownership for it.

Carlos and I shared the task of construction planning. We met several times at the Hacienda, discussing materials, scheduling, and labor payments. Using transportation provided by the design-build firm we easily acquired the local materials and stored them at the Hacienda. All non-local materials were bought in town at a local hardware store, delivered, and stored on site. This prevented costly material delays during the construction.

The scheduling was based on our goals of project completion, and a decision was made to pay the local labor, not by the hour or day, but by the task during the excavation. In this way the laborers dug two kilometers of trenches in just one week, faster than expectations. This set a pace for the project, and momentum continued. The old water system had to be shut down while we worked, leaving the Hacienda without water. This added a little pressure to keep things moving quickly and required my attention throughout the construction.

Photo 12: A two-chambered tank is built to ease maintenance and cleaning

As expected, things moved faster than with public projects. This was due to funds and transportation being readily available. These luxuries were rare in projects, but it was a new challenge to manage a budget closer and work at a much faster pace.

After completing the construction of the conduction line the supervising engineer asked me to design a tank and also the distribution network. Altering designs I had previously made, I designed a two-chambered tank with multiple exits so that one chamber could be closed for maintenance or cleaning and there would still be water for the Hacienda. I had many resources to draw from so I was confident in the structural integrity given the modifications for the two-

compartment model. The design-build firm's in-house contractor oversaw the construction and I was there to make sure the details of the design were accurate.

Turn-over

The Hacienda's water now comes from two mountain springs, two kilometers away, and flows to their new double-chamber tank. The water is used in the eight new guest rooms, two kitchens, laundry facilities and common baths. The system has been working flawlessly for over a year and Carlos Muco, San Lucas' facilities manager is still there to maintain the system. He was involved in the preliminary studies, consulted during the design and managed each detail of the construction. He brought the design together with the construction, an excellent practice in constructability. Carlos Muco, more so than the design or the construction, has and will insure the success of this project.

7.4 Discussion

Each of these projects presented unique challenges and opportunities to implement different strategies. These situations proved to be great learning opportunities for me and other participants involved. The following section highlights some of the problems that were encountered and some of the successful strategies implemented.

7.4.1 Problems

- After spending months working on the studies and design of the storm water culvert (Case Study #1), the mayor decided to disregard the lowest bidder approach in our contractor selection and hired a contractor of his own choosing. If this is to be the case, we should have hired the contractor from the start of the project. Later, the same contractor made changes to the scope of the design to make the construction easier. Knowing this ahead of time could have made the design and estimates more accurate, saving material and labor expenses. Luckily, I worked closely with the contractor throughout the construction in a construction manager's role and changes could be made in the field.
- Later in the same project, local materials were procured on a day–to-day basis. We did

not plan ahead. Heavy rains caused the river to swell and prevented us from taking sand and gravel from the banks. The municipal truck also broke down leaving us with no choice but to delay the project.

- During the six-community water project (Case Study #2) I trusted the design, disregarding the local community members who told me the system could not support the pressure needed for water to reach the previous tank site. They were right, but I insisted that we try it. After several efforts and few extra days, I changed the plans and did exactly what they had recommended. Luckily, they harbored no resentment toward me for wasting their time and energy. I am not sure what I would have done differently. I would not trust the community members blindly, but I should have weighed their input heavier. Our involvement as designers during the construction process allowed us to make these changes.

7.4.2 Successful Strategies

- In both the six-community water project (Case Study #2) and at Hacienda San Lucas (Case Study #3) the construction personnel were involved in the construction throughout the entire project. The contractors and local community members influenced and changed many aspects of the design through their participation in the studies and during the design. At Hacienda San Lucas I was sub-contracted by a design-build entity. Working in this project, I had input from construction personnel throughout the project.
- In all three projects I participated throughout the construction process, not only to make changes and facilitate the process, but to learn about local techniques and innovations. I incorporated these techniques and innovations during the design phase of future projects.
- Each of these projects was initiated by the community owners. In this way the communities were involved in the decision-making process from the very beginning. In each of the drinking water projects the community owners, construction personnel and designers participated throughout the planning process. This involvement led to a successful start to the community's ownership of their respective projects.
- Flexibility in the planning stage allowed input from previous experiences. Local construction knowledge and payment structures were incorporated into all three projects. Previous designs were also adapted, revised, and used for the tank construction at Hacienda San Lucas.

