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EVALUATION OF PRE-ENGINEERED & PREFABRICATED APPROACHES TO INFRASTRUCTURE DEVELOPMENT

ESS WORK ASSIGNMENT NO. 5

FINAL REPORT (APRIL 19, 2018)

USAID AE WORLDWIDE IDIQ NO.: AID-OAA-I-15-00051
TASK ORDER NO.: AID-OAA-TO-16-00028

April 19, 2019

DISCLAIMER

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ABSTRACT

Various construction techniques have been used in the development of education infrastructure throughout the world. In evaluating the use of prefabricated construction methods in the development context, there is significant evidence indicating that these methods do not deliver the anticipated advantages commonly perceived as hallmarks of the technique. Through this analysis, various examples of prefabricated school construction have been identified that challenge the common assumption that the use of prefabricated construction methods is the most efficient method of construction in that it is faster, less expensive, and results in higher quality than the use of traditional construction methods.

Over the last several decades there have been trending shifts in policy as pertains to funding, procurement, and management of education infrastructure construction in developing nations. There is evidence that centralized systems of decision making and management result in less effective outcomes than localized systems of management. Greater integration of local-owner and end-user decision-making at the initial stages of planning and design of education infrastructure in developing countries leads to better overall project outcomes.

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ACRONYMNS & ABBREVIATIONS

ABUTIP	Agence Burundaise des Travaux d'Intérêt Public
ACA	Agence Cooperation et Aménagement
ADAUA	Association pour le Développement d'une Architecture et d'un Urbanisme Africains
AFDB	African Development Bank
AFVP	Association Francaise des Volontaires du Progrès
AFDS	Association du Fonds de Développement Social
AGDS	Agence de Gestion de la Dimension Sociale du Developpement
AGECABO	Agência Cabo-Verdiana de Promoção do Emprego e do Desenvolvimento Local/Cabo Verdean Agency for Public Works
AGEFIB	Agence de Financement des Initiatives de Base
AGETIP	Agence d'Exécution des Travaux d'Intérêt Public
AGETIPA	Agence d'Exécution des Travaux d'Intérêt Public (Madagascar)
AMDU	Mozambican Association for Urban Development
AMEXTIPE	Agences Mauritanienne d'Exécution des Travaux d'Intérêt Public pour l'Emploi
ATETIP	Agence Tchadienne d'Execution de Travaux d'Interet Public
BAD	Banque Africaine de Développement
BADEA	Banque Arabe pour le Développement Economique en Afrique
BCI	Budget Consolidé d'Investissement
BEPS	Basic Education and Policy Support
BESIP	Basic Education Sector Investment Program
BESSIP	Basic Education Sub-Sector Investment Program
BID	Banque Islamique de Développement
CBO	Community-based organizations
CDC	Community Development Committee
CDD	Community-driven Development
CMA	Contract management agency
CRESED II	Second Education Sector Development Project
DANIDA	Danish International Development Agency
DCES	Direction des Constructions et des Equipements Scolaires
DFID UK	Department for International Development
EDI	Economic Development Institute
Edu-II	Second Education Project
Edu-III	Third Education Project
Edu-V	Fifth Education Project
EFA	Education for All
EFA-FTI	Education for All–Fast Track Initiative
ESCP	Education Sector Consolidation Project
ESP	Education Sector Project
ESSIP	Education Sector Strategic Investment Plan
ESSP	Education Sector Strategic Plan
EU	European Union

FA	Financing Agreement
FDA	French Development Agency (FAD)
FCFA	Franc Communauté Financière Africaine
FID	Fonds d'Intervention pour le Développement
FID-EPT	Fonds d'Investissement pour le Développement—Education pour Tous
FINNIDA	Finnish International Development Agency
GEAI	Groupement d'Etudes pour une Architecture Industrialisée
GMT	Grassroots Management Training
GRIP	Grassroots Initiative Project
GRZ	Government of the Republic of Zambia
HIPC	heavily indebted poor country
HRDP	Human Resources Development Project
ICB	International competitive bidding
IDA	International Development Association
IDB	International Development Bank
ILO	International Labor Organization
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau (German government–owned development bank)
LCB	local competitive bidding
LG	local government
LGDP	Local Government Development Project
LICUS	low-income country under stress
MASAF	Malawi Social Action Fund
MDG	Millennium Development Goals
MINED	Ministère de l'Education
MoE	Ministry of Education
MoRD	Ministry of Rural Development
MPP	Micro-project Program
MPU	Micro-project Unit
MPW	Ministry of Public Works
NCB	national competitive bidding
NGO	nongovernmental organization
NIGETIPE	Agence Nigerienne d'Exécution des Travaux d'Intérêt Public
NRIP	National Rural Investment Project
NUSAF	Northern Uganda Social Action Fund
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Petroleum Exporting Countries
OPEP	Organisation des Pays Exportateurs de Pétrole
OPSUP	OPEC Primary School Upgrading Project
OSEO	Ouvre Suisse d'Entraide Ouvrière

PAC	Projet d'Appui aux Communes
PADEB	Basic Education Project
PAOEB	Projet d'Appui à l'Organisation de l'Enseignement de Base
PASE	Projet d'Appui au Secteur de l'Education
PCPEP	Projet de Construction de Prototypes d'Ecoles Primaires
PCPEPMRG	Projet de Construction de Prototypes d'Ecoles Primaires en Milieu Rural de Guinée
PCU	Project Coordination Unit
PDRH	Projet de Développement des Resources Humaines
PEDP	Primary Education Development Project
PEQT	Projet Education de Qualite pour Tous
PFDS	Projet de Fonds de Développement Social
PIU	Project Implementation Unit
PMC	Project Management Committee
PNDSE	Programme National de Développement du Secteur Education PNUD Programme des Nations Unies pour le Développement
PROMEF	Projet de Consolidation et de Modernisation de l'Education et la Formation
PPTE	Pays Pauvres Très Endettés
PUSE	Programme d'Urgence pour le Secteur de l'Education
PWECP	Public Works and Employment Creation Project
QUIPS	Quality and Improvement in Primary Schools
SESP	Second Education Sector Project
SF	social fund
SFG	School Facility Grant
SHRDP	Second Human Resource Development Project
SRP	social Recovery Program
SSDP	Social Sector Development Project
SWAPs	sector-wide approaches
TESP	Third Education Sector Project
UNCDF	United Nations Capital Development Fund
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USAID	United States Agency for International Development
VCSP	Village Community Support Project
ZAMSIF	Zambia Social Investment Fund
ZEPIU	Zambia Education Project Implementation Unit

EXECUTIVE SUMMARY

INTRODUCTION

USAID contracted Perez, APC to conduct an analysis of available documented data on prefabricated schools erected or planned for developing countries and in the context of initiatives implemented under the USAID umbrella. The goal of Evaluation Team is to provide an objective tool by which agency leaders, program designers, and governmental authorities can use during initial decision making to decide on the most suitable construction technique for the project at hand.

Data generated in this analysis is focused on research performed on prefabricated education development projects. However, the preponderance of published data is in response to needs in sectors other than education. Most of the data uncovered relates to prefabricated housing development. Even within this limitation, the findings on prefabricated schools and other projects that utilize prefabricated construction systems provide valuable insight and direction for the development of guidelines to determine the conditions under which the use of prefabricated construction will result in the most favorable outcomes.

HYPOTHESIS

In the context of development provided by western aid organizations there exists the general idea that the use of prefabricated construction will universally result in quicker project delivery times, high quality outcomes, and reduced construction costs.

This research analysis and evaluation seeks to firmly establish that specifically in regard to education development, prefabricated construction does not result in faster, better, cheaper project outcomes.

HISTORY OF PREFABRICATED CONSTRUCTION

A historical overview of select prefabricated construction projects pinpoint key elements of the evolution of the general concept of prefabricated construction. The historical analysis identifies that:

1. Success in prefabricated construction can be attained through efficiency of the production of components, and simplicity of the design and erection of the building.
2. Success depends on adequate means of distribution being in place.
3. Prefabricated system costs must be aligned with other established measurable methods of construction.
4. Prefabricated construction success relies on system durability
5. Vernacular architecture, culture and social norms must be considered, and end-users must be engaged from project inception.

GLOSSARY

A primary exercise of this research is to define the terms commonly used in the context of prefabricated construction. Such a glossary is provided as part of this evaluation. The Glossary is intended to be a broad introduction to language and key concepts that one would encounter in the international development context.

PREFABRICATED CONSTRUCTION TODAY

A select few contenders stand out as the predominate prefabricated construction systems, particularly in western developed nations. They include:

- Modular/Mobile Systems

- Pre-engineered Metal Buildings
- Precast Concrete Panel Systems

TYPES OF PREFABRICATED CONSTRUCTION

As prefabricated construction systems and methods have evolved, technologies have advanced advances, markets have broadened acceptance, and various economic factors have converged, three overarching prefabrication conceptual methods have predominated. They are:

- Modular Systems
- Hybrid Systems
- Panelized Systems

RESEARCH EVALUATION METHODS

The data and conclusions compiled in this evaluation are generated from Literature Review, Policy Analysis, Key Expert and End-User Interviews, and Field Assessments. Standardized data points are established and qualified in response to the various items researched. The standardized data points are:

- Usability,
- Ability of the system to meet local code/building standards,
- Environmental Compliance,
- Site Conditions,
- End-User acceptance,
- Sustainability,
- Constructability,
- Local Labor (and Skillsets),
- Cost (including logistics),
- Schedule,
- Quality,
- Material Life Cycle,
- Procurement (including overall acquisition approach), and
- Policy

The Purpose of this system is threefold:

1. To evaluate the effectiveness of the use of prefab construction in the USAID development context;
2. To validate common perceptions regarding the merits of prefab construction versus conventional construction; and
3. To establish evidence for when prefabricated construction may be appropriate to facilitate decision-making regarding the selection of prefab construction versus conventional construction solutions.

RESEARCH LIMITATIONS

Even with a consistent set of evaluation criteria and a clear stepwise process for analysis, the following items are the main limitations of this evaluation process:

1. Inability to review USAID construction projects and contracts
2. Difficulty of comparing projects in dynamic environments

3. Inability to directly compare cost and schedule
4. Small number of projects
5. Biases in sample selection
6. Reliance on USAID for guidance

LITERATURE REVIEW SUMMARY STATEMENT

As various construction techniques have been implemented in providing education infrastructure throughout the developing world, there is significant evidence indicating that prefabricated construction methods do not deliver the anticipated advantages commonly perceived as hallmarks of the technique. There are many examples of prefabricated school construction that have proven to not have been built faster, at lesser expense, nor at greater durability than other methods of construction.

Additionally, over the last few decades there have been trending shifts in policy as pertains to funding, procurement, and management of education infrastructure construction in developing nations. There is evidence that centralized systems of decision making and management result in lesser effective outcomes than localized systems of management. Greater integration of local-owner and end-user decision-making at the initial stages of planning and design of education infrastructure in developing countries leads to better overall project outcomes.

POLICY ANALYSIS

The US Federal General Services Administration, with the use of the Federal Acquisition Regulations' definition of construction, have allowed some organizations within the federal government to by-pass normal controls over infrastructure space planning and facility management by considering on-site construction of prefabricated components 'assembly' rather than 'construction.'

USAID, like the GSA, use the definition of construction outlined in the Federal Acquisition Regulations (FAR). There are two mandatory references that include construction- ADS Chapter 201 and ADS chapter 303. Without a more specific and comprehensive definition of construction, prefabricated construction is not covered under these mandatory references. The flexibility of this definition allows USAID and the GSA to work around many of the controls placed on construction projects by employing prefabricated building solutions.

The United States Department of Defense uses a more comprehensive policy to govern prefabricated construction, but even with more clearly defined rules for this type of construction, the 2018 Office of the inspector General recommended an update to how it classifies re-locatable buildings and a shift in purview to the Department of Public Works to ensure proper space planning, inventories and control.

Other International Organizations interviewed in the report are the Swedish International Development Cooperation Agency (SIDA), United Nations Office for Project Services (UNOPS), International Organization for Migration (IOM),United Nations Human Settlements Programme (UN-Habitat), and the World Bank.

KEY INFORMANT INTERVIEWS

Overall, most Expert Interviewees state a preference for conventional construction over prefabricated construction methods. The main concern communicated by the experts is the lack of material availability for repairs and the end-user lack of familiarity with prefabricated construction methods. With one exception, the experts confirm that prefabricated construction is not cheaper or faster than conventional construction methods. They all confirmed that prefab systems are not sufficiently durable for most longer-term development needs.

End-User Interviews provide another important (and often longer lasting) insight into the benefits and drawbacks of prefabricated building deployment. The value in End-User interviews conducted for this report is the comparison of prefabricated buildings with conventionally constructed buildings of the same program. When looking at examples of schools and clinics (one of each- prefabricated and conventionally constructed), End-Users agree that in all areas except for Cost and Schedule, conventional construction meets their needs better.

FIELD ASSESSMENTS

The Field Assessment Team led the assessment of existing projects in Nepal and Malawi in order to establish the advantages and disadvantages of construction types across different programs. A qualified panel of End-Users aided in the acquisition of data needed to evaluate the selected projects. In Nepal, recent construction has taken place to respond to a 2015 earthquake that destroyed significant infrastructure. Over 350 prefabricated clinics were constructed in and around the affected area. This study assesses some of those facilities in conjunction with traditionally constructed clinics erected at the same time. The structures in Malawi are schools. Even though the construction of both the prefabricated and traditionally constructed schools occurred 15+ years ago, the information gained in evaluating their current condition gives valuable insight into the longevity of each style of construction. Across the projects evaluated in the field assessment, the main ideas that hamper adoption of prefabricated building construction are the lack of sustainability and building longevity, and the difficulty in modifying the layout of a facility. In both cases, prefabricated building construction leaves users without the skills to modify their environments, and differences in construction methodology leave communities without the ability to repair prefabricated structures as they sustain use past their designed lifespans.

CONCLUSIONS

When applying the evaluation criteria throughout the report, most findings determine that the cost of prefabricated structures is too high. The data mostly categorizes prefabricated building systems as poorly usable, irresponsive to local conditions. The most consistently cited drawback to prefabricated building construction throughout the investigation was their poor sustainability and longevity. Often, with integrated and prefabricated systems, components and materials are not as durable as sourced components and material used in traditional methods of construction. The problem in almost all instances is exacerbated by end-users who are ill-equipped to make modifications or repairs to a pre-engineered system. Prefabricated systems do benefit building projects that are in need of tight scheduling, constructability (assembly), and are generally constructed of quality materials. The most obvious conclusion is that for prefabricated building systems to be successful, they cannot only be a quick and efficient solution, but must be deployed with consideration to the full life-cycle of the building and community in which the project is deployed.

RECOMMENDATIONS

In order to increase the success in which prefabricated building solutions are utilized in projects, this report recommends that USAID strengthen its policies to ensure that prefabricated construction follows the same guidelines as conventional construction projects. As a matter of general agency policy, it is recommended that USAID:

1. Publish and issue a short document that describes prefabricated construction limitations
2. Specifically call out and define prefabricated construction in its construction-related operating policies
3. Include factory witness tests for major or complex equipment purchases including prefabricated construction materials as a best practice

Further, it is suggested that in contemplating the use of prefabricated construction methods, USAID consider recommendations identified through the review of other US government agency and/or donor organization policies that include:

1. Procurement should be coordinated through the Installation's Department of Public Works to make sure that the DPW is included in the installation's space planning and are properly inventoried and controlled (US DoD)
2. Consideration should be given to architecture, logistics, size limitations and cost when considering the use of prefabricated construction methods (UNOPS).

Finally, the literature review identifies specific recommendations related to school infrastructure development programs, which include:

1. An Operations and Maintenance plan be created for each prefab facility before construction completion
2. Build in capacity of local artisans for maintenance of the specific construction systems.
3. Users (supervisors and teachers) must be trained in how to use and care for the facilities
4. Developers plan for realistic capacities. Prefab school facilities are not suitable as overcrowded schools. Overcrowding creates significant challenges for the maintenance and care of prefabricated facilities. In the case of the Lilongwe school, over 150 students are crowded in one classroom, which is designed for 60 students.

ANNEXES

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1. INTRODUCTION

USAID contracted Perez, APC to perform an analysis of available documented data on prefabricated schools erected or planned for developing countries and in the context of initiatives implemented under the USAID umbrella. Our research has revealed little data that may be specifically categorized as schools for USAID. Far more data has been generated and documented on prefabricated construction projects in response to needs in other sectors, particularly with regards to housing. That said, Perez, APC has incorporated the findings on prefabricated schools with some of the recurring findings that the research indicates is applicable to prefabricated construction throughout developing countries, regardless of sector.

The specific purpose and intent of this document is to be an objective tool for USAID agency leaders, program designers, and governmental authorities to use during initial infrastructure decision-making in response to international assistance-type projects.

This document shall present research via literature review, case studies, expert interviews, SWOT analysis, cost considerations, common perceptions/misperceptions, and policy reviews as they pertain to prefabricated construction. The conclusions and recommendations, herein, are based on the aggregate data compiled through this evaluation.

1.1 EVALUATION PURPOSE

The purpose of this document is to serve as a tool for USAID and other development agencies and national government leaders, managers, and decision-makers to use in developing facility infrastructure programs, especially when prefabricated construction methods are being considered. Additionally, this document may inform future USAID programs and policy approaches to prefabricated infrastructure development.

1.2 EVALUATION QUESTIONS

Among the questions this evaluation seeks to answer include the following:

- What is prefabricated construction? Is there a difference in how the terms prefabricated construction and pre-engineered buildings are used within and outside of USAID?
- Why consider prefabricated construction over conventional construction? What are the real and perceived technical and operational advantages and challenges of prefabricated construction?
- Does prefabricated construction save time and money, and deliver a better project when used for infrastructure development?
- Is prefabricated construction a viable solution for education infrastructure development?
- What are the real and perceived policy advantages and challenges to prefabricated construction? What are the critical policy considerations that need clarification or refinement under USAID when considering or implementing prefabricated construction for aid projects?
- After prefabricated construction is determined to be the chosen method of construction, what critical steps should be taken to ensure successful outcomes?

2. OVERVIEW OF PREFABRICATED CONSTRUCTION

2.1 A HISTORY OF PREFABRICATED CONSTRUCTION

Prefabricated construction methods are not new and have existed for as long as humans have been making things. Prefabrication is a process that allows for elements to be constructed apart from a building site, transported, and then installed at the site.

The expansion of mechanized systems of manufacturing in the 18th and 19th century and the population growth that occurred after World War I and World war II in the 20th century gave rise to our current prevalent systems and methods of prefabricated construction. To illustrate that history, four notable historical examples are reviewed as part of this assessment. The Crystal Palace, London, U.K. (built 1851, relocated 1852), Sears Catalog Homes (1908-1940), Habitat 67, Montreal, Canada (1967), and La Maison Tropicale, Brazzaville, Republic of the Congo (1951).