8.0 Integrating Constructability into Development Work Project Delivery

Infrastructure projects in the developing world involve uncertainty due to transportation problems, cultural differences, failing equipment, and remote sites, to name a few. With few resources and underdeveloped delivery approaches, problems and risk are difficult to manage. Constructability is formally practiced in international development work. Formal programs are not realistic given the scope and budget of most projects, but small measures can be taken to effectively integrate construction knowledge and personnel into every phase of a project. The flexibility of these projects provides opportunities to implement small constructability measures. These measures improve sustainability, aiming to improve design and construction and facilitate long-term maintenance of a project. Achieving sustainability depends on these four factors:

1. Design for sustainability and quality construction: A good design focuses on community needs, future maintenance, and will facilitate quality construction. Quality construction ensures that a project lasts and functions properly with minimal maintenance.
2. Well-trained local personnel and follow-up: After project turnover, a community-based administrative board is responsible to maintain and operate the project. Local community members rarely have the experience or knowledge for this responsibility and it is up to the development agency to train local staff and follow-through with the community during their first months of maintenance.
3. Affordable maintenance: Infrastructure projects are usually expensive, beyond the means of local communities. Maintenance is expensive, but if considered during design can be affordable for the community. A community must establish a locally managed tax system so that it has the means to pay for material and labor and other maintenance expenses.
4. Local ownership of the project: After project completion, the local community acts as the sole owner of the project, not as mere recipients. To achieve this, the community is allowed to participate in the decision-making process from the beginning of the project and is required to have a stake in the project, either financially, in labor hours, or by providing materials.

By achieving these four factors, a project is well-built and manageable for a community to maintain and operate. Infrastructure development must not be executed merely as construction, but as a social program extending throughout the entire community.

8.1 Project Delivery

As mentioned earlier, infrastructure development projects in Honduras do not follow any pre-defined structure. International development projects do not incorporate construction expertise in the design, similar to the design-bid-build system. But similar to the construction management system, the development agency assumes the role of a construction manager. Understanding these similarities, we can incorporate proven strategies to improve efficiency in these projects. Project delivery approaches are flexible in developing countries, allowing for change and improvement in development work.

Due to late contractor involvement, design-bid-build encounters more problems and involves more disputes than design-build and construction management deliveries (Love et al., 2004). Design-bid-build inherently excludes the contractors, experts in constructability practices, from participation until the design is complete (Haltenhoff, 1999). By bringing contractors into the project earlier, design-bid-build can add construction expertise in design. This creates partnering between the designer and contractor similar to what is inherent in design-build or construction management. Expanding the partnership between the designer and contractor is necessary for constructability practices. Including community owners in these early decision-making phases also incorporates local knowledge into design and builds community ownership of the project.

Construction managers provide valuable construction expertise during design in the construction management delivery system. Acting in this role, development agencies need to involve construction personnel in design. Development agencies can either staff a contractor or hire contractors during the design to gain construction knowledge early. As illustrated in Figure 15, involving potential contractors in the detailed design phase also provides continuity of construction personnel between the design and construction. If the contractor is involved early he can express his needs and learn those of the other participants. Through partnering, the parties can understand each other's needs and common goals can be created. However, the owner's goal of a cost-effective project may conflict with the contractor's profit motive.

Incorporating these changes into typical project delivery is a viable way to address constructability issues in Honduras. The changes are small and affordable, effectively improving

sustainability. Based on the research outlined in this report, Figure 15 shows a proposed delivery system for development work aimed to maximize community participation and involve a contractor in the design.

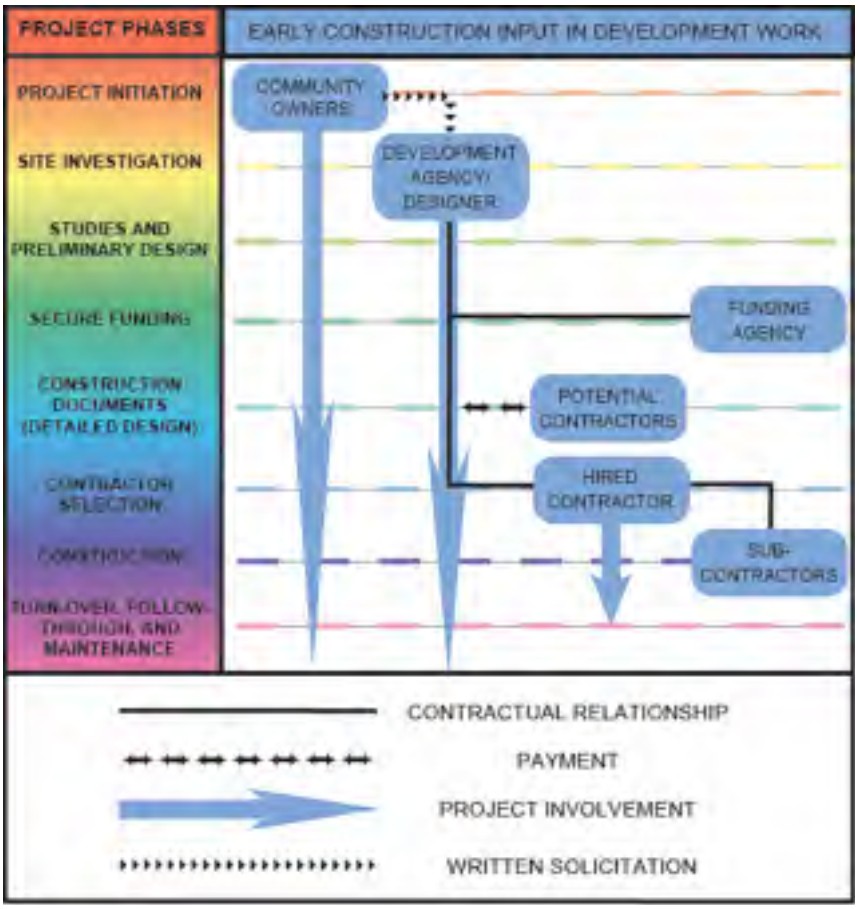

Figure 15: A Proposed Project Delivery Approach in Development Work Aimed to Maximize Community Participation and Involve Contractor in Design

8.2 Early Integration of Construction Knowledge

Contractor involvement in design is a central characteristic of any constructability program. It is difficult to involve contractors early in a project, especially if it is designed long before funding is secured and the construction begins. By adapting the project delivery as described above project can increase contractor participation earlier in a project when it is more effective.

In case study 2, potential contractors were hired during the detailed design phase to visit the site and discuss the project's design. This eliminated many obvious problems. Reworking and

finalizing the design after the contractor has been hired allows changes to be made based on the joint decisions of the owner, designer, and contractor. This allows for incorporation of construction knowledge, even when construction personnel is not involved during preliminary designs, and can initiate partnering between participants soon after the contractor is hired.

Perhaps the greatest fault of infrastructure development in Honduras is not involving contractors, the experts in construction, and using their knowledge during the preliminary stages of construction projects. The design and construction phases are isolated from each other, preventing professionals from incorporating construction knowledge from the field into design. Bridging the separation between design and construction is possible within Honduras' flexible project delivery approaches and can drastically improve project quality, participant involvement and sustainability.

8.3 Contractor Selection

A two-stage selection process can effectively incorporate construction expertise earlier in a project. During a prequalification stage, three or four contractors are chosen based on their previous experiences and successes in similar projects. Referring to Figure 15, this short list of potential contractors can be hired on a short-term contract during the detailed design phase of a project. These contractors can go to the site and review the project with the designer. This allows them to become familiar with the project before the bidding and allows the designer to incorporate construction insight into the design. The development agency can also use this opportunity to learn which contractor is the most capable to do the job.

This process lends itself to the quality of the design and the construction. Although the single-stage selection is suited and suggested for simple projects, the two-stage process ensures contractor competence and allows earlier incorporation of construction knowledge. These two benefits are found in the design-build and construction management systems where constructability is inherent.

8.4 Local Construction Techniques and Knowledge

Local practices can benefit projects by using more efficient techniques and making construction more manageable for local communities. Some practices, however, may comprise

quality. Development agencies can aid development work by embracing beneficial practices and discouraging those that compromise quality. Utilizing local construction techniques and knowledge not only improves construction, it allows local communities and contractors to participate in and influence the design, construction, and management, thereby assuming a larger role in the ownership of the project.

8.5 Pre-Existing Design Documentation

Poor construction documentation can lead to conflicts and problems during the design of a project. The specifications and drawings used in rural water system construction in Honduras are usually standardized. This practice saves time, but since these documents are rarely tailored to each separate project they may not be appropriate given the site conditions. Engineers must revise standard documents, drawings and specifications to ensure that they are consistent with the demands of the given site and project.

If pre-existing design documentation is incorporated into a project, the contractor and local community must be consulted and the plans reviewed at the site. This facilitates a discussion about the feasibility of the plan and the challenges that may arise. Contractors have worked with standard documents and can explain how they were inadequate in the past. Standard documents do not incorporate local material types, such as limestone or slate, nor do they take into account soil conditions that must be considered in design. This construction knowledge and local expertise must be incorporated into the design documentation in order for it to be used effectively.

8.6 Construction

Construction quality depends not only on the competence of contractors, but also on the development agency. The development agency can retain payment to the contractor if his work is inadequate. Frequent visits to the site will maintain a high quality of work. Designer involvement throughout construction is also an opportunity for designers to learn more about construction and local knowledge. There is a wealth of knowledge in the field, but in Honduras designers are divorced from construction. If designers incorporate this local construction knowledge into the design, fewer problems will arise during construction. Design and planning

must accommodate the needs and abilities of the contractor and community members who build the physical works. This is effectively accomplished through the designer involvement in construction.