Due to the complexity of the subject, it is not the intention of this document to provide the complete history of prefabricated construction. The four examples cited touch upon only a few critical points that have influenced the evolution and implementation of prefabricated construction as it stands today.

CRYSTAL PALACE, LONDON, UK (BUILT 1851, RELOCATED 1852; DESTROYED BY FIRE 1936)

The Crystal Palace; Interior View (Image by J. McNeven - collections.vam.ac.uk, Public Domain)

The United Kingdom is the birthplace of the Industrial Revolution. From the period that extended from the late 1700's through the late 1800's, radical advances were made in the manufacture of all manner of goods. Prior to this time, virtually everything was made by hand or with simple machinery in small shops or individual's homes. During this time, new technologies were created, manufacturing machines were

invented, and systems of mechanized production were devised that did, in fact, make the production of goods faster, better, and cheaper. [53]

Systems of mechanization led to increased production output and vastly improved product standardization. Thousands of one item could now be made indistinguishable from and interchangeable with one another. Advances in the production of steel and cast iron significantly improved the quality of the finished product and reduced production costs such that a building construction industry with resultant technological advances also expanded during this period in time. Cast iron and steel became important building components. Similarly, the invention of the internal combustion engine and the steam engine resulted in new methods of transport. Trucks and trains could now more rapidly move building materials to construction sites.

The Crystal Palace was conceived and built as the exhibition hall for London's Great Exhibition of 1851 which displayed the advancements of the Industrial Revolution, and itself displayed advances of modern construction techniques in its use of off-site fabricated cast iron and glass elements. [53]

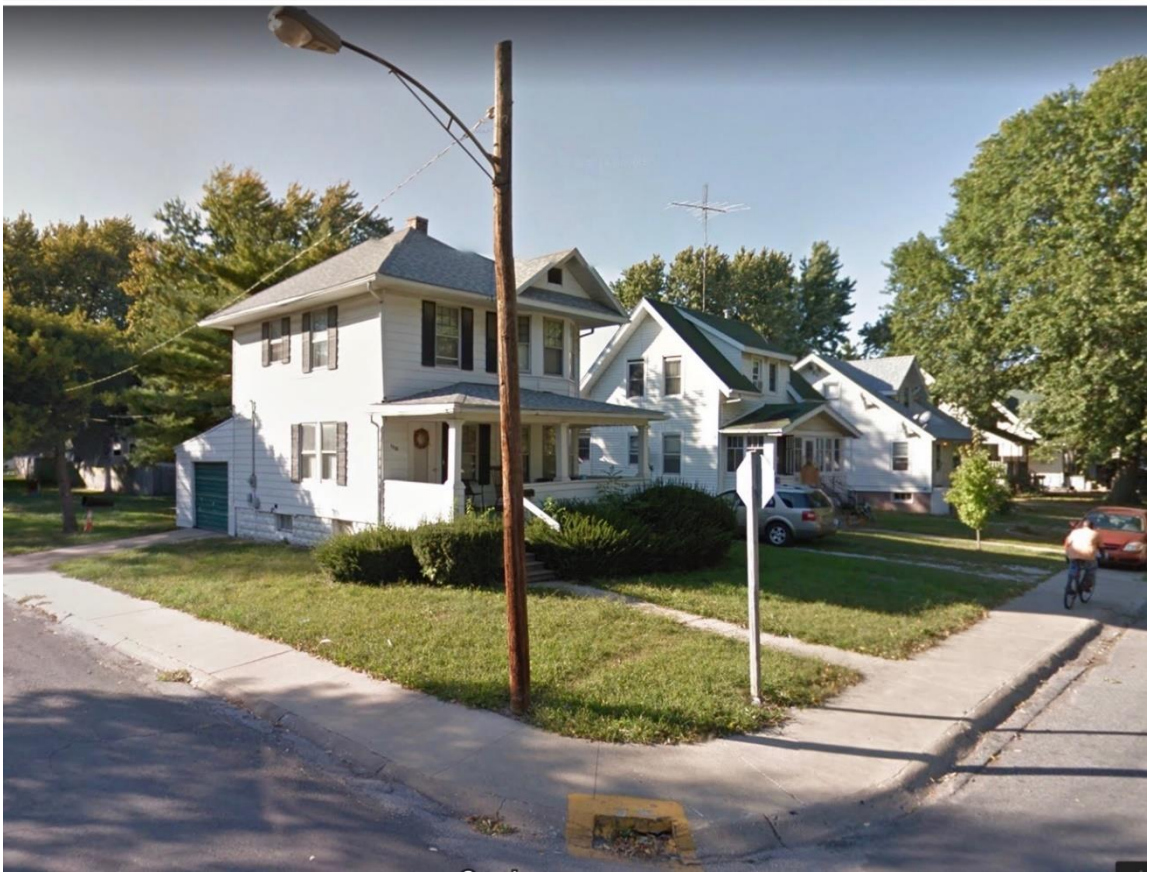
Noted horticulturalist Joseph Paxton had previously explored the design and construction of greenhouses. The production advances in plate glass and cast iron made these items inexpensive and readily available. In June of 1850, Paxton received the commission for the design of the Crystal Palace. The building was designed and built in less than eight months, it was constructed under budget, and the Great Exhibition opened on time in May of 1851, as originally planned. [53]

The Crystal Palace is a notable prefabricated building for a few reasons. First, the building was designed based on the dimensional limits of the plate glass used to construct the walls and roof. The largest sheet of glass measured 9 inches by 49 inches. Tens of thousands of these panels were manufactured. Similarly, columns and framing were designed to accommodate the live load limits of cast iron and were also manufactured as repeatable elements. Finally, as the building had always been intended to be temporary, when the Great Exhibition concluded, the building was disassembled, removed from its original site, and then reconstructed on another site across town where it remained until it was destroyed by fire in 1936. [53]

SEARS CATALOG HOMES, EAST COAST AND MIDWEST US (1908-1940)

Another impact of the Industrial Revolution, besides advances in technology, was the expansion of commerce and capitalism. In the first half of the 19th century, American retailer Sears, Roebuck and Company successfully marketed and sold products via mail-order catalog. One of the enduring examples of this company's commercial achievement is the Sears Catalog Home. Between 1908 and 1940, Sears sold more than 70,000 catalog homes throughout the United States. [54]

Sears was not the first company to sell mail order homes, and Sears did not invent, create, or advance any building technologies. Sears did, however, make the most of conditions and technologies available at the time. The steam engine fostered the expansion of rail lines across America and the subsequent expansion and efficiencies of the U. S. Postal delivery service. Sears mail-order catalogs were already seen by millions of Americans. The idea of selling homes was conceived when a Sears manager observed that there were warehouses filled with building materials. That led him to the idea of packaging the parts of an entire house as a kit and selling it via the Sears mail-order catalog. [54]



Sears Catalog Homes, Carlinville, IL (Screen Capture via Google Earth 2018) In 1918, Standard Oil Company ordered Sears Catalog Homes to be built for workers at its coal mines in Carlinville, Illinois. 156 houses were constructed in 9 months. More than 100 of the structures are still standing today.

Sears Catalog Homes are notable prefabricated construction because they are the model example of the "kit house" in North America. An individual would select a home from the Modern Homes catalog and order it by mail. The homes were divided into three separate pricing categories and offered the latest technologies available, including central heating, indoor plumbing, and electricity. Weeks later, a package of 12,000 parts would be shipped by rail car to the individual. Commonly, the owner, friends, family and neighbors would then take the kit to the building site and assemble the home. [54]

HABITAT 67, MONTREAL, CANADA (1967)

For his architectural graduate thesis at McGill University, Moshe Safdie re-envisioned the urban, residential apartment block. Safdie had observed that in many large metropolitan areas across North America, middle class populations were leaving the cities to reside in the suburbs. He sought to create densely populated living spaces that had an organic connection to the outdoors. He wanted each living space to be as unique and connected to nature as any suburban home. [54]

Habitat 67, Montreal, Quebec, CN (Screen Capture via Google Earth 2018)

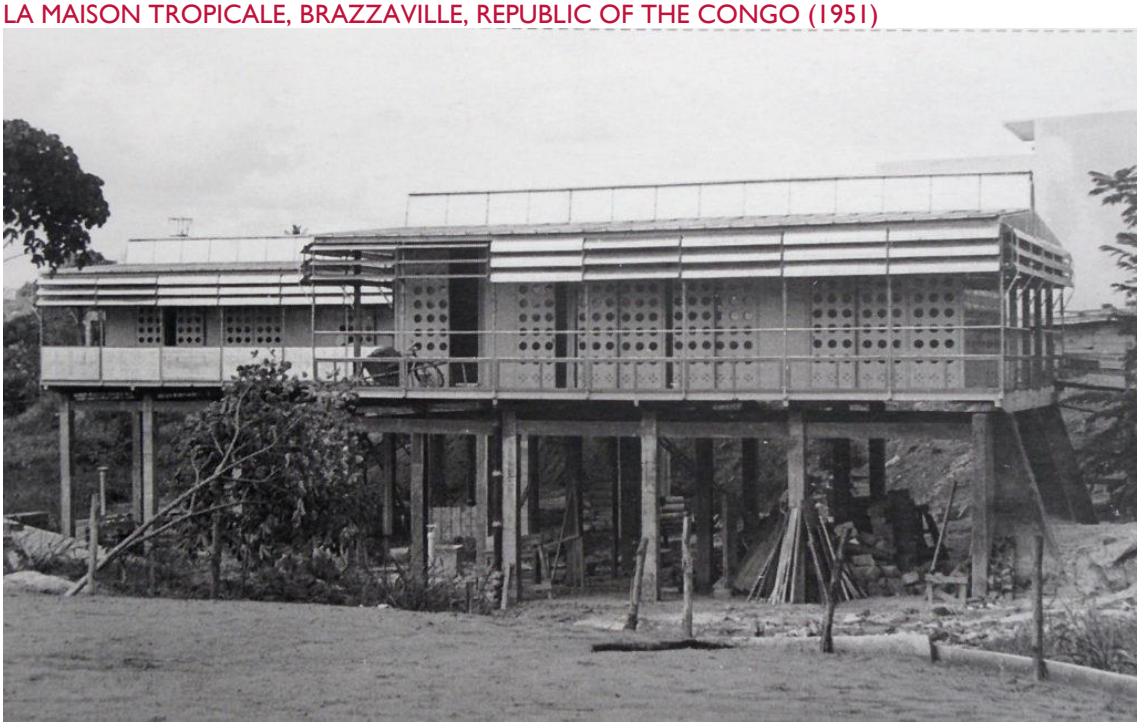
Safdie's design goals for his urban apartments closely aligned with the theme of the 1967 International and Universal Exposition (Expo '67) hosted in Montreal as the World's Fair. The theme "Man and His World" was intended to elicit introspection regarding how humans might approach a future on Earth with hope, awareness and a sense of solidarity with one another and all creation. [54]

Encouraged by his thesis adviser, Safdie presented his design before the Expo Commission, and his concept was selected to be constructed. Habitat 67 was built as a living exhibition hall showcasing the future of urban dwelling. [54]

Habitat 67 was constructed of prefabricated concrete modular building units. A concrete plant was set up adjacent to the building site where the 20' x 40' x 10' concrete box modules were formed and finished on the interior. The modules were hoisted into place and were structurally tied together through post-tension cables and welded steel elements. While Habitat 67 remains an influential architectural icon, its costs were astronomical. The average per unit cost was C$140,000 in 1967. This would equate to C$992,600 today, which was well beyond the price of the middle class for which it was intended. Due to the cost, the project was dramatically scaled down from 1,000 units to 158 units and it was never duplicated. [54]

Habitat 67, Montreal, Quebec, CN (Image by Vassgergely at the English language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3086441)

LA MAISON TROPICALE, BRAZZAVILLE, REPUBLIC OF THE CONGO (1951)



La Maison Tropicale, Brazzaville, Republic of the Congo (Image credit; https://failedarchitecture.com/wp-content/uploads/2013/04/Screenshot-2018-05-17-18.50.40-1499x750.png)

In the 1940s, noted French architect and industrial designer Jean Prouvé conceived "La Maison Tropicale" concept as a prefabricated building solution for the tropical climates of Africa. Designed as kits of steel and aluminum frames and panels that were "flat-packed" for shipment on cargo planes, the system was based on theories of modern universalist design philosophies. [55]

> "In many ways, La Maison Tropicale exemplifies modernist ideas about architecture. At the time Prouvé designed the house, architecture was seen as a powerful tool in bringing about social transformations. Rationalization and standardization in design and urban planning were thought to provide solutions to social problems. This idea merged with universalism; the widely held modernist belief in a universal human subject and a world in which cultural differences could be overcome. It was assumed that the discoveries of science could determine the needs of this universal subject and as such of the needs of humanity. Technical planners and architects were thought to be able to meet these needs and create spaces that would function equally anywhere."
>
> "Simultaneously, this universalist philosophy pointed to the fact that apart from a

modernist design, La Maison Tropicale was very much a colonial object. It was assumed that European modern architecture was superior to local building styles and that French prefabricated housing was better suited to the climate than the local vernacular. Instead of using local building materials, the French promoted the use of aluminum, brick and cement. The French state-owned company Aluminum Français extracted raw materials from the West African colonies, which were refined into aluminum in France. This refined aluminum was subsequently used to construct Prouvé's Maison Tropicale. Taken from West Africa, this aluminum was returned to West Africa as a different, finished product – a product that showcased the "technical superiority" of the French. The French colonials regarded their modern and innovative architecture as an expression of their superiority over the indigenous people, and therefore used it to exert cultural dominance. The French project failed. Instead of realizing the fabrication of La Maison Tropicale as a large-scale solution as planned, only three prototypes resulted – built and placed in Congo and Niger."

"In order to shine light on the local reception of La Maison Tropicale, African intellectual Mantia Diawara made the documentary Maison Tropicale in 2008. This documentary shows where the Maisons Tropicales stood before they were removed in 2000, and what the house meant to the local people in Brazzaville and Niamey. Locals were interviewed about their memories of the house and how they had experienced its presence. In the documentary it appears that a majority of the people felt a certain fear of the houses. They were seen as alien objects. La Maison Tropicale was completely different from the local building style, and the desired social interaction between the houses and African society did not occur. Its modernistic character – that receives limitless praise today – did not fit the African context." [55]

LESSONS FROM HISTORY

Each of the historical examples cited above indicate some vital component of the evolution of prefabricated construction, or some critical lesson to be observed.

The example of The Crystal Palace identifies that from early on, success in prefabricated construction can be attained through efficiency of the production of components, and simplicity of the design and erection of the building.

The example of the Sears Homes highlights that commercial success can be attained for manufacturers when there are adequate means of distribution in place, and when there is sufficient volume of sales of the prefabricated units to keep the prices optimally low for consumers. For consumers, the Sears Homes highlight that low price, end-user input and durability of the buildings are key factors of success.

Habitat 67 provides a solid example of a type of prefabricated, modular construction.
The lesson to be observed, though, is that even the simplest prefab concept can belie real world costs. Likely, the designers of Habitat 67 failed to consider the resultant cost implications of their complex building form.

The final example of La Maison Tropicale identifies, perhaps, a most critical lesson that may not receive adequate focus in the implementation of international assistance-type development projects. If end-users are detached from the initial design and planning stages of a project, and if the final building form is alien to the end-users, then there may not be any success regardless of the conceptual strength of the prefabricated system.

2.2 GLOSSARY OF TERMS AND PREFAB CONCEPTS

A primary exercise in this research endeavor is to define the terms commonly used in the context of prefabricated construction, including the word "prefabricated". [04]

National and regional context plays an obvious role in the specific terms used to describe pre-manufactured building systems. For instance, in the United States, the terms prefabricated (prefab), and pre-engineered are frequently used interchangeably, although the two terms do not necessarily share the same meaning. In the United Kingdom, the term off-site manufacturing is used and means the same as prefabricated.

Other national and regional terms are included in the Glossary. While the following list is by no means exhaustive of all the technical terms and industry lingo related to prefabricated construction, the Glossary is intended to be a broad introduction to language and key concepts that one would encounter in the international development context.

GLOSSARY OF TERMS

Buildability: Buildability has been defined as 'the extent to which the design of a building facilitates the ease of construction, subject to the overall requirements for the completed building'. The definition has two major implications:

1. Buildability exists on a scale from good to bad. A design with good buildability takes close account of the way it is to be constructed and vice-versa.
2. Each building has overall requirements which may necessitate the acceptance of less than good buildability. [06]

Component: Component is a constituent part. [52] In the context of prefabricated construction, component is any of the required pieces necessary to complete assembly of the whole building.

Conventional Construction: Conventional construction is any traditional method of building utilizing vernacular materials, techniques, forms, etc. As it relates to prefabricated construction, conventional construction is the standard method of transporting and stockpiling building materials at the construction site and erecting the building from the stockpiled materials.

Conventional Construction – Residential "Stick-Built" Wood Framing (Image by M. Clayton 2014)

Dry Construction: Dry construction is a term observed to be used synonymously with prefabricated construction. It specifically refers to the utilization of prefabricated structural elements to form the building shell, with "dry" materials such as plywood and gypsum board sheathing used to finish the interiors. No wet mortars or plasters are used. This term and this method of construction is most prevalent in the Asia-Pacific region. [ ]

Industrialization: Industrialization is defined essentially as an organizational process – continuity of production implying a steady flow of demand; standardization; integration of the different stages of the whole production process; a high degree of organization of work; mechanization to replace human labor wherever possible; research and organized experimentation integrated with production. [ ]

Hybrid Systems: Hybrid prefabrication systems refer to hybrid module-plus-panel or semi-volumetric systems. These systems use volumetric units for the highly serviced areas such as kitchens and bathrooms and construct the remainder of the building using panels or by another means. Hybrid prefabricated systems are regarded as combining the benefits of two prefabricated construction systems, while allowing for more flexibility and consumer choice. They can be used for additions and alteration in order to extend buildings with minimal disruption. [06]

Kit-of-Parts: The kit of parts theory refers to the study and application of object-oriented building techniques, where building components are pre-designed / pre-engineered / prefabricated for inclusion in a joint-based (linear element) panel-based (planar element), module-based (solid element), and deployable (time element) construction system. [39]

Kitset: Refer to Kit-of-Parts. This term is used regional to New Zealand. [06]

Manufactured Building / Mobile Building: Manufactured Buildings (commonly known as mobile homes in the United States) is a type of prefabricated (building) that is largely assembled in factories and then transported to the sites of use. The buildings are permanently mounted on chassis for continued transportability. The definition to the term "mobile home" is regulated in the United States by federal law (Code of Federal Regulations, 24 CFR 3280). [40]

Modern Method of Construction (MMC): The MMC is the term used by the UK government to describe a number of innovations in house building, most of which are offsite technologies, moving work from the construction site to the factory. [45]

Modular: Modular design is a design and construction approach that breaks up a system into smaller parts called modules that can be independently created and then used in different building and construction systems. Modular buildings employ a set of components and reusable modules that can be disassembled and reassembled over time, making this system incredibly flexible for varying and ever-changing space usage needs over the life span of a building. A downside to modularity is that low quality modular systems are not optimized for performance. This is usually due to the cost of putting up interfaces and systems between modules. [41]



Modular Retail; drainage at Modular Classrooms; Modular Classrooms (Images by M. Clayton 2017-18)

Modular Construction: In modular construction, sections of a building are fabricated at an off-site location. The individual sections of the building are then loaded onto flatbed trucks and then delivered to the construction site. Once at the site, the sections are hoisted by crane into their respective locations and joined together on the building's foundation. [41]

Off Site Manufacturing (OSM): Off-site is a term used to describe the spectrum of applications where buildings, structures or parts are manufactured and assembled remote from the building site prior to installation in their final position. In other words, moving operations that are traditionally completed onsite to a manufacturing environment. The offsite spectrum is extensive and, currently, the sector is diverse and fragmented. [06]

Panelized Construction Panel, Panelized, Panelization Buildings: Panelization describes framing of light wood or light gauge-metal-framed walls produced in a factory. This process speeds up the delivery of walls to a site where framing crews install quickly when compared with onsite framing. The ideal behind panelizing, what would usually be a site-framing process, is to lower cost and increase speed.


Steel Frame Panel System (Images by M. Clayton 2011)

Panel systems have been developed because of the flat nature of many building products such as metal and wood sheet material, interior finishing panels, and the ease of using the panel cavity for distribution of services such as plumbing and electrical lines. [06]

The construction of such systems can include up to four different types: Wood, SIPs (Structural Insulated Panels), Metal Panels, and Concrete Panels. Other types can include exterior glass (glazing) unit panels, and tilt-up concrete construction. [06]

These are planar units that do not enclose usable space, such as panel systems and cladding panels. They may include windows, doors or integrated services, and are either open-framing or closed-in with clad

and/or lining. They are transported to site as flatpacks. A large part of panel-based prefabrication includes compressed timber sheet products. [06]

Precast Concrete Panels: Refer to Prefabricated Panel Construction.

Prefabrication: Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. Windows, doors, and wood trusses are standard, commonly accessible and commonly utilized prefabricated building components. [06]

Prefabricated Construction: Prefabricated construction is a method of building that employs the use of factory-made components or units that are transported and assembled on-site to form a complete building. The most widely used form of prefabrication in building and civil engineering is the use of prefabricated concrete and prefabricated steel sections in structures where a particular part or form is repeated many times. It can be difficult to construct the formwork required to mold concrete components on site and delivering wet concrete to the site before it starts to set requires precise time management. [06]

Prefabricated Panel Construction: A building technique that utilizes an interlocking and panelized system to create exterior walls of a structure. The panels are constructed off-site and then shipped and installed on the site. The panels can either be self-supported or supported using a building wide structural frame system. [06]

Pouring concrete sections in a factory brings the advantages of being able to re-use molds and the concrete can be mixed on the spot without having to be transported to and pumped wet on a congested construction site. Prefabricating steel sections reduces on-site cutting and welding costs as well as the associated hazards. [06]

Pre-Engineered Building (PEB), Pre-Engineered Metal Building (PEMB): A building system that is designed utilizing modular metal building components and assembled on-site in a short amount of time. [06]

A PEB is designed by a specialized supplier or PEB manufacturer, to be fabricated using best suited inventory of raw materials available from all sources and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. Within some geographic industry sectors these buildings are also called Pre-Engineered Metal Buildings (PEMB) or, as is becoming increasingly common due to the reduced amount of pre-engineering involved in custom computer-aided designs, simply Engineered Metal Buildings (EMB). [06]

Standardization: The process of implementing and developing technical standards based on the input and consensus of different parties that include design firms, users, interest groups, standards organizations and governments. Modular design is an attempt to combine the advantages of standardization (high volume normally equals low manufacturing costs) with those of customization. [06]

Structural Insulated Panels (SIPs): Exterior Wall/Floor/Roof, (etc.) panels that are typically made using expanded polystyrene (EPS), or polyisocyanurate rigid foam insulation sandwiched between two structural skins of oriented strand board (OSB) or other related material.

OSB SIPs (Image by M. Clayton 2009)

SIPs are used as building panels for floors, walls and roofs in residential and commercial buildings. SIPs are one type of panelized prefabrication, as defined above. [06]

Stick-Built: Stick-built building is the most common & traditional building method of home construction in the United States and refers to a home that is built 100% on-site from the ground up in complete accordance with all local, state, and regional guidelines. All materials are delivered to the job site, and the construction is performed by various subcontractors and 3rd-party vendors. All of the work happens onsite as opposed to in a factory. While Stick-Built homes may be the most popular due to the option of complete customization, they normally take a little longer to construct due to weather delays, high moisture content in lumber, coordination issues, inspection delays/rework due to failed inspections, etc. [47]

Tilt-Up Construction: A type of building and construction system where individual panels are hoisted vertically into place and installed on site. Materials for the tilt-up system are usually comprised of concrete. [06]

Construction: Concrete elements (walls, columns, structural supports, etc.) are formed horizontally on a concrete slab; this normally requires the building floor as a building form but may be a temporary concrete casting surface near the building footprint. [06]

After the concrete has set, the elements are "tilted" to the vertical position with a crane and braced into position until the remaining building structural components (roofs, intermediate floors and walls) are secured. [06]

Concrete elements can also be formed at factories away from the building site. Tilt-up buildings differs from prefabricated buildings, in that all elements are constructed on the job site. This eliminates the size limitation imposed by transporting elements from a factory to the project site. [06]

Though it is a cost-effective technique with a shorter completion time, poor performance in earthquakes has mandated the implementation of significant seismic retrofit requirements in older buildings. [06]

Volumetric Construction: Refer to Modular Construction.

2.3 KEY TYPES OF PREFABRICATED CONSTRUCTION

As prefabricated construction systems and methods have evolved, technologies have advanced, markets have broadened acceptance, and various economic factors have converged, three overarching prefabrication conceptual methods have predominated. They are:

1. Modular Systems
2. Hybrid Systems
3. Panelized Systems

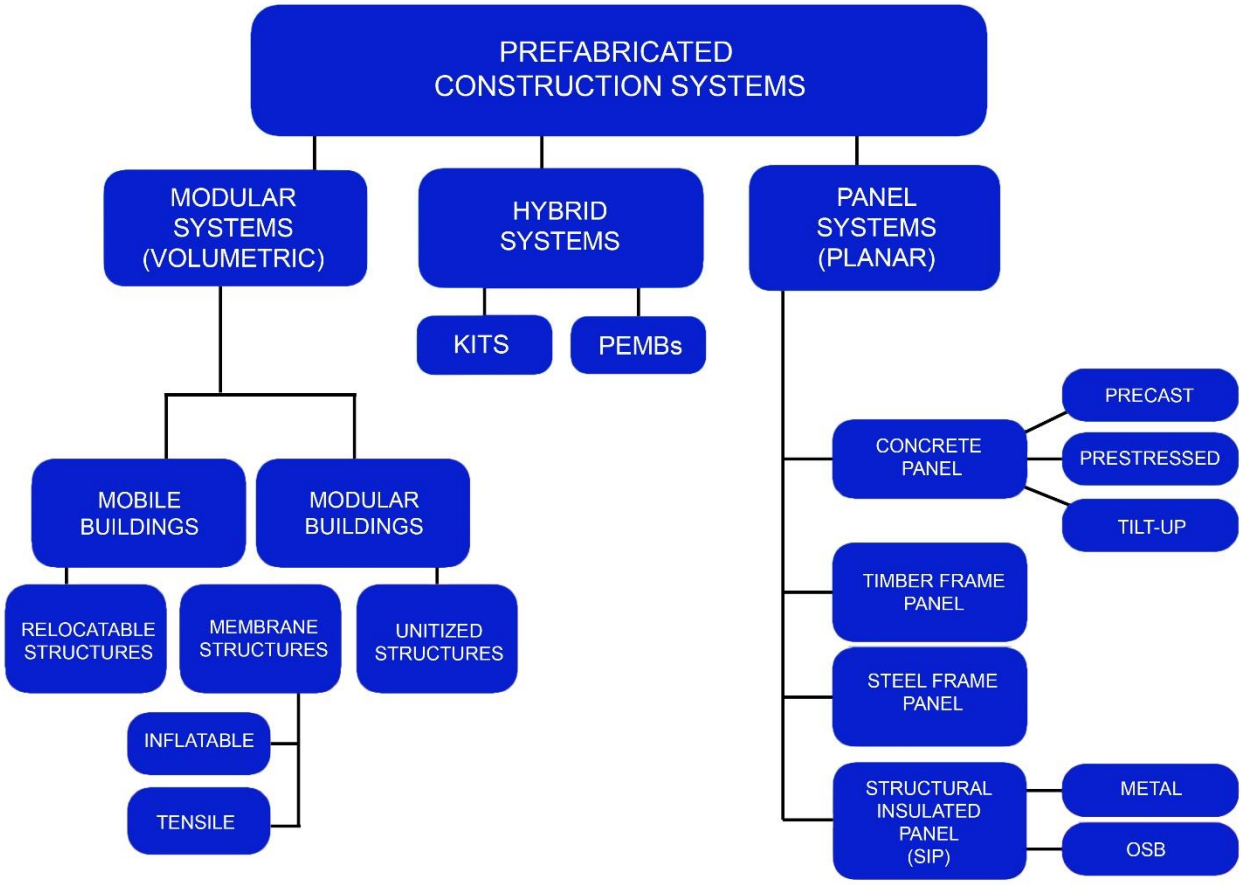


Figure 1. Diagram of key types of prefabricated construction

PREFABRICATED CONSTRUCTION TODAY

After World War II, the popularity of the mail-order kit home began to wane in the U.S. In its place as the most prolific form of prefabricated construction arose the mobile home. Mobile homes, or manufactured homes, are completely manufactured and finished at a factory and are permanently mounted on a chassis with wheels. These rectangular, box-like structures are towed to a building site where they may be temporarily or permanently located once the wheels are removed.

To a large extent, many of the common perceptions or misperceptions of prefabricated buildings being

cheap, poorly constructed and unattractive are rooted in the evolution of the mobile home in the United States. Despite the positive aspects of being inexpensive and transportable, mobile homes suffer derisive associations of being housing for lower social and economic classes. These perceptions have stubbornly endured even as mobile homes have advanced in performance and aesthetics. [06]

Over the years, the form of the mobile home has been modified, adapted and improved for other uses. Today these adapted mobile/relocatable and modular structures are routinely used as classrooms, offices, and storage spaces.

Another form of prefabricated construction in common use today is the pre-engineered metal building (PEMB). Pre-engineered metal buildings can be found in use most frequently as industrial buildings due to the open floor space afforded by their long-span structural framing. Virtually any building use, though, can be contained within the framing and skin of a pre-engineered metal building.

Pre-engineered Metal Building (images by M. Clayton 2018)

Prefabricated concrete panelized systems are currently employed around the globe to meet the needs of hotel, residential and storage developments. In locations adjacent to major cargo shipping ports, re-adapted metal shipping containers are being transformed into houses, apartments, and retail use buildings.

Metal Shipping Container House (image by M. Clayton 2018)

It is important to point out that in addition to prefabricated systems of whole buildings, throughout western developed countries, prefabricated component parts of buildings are only as far away as the nearest hardware store. Pre-hung doors and standard-sized kitchen cabinetry are merely two of a multitude of ubiquitous building components that are available to a mostly residential construction market.

In review of the various systems and how they are applied, it becomes apparent that only certain asset classes and building sectors lend themselves to optimally efficient prefabrication. The sectors that benefit most, are those with redundancies of the built elements. These sectors include housing, education buildings, hospitals, warehouses and storage facilities.

While a variety of systems have been employed by USAID and other aid and assistance agencies to address development needs, the research compiled herein indicates that the most successful deployments, installations, and outcomes occur when mobile or modular systems are used in a select set of circumstances.

Development of schools, though, is not one of the circumstances where mobile or modular prefabricated construction has the greatest potential for success when addressing the long-term infrastructure needs of developing nations.

Regarding the state-of-the-art of the design process for prefabricated construction today, architects, engineers, and manufacturers have access to Building Information Modelling (BIM) software platforms. Through BIM, today it is possible to construct a digital model of a building that is able to simulate real-world physical attributes. Various iterations of the model may be run which can then be studied and modified to suit specific needs. The digital model is a database from which reports, schedules, material quantity take-offs, and a wealth of other information are compiled, and which may be provided as part of the Construction Documents. With the aid of virtual reality (VR) and augmented reality (AR) tools, the designer or end-user may perform a virtual walk-through of the building, or experience the building placed virtually on its actual construction site. When BIM is leveraged to its fullest capacity, the digital model may be used as the template for manufacturing the component parts of a prefabricated building, as the digital files are provided to presses, routers and three-dimensional printers. BIM software can also be used to assist in sequencing the manufacturing, packing and shipping of the components. All of this is stated simply to identify and to underscore that the integrated design approach afforded by BIM has the potential to bolster the efficiencies inherent to prefabrication. BIM also has the potential to provide a streamlined, but substantial additional layer of quality assurance to prefabricated construction from project conception through component or module fabrication.

SUMMARY DETERMINATIONS FROM LITERATURE REVIEW

A list of reference documents provided by USAID was utilized as a starting source for the literature review. This list was supplemented with additional documentation identified through internet research, academic research sources, and other sources.

The preponderance of published, documented research addresses issues relates to fulfilling the need for housing in developing nations, as differentiated from the specific task of this assessment to research prefabricated schools.

Regardless of construction sector, in the context of aid development, with few exceptions the documentation discovered consistently confirm that prefabricated construction does not deliver the presumed faster, better, cheaper outcomes.

Regarding Policy, several references in the literature review state that when development projects are implemented, decentralized systems of engagement and decision-making lead to project outcomes in which end-users become invested. This investment results in facilities that respond to specific community needs, and which are more wholly-embraced.

3. EVALUATION FINDINGS

POLICY ANALYSIS

This section primarily addresses Federal Acquisition Regulations (FAR) and USAID polices that impact the use of prefabricated construction. This section also reviews how other US agencies and international development organizations address prefabricated construction in their policy and practices.

The essence of this section is that the Federal Acquisition Regulation and USAID Construction-related Operational Policies (ADS) use a construction definition that does not cover prefabricated structures. Therefore, prefabricated construction can be purchased as supplies, which includes its assembly on site and limited site preparation. Therefore, assessments, planning, control and oversight, required in the execution of infrastructure projects are not required for prefabricated construction.

3.1 REVIEW OF FEDERAL ACQUISITION REGULATIONS POLICY

FEDERAL ACQUISITION REGULATIONS, GSA SCHEDULE 56 AND USAID CONSTRUCTION-RELATED OPERATIONAL POLICIES

The FAR's definition of construction defines construction by work conducted at the site. The following is the definition of construction provided in Part 2 of the FAR:

> *"Building or work" means construction activity as distinguished from manufacturing, furnishing of materials, or servicing and maintenance work. The terms include, without limitation, buildings, structures, and improvements of all types, such as bridges, dams, plants, highways, parkways, streets, subways, tunnels, sewers, mains, power lines, pumping stations, heavy generators, railways, airports, terminals, docks, piers, wharves, ways, lighthouses, buoys, jetties, breakwaters, levees, canals, dredging, shoring, rehabilitation and reactivation of plants, scaffolding, drilling, blasting, excavating, clearing, and landscaping. The manufacture or furnishing of materials, articles, supplies, or equipment (whether or not a Federal or State agency acquires title to such materials, articles, supplies, or equipment during the course of the manufacture or furnishing, or owns the materials from which they are manufactured or furnished) is not "building" or "work" within the meaning of this definition unless conducted in connection with and at the site of such building or work as is described in the foregoing sentence, or under the United States Housing Act of 1937 and the Housing Act of 1949 in the construction or development of the project."*

Using this definition, the US Federal General Services Administration (GSA) includes prefabricated construction in its GSA Schedule (GSA Schedule 56 – Special Item Numbers (SIN) 36110 A – H Pre-Engineered and Prefabricated Buildings and Structures). The GSA schedule materials and services are procured under FAR subpart 8.4 - Federal Supply Schedules. The prefabricated supply schedule also includes installation and site preparation of the prefabricated units (SIN 36132). In 2010 the Government Accountability Office (GAO) reviewed a protest (File B-402292) where a vendor argued that installation and site preparation of prefabricated units were in fact construction. GAO denied the protest stating that the works were considered assembly rather than construction. Important to note in this determination, is that the RFQ for the requirement did not contain any construction clauses or Davis Bacon Act wage rate requirements. Related construction services required for the project included fire sprinkler and lighting installation. However, these services were performed by other vendors. In most instances, these ancillary services would be included in the procurement, and therefore would be considered construction as defined by FAR 2.101.

Unfortunately, the definition has allowed some organizations within the Federal Government to by-pass normal controls over infrastructure space planning and facility management. The Department of Defense Inspector General's Semi-Annual Report to Congress in 2018 described how temporary facilities were used for by the Navy and Marine Corp as permanent facilities and misspent up to $2.7M on rental and purchase of relocatable buildings. The report states that:

> DPW personnel misclassifying these facilities potentially circumvents the military construction process by using short-term requirements for long-term needs. As a result, Navy and Marine Corps use of relocatable buildings to meet requirements may not be the most effective use of appropriated funds [57]

3.2 REVIEW OF USAID POLICY

USAID CONSTRUCTION-RELATED OPERATIONAL POLICIES AND ENVIRONMENTAL REGULATIONS IMPACTING PREFABRICATED CONSTRUCTION PROCUREMENT.

USAID operational policies have two mandatory references that include construction:

1) Construction Risk Management – A Mandatory Reference for ADS Chapter 201
2) Implementation of Construction Activities – A Mandatory Reference for ADS Chapter 303.

These mandatory references are intended to describe which acquisition instrument is appropriate for construction as well as risk screening of a program's construction activities prior to implementation. Both use a similar definition for construction provided in the FAR with exception of USAID's exclusion of non-structural and cosmetic work in its definition.