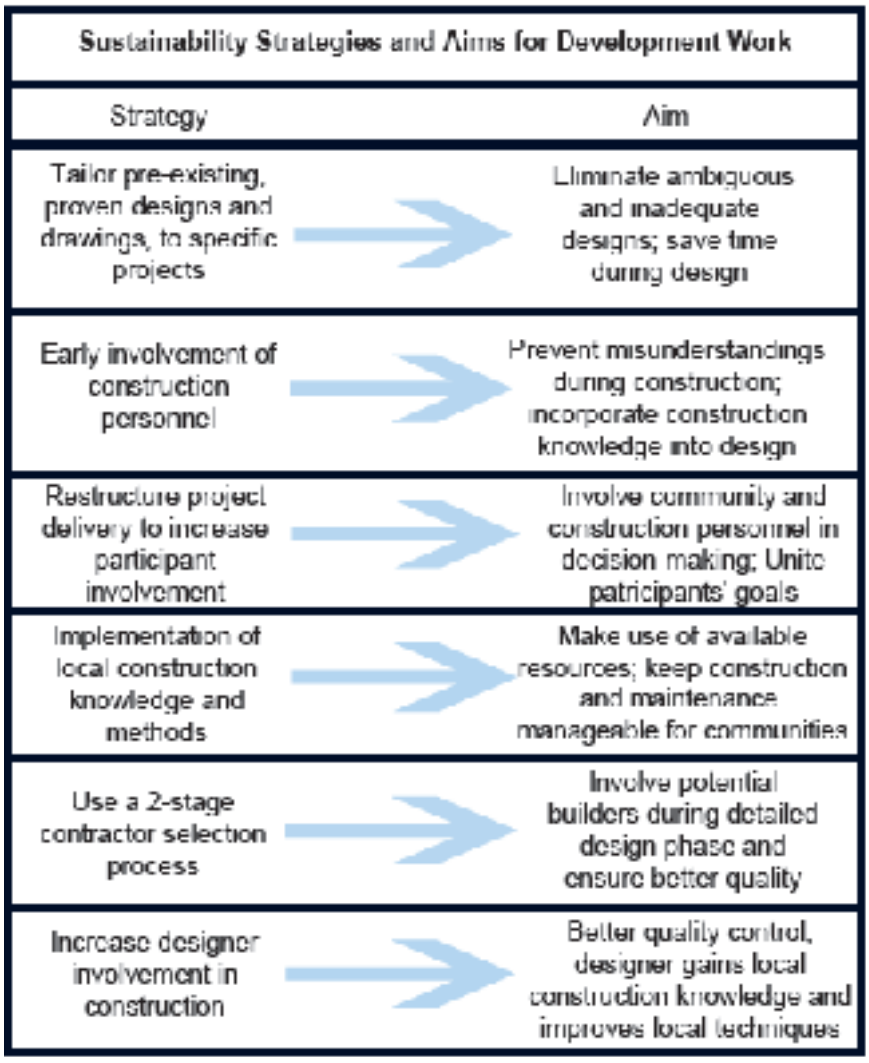

Figure 16: Strategies and Aims to Improve Sustainability in International Development Work

9.0 Conclusion: A Sustainable Approach

Improved cooperation between agencies and communities and the integration of projects into the community will allow projects to reach across sectors and address issues of education, health, community organization, water resources, economics, environment, sanitation, and

accessibility. Projects strive to be community-building because in the end the community will determine its success and sustainability.

This research report has described how better constructability practices can help achieve sustainability in development projects located in the developing world. Constructability practices focus on quality and manageability, but also rely on social aspects such as partnering to be successful. Community participation and contractor involvement in decision-making throughout the project is vital to any constructability program. These strategies and aims, outlined in Figure 16, are based on my experiences in the developing world and the best practices learned in the industrialized world. Sustainability is the prime objective in development. A sustainable project is one of high quality, manageable, and socially-integrated within the community.

According to UNICEF (1999), the goal of sustainable development can only be achieved in fragile regions of the world through deepening democratic values and participation at the grassroots level. Sustainable infrastructure development can only be possible if the community is empowered through decentralization and is free to make decisions in the implementation and management of projects. A decentralized approach will allow implementation to take place at a local level and target the greatest needs.

Communities must be involved in the decision-making process from the beginning. This has been referred to as a 'demand-responsive approach' in which the communities take responsibility for the actions and decisions involved in the development process. This approach keeps the scope of the project within the understanding of the community and allows them to effectively gain ownership of it (Breslin, 2003). If communities do not play a major role in the decision-making process, how can we expect the scope of the project to meet their needs and be a project that they can sustain?

An overall, sector-wide approach to development by large national institutions, local government, funding agencies, NGOs and communities must integrate water resources, sanitation, health, education, and the environment. These agencies must work closely with communities and allow them to make the decisions which will shape their development. In this way it will be possible to achieve sustainability in development and to provide clean water to the remaining 25% of the population in countries like Honduras who still lack access to safe drinking water.

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