3.2.1 CONSTRUCTION POLICY

In fact, prefabricated construction is currently being undertaken at USAID without following the USAID construction-related mandatory references or FAR construction requirements. The solicitation of one health-related project, which includes constructed prefabricated warehouses, specifically prohibited the use of construction as defined by the USAID Mandatory Reference as described below:

> Construction. The Contractor will not perform any construction under this IDIQ, as that term is defined by USAID policy (See USAID Implementation of Construction Activities, ADS Mandatory Reference 303maw). However, the Contractor may be called upon to provide technical assistance to advise country counterparts on what steps need to be taken to perform necessary improvements to warehouses, clinics, and laboratories (structures) to reach WHO Good Manufacturing Practices (GMP) standards.

It is evident that in some instances USAID contracting officers may be using the precedence set by GSA and allowing the purchase of prefabricated systems as materials rather than as construction thereby bypassing many of the controls placed on construction projects. This may likely be attributable to the additional activities, approvals and time required to get USAID infrastructure projects approved and completed. Therefore, Missions may see prefabricated construction as a legitimate way of bypassing this process to quickly get simple building projects underway and show results.

Other than the construction-related mandatory references, our research identified only two other operating policies that impact prefabricated construction. The first policy is ADS 310 – Source and

Nationality requirements. The USAID statutory procurement authority, Section 604(a) authorizes procurement "from the United States, recipient country and developing countries other than advanced developing countries." This regulation establishes the geographic code 937. This code excludes most prefabricated suppliers unless their factory and much of their management team are located in the recipient country. This requirement may make purchasing prefabricated systems difficult in many locations. For example, South Africa, where much of Africa's prefabricated manufactures are located, is not among eligible countries. However, this can be rectified through an exception during the project activity design phase.

The second policy is ADS Chapter 315 Cargo Preference. This policy objective is to ensure that USAID-financed ocean shipments of commodities comply with the requirements of the Cargo Preference Act and the regulations issued by the Maritime Administration of the U.S. Department of Transportation. A USAID prefabricated construction implementer experienced project delays due to the limited number of US-Flag carriers able to ship materials from its point of manufacture.

3.2.2 ENVIRONMENTAL COMPLIANCE POLICY

USAID environmental regulations do not directly address construction. From a policy standpoint, there is not a difference in how USAID environmental policies are carried out with regards to conventional verses prefabricated construction. However, in instances where prefabricated construction has not been considered construction, it reduces the likelihood of USAID engineers engaged in project development as recommended in the USAID Construction Risk Management Mandatory Reference. If USAID engineers are engaged in project development and in developing the environmental assessment documents, construction-related environmental impacts may be more readily identified and addressed.

3.2.3 MONITORING AND EVALUATION POLICY

USAID must diligently enforce their own self-performed evaluation of the documentation, implementation and outcomes of projects and activities per USAID's Evaluation Policy requirements. The lack of self-enforcement of this particular policy results in a void in the knowledge base that could assist in decision-making for future projects or adjustments to policy.

3.3 REVIEW OF OTHER AGNECY POLICIES ON PREFAB

3.3.1 UNITED STATES DEPARTMENT OF DEFENSE (DOD) POLICY

United States Department of Defense Prefabricated Construction

DOD has recognized some of the limitations of prefabricated construction and has made attempts to control its use and establish standards. Over the years the department of Defense has encountered issues with prefabricated construction both domestically and abroad. Prefabricated buildings are a hand-receipt item rather than infrastructure, so it is easier to procure. In 2009, GAO issued a report showing that the services lacked sufficient oversight over their temporary facilities. [58] Also, DOD encountered numerous health/safety, environmental and logistical issues with prefabricated facilities in contingency environments.[59] The Defense Department has developed instructions and policies to limit associated site development and bring this development within the Military Construction Process (MILCON). MILCON is the way for to the military to centrally oversee and manage its global infrastructure footprint. Also, the United States Corps of Engineers (USACE), who manages most of the Department of Defense's construction, is moving away from commercially available prefabricated systems for its contingency operations given the issues that they have encountered. [58] The following are some examples of the controls DOD has put in place to manage the use of prefabricated construction.

- DOD Instruction 4165.56 confirms that "Site Preparation to erect or install relocatable buildings that results in real property improvement is classified as construction and is funded by O&M or military construction (MILCON)." This document helps ensure that any permanent foundations or site utilities are funded through the MILCON process.
- The Army Interim Policy for Relocatable Buildings defines relocated-able buildings as: acquired equipment (personal property) used as a building; meets the "20% rule" (no more than 20% of the funds are for site and utility preparation); is for an interim use (usually 3 years or less). The policy also says that site preparation is classified, real property construction requiring MILCON OR OMA funds.
- UFC 1-201-01 NON-PERMANENT DOD FACILITIES IN SUPPORT OF MILITARY OPERATIONS. This Unified Facility Code (UFC) provides life safety and "habitability-related" design requirements for non-permanent facilities designed and constructed for use by the Department of Defense in support of military operations outside the United States where permanent construction is impractical.
- USACE has created the Center for Standardization of Non-Permanent Facilities. This team has developed design specifications for non-permeant facilities, particularly for contingency environments.

Even with these controls in place, abuse of prefabricated construction continues to occur. The 2018 the Office of the Inspector General has recommended to the Assistant secretary of Defense for Energy, Installations and Environment to update its guidance on how to classify re-locatable buildings. It also recommends that Navy and Marine Corps temporary facility procurement is coordinated and controlled through the installation's Department of Public Works (rather than through command organizations) to make sure temporary buildings are included in the installations' space planning and are properly inventoried and controlled.[57]

3.3.2 OTHER INTERNATIONAL ORGANIZATION POLICY & PUBLISHED RECOMMENDATIONS

We also interviewed various other international agencies, including Swedish International Development Cooperation Agency (SIDA), United Nations Office for Project Services (UNOPS), International Organization for Migration (IOM) and United Nations Human Settlements Programme (UN-Habitat). Although all cautioned about the use of prefabricated construction in development settings, only IOM had specific prefabricated guidance in their Transitional Shelter Guidelines. These guidelines stated that imported prefabricated shelters were not appropriate for transitional housing. The document states that:

> *Imported, prefabricated shelters are not appropriate because they do not respond to local contexts. Their fabrication, importation and construction take so long as to constitute another phase of response and delays reconstruction [and] their overall cost is often comparable to that of reconstruction. Tents would normally be used when there are insufficient local alternatives and when stockpiles can be airlifted. For these circumstances new transitional tents are under development. This development aims to prevent wastage of financial and physical resources through, for example, using a frame that can be upgraded with local materials. [58]*

Gordon Nuttal, an architect and head of Standards for UNOPS, did provide "Technical Guidance for Prison Planning." This is a planning and design tool UNOPS developed for United Nations Peacekeeping Operations (UNPKO). Although the document does not take a hard line for or against prefabricated construction, it does caution project planners with its limitations in an annex describing rapid

deployment options. In this annex, the guidance recommends that the prison planner consider the architecture, logistics, size limitations and costs with prefabricated structures. Below are excerpts found in Annexure 1: Rapid Deployment Options.

> *ARCHITECTURAL IMPACT*
> *… It may be substantially easier to obtain approval for a design based on traditional forms, building sizes and colors used by local contractors rather than an imported solution that is alien to its surroundings.*
>
> *Another consideration may include particular visual aims to help blend the facility into an existing neighborhood. As this is not achievable without a carefully customized design, standardized prefabricated solutions are not appropriate for this purpose.*
>
> *CONSTRUCTION TYPE AND MATERIAL CHOICE*
> *… A typical on-site construction technique (that uses a conventional concrete frame and slab with brick/block infill or fully reinforced concrete structure) may not be as expedient as prefabricated solutions that can be rapidly commissioned after delivery to site. The choice of materials for prefabricated modular solutions may vary from lightweight containerized solutions fabricated from typical shipping container sizes, or steel fabricated arch structures, to heavy concrete prefabricated panelized component systems as per some of the recent prison systems developed in the USA. This determination will partially depend on the necessary security levels, site conditions and accessibility considerations.*
>
> *The capacity to maintain and support the operational needs of the facility should also be considered. High technology solutions for materials or fittings may not be able to be maintained, leading to rapid abandonment of the facilities or adhoc solutions that compromise the safety and security of the prisoners. The choice of materials and fabrication technique may also need to consider the possible negative implications of using lightweight systems if the short-term solution is later modified to deliver a longer-term facility.*
>
> *"Where time is a critical issue, prefabricated solutions can be delivered fairly quickly, particularly if many of the components are already constructed and stockpiled and may be rapidly commissioned, ready for use. Such systems can be even more efficient with an established supply chain and logistics process developed and customized to suit the specific nature of prisons infrastructure deployment. However, significant transport and logistical issues may preclude the use of heavy duty robust prefabricated solutions."*
>
> *DEPLOYMENT METHODOLOGY*
> *…Where time is a critical issue, prefabricated solutions can be delivered fairly quickly, particularly if many of the components are already constructed and stockpiled and may be rapidly commissioned, ready for use. Such a system can be even more efficient with an established supply chain and logistics process developed and customized to suit the specific nature of prisons infrastructure deployment. However, significant transport and logistical issues may preclude the use of heavy duty robust prefabricated solutions. With regard to cost, most modular systems cost the same or are even more expensive than in situ building processes. [59]*

3.3.3 WORLD BANK POLICY

The World Bank has decades of school construction experience, which included prefabricated construction programs in Pakistan and the Philippines. These programs were designed to take advantage

of large contracts with modern manufacturing to rapidly deploy large numbers of classrooms. In both cases the prefabricated programs failed, and costs were substantially higher than traditional construction. [20] Although the World Bank does not have any specific regulations or standards, it does have a publication, School Construction Strategies for Universal Primary Education in Africa, that reviews these and other prefabricated projects and technology and recommends that schools in developing countries are not constructed with prefabricated systems. The World Bank published document Education for All: Building the Schools says that "Simple Modern Technology works" and provides the following reason.

> *Many early projects experimented with a range of "appropriate" technologies and procurement approaches. Most of these projects met difficulties because the designs called for construction techniques unfamiliar to local craftsmen, and not easily implemented by small-scale local contractors. The cost of providing technical support often exceeded any expected savings. The most successful classroom construction programs have been based on proven modern technology, with modest architectural standards and a minimum durability of 25 years. [27]*

3.4 COMPARISON OF CASE STUDIES FROM LITERATURE ANALYSIS

USAID Energy and Infrastructure Office provided an initial bibliography of 42 articles regarding prefabricated construction. This bibliography included prefabricated construction from developed countries, developing countries as well as regulations, standards and reports by agencies within the US government (primarily the Department of Defense – related). We also identified additional literature, mostly looking for information related to cost differences between prefabricated and conventional construction.

We found that many of the articles made unsubstantiated claims about prefabricated construction or based their assumptions on prefabricated construction in the context of a developed country where labor is scarce, and transportation is inexpensive. This contrasts with developing countries were transportation and logistics are often complex and labor is cheap and abundant. Using these criteria, we limited our review to 11 articles, which are listed in Appendix 7.

The following table includes strengths and weaknesses of various systems identified through the literature review. The literature review provided examples where prefabricated construction was faster and less expensive (Mostafa et al. 2014). Other articles proposed that prefabricated construction was more expensive (Theunynck, 2009) (Haron et al 2005). It is therefore evident that context largely drives potential prefabricated benefits or threats.

Table 3-1 Strengths & Weaknesses of Prefabricated Systems

Strengths	Weaknesses
Prefab can provide better results in some markets where there is little skilled labor (Kolo et al 2014)	Significant front-end investment and hard to get initial investment out (Evans 2011, Smith et al 2016, Kolo et al 2014)
Prefabricated construction can be cheaper and delivered faster some contexts, such as housing in Tanzania and India (Mostafa et al. 2014)	Lack of supportive standards for prefabricated construction in many countries (Kolo et al 2014, Mostafa et all 2014)
	High cost for major school building construction programs (Theunynck 2009), (Haron 2005)
	Reduced labor requirements and need to use specialized laborers for project implementation frustrates local community members (Theunynck, 2009).
	Poor project results such that the final report author recommended prefabricated construction not be used in the future (World Bank 1997, Cuny 1980)
	Prefabricated construction is a western technology and is often foreign in developing countries (Correia 2014, Rossen 2018)
	Difficult to re-train a local conservative construction market into using alternative construction methods and materials (Smith et al. 2016)

RESEARCH SUMMARY

The following table describes prefabricated construction based upon the 9 methods of characterizing prefabricated construction previously presented. A majority of the papers, especially those based upon historic projects, described negative results. This starts with the failed Ghana prefabricated housing program through to the 5 expensive or failed prefabricated schools program described by Theunynck in the Schools Construction Strategies report issued by the World Bank.

The greatest concern identified in the report was related to end-user acceptance of prefabricated construction. Even the articles that placed prefabricated construction in a more positive light, identified this as the greatest issue that prefabricated construction must overcome (Kolo et. al. 2014). The other negative issue raised by many of the articles was excessive cost. The final article by Haron et. al. evaluated the cost for panelized construction vs. conventional construction for a multi-story school facility in Malaysia and found that prefabricated construction was more expensive. Haron attributed this to greater competition and more skilled labor who are experienced with conventional construction (Haron 2006). Theunynck came to a similar conclusion in that the large prefabricated construction school programs limited the competition to a select group of international contractors capable of financing such an endeavor (Theunynck 2009).

Unfortunately, there was little data related to project quality or sustainability in the reports. Cuny was the only author that briefly addressed the issue of sustainability and quality when he described some of the poor detailing and connections of prefabricated systems provided for post-hurricane shelters in the Caribbean (Cuny 1980). Surprisingly there were no articles that specifically addressed prefabricated sustainability, which seemed to be the greatest issue identified in our interviews and field research.

Table 3-2 Summary of Prefabricated Construction Conclusions

Key: Positive | Neutral | Negative

	Title	Overall	Usability	System Meets Local Conditions	End-user Acceptance	Sustainability	Constructability	Cost	Schedule	Quality (meets specifications)
HOUSING CONSTRUCTION										
A	Prefabricated Housing, a Solution for Ghana's Housing Shortage									
B	Offsite Manufacturing: The way forward for Nigeria's Housing Industry									
C	Housing industrialization, success and failure, universal and local: Limits for housing globalization									
D	La Maison Tropicale: From Failure in Niamey to Masterpiece in NYC - Failed Architecture									
SCHOOL CONSTRUCTION										
E	School Construction in Developing Countries: What Do We Know?									
F	School Construction Strategies for Universal Primary Education in Africa: Should Communities Be Empowered to Build Their Schools?									
G	Implementation Completion Report, Kingdom of Morocco, Rural Primary Education Project									
H	Building Cost Comparison Between Conventional and Formwork System: A Case Study of Four-story School Buildings in Malaysia									
I	Prefabrication in Developing Countries: a case study of India									
OTHER										
J	Application of wind engineering research in the developing countries: Lessons from the Caribbean and India									
K	Offsite Manufacturing in Developing Countries: Current Situation and Opportunities									

3.5 PREFABRICATED CONSTRUCTION EXPERT INTERVIEWS

KEY INFORMANT INTERVIEWS

We've conducted interviews with a range of engineers, architects and development professionals that have been engaged in or witnessed prefabricated construction programs to understand their experiences as related to our literature findings; a total of 11 interviews have been conducted to date. We had a range of responses, but most interviewees, particularly those with significant development experience, were of the opinion that prefabricated construction is rarely the right choice for development settings and projects.

The results of the interviews are organized into 6 parts: 1) Overview of Interviews Performed; 2) Prefabricated strengths and weaknesses; 3) Prefabricated construction threats and risks; 4) Prefabricated construction best practices; 5) Potential opportunities identified through the interview; 6) interview conclusions and summary.

Table 3-3 Overview of Interviews Performed

Organization Interviewee Project Types	Interviewee Experience & Background	Discussion Overview
Médecins Sans Frontières (MSF) Carlos Cortez Henriquez Field Hospitals	Carlos Henriquez is a Construction Engineer with 17 years of experience. He is currently an engineer and logistics coordinator at MSF. Mr. Henriquez has overseen the development of a prefabricated construction model and then the subsequent implementation and field construction of that model in South Sudan.	MSF went through several concept iterations for prefabricated field hospitals before landing on the current model. The currently utilized system consists of panelized aluminum framing. The system includes a raised, overhanging roof design that allows space between the roof and the building which reduces solar heating of the roof surface and improves ventilation within the building. This system is deployed in South Sudan, Sierra Leone, and Mauritania. MSF are preparing to deploy the system in Afghanistan. MSF procures, coordinates, transports and manages the field installation of their systems.
United States Air Force Civil Engineering Command (USAF CEC) Antonio Dorsey Offices; Housing	Anthony Dorsey is an architect for the USAF CEC. He was the project manager for prefabricated facilities in the United Arab Emirates (UAE).	The Air Force structures in the UAE were metal frame and metal panelized 100mm polystyrene construction. The building superstructure and panels were welded together in the factory and placed as full units with a large crane. Mr. Dorsey felt the final quality was good for US military use as a short-term-forward operating facility.
SIDA Thomas Melin Refugee Response (Multiple Building Types)	Thomas is an architect / planner at SIDA. He has over 30 years of development experience.	Mr. Melin stated that the average length that a refugee lives in 'temporary' locations is 17 years. This has led to a re-thinking of emergency situations with a more emphasis upon planning with the long-term in mind. In his experience prefab has posed significant problem in refugee or disaster settings, particularly with regards to community acceptance and sustainability.

USACE –Center for Contingency Standardization Dale Hartmann Operations Facilities, Housing, Maintenance Structures	Dale Hartmann has 30 years of military engineering experience and is currently the head of the USACE Center for Contingency Standardization.	The Middle East District of USACE has overseen billions of dollars in development, and much of it has been prefabricated construction. USACE is moving away from typical commercial prefabricated construction, though. The Contingency Center for Standardization has developed two of their own construction systems as a response to addressing issues of concern. One system is a metal sandwiched insulation panel (SIP) that uses non-flammable rockwool insulation. The system can be developed with common materials, installed without machines and can be transported to the construction site by light trucks. The second system is stabilized packed earth block construction. This system has been successfully deployed in 23 sites by military construction units. Minimal training is needed for installing this system.
Cobo Construction Alex Cobo Primarily Schools & Education Facilities	Alex Cobo owns Cobo Construction and has 35 years of general construction experience in the US, Nigeria and Mali. He oversaw modular school construction in US and conventional schools in Mali.	Mr. Cobo began by saying that although he has explored its use in Africa, he has not found a prefabricated system that is cost effective. In addition to cost, Alex was concerned with prefabricated durability given most prefabricated systems have much weaker walls and the doors/windows are lighter. In Africa typical doors/windows are heavy and louvered, which rarely work with light prefabricated systems.
John Snow Inc. (JSI) Shahzad Akbar Healthcare Consultation Centers, Health Storage Warehouses	Shahzad Akbar is a 15-year procurement and supply chain professional in the management and implementation of international development and public health programs. He has overseen the procurement of prefabricated construction systems for JSI in Zambia.	JSI has a Public Health Contract with USAID in Zambia that included the need to build consultation centers and health warehouses. JSI had engineers lay out the project sites (which were generally attached to existing clinics) and develop the procurement requirements based upon local codes and environmental conditions. The contractors did need to install the facilities with cranes at the site. Overall Mr. Akbar and JSI were content with the outcomes and the buildings met program needs. Mr. Akbar said that prefabricated buildings are becoming more common in Africa and sees prefabricated construction as an excellent alternative for getting construction underway.
UNOPS Gordon Nuttall Multiple Building Types	Gordan Nuttall, a trained architect with over 30 years of international experience, is currently head of standards for UNOPS.	Although UNOPS does not have any specific guidance regarding prefabricated construction, Mr. Nuttall did provide a prison design document for DPKO. In this document, UNOPS cautioned prison planners from immediately thinking prefabricated construction is the appropriate option. UNOPS does provide international

		organizations the ability to purchase 20' or 40' containerized modular units that public agencies can purchase for housing, offices, showers, bathrooms etc.
USAF CEC Daniel Weeks Offices, Housing, Police Stations, Classrooms	Daniel Weeks is a US Airforce Civil Engineering Officer. He was deployed to Afghanistan and oversaw prefabricated construction and installation for the US Military and Afghanistan Security Forces	Nearly all construction that Mr. Weeks oversaw in his deployments to Afghanistan was prefabricated. These prefabricated units were constructed from 20' and 40' containers. The container fit-out was designed by a US engineering firm with standard drawings for multiple types of facilities (housing, bathrooms, offices, classrooms, armories). Afghan companies completed the fit-out and site installation. The units could be configured and stacked.
UN Habitat Laura Petrella Refugee Response (Multiple Building Types)	Laura Petrella is a planner with nearly 25 years of international development experience. She is the leader of the city planning team in the UN human settlements program. In that role she is exploring urban design issues specifically as they relate to refugee resettlement.	Ms. Petrella and the urban development team are engaged in re-thinking and assessing how refugee communities are developed. These are long-term developments rather than short-term events and UN Habitat team does not necessarily see immediate solutions as appropriate. Also, construction is a major economic sector and prefab somewhat bi-passes this development consideration. The other issue that Ms. Petrella and her team raised was the importance of understanding the unequal relationship between donors and recipients and how this relationship impacts infrastructure options.
IOM Brian Kelly Refugee Response (Multiple Building Types)	Brian Kelly is a development professional with over 20 years of experience. Mr. Kelly was the Project Manager for the development of IOM's Emergency Shelter Guidelines which specifically address temporary housing needs for migrating communities, usually in crisis situations.	Mr. Kelly states that for transitional communities prefabricated construction is not an appropriate option because: 1. Prefab is about the same price as permanent solutions. 2. Refugees are often located in very insecure location with land tenure issues. 3. Shelter needs to be considered a process and support change, and 4. Prefabricated facilities are difficult and costly to maintain.
USAID - Malawi Radhan Cumaraswamy Schools and Warehouses	Radhan Cumaraswamy is the USAID Infrastructure Specialist in Malawi.	Mr. Cumaraswamy has developed the scope of work for the procurement of prefabricated schools in Malawi. In developing this procurement, he has reviewed multiple prefabricated schools and buildings throughout Malawi and South Africa. He has also reviewed the successful USAID "pharmacy in a box" project in Malawi. We primarily discussed USAID drivers and when prefabricated construction might be successful.

Table 3-4 Prefab Strengths and Weaknesses--What do the Experts Say?

Interviewee	Strengths	Weaknesses
Médecins Sans Frontières Carlos Cortez Henriquez	• Less materials to ship for an austere environment. In areas where materials are not available, it is cheaper and easier to ship. • Quick installation once materials are on site. With all the site work completed ahead of time and a knowledgeable team leader, a small crew can install the facility within 21 days. • Quality is known from the start. You don't have to worry about the material quality – you know what you are getting from the factory.	• Cost (2x cost of other types). • Logistic coordination is intense. Much more difficult issues with customs. Also, logistics need to be planned from factory to site. • Since the floor is not concrete, it has much lower load capacity than what is needed for a field hospital. • Buildings can be hot if not oriented correctly. Since the structure is aluminum it becomes quite hot and if not shaded can transmit heat to the inside. Similar issues with windows and must be addressed.
US Air Force Antonio Dorsey	• Fewer cost changes during construction. Since the unit is set from the start there are few cost changes. • Well-insulated and overall good environmental conditions. The prefab units had 4" of insulation and there were no issues with cooling the units in extreme climates.	
SIDA Thomas Melin		• Prefab construction does not fit well with community customs and practices. It is difficult to build and develop communities around prefabricated construction. Most don't fit the local vernacular, building practices and the way people live. • There are rarely cost or schedule benefits to prefabricated construction. Construction requires the same amount of site work, including the installation of utilities, which is significant in time and cost. The building cost itself is not cheaper than conventional construction. • It is difficult for communities to sustain prefabricated construction. If the system is inconsistent and spare parts are not in inventory, it is difficult for end users to maintain the facilities. Also, the systems are normally made so that it is difficult to repair or replace parts if they are damaged.

		• There are often issues related to disposing or reusing prefabricated facilities. Mr. Melin has never seen anyone able to redeploy prefab facilities. In every case it is too expensive to deconstruct and transport out of the location and the panels are damaged during disassembly. Also, prefabricated construction materials cannot be easily reused.
USACE Dale Hartmann		• Prefabricated construction is usually not as fast and there are greater scheduling risks. There is a long supply chain and any break in that chain means you don't get a critical facility up and running and have no workaround. That can include transportation delays, missing or damaged parts, etc. • Typical prefabricated construction has poor insulation properties and are expensive to cool / heat. Prefab construction generally has metal studs so even if the building is insulated, the studs transmit significant heat and cold dropping the R-value over 50%. • Prefab is does not meet normal standards. Given that most prefabricated facilities are considered temporary, they do not need to meet regular building codes impacting longevity and safety. • Prefab construction can off-gas deadly gasses if it catches on fire. Many of the common metal-sandwiched foam insulation have insulation that off-gas dangerous gases if it catches on fire. • Prefabricated construction rarely meets its design life. The common sandwich construction is not water-proof and moisture easily gets between the insulation and metal. The insulation holds water and corrodes the metal from the inside. If the units are anywhere near saltwater they essentially dissolve in a few years. Also, the panels are often damaged during transportation and installation, which severely reduces the lifespan. • Prefabricated construction nearly always requires cranes, qualified riggers and safe rigging equipment. In many cases the military operates where none of these were present. Rigging safety is a specific concern as the rigging straps have a specific life-span and are often over-used and frayed. • Prefabricated construction cannot be re-used and pose issues during disposal. The panels are generally damaged, pieces are missing, and instructions are no longer available. Also, the sandwiched insultation is a hazardous material and the USG is currently struggling with disposal in many locations.
Cobo Construction Alex Cobo		• Prefabricated construction is costlier. • Prefabricated construction is less sustainable especially for high use environments. Since the walls

		are less robust for prefab facilities, they must have lighter doors and windows. In Africa, school doors and windows are louvered and heavy allowing light and air to come in and support the heavy use of such facilities. Also, floors must be concrete to withstand heavy use.
John Snow Inc. Shahzad Akbar	• Fewer schedule delays. Contractors had knowledgeable teams that are used to installing the prefab system. • Simplified procurement. Prefabricated procurement has fewer changes. • Better quality outcomes. Factory-produced material have better quality control and outcomes.	
UNOPS Gordon Nuttall		• Prefab is not cost effective unless it's a large program. Even then its typically a huge program that requires significant management of the entire supply chain such as the current UK prefab prison building program. • Prefab is rarely culturally appropriate. One must consider what is considered community and how structures fit. In Asia prefab buildings do not fit given how neighborhoods are structured. • Prefab is lightweight and is not as durable. In nearly all cases prefabricated construction is lightweight and the spacing between structural elements are often 3m or more. This allows for significant bending in the units and rapid damage over time. • Prefabricated construction cannot be modified. It is impossible to make field modifications once the system has been construction. More importantly, you can't add things to the roof or structure (e.g. a solar unit, air conditioning unit, etc.). Any additional loading or cutting will impact the structural integrity as it is designed with no additional load tolerance.
USAF CEC Daniel Weeks	• Required little on-site work to install. In cases where workers need to be cleared and when getting people on site takes time, prefab limits the amount of labor required at the project site. • Can be procured, built and installed quickly. The US Military used a standard design with pre-cleared vendors who understood the requirements and could quickly deliver the modular units. • Can be installed in remote areas. In Afghanistan it was hard to find materials or identify labor in	• Prefabricated construction requires significant energy for heating and cooling. The containerized units used in Afghanistan were not well insulated and required mechanical heating and cooling. • Does not provide good cross breeze and is not well-suited without mechanical heating / cooling. In some cases, the Afghan security forces abandoned the facilities as they were too uncomfortable and hot. • No blast protection.

	remote areas. This provided a rapid, simple solution.	
UN Habitat Laura Petrella		• Represents a lost livelihood opportunity. Construction makes up a significant percent of any economy (over 10% in developing economies) • Does not allow growth and building modifications. • By its nature it by-passes the community participatory process. • It is generally not sustainable – you need to import it and it does not include local materials. • Does not normally fit with local building uses or with how communities and infrastructure interact. • Generally, does not support passive heating or cooling.
IOM Brian Kelly		• Prefabricated negates the value of any earlier input. Shelter and building development are process not events. • Prefabricated negates the value of any earlier input. Shelter and building development are a process not an event. • Does not typically allow movement which is required given land tenure concerns. We have the responsibility to give to the most vulnerable, yet they often are the least land secure. • Doesn't use or integrate with indigenous architecture. It's a supply-chain driven product and not a community driven product. • Is not sustainable. You don't have a supply chain when things break. • It does not support community participation. People care with what they helped make (e.g. remember the study where people are more likely to use a mosquito net they buy?). • Material can't be re-used. The utility of prefab is quickly lost if the needs change. Most current shelter systems are designed for multiple uses and phases.
USAID Radhan Cumaraswamy	• Rapid Procurement and Installation. USAID can procure the units much faster and installation for simple systems is rapid. • Provides a quality outcome with less oversight. Conventional construction oversight is labor-intensive and sometimes it's difficult to find and deploy enough capable staff.	• Fire Safety is Problematic. The polystyrene sandwiched panels can become a fire hazard. • Is not appropriate for complex facilities. It is difficult to modify prefabricated or modular units.

Table 3-5 Potential Threats & Risks When Implementing Prefabricated Construction

Interviewee	Prefabricated Construction Threats & Risks
Médecins Sans Frontières Carlos Cortez Henriquez	• **Site Planning should be the same as conventional construction.** Site planning and site preparation was a critical component to project success and site preparation is generally the same as conventional construction. In MSF's case they had very detailed site drawings and in most cases, they tried to complete the site construction prior to bringing the prefabricated system to the site. • **The system must be designed for the specific environment conditions.** • **Building orientation should be well thought out.** Building orientation was an important aspect of site planning so that the system took advantage of prevailing breeze and shade. Shading is critical for improving internal comfort. • **Transportation must be considered from start to finish.** Make sure you know the entire logistics trail from start to finish, especially with regards to customs (where it can get delayed) as well as delivery to the final site (e.g. by boat, lorry, etc.). • **Conduct detailed inventory of parts / secondary QC check before shipment.** Prior to shipping do a detailed material inventory as missing a small piece can be catastrophic. Also make sure that containers are loaded correctly, and you know where material is located prior to shipment.
USAF CEC Antonio Dorsey	• **Project Foundations require tighter tolerances.** Get the foundation correct as this will impact how easily and quickly the building can be installed. • **Oversight and control are the same for conventional construction-includes oversight at the factory.** Many of the same issues as conventional construction occur with all elements, which means that it is important to oversee factory fabrication. It is much easier to fix problems in the factory than at site when it is too late.
SIDA Thomas Melin	• **Re-use or disposal of the material should be considered.** In nearly all cases it is too expensive to deconstruct and transport out of the location. In many cases the material is left as an eyesore because unlike conventional construction, it is difficult for anyone to reuse the materials.
USACE –Center of Standardization for Non-Permanent Facilities Dale Hartmann	• **Prefabricated construction often requires cranes, qualified riggers and safe rigging equipment.** Rigging safety is a concern especially as the rigging straps have a specific life-span and are often over-used and frayed. Furthermore, lifting equipment is often unavailable and even if it is, operators are not used to following safe practices. • **Understand the full supply route and supply chain.** The supply chain can be quite long and cross multiple countries. Be aware of the route, customs requirements and in the last section the roads and bridges (bridge width was often an issue the US military encountered).
Cobo Construction Alex Cobo	• **Prefabricated construction needs a good foundation and the building must be anchored.**

	Often people think that prefabricated construction does not need a strong foundation. Since the structure is light, it should be securely anchored to the foundation to reduce the chance of wind damage. • **Foundation anchors require close tolerances for the structure to fit properly.**
John Snow Inc. Shahzad Akbar	• **Understand how US carrier requirements may impact shipment**. Since the materials are typically sourced outside the country, US-flag carrier requirements can create a substantial delay.
UNOPS Gordon Nuttall	• **Consider cultural contact and appropriateness**. The neighborhood and other architectural units need to be evaluated so prefabricated construction fits with its surroundings.
USAF CEC Daniel Weeks	• **Understand heating and cooling requirements**. Many prefabricated systems are designed for use with mechanical cooling or heating. Such systems may have limited use if mechanical heating/cooling is unavailable.
UN Habitat Laura Petrella	• **Consider the unequal donor-recipient relationship.** The unequal relationship already strains the interaction. Support is best provided in a participatory method and one should be cautious of how prefabricated construction may negatively impact that process.
IOM Brian Kelly	• **Consider Land Tenure.** If prefabricated construction is used during a disaster or post-disaster period, understand the impacts of land tenure as prefabricated construction cannot be easily moved.

Table 3-6 Best Practices Considerations

Project Phase	Best Practice Considerations
Pre-Design **Feasibility Assessment & Program Development**	• **General:** Before considering prefabricated construction, understand its limitations, particularly with relation to cost, sustainability and use limitation. • **General**: Do not immediately conclude prefab. Do an analysis of options, conditions and especially understand transportation and security requirements. Understand how material will travel from start to finish in detail (e.g. bridge widths, roadway, customs, banditry etc.). • **Cumaraswamy**: Understand the oversight requirements and complexity especially for many small sites. • **Nuttall**: If you are considering prefab for temporary construction, other solutions may be more appropriate such as tents, existing buildings etc. • **Cortez H**: Understand the context and local conditions. If its speed and lack of local materials, then consider prefabricated construction. If not, conventional construction is likely a more cost-effective option. • **Cobo**: Consider prefab for controlled environments with complex equipment (e.g. labs, x-ray or other medical faculties, power plant control rooms, and possibly cold storage facilities). • **Nuttall/Me**lin: Recognize the local building customs and practices. Does the prefabricated system fit into that system or community? And for emergency situations, recognize that the construction will probably be around longer than you think.

	• **Nuttall/Petrella/Kelly**: Recognize that infrastructure is a process and that building use may change. Modifications are often difficult or impossible with prefabricated construction. • **Melin / Hartmann**: Consider the material life cycle and disposal of the material at the end of its lifespan. • **Cortez/Weeks**: Understand the benefits and limitations of the proposed system with regards to heating, cooling, ventilation and lighting. • **Petrella/Kelly**: Include the end-user in the project development, design and implementation process.
Design Development Activities and Building Considerations	• **Cortez H and Hartmann**: As with all construction, consider and develop the site, including drainage, foundations and utility connections. • **Cortez H**: Consider building orientation to take the greatest advantage of passive ventilation and building heating / cooling. • **Cobo and Akbar**: Engage an engineer that understands local requirements, standards and practices. • **Hartmann**: Consider the roof design as this is a major failure point and flat roofs are especially prone to failure. • **Hartmann/Cumaraswamy**: Understand and consider material fire safety. • **Hartman**: Identify if supply parts and materials can be sourced in the local market. • **Cobo and Weeks**: Understand the requirements, particularly making sure that fittings, fixtures, windows and doors are sufficiently robust for heavy use.
Procurement	• **Akbar**: Favor local suppliers / installers who know the local operating conditions and do their own construction. • **Akbar**: Allow short-listed contractors to provide feedback and recommendations for cost improvements or to identify considerations. • **Cortez H**: Have a clear scope of your needs but allow the supplier flexibility on materials, sizing and structure to maximize their standard tooling and system.
Construction/ Program Oversight	• **Cobo/Dorsey**: Maintain the similar level of oversight as conventional construction (though for shorter periods). • **Cortez H/Dorsey/Weeks**: Conduct factory assessments prior to shipment to verify that materials meet agreed specifications and quality requirements. • **Hartmann/Dorsey/Cobo**: Understand and take care to make sure that the foundation and building connections are installed correctly. A mistake can be costly.

POTENTIAL OPPORTUNITIES WHEN IMPLEMENTING PREFABRICATED CONSTRUCTION

The following describes some of the opportunities that relate to prefabricated project development and infrastructure development identified during our interview process.

1. *Prefabricated facilities for controlled environments with complex equipment:*

Alex Cobo witnessed prefabricated medical units with pre-installed x-rays, MRIs at several private hospitals and clinics in Nigeria. Such equipment requires experts from the equipment manufacturer for installation and commissioning. In-country installation and commissioning costs are often very expensive due to travel requirements for manufacturer personnel. Therefore, installing these systems in a modular unit can significantly reduce that cost. We would expect this to also work for control rooms (e.g. water plans, power generation facilities).

2. *Stabilized Earth Block Construction:*
The US military and UN Habitat are promoting the use of stabilized earth construction as an alternative to prefabricated construction. USACE Middle East District (MED) Center for Standardization of Non-Permanent Facilities have conducted studies, developed plans, and developed training on how to construct with stabilized earth block. They have modified common practices to improve structural integrity. To deploy the system, USACE purchases specific earth-block machines as commercial items for around $30K and ships them to remote locations. Dale Hartmann and his team at USACE are an available resource and can be reached at: (540)665-2684, Dale.r.hartmann@usace.army.mil. Similarly, UN Habitat has a document regarding interlocking earth block construction and some best practices in Uganda. This document can be found at: https://unhabitat.org/books/interlocking-stabilised-soil-blocks-appropriate-earth-technologies-in-uganda/

3. *UNOPS Standardized Modular Units:*
The UNOPS has developed a set of standard modular prefabricated units that are based upon 20' – 40'containers for housing, offices, kitchens, medical facilities etc. The unit cost is very reasonable (around $6,000 for a 20'container vs. around $2,500 for an empty container). These prefabricated units are available through UNOPS managed UN Webbuy: https://unwebbuyplus.org. UN Web Buy is for projects that are consistent with UN goals and objectives for assistance in developing countries. Eligible clients include organizations within the UN system and organizations cooperating with the UN system such as donor governments, aid organizations and internationally recognized NGOs.

4. *SHERPA for sustainable housing design in the Global South:*
Habitat has developed a housing assessment tool to help communities maximize sustainable through a holistic and process view of housing infrastructure for both rural and urban areas. It evaluates sustainability based upon 4 pillars – environmental, cultural, economic and social. The UN Habitat team we talked to has been using this to help inform their design process at the refugee camps in North Kenya. The UN Habitat team thought that such a tool or tool concept could be used to help develop any building-related program. A presentation of SHERPA can be found at: https://www.sherpa4housing.org/files/SHERPA%20Presentation.pdf. Also see: https://unhabitat.org/sherpa/.

5. *Using Prefabricated Building Concepts for Traditional Building* Elements:
The UN Habitat Team thought that prefabricated manufacturing concepts may have usefulness with infrastructure elements that would support traditional building methods. An example is prefabricated roof trusses and bamboo mats needed in the Somali refugee camps in Northern Kenya. Other examples might be window / door fabrication.

The development of small field factories to manufacture building elements within refugee communities could support all sustainability pillars and provide needed materials for community development.

6. *Simple, Robust, Prefabricated Construction System:*
Radhan Cumaraswamy witnessed prefabricated structures that were built for construction labor in the 1960s and are currently used for student housing. They were constructed of asbestos-based panels and a robust steel superstructure. Unfortunately, there is no cost-effective and durable replacement for asbestos, but this example does prove that robust prefabricated structures do exist and can achieve extremely long life-spans and can be reused and modified. However, these types of facilities somewhat bypass the supposed benefit that light-weight materials provide.

KEY INFORMANT INTERVIEW SUMMARY

Overall, the interviewees, particularly those with development experience, preferred conventional construction. One of the major concerns was limited end-user involvement and lack of use of materials and structures that end-users understand. Laura Petrella, from UN Habitat, said it best when she described the problems surrounding the unequal relationship between donors and beneficiaries and how important it is to have community involvement to maximize infrastructure's benefits. Given its nature, prefabricated construction is often an example of that unequal relationship and by its nature limits participation.

In general, the interviewees experiences contradicted the common perception that prefabricated construction is cheaper and even faster. As Thomas Melin, an architect and 30 plus-year development professional at SIDA stated, "Why would you want to use a prefabricated system that costs more, rarely saves time and brings in a whole host of other issues?" Mr. Melin also raised the concern that construction should be appropriate and fit within a community; prefabricated construction rarely considers that fit. Similarly, Gordon Nuttall, an architect and head of standards at UNOPS, described how buildings are always around longer than planned and are regularly modified. Any modification to prefabricated construction poses problems to the structure's loading capacity and sustainability.

The negative aspects aside, there were some examples in which prefabricated construction provided cost-effective and appropriate solutions. Alex Cobo of Cobo Construction witnessed prefabricated private medical facilities used effectively in Nigeria. Complex medical equipment, such as an MRI or X-ray were shipped together with its modular operating facility. In this example it was cost prohibitive for the supplier to send a specialist team to install the equipment and therefore ready-installed systems were cost effective. Carlos Cortez Henriquez of MSF had a very small construction window in South Sudan with no local construction materials or construction labor. A prefabricated solution provided a low-weight, low-labor, rapid response to an extremely austere environment.

Finally, Radhan Cumaraswamy of USAID Malawi described the "Pharmacy-in-a-Box" program. In this case, USAID procured and installed 115 prefabricated climate-controlled medical storage warehouses for installation at various medical facilities around Malawi. A prefabricated system was a cost effective, rapid and well-insulated solution that supported other USAID health programs and objectives. A conventional solution would have taken significantly longer to procure and would have required much more oversight and control at numerous small sites. Additionally, meeting the building tightness and insulation requirements would have been problematic for most local contractors.

The following graphic summarizes the interviewees' experience regarding the stated Qualifying Attributes.

Table 3-7 Summary of Prefab Qualifying Attributes

Key: Positive | Neutral | Negative

	Qualifying Attributes of Prefabricated Construction							
Organization and Interviewee	**Usability**	**Meets Local Cond.**	**End-user Accept.**	**Sustain-ability**	**Construct-ability**	**Cost**	**Schedule**	**Quality**
Médecins Sans Frontières Carlos Cortez Henriquez								
USAF CEC Antonio Dorsey								
SIDA Thomas Melin								
USACE Dale Hartmann								
Cobo Construction Alex Cobo								
John Snow Inc. Shahzad Akbar								
UNOPS Gordon Nuttall								
USAF CEC Daniel Weeks								
UN Habitat Laura Petrella								
IOM Brian Kelly								
USAID-Malawi Radhan Cumaraswamy								

3.6 PROJECT FIELD ASSESSMENTS AND DISCUSSIONS WITH END-USERS

Nepal	Health Clinics	Recent Construction (1-2 years)
Malawi	Schools	Older Construction (15 years +)

The field assessment portion of this evaluation observed two very different projects sites in distinct geographic settings. Field Assessment Site No. 1, Nepal Health Clinics, is a recently constructed health facility in a post-disaster environment. Field Assessment Site No. 2, Malawi Schools, were constructed under "normalized" conditions 5-20 years ago. The evaluation team conducted the Nepal Field Assessment in October 2018 and USAID engineers conducted the Malawi Field Assessment in September 2017.

The Field Assessments evaluated building utility, sustainability and overall quality. Assessment findings aligned with the literature review determinations and interview results. The one observed exception to the findings is that in Nepal, prefabricated construction costs were reportedly lower than conventional.

As the result of these two Field Assessments, the primary issues with prefabricated construction are observed to be:

1. Lack of sustainability and building longevity. The photo to the right of Malawi Schools shows a prefabricated building on the left that will soon collapse. Built 15-20 years ago, it sits next to school built nearly 40 years ago that was constructed using conventional methods. Also, the end-users did not have access to appropriate repair materials or the ability to repair the prefabricated buildings.

2. Difficulty in modifying facility layout. All of the prefabricated schools in Malawi have been modified, but, modifications in prefabricated facilities are difficult and can reduce the building longevity.

The results of the Field Assessments are organized into six parts:

1. Overview of Project Field Assessments
2. Field Assessment Findings
3. End-user Discussions
4. Nepal Prefabricated Implementer Discussion
5. Prefabricated Strengths and Weaknesses
6. Summary of Results

Vama School Complex Prefabricate vs. Conventional Constructon (image by IMC Staff 2018)

3.6.1 OVERVIEW OF PROJECT FIELD ASSESSMENTS

Nepal experienced a major earthquake in April 2015 that destroyed a significant portion of infrastructure. In the aftermath of that earthquake, there was an immediate need to repair or replace damaged health clinics. Numerous organizations engaged in responding to this need, largely by using prefabricated building systems. Over 350 prefabricated clinics were constructed in and around the earthquake-affected areas of Nepal. 74 of these facilities were completed by the United Nations International Children's Emergency Fund (UNICEF) alone. The Field Assessment evaluation team met with the UNICEF engineering team and reviewed Three clinics they constructed as well as prefabricated clinics implemented by the German Technical Cooperation Agency (GTZ) and Opportunity Village Nepal. Three conventionally constructed facilities were reviewed that were built by the Government of Nepal over the past 1-2 years.

In contrast, the prefabricated facilities in Malawi were constructed to support growing communities with increasing numbers of students. In all but one of the assessed cases, there were existing conventionally-constructed school buildings in the same campus. Most of the conventionally constructed buildings were built approximately 35 years ago. Three of those buildings are of the same prefab system, and it is determined that they were constructed approximately 20 years ago by either a tobacco company or UNICEF. The other assessed prefabricated facility was implemented by the government of Korea and was constructed 5-6 years ago.

The table below provides a comparison of Field Assessment Sites.

Table 3-7 Comparison Overview of Field Assessment Sites

Location & Type	Type	Implementer	Number Reviewed	Discussion of Construction
Nepal Health Clinics	Prefab	UNICEF / GIZ and Opportunity Village	5 Sites	UNICEF implemented clinic reconstruction program after the 2015 earthquake. 74 structural metal insulated paneled clinics were installed with an average size of about 100 square meters. Most of the clinics are completed, but the program is set to end in December 2018. The clinics have a planned life-span of 10 years. GTZ implemented a wood-reinforced panel design and the Opportunity Village Nepal implemented a concrete – insulated panel design.
	Conventional	Nepal Government	3 Sites	The Nepal government is overseeing construction of health clinics after the 2015 earthquake. These were two-story brick facilities. One assessed clinic was built just before the earthquake 5 years ago.
Malawi Schools	Prefab	Tobacco Companies or UNICEF; and Republic of Korea	4 Sites	Three sites – Shire, Nkomadri and Mvama were older facilities. Tobacco companies or UNICEF (end-users are unsure of the implementer) installed schools around the capital of Malawi about 15-20 years ago. These schools were constructed with structural insulated panels. The fourth site– Tsabango 1 was funded by the Republic of Korea and dedicated in 2013. This facility was constructed of a robust metal superstructure with weaker insulated panels.
	Conventional	Various Implementers	3 Sites	All of the campuses with the exception of Nkomadri have conventional masonry school buildings. These buildings also have wood timber roof frames and metal roofs. Reportedly, most of the schools were constructed through World Bank funding in the 1980s.

3.6.2 FIELD ASSESSMENTS FINDINGS

This section contrasts prefabricated construction with conventional construction. The assessments in Nepal and Malawi were conducted differently. In Nepal the sites were spread out, so the 5 prefabricated facilities are contrasted with the 3 conventional facilities. In Malawi prefabricated and conventional

constructed facilities were located in the same campus, so assessments are described by site – Shire, Nkomadri, Mvama and Tsabango

1. Field Assessments were observed against the following prefabricated Qualifying Attributes:

Usability: Usability considers the building's capacity to support the end users' needs and comfort. This includes building size, room configuration and temperature/lighting issues. This also includes the evaluation of passive design elements, such as which effect facility comfort.

Sustainability: Sustainability considers the building's longevity. This includes design criteria, site preparation and if the end-user could effectively maintain the facility over the anticipated life cycle of the building.

Quality of construction / materials: This attribute considers the building's physical condition – both material strength and current condition. Since the facilities are new in Nepal, there are fewer issues that are assessed in as failures. In contrast, the facilities in Malawi are much older and have experienced significantly more wear and show evidence of construction and material failure.

3.6.3 END-USER DISCUSSIONS

3.6.3.1 NEPAL HEALTH CLINICS

TABLE 3-8 NEPAL HEALTH CLINICS: USABILITY

Usability Overview	
Prefabricated Construction	**Conventional Construction**
• The buildings met end-users' basic needs and were fully operational. • End-users complained that two facilities get hot and that there are chemical smells when the buildings are warm. • End-users complain that private consultations are difficult, due to lack of sound insulation. • End-users are unable to install heavy medical equipment on the walls. • End-users of all facilities would prefer conventionally constructed buildings.	• The buildings met end-users' basic needs and were fully operational. • Layout aligns more closely to end-user requirements, especially related to storage.

8 facilities were assessed in October 2018, after the warm period and before the rainy season. In general, the end users are happy to have facilities to utilize, in the wake of the earthquake. However, in every case the end-users would have preferred conventionally constructed buildings. Conventionally constructed clinics have more rooms and have sufficient storage. This is something end-users complained about with each of the prefabricated facilities.

The prefabricated buildings in Nepal exhibit several shortcomings in how they are constructed. End-users are not able to install heavy medical equipment on the walls. End users indicate that the facilities are not constructed to be sound-proof between rooms, so they cannot hold confidential conversations with patients.

At two facilities, end-users complain that the buildings get hot. At one facility, users state that when the building is excessively warm, there is a chemical smell, that may be the result of off-gassing from flooring adhesive.

All facilities take advantage of natural lighting, and the natural ventilation is also well-designed. However, it is unclear if the buildings are optimally placed on their respective sites.

In general, all the Nepal facilities are useable and meet the basic needs and requirements of the end-users.

Nepal: Exterior of Chaugadha Health Post
(Image by IMC staff, 2018)

Nepal: Nalang Health Post (prefab)
(Image by IMC staff, 2018)

Nepal: Abukhaireni Health Post (conventional)
(Image by IMC staff, 2018)

Nepal: Bakhrang Health Post (prefab)
(Image by IMC staff, 2018)

TABLE 3-9 NEPAL HEALTH CLINICS: SUSTAINABILITY

Sustainability	
Prefabricated Construction	**Conventional Construction**
• Replacement materials are not present in the market place • Workers have no experience with prefabricated material. • The design-life of the facilities is 10 years.	• Replacement materials can be found on the market and end-user has the capacity to maintain the facility. • Overall the facility was well-constructed and with effective maintenance should last up to 50 years.

The buildings appear to meet local design requirements, with the exception being the prefabricated Opportunity Village building at which a premature roof failure is likely due to a poor design. Site work, though, appears to be well-planned at all of the conventional and prefabricated facilities.

The main issue with Sustainability is that end-users are not able to find replacement materials for the prefabricated buildings in the local market.

Most of the clinics are located far from Katmandu and the prefabricated materials required to repair the buildings are not found in the local market. Moreover, local workers have no experience working with the prefabricated materials.

Some of the buildings already have leaking roofs. Local workers will have difficulty making repairs to the roofs, much less identifying the underlying causes of the leaks. This contrasts with the conventional construction where materials are present in the local market and workers understand the construction techniques.

Nepal: Khoplang Healt Post drainage (conventional)
Image by MC staff, 2018)

Nepal: GTZ Facility drainage (prefab)
Image by IMC staff, 2018

TABLE 3-10 NEPAL HEALTH CLINICS: MATERIAL CONDITION

Material Condition	
Prefabricated Construction	**Conventional Construction**
• The prefabricated construction quality is not as good as the conventionally-built facilities. At some buildings there are gaps between the wall panels, as it seems that the workers did not know how to properly install the panels. • At two facilities, end users complain of roof leaks which are likely due to poor construction. • Doors / Windows are less robust than at the conventional buildings. • Plumbing joints are leaking in 4 out of the 5 prefabricated facilities. One facility showed signs of serious water damage from plumbing leaks. • The roof at the Opportunity Village is partially collapsed.	• Overall construction quality is very good. • Doors and Windows were robust. • Roof design is problematic. The flat, reinforced concrete roof design does not seem to have adequate waterproofing. • At the sloped roof, the builder installed a plastic-type covering that had been damaged in a storm and was not repaired. The detail of the roof flashing installed at the building perimeter is inadequate and has interior damage from water infiltration.

Overall, the material and construction quality are significantly worse at the prefabricated buildings than were observed at the conventionally constructed buildings.

Nepal: Nalang Health Post lightweight doors (prefab), Image by IMC staff, 2018

Nepal: Khoplang Health Post heavy dors (conventional), Image by IMC staff, 2018

In Nepal, as evidenced through field observations, local workers and builders have difficulty assembling prefabricated components. A number of end-users have complained about roof leaks during the rainy season. One facility has gaps in the perimeter roof flashing. Deficient installation has resulted in leaking plumbing. At one building, the leaks have caused extensive water damage.

Another concern is the durability of the construction materials. The doors and windows of the prefabricated building are not heavy duty, as they appear to be on the conventional construction. Although no windows or doors have failed, they are not sufficient for the heavy use a health facility might receive.

A third concern is the structural integrity of the buildings. A roof had partially collapsed at one of the first prefabricate buildings constructed after the earthquake at the Nepal Opportunity Village. As shown in the photo it is evident that the roof design was not adequate for the facility.

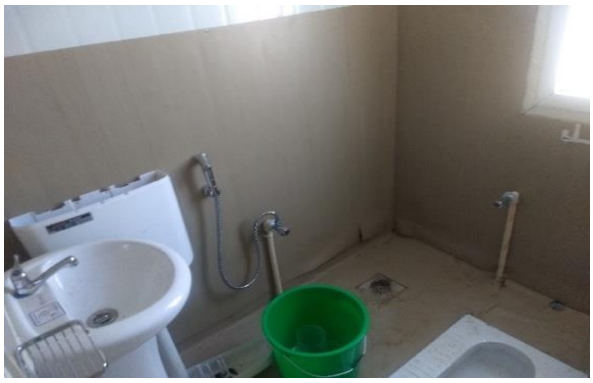
In contrast the conventional construction was generally quite good. Plumbing leaks were present in one building. In contrast to the prefabricated facilities, the doors and window were very robust. Are not The one major failure identified in the conventional construction was the roof at Abukhaireni health post. The flashing was not properly installed, and it seems that part of the roof was damaged in a storm. This roof was made of a plastic-type roof material and required construction method not common in Nepal according to our field engineer.

In general, we have some concern that the facilities will not meet their 10-year design life given the issues identified with construction as well as the less robust materials used in its construction.

Nepal: Opportunity Village, partial roof collapse (prefab), Image by IMC staff, 2018

Nepal: Opportunity Village, deficient gutter installation (prefab), Image by IMC staff, 2018

Nepal: Opportunity Village, poor plumbing installation (prefab), Image by IMC staff, 2018



Nepal: Opportunity Village, water damage at walls (prefab), Image by IMC staff, 2018

Nepal: Opportunity Village, open joint at exterior wall panels (prefab), Image by IMC staff, 2018

Nepal, inadequate flashing (conventional), Image by IMC staff, 2018

4.6.3.2 MALAWI SCHOOLS

TABLE 3-11 MALAWI SCHOOLS: USABILITY

Usability	
Prefabricated Construction	**Conventional Construction**
• No passive design elements • Facilities required modification • One end-user commented the prefab facilities were hot.	• Use of passive design elements • No modifications

Malawi: Nkomadri, passive ventilation (conventional), Image by IMC staff, 2018

Malawi: Tsabango I School, passive lighting (conventional), Image by IMC staff, 2018

In Malawi, the field assessments were performed in September, before the hottest period of the year. Therefore, it was difficult to assess the differences between the conventional construction versus the prefabricated construction with regards to internal building temperature. None of the prefabricated schools appear to take advantage of site placement or consider passive ventilation, cooling and lighting.

Malawi: Nkomadri School, adobe brick partition, Image by IMC staff, 2018

Malawi, attempted modification, Image by IMC staff, 2018

By contrast, the conventionally-built schools include natural ventilation holes placed high along exterior walls. And in some cases, honey-combed perforated panels brick elements are installed at exterior walls to provide natural lighting.

One issue that stood out was that in nearly every case, the end-users tried to modify the prefabricated facility by adding additional partitions or other building elements such, as a solar panel, as was done at the Shire school. The added partitions are constructed of adobe brick or wood finished with wood/paper-based paneling.

Although in most cases, the partitions did not appear to negatively impact the structure, any modification to the prefabricated structure is a significant concern as most prefabricated structures are designed with all elements providing structural support.

Also, the severe damage found at the Mvama site may have occurred when the end-user tried to remove panels to install partitions or other elements in the building. Evidence of attempted
modification to the panel was present at this site as shown in the enclosed photo.

TABLE 3-12 MALAWI SCHOOLS: SUSTAINABILITY

Sustainability	
Prefabricated Construction	**Conventional Construction**
• Facilities met local conditions • Strong well-built foundations • End-users lacked the ability to sustain facilities • Replacement parts uncommon in the market	• Facilities designed to local conditions • Strong well-built foundations • End-user and local contractors can repair the facility • Replacement parts are common.

Malawi, adobe bricks used to hold back siding (prefab), Image by IMC staff, 2018

Malawi, metal wire fasteners at damaged panels (prefab), Image by IMC staff, 2018

In every case, the building foundations are concrete slabs. No foundation settling is observed at either the prefabricated or conventionally-construction buildings. The only issue observed is related to site drainage as there was evidence of runoff scouring the building corners. This condition is present at both prefabricated and conventional building foundations.

The end-user does not have access to appropriate materials to make building repairs. Instead, they attempted repairs using common construction materials and techniques. For example, the end-user tried to use adobe bricks to hold down wall panels that had become detached from its framing and they used wire to stitch together separating wall panels.

TABLE 3-13 MALAWI SCHOOLS: MATERIAL CONDITION

Material Condition	
Prefabricated Construction	**Conventional Construction**
• 2 out of 4 sites have buildings with observed severe damage where complete failure is likely eminent. • The older prefabricated buildings seem to be constructed more durably and are holding up better. • The newer prefabricated building constructed of lightweight materials is performing poorly.	• 1 out of 3 facilities has structural damage – mortar is wearing away. • Overall, the buildings and materials are still in reasonably good condition after nearly 40 years.

The conditions at the first three sites are vastly different. At the Sire School, the prefabricated buildings are in relatively good shape. They are dirty and worn on the outside, but there is no evidence of failure. The steel-framed windows and doors are in fairly good shape and are still. At the interior, the added wood/paper-based partitions appear to be extensively damaged, possibly from water. However, there is no apparent evidence of water damage on the ceiling tiles.

Malawi: Sire School, facility observed in good condition (prefab), Image by IMC staff, 2018

The prefabricated Nkomadri School facility is in poorer condition and the interior metal panels are heavily worn but are still structurally sound. The panels show sign no separation and no sign of water leakage is evident.

However, in contrast, the Nkomadri conventionally-constructed school built in the 1980s is still in relatively good condition. There is some spalling of the concrete floor, but such damage is common and does not impact the facility usability. The overall brick structure, timbers and roof are in good condition.

The Mvama prefabricated schools are in very poor condition and are at the point of failure. In many cases the structural panels are separated from the polystyrene insulation. Since the panels and insulation provide structural support, these facilities are at the point of failure. It is unclear if the damage is due to the end-user trying to remove the panels, or if the damage was related to normal wear.

In contrast, the conventionally-constructed facilities at Mvama are in much better condition.

Malawi: Mvama Schol, failure of wall panels (prefab), Image by IMC staff, 2018

Malawi: Mvama School, failure of wall panels (prefab), Image by IMC staff, 2018

Malawi: Nkomadri SChol, 1980s building in good condition (conventional), Image by IMC staff, 2018

At the Tsabango 1 campus, funded by the Republic of Korea, was completed around 2012. Even though the structures were completed only 6 year ago, they are in extremely poor condition. The poor condition might largely be attributed to the lightweight wall panels, doors and windows. The Tsabango 1 school has a very different structure in that there is a strong metal super structure covered with a thin cladding that provides minimal structural support at the walls.

The flashing is missing in many areas of the Tsabango 1 Schools, particularly at the building corners. This allows the exterior metal to separate from the interior insulation.

The doors and windows are less durable than the steel doors and windows of the other prefabricated facilities. The windows are aluminum and the doors are made of thinner grade metal. After 5 years of use they are not in good working order. At nearly all the buildings observed, the doors do not open properly or are missing altogether. This seems to be particularly the case with double doors. Door handles are missing in many cases.

An interior partition made of a lightweight metal insulated panel failed in one of the buildings. A field repair was attempted using reinforcing of thin wood strips.

There is also a conventionally-built facility at the same site. The interior is in fairly good condition, however there is evidence of water damage at roof timbers. Also, the masonry work is of poor quality and the mortar seems to be worn away. The worn away mortar and brick are exposing the roof beam connections. This is the likely source of water that is causing the damage seen on the interior of the building at roof timbers.

Malawi: Tsbango I Schools, failure of mortar and bricks (conventional), Image by IMC staff, 2018

Malawi: Tsbango I Schools, substantial metal structure (prefab), Image by IMC staff 2018

Malawi: Tsbango I Schools, malfunctioning/missing doors, (prefab), Image by IMC staff, 2018

Malawi: Tsbango I Schools, partition failure, (prefab), Image by IMC staff, 2018

Malawi: Tsbango I Schools, wal panel failure and missing corner flashing (prefab), Image by IMC staff, 2018

3.7 PROJECT COMPARISONS

3.7.1 NEPAL HEALTH CLINICS: OWNER – MINISTRY OF HEALTH AND POPULATION (MOHP)

The Field Evaluation Team met with Sunil Khadka, who is Lead Adviser at Nepal Health Sector Support Program (NHSSP). NHSSP is a program funded by the UK government with one of its two components supporting the MoHP by retrofitting its infrastructure to withstand future earthquakes. Sunil is a planner and has been supporting the Ministry of Health with Infrastructure development and management since 2010. The following section summarizes comments from Mr. Khadka:

> *Prefabricated construction has been in the Nepal for a number of decades and it became extremely popular with NGOs and INGOs for building health clinics immediately after the earthquake of 2015. Many NGOs felt prefabricated construction was more cost effective, earthquake-proof and had a shorter construction period, which would help get health services back up as quickly as possible. Mr. Khadka felt that many of these organizations fell for misleading information and did not fully understand prefabricated systems before developing plans and purchasing prefabricated materials. Also, there were no ministry of health standards for construction and quality control. Furthermore, the existing construction labor pool had experience with conventional construction, but not with prefabricated construction and they were engaged without sufficient training and oversight.*
>
> *Unfortunately, because of the popularity of prefabricated construction and lack of standards, some inferior products were introduced. Of particular concern was the use of "PUF" panel construction (corrugated metal and polystyrene insulation) that were a health and fire hazard and should not be used for regular occupancy.*
>
> *Although prefabricated construction is generally faster and cheaper, there were often construction delays. Such delays were primarily due to skilled labor shortages, inefficiencies of the implementing partners or their contractors and re-work by contractors who didn't understand how to properly install the prefabricated system. The other major issue was due to transportation in rural areas. Also, construction materials are often damaged in transportation, which was particularly problematic for cement board type panels. The other issue is installing wiring and plumbing, which often needs to be on the surface and in some cases the prefabricated system did not support installation of plumbing or electrical systems.*
>
> *Nepalese engineers and contractors are more familiar with the conventional construction practices and the known proper codes and standards. MoHP has attempted to fix some standards for design and construction of the prefabricated facilities in response to some of the early issues. However, the standards are being implemented without a proper long-range study. Moreover, no standards have been developed for the multistoried.*

Extensive study is needed for proper prefabricated construction in Nepal. Proper training and coaching should be provided for the adequate skilled manpower to run the project and to get all the advantages out of the prefabricated construction.

3.7.2 NEPAL HEALTH CLINICS: END-USERS

In Nepal the Field Evaluation Team was able to meet with the end-users at all the facilities. Although the end-users were dissatisfied with the prefabricated facilities, the buildings did respond to most of their basic and immediate needs. At the same time, all of the end-users of the prefabricated facilities would have preferred conventionally-constructed buildings.

The end-users raised the following concerns with the facilities:

- The layouts did not meet their needs. In particular, they needed more storage space.
- Since the walls were not strong, they could not install medical equipment to the walls.
- The structure was not sound-proof so it was difficult to conduct private meetings with clients.

3.7.3 MALAWI SCHOOLS: OWNER - MINISTRY OF EDUCATION (MOE)

The Ministry of Education (Education Infrastructure Management Unit) is the main implementor of education infrastructure in Malawi. Unlike the prefabricated clinic program in Nepal, prefabricated school construction is uncommon in Malawi. The ministry personnel have never been directly involved in the prefabricated facilities construction. Therefore, the ministry personnel could not provide any first-hand knowledge of prefabricated construction, but they were able to describe their thoughts and concerns with prefabricated construction.

3.7.4 MALAWI SCHOOLS: END USERS

The Field Evaluation Team met with and consulted with the end-users of two prefabricated schools - The Blantyre City Council and the Salesian Fathers (Area 23 Lilongwe). Similar to Tsabango 1 Schools, which were visited by USAID, the Lilongwe school was implemented by the South Korean Government and used the same system. The table below describes the two programs, the technology and their key experiences with the prefabricated systems.

TABLE 3-14 : MALAWI SCHOOLS: COMPARISON OF BUILDING TECHNOLOGY USED

Project Location	Date Completed	Technology	Conditions
Blantyre – (funded by UNICEF)	1997	Non-insulated metal panels; roof provides no natural lighting	Encounters temperature extremes; natural light only from windows
Lilongwe (Funded by South Korea)	2014	Insulated metal panels, transparent roof material allows in light	Moderated temperature; more natural light (windows and roof)

Overall the end-user respondents of the Lilongwe school recorded a better learning environment than Blantyre largely due to the differences in technology. The Lilongwe school had less of a temperature swing and better lighting. The end-users noted that the classrooms are less dusty since the windows have glazing. However, in some cases the glass is broken, which allows dust to enter.

The end-users strongly agree that prefabricated buildings are better able to withstand strong winds and earthquakes. In both cases, the facilities have strong frames that were installed by professionals. In fact, the installer for the Lilongwe school is from South Korea. The end-users felt that conventional construction quality control is often poor, and those schools may not be able to withstand strong winds. They also felt that the prefabricated buildings are lighter and made of metal, which makes them more suitable for earthquakes, which do occur in Malawi.

End-users strongly agree that prefabricated construction is difficult to maintain. All prefabricated materials are imported, but conventional repair materials are readily available locally. For the prefabricated facilities, this forces communities to use alternative repair methods or leave damages unattended. In contrast, conventional construction is easy to repair due to material availability.

The end-users feel that conventionally-constructed facilities will last much longer than prefabricated facilities. Whereas if conventionally-built schools are maintained, the building lifespan is almost indefinite. Such is not the case with the prefabricated construction, primarily because little to no proper maintenance is done given the unavailability of maintenance materials and lack of experience by local construction technicians or labor.

In terms of construction, the end-users felt that prefabricated facilities are easier for local contractors to construct, but only with proper quality control and oversight. However, the respondents feel that prefabricated facilities require equipment not readily available in the market place for maintenance and repairs. At the same time, the respondents state that prefabricated construction is safer given its light weight as compared to conventional construction.

The existing prefab schools are in cities and transportation is not a major problem. However, the end-users did feel that transportation to rural schools is more difficult. With conventional construction, bricks are made on or near the project site.

None of the respondents know how much the prefabricated facilities cost. The Ministry of Education advised that a standard conventional two classroom block (23m x 8m) cost US$55,000. The respondents are unable to confirm if the prefabricated construction is more or less expensive.

End-user respondents agree that prefabricated projects can be completed faster than conventional construction. The Lilongwe respondent mentioned that, excluding the foundation, it takes ten days to build a school. A similar school using conventional methods can take up to two years. Furthermore, they felt that there are fewer construction delays especially given the up-front availability of the materials once the system is shipped to the site. Therefore, respondents view the speed of prefabricated construction as a benefit given the large backlog of schools required in Malawi.

The end-users feel that prefabricated facilities have fewer quality issues than conventionally-built facilities because of specialized builders and factory-tested materials. In conventional construction, quality issues are significant. In many cases building materials are not officially tested and quality assurance during construction is sometimes poor.

All end-users singled out operation and maintenance of the prefab infrastructure as the most important issue for the sustainability of the infrastructure. Both schools now have serious maintenance issues. Therefore, moving forward, respondents recommend that:

- An Operations and Maintenance plan is created for each prefab facility before construction completion.
- Build in capacity of local artisans for maintenance of the specific construction systems.
- Users (supervisors and teachers) must be trained in how to use and care for the facilities
- Developers plan for realistic capacities. Prefab school facilities are not suitable as overcrowded schools. Overcrowding creates significant challenges for the maintenance and care of prefabricated facilities. In the case of the Lilongwe school, over 150 students are crowded in one classroom, which is designed for 60 students.

Malawi: Blantyre School, repair of wall panls (prefab), Image by IMC staf,f, 2018

Malawi: Blantyre School, repair of wall panels (prefab), Image by IMC staff, 2018

Malawi: Lilongwe School, damaged windows (prefab), Image by IMC, 2018

3.7.5 NEPAL: DISCUSSION WITH UNICEF AS PREFAB IMPLEMENTOR

The UNICEF construction program is on-going, and the Field Evaluation Team met with Uddhad Poudel, a UNICEF Engineer. Mr. Poudel indicated that UNICEF decided to use prefabricated systems to complete construction in response to the significant, immediate need for health facilities in the wake of the 2015 earthquake. UNICEF engaged the Ministry of Health Technical Advisor to assist in identifying the right building system and layout. The selected system uses fiberglass insultation instead of inflammable insulation products such as polystyrene. Additionally, UNICEF recognized the fact that local labor is not adequately experienced with prefabricated systems and they therefore provided construction training in advance of the start of work.

UNICEF did experience construction delays due to the 4-month monsoon season, which makes transportation impossible in some parts of the country at that time of the year.

3.7.6 END-USER SUMMARY OF PREFAB STRENGTHS AND WEAKNESSES

The following is a summary of strengths and weaknesses provided by the End-user and based upon the assessment results:

TABLE 3-15: END-USER SUMMARY OF PREFAB STRENGTHS AND WEAKNESSES

	Strengths	Weakness
Nepal Clinics	• Provided rapid services after the earthquake • Quick return on investment • Construction was typically cheaper • Prefabricated systems are readily available in the Nepal market • Lightweight materials are cheaper and easier to transport to remote sites.	• Poor quality materials • Limited skilled workers who understand how to install prefabricated facilities. • Common PUF systems found in Nepal can be dangerous and a fire hazard. • There are no good establish standards for prefabricated construction in Nepal • Prefabricated cement-board panels are often damaged in transportation. • Not as strong as conventional construction. • Different companies can have vastly different quality standards making it difficult to compare systems.
Malawi Schools	• Prefabricated buildings are found in the market place (particularly used in South Africa). • Faster construction • Initial construction quality is typically better • Provides better earthquake capacity	• Generally weaker materials, particularly doors, windows and fixtures that failed more quickly. • Panels separating and will not last 20 years. • Users have tried to modify the systems, which is not possible. • Repair materials were not available.

The following table describes the general outcomes of our field analysis and discussion with end users. As shown, conventional construction strongly out-weighs prefabricated construction in nearly all areas.

Table 3-16 Summary of Field Assessment Outcomes

Key: Positive | Neutral | Negative

Loc	Type	Usability	End-user Acceptance	Sustainability	Constructability	Cost	Schedule	Quality
1	Prefab – Nepal Clinics							
2	Prefab –Malawi Schools							
1	Conventional - Nepal Clinics							
2	Conventional – Malawi Schools -							

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

4.1.1 SUMMARY OF EVALUATION FINDINGS

The results of the Field Assessments align with the results from the Literature Review and discussions with industry experts. The only difference is that UNICEF says that prefabricated construction is better for remote areas, as it is easier to get materials in, which contrasts with some of the literature, but aligns with the experiences of Carlos Henriquez of MSF.

The major issue with prefabricated construction is related to facility sustainability and longevity. As the results of the assessment indicate, materials for prefabricated facilities are not as durable when as conventional construction is implemented. This lack of durability leads to greater maintenance requirements. Then, unfortunately, end-users and local workers who must engage in making repairs do not have access to the same materials or understand how to make the repairs with unfamiliar prefabricated materials. This results in rudimentary and unsuccessful repairs such as those identified in Malawi.

Moreover, the results in Malawi show that end-users frequently need to make modifications to the buildings in order to meet their specific needs. It is difficult to modify or expand the prefabricated buildings. This limitation severely restricts the facilities long-term usability. Given the limitations and concerns that end-users expressed with the layout of the Nepal facilities, it could be expected that Clinic users will try to make similar modifications over the life of these buildings also.

The major take-away is that a building's full life-cycle should be considered in a development context and that infrastructure should be expected to be used for a long period of time. As we see in Malawi, school facilities built in the 1980s provide effective learning environment over 30 years later and clearly can provide good learning environments for decades to come. Unfortunately, most return-on-investment models weigh short-term returns higher (making earlier years more important than later years) and donors are driven to produce quick results. However, developing countries lack access to capital and therefore do not have the ability to make large long-term infrastructure investments. This should be part of the equation as USAID considers prefabricated versus conventional construction.

4.2 RECOMMENDATIONS

POLICY CONSIDERATIONS AND RECOMMENDATIONS

Although prefabricated construction may be an appropriate solution in some cases, its use in a development setting is limited. Therefore, we recommend USAID strengthen its policies to ensure that prefabricated construction is treated like any other construction project.

1. **Publish and issue a short document that describes prefabricated construction limitations.** Such a document could be provided to missions to understand the limitations of prefabricated construction and why it's necessary to consider alternatives. We suggest that this directly target some of the misconceptions that many have regarding the benefits of prefabricated construction.

2. **USAID should specifically call out and define prefabricated construction in its construction-related operating policies. As we will show, the planning, oversight and control of prefabricated construction is essentially the same as**

conventional construction. Outcomes will likely be better if prefabricated construction is included in the construction policy. Although the policy would seem to include prefabricated construction, to make sure this is clear prefabricated construction should be specifically called out.

3. **USAID should consider include factory witness tests for major or complex equipment purchases including prefabricated construction as a best practice.** Nearly every interviewee said there were issues with the materials and a factory assessment prior to shipment was something they would recommend. Therefore, USAID may consider modifying its construction risk management policy to include a section recommending factory witness tests for major or complex equipment by a qualified person (e.g. building architect or engineer for prefabricated facilities). This would also require that material procurement include a clause allowing USAID or it's representatives to conduct factory inspections before shipment to the site.

ANNEXES

ANNEX 1. SCOPE OF WORK

Evaluation of Pre-Engineered and Prefabricated Approaches to Infrastructure Development at USAID

Introduction

The purpose of this work assignment is to provide evaluation services to increase USAID's knowledge about the use of pre-engineered buildings in meeting development objectives of USAID programs. Critical questions to be addressed by the evaluation include:

1. What is pre-engineered or prefabricated infrastructure? (Materials, methods of fabrication, etc.): How is it defined inside and outside of USAID?
2. What are the real and perceived *technical/operational* advantages and challenges of pre-engineered/prefabricated infrastructure?: Quality, sustainability (social/cultural/climate considerations, O&M considerations, etc.), timeliness, relative cost, etc.
3. What are the real and perceived *policy* advantages and challenges of pre-engineered/prefabricated infrastructure? When and how is pre-engineered/pre-fabricated building NOT considered construction? What regulations and policies dictate the use of pre-engineered/prefabricated infrastructure in certain programmatic settings?
4. What successes, challenges/failures, and lessons learned can USAID collect from our own recent history (last 5-7 years) with pre-engineered/prefabricated construction?
5. What are the gaps in policy and guidance that USAID should address to provide further clarification and support to the appropriate applications of pre-engineered/prefabricated approaches to infrastructure development?

Background

When compared with traditional construction, prefabrication offers the promise of better built and better designed buildings delivered more quickly and at a reduced cost. As with all infrastructure projects, fulfilling this promise requires a careful balance between "faster/better/cheaper" and important sustainability considerations that may benefit from a more drawn-out and customized approach to design. Unfortunately, at USAID as elsewhere, the urgency to complete a construction project and the desire to stretch program dollars almost always places priority on physical construction over the design process.

With this evaluation, USAID would like to develop an understanding of the policy and technical/operational realities of pre-engineered/prefabricated building approaches to inform future USAID program decisions and policy/guidance development.

Task 1 - Evaluation Background and Definitions

The mass production of well-built, well-designed buildings that provide healthy, durable and economical environments has been the dream of architects and engineers since the beginning of the Industrial Revolution. The evolution of prefabricated infrastructure during this time has resulted in a broad range of definitions, materials and methods of assembly. The contractor will provide a brief history of prefabricated infrastructure construction, an overview of the current state-of-the-art approaches to prefabricated infrastructure (relevant to USAID), and a glossary of terms and ideas.

Task 2 - Technical and Operational Considerations

What are the real strengths, weaknesses, opportunities and threats for prefabricated infrastructure and how do these aspects differ from the common preconceptions? The contractor will provide an analysis of the technical realities of prefabricated infrastructure and how those realities relate to the experiences of USAID staff and its beneficiaries. This analysis will be illustrated by examples of prefabricated 2construction supported by USAID and other development organizations.

The analysis under this task should consider discussion of advantages, disadvantages and limitations for the following general criteria:

- Timeliness
- Cost
- Quality
- Design
- Sustainability

Task 3 - Policy Analysis

The contractor will identify and review policy and regulation guiding the selection and implementation of pre-engineered/prefabricated approaches for building at USAID. What influence do existing USG/USAID policies, contracting, and procurement procedures have when deciding between conventional and prefabricated construction? Is current internal programmatic guidance limiting construction to pre-engineered/pre-fabricated approaches supported by policy and regulation? What gaps and/or inconsistencies exist in the policy that would support selection of the best and most appropriate approach? This analysis will be supported by examples of USAID construction contracts and procurements.

Task 4 - Recommendations for Appropriate Pre-Engineered/Prefabricated Solutions

The promise of prefabricated buildings (their potential to supply high quality and low cost solutions for schools, clinics, homes, and other structures) demands that we return to the idea and search for approaches that will allow USAID to maximize its infrastructure investments. The contractor will summarize the general range of pre-engineered/prefabricated building solutions available to USAID and develop a matrix or other tool to identify the prevailing context (funding, program, partnerships, local capacity, etc.) required for a particular pre-engineered/prefabricated solution to be appropriate.

Some specific questions for consideration in this analysis include:

- What prefabricated building materials and methods of construction allow for repair and construction in developing communities?
- How do we increase cultural responsiveness?
- How do we integrate passive environmental design approaches?
- How do we minimize site work without jeopardizing structural integrity?

Deliverables

The deliverables for this evaluation activity will be an evaluation report outline, draft report and a final report and presentation. The contractor will structure the report to summarize the analysis required in the SOW

and to respond to each of the critical questions posed by USAID. The report outline shall be submitted for USAID comment within 2 weeks of the commencement of evaluation activities. Draft and final reports must also be submitted for review and comment by USAID before final acceptance.

Estimated LOE

1. Evaluation team leader (45 days)
2. Pre-engineered Building Specialist (10 days)
3. Production/Supply Chain Specialist (5 days)
4. Editor (10 days)

Illustrative List of USAID Pre-engineered/Prefabricated Building Activities

1. Schools in Malawi (ongoing)
2. Nepal Schools

ANNEX 2. QUESTIONAIRE AND ASSESMENT TOOLS

Prefabricated Implementor (only) Questionnaire Supplement

This section is provided to prefabricated implementers to better understand their experience with prefabricated facilities and construction as it compares to their experience with conventional construction. This include:

1. Assessing their how implementers perceive prefabricated construction in relation to conventional construction and an analysis of Strengths, Weaknesses, and Opportunities (SWOT) of Prefabricated systems (as compared to conventional systems)
2. Understand their key 10 risks with prefabricated construction.
3. Identify their best practices / lessons learned when executing their prefabricated construction program.

Please note that opportunities represent ways in which prefabricated systems could provide a unique opportunity to improve this aspect of building systems. For instance, automated SIP panel manufacturing systems is an opportunity to improve use by allowing greater flexibility in building sizes.

Comparison Analysis Prefabricated and Conventional Construction	
USEABILITY	
Prefabricated systems achieve their purpose (e.g. better learning, health, warehouse environment).	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated buildings are more likely to support passive design for lighting, heating and cooling.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated buildings are more likely to meet a set of recognized codes (e.g. fire, heath, electrical, ADA requirements, etc.).	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Usability SWOT Analysis	
Prefabricated Usability Strengths (compared to Conventional Construction):	
Prefabricated Usability Weaknesses:	
Prefabricated System Opportunities:	

Comparison Analysis Prefabricated and Conventional Construction	
System Meets Local Condition	
Prefabricated buildings are generally able to withstand strong winds and meet wind design standards? .	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated buildings are generally in earthquake prone areas.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated systems are typically better for humid climates (e.g. areas with higher rust, condensation, mold etc.).	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated building is more likely to meet local building codes.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Local Conditions SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	
Prefabricated Opportunities:	

Comparison Analysis Prefabricated and Conventional Construction	
End user Acceptance	
End-users are will prefer prefabricated projects.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated End-User Acceptance SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	

Comparison Analysis Prefabricated and Conventional Construction	
Sustainability	
Prefabricated facilities are easier for end-users to maintain.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Communities can get repair materials for prefabricated facilities.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □

Prefabricated facilities will last longer.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Sustainability SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	
Prefabricated Opportunities:	

Comparison Analysis Prefabricated and Conventional Construction	
Constructability	
Prefabricated facilities are easier for local contractors to construct.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated facilities can be constructed with equipment that is common and regularly used in the market place.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated facilities can be constructed more safely than conventional construction.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Transportation to the field site is not a major issue for prefabricated construction.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Constructability SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	
Prefabricated Opportunities:	

Comparison Analysis Prefabricated and Conventional Construction	
Cost and Schedule	
Prefabricated facilities provide the same product / outcomes for a cheaper cost.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □

Prefabricated projects can be completed faster than conventional construction.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
There are fewer issues with program delays with prefabricated construction.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Cost / Schedule SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	
Prefabricated Opportunities:	

Comparison Analysis Prefabricated and Conventional Construction	
Quality	
Prefabricated facilities have fewer quality issues (poor workmanship).	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Materials in prefabricated facilities are tested more rigorously.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
The general quality of materials in prefabricated facilities are better than conventional facilities.	Strongly Agree □ Agree □ Neutral □ Disagree □ Strongly Disagree □
Prefabricated Quality SWOT Analysis	
Prefabricated Strengths (compared to Conventional Construction):	
Prefabricated Weaknesses:	
Prefabricated Opportunities:	

Recommendations for Prefabricated Implementation
Project Development / Feasibility Assessment
Which types of projects are best for Prefabrication and why? Example: Health clinics, Schools, medical warehouses, cold storage, markets facilities, etc.
Recommendation on implementing Mechanism – *Cooperative Agreement, Construction Contract – Design – Bid - Build, Construction Contract – Design/Build, Host Nation Implementation. Discuss in context of community engagement and provide reasons why.*
Design Development
Procurement
Construction and Oversight

Please Identify the top 10 issues that must be considered for the success of a Prefabricated Construction Program. (#1 is the most important consideration and so forth). Below are examples. Write ins are available.

_____Usability – Prefabricated facility does not meet needs (e.g. too small or improper internal conditions such as temperature, lighting, cleanliness etc.)

_____Usability – Prefabricated buildings do not meet International Fire codes or disability needs (US ADA legal requirements).

_____Local Conditions – typical prefabricated systems do not meet local conditions (e.g. wind / seismic / temperature / humidity) causing safety issues and or early failure.

_____Local Conditions – the site or site preparation is not adequate (e.g. foundations / footers, drainage, access, slope stability issues

_____Local Conditions – Utilities inadequate for the system (water, electric etc.)

_____Local Conditions – Prefabricated facilities do not meet local code requirements.

_____Sustainability. Imported facility with difficulty in procuring replacement parts. Facility does not support alternative repairs (e.g. siding or roof repairs).

_____Sustainability. The system maintenance costs are excessive, or maintenance requirements are complicated.

_____Sustainability. Materials are not as durable, reducing the service life (e.g. plastic siding breaking down in UV light, poor roof covering, etc.).

_____Community Acceptance – Community is not interested in using Prefabricated facilities.

_____Constructability – Unique prefabrication installation requirements (e.g. rigging or large equipment not common in the country).

_____Constructability – Remote sites where it is difficult or impossible to deliver large materials.

_____Cost – Having sufficient unit volume to make prefabrication a cost effective.

_____Schedule. Shipment delays and supplier import issues.

_____Schedule. Getting sufficient volume to get into the supplier manufacturing cycle (e.g. small lots are often delayed).

_____Schedule. Difficulty in getting to site during rainy / snow season.

_____Quality. Material is damaged during shipment

_____Quality. Improper installation

_____Quality. Poor quality prefabricated materials (including electrical and plumbing)

Write Ins (allow multiple)

_____

_____

ANNEX 3. OVERVIEW OF PREFAB: IS PREFAB RIGHT FOR MY PROJECT?

Prefabricated construction is often thought of as an easy, rapid, cost-effective infrastructure solution.

Prefabricated construction systems and options are endless. However, we will define prefabricated construction as complete lightweight panelized or modular systems. Most of the systems observed or discussed are have a metal exterior with some type of foam or fiber-based insulation.

Before considering a prefabricated system, its strengths and limitations, should be understood. The bottom line is that prefabricated construction is not a simple solution and, as with any infrastructure project, it requires an understanding of the construction context and requires proper planning and oversight.

There has been a significant push for prefabricated solutions since after World War II, when a huge increase in housing stock was needed in Europe and the United States. During the same time many of these prefabricated concepts were unsuccessfully tried in the developing world. In the development world prefabricated construction continues to gain popularity due to high construction labor costs. However, the underlying drivers of prefabricated construction in a developed context is different.

Prefabricated Construction Drivers	**Developed Economy**	**Underdeveloped Economy**
Expensive Labor	Labor is often the greatest construction input cost.	Labor costs are significantly lower.
Skilled Labor	There is a ready labor force experienced with prefabricated construction.	There is often a limited labor force experienced with prefabricated construction.
Relatively inexpensive equipment costs	Lifting equipment and qualified operators are readily available.	There is often a shortage of equipment and operators. Equipment costs are comparatively expensive.
Ease of material transport.	Transportation is cheap and material can be delivered to most locations.	Transportation is expensive. Material delivery is problematic in many locations.
Excellent supply chain	Prefabricated systems and parts are readily available.	Prefabricated systems are often imported and repair parts are not as common.

Misunderstandings of these drivers has often led to some misperceptions regarding prefabricated construction in developing countries. The following are some of the common prefabricated perceptions.

Perception	What we have found.
Prefabricated construction is cheaper.	Prefabricated construction is often a more expensive option.
Prefabricated construction is faster	This can be the case; however, the supply chain can be more complex (especially when purchased outside the country) and any break in the chain can cause significant project delays.
Prefabricated construction does not require as much site preparation.	Prefabricated construction typically requires the same level of site preparation with utilities and drainage. In fact, connections can be more complex and pose problems for inexperienced contractors.
Prefabricated construction provides a higher quality result.	This is true given its development in a controlled environment. At the same time prefabricated construction can have similar material defect issues, and inspections and oversight are just as important.
Prefabricated construction does not require site oversight or control.	Although site construction is shorter, field oversight is still important and requires the same level of care to ensure that the site and building is installed correctly.
Prefabricated construction is a good solution for remote areas	In many cases it is impossible or extremely expensive to get the materials to site.
Prefabricated construction is better insulated.	Prefabricated system can be sealed better; however, they often have a steel superstructure that can reduce the overall insulating capacity by half.

Strengths:

Quick Simple Procurement. Prefabricated construction can be procured as a commodity rather than as construction.

Reduced Construction Period. The site construction period is typically much shorter. That also reduces the amount of field oversight required.

Quality. Since the materials are from a controlled environment, quality outcomes are more easily met.

Weaknesses

End-user Acceptance. Prefab systems are by their nature Western constructs and generally do not align with the local architecture, community fabric and the way communities are structured.

Inability to alter the facility. It may be better to consider buildings as a process and therefore are regularly modified as needs change – equipment is added, and rooms are modified. Any modification to prefabricated construction will most likely impact the buildings structural integrity.

Sustainability. There have been significant issues with prefabricated material sustainability. The first is that replacement parts are often unavailable. Second, the common sandwich panels do not meet their life expectancy due to moisture penetrating or enveloping the panels. Finally, by its nature the system is less robust than typical construction and often cannot take the long-term stresses posed by public facilities.

Cost. In most cases prefabricated construction is more expensive than conventional construction.

So when could a prefabricated facility work?

Complex Equipment Rooms. Medical equipment or control equipment often requires manufacturer installation. This can be cost prohibitive. Installation can be done in a prefab facility and then sent as a unit to the site.

When there are no local materials or manpower available. Doctors without Borders has successfully used prefabricated medical facilities in locations requiring speed and in location with limited materials or construction labor.

Simple, low-use facilities. Warehouses, cold storage and other limited-use facilities have less stress and are less likely to require changes. Prefab may be an option especially if it supports other development requirements.

Engage USAID Engineering and weigh your options.

Even simple infrastructure development is complex and in no case should prefabricated construction be identified as the only option. Before settling upon a solution, engage the USAID engineer team to provide options and help develop an appropriate solution that will meet your long-term development objectives.

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ANNEX 5. LITERATURE REVIEW

01 **Good Practice Guide - Shelter and School Construction**
Inter-Agency Network for Education in Emergencies (INEE)

MC This document provides no concrete examples of any buildings. However, it may be useful in our generation of questions that need to be included on the following:

- Assessment
- Questionnaire to Owner/End users
- Site Survey
- PEB Designers

"Involve the community in school placement, design and construction

Communities should be actively involved in deciding how the schools will be constructed, where, by whom and what the community will contribute to the construction. Frequently, communities contribute labor for carrying water, sand or making the walls, while the NGO provides the roofing, doors, windows and furniture. When considering community-initiated schools, it is important to consider the time frame for completion and quality of construction. Frequently, communities overestimate their resources and underestimate the constraints on their time.

School Location Selection

• Considering the demographics of the community, water and sanitation, where is the best place to put the schools? How will this affect the placement of pre-primary, primary and secondary schools?

• What is the farthest that children will have to walk to school? Will this limit their ability to attend school? • Is there ample space for expansion?

• Will water be available on site? • Does the location of latrines on the site pose a problem for existing water supplies? Where will latrines be expanded?

• Is sufficient space for recreational activities and expansion? Space for a football, volleyball or basketball pitch?

• Who has been involved in the site selection? Community leaders? Government? Local community? Construction engineer? Social worker?

• Who owns the land? Documentation? If the land is government land, has permission been received?

School Construction

• Are local building standards being followed? If there are variations, have these been approved?

• How were the plans for the schools developed? Were they based upon local plans or created especially for this situation? Do the plans provide sufficient space and materials for the implementation of the curriculum?

• Do the plans include the building of latrines? Are their equal facilities for both male and female students and teachers?

• Is the school accessible for children with disabilities? Are the doors wide enough for children with crutches or in wheelchairs? If there are stairs is there a ramp? Are the toilets wide enough for children with crutches or wheel chairs?"

02 **ASOCSA CIB Workshop Report Final**
(International Council for Research and Innovation in Bldg. and Constr.)
Queensland University of Technology, Brisbane, Australia
Associate Professor Robert L. Owen

MC This document provides no concrete examples of any buildings. See talking points extracted below:

This document is the summary of a workshop held to consolidate an understanding of infrastructure delivery methods. It establishes as one of its tenets the aim "to accelerate the development of sustainable, cost-efficient and desirable housing for African economic immigrants and others living in makeshift and slum dwellings." (For the Republic of South Africa) The workshop focused on articulating "Integrated Design Delivery Solutions." The primary points made can be applied to any project employing integrated design strategies. The document also indicates the "Lean Construction" strategies are of benefit.

"It is possible today to develop modular buildings in such a way that even unskilled residents can assist in their construction, and even their appropriate design. The buildings can be sited nearly autonomously from infrastructure, thus relieving the tensions and cities and

townships, whilst providing humane accommodation for he economically disadvantaged. Development of suitable solutions could either be conducted with other similarly stressed countries or developed in-country and the expertise exported."

"Modular construction is seen as a potential solution to both the current urgent need for humane homes for economic migrants and for future high-quality construction. Future homes should encompass concepts such as "house in a box" able to be folded up and moved. Eco-efficiency should then be comparatively effortless through the use of new materials, which are more sensitive to the imperatives of biodiversity."

03 **Behavior of Prefabricated Structures in Developed and Developing Countries**
Omid Reza Baghchesaraei, Hossein Hosseini Lavasani, Alireza Baghchesaraei

MC This document provides no concrete examples of any buildings. The writer has a limited comprehension of written English. Some solid ideas are expressed.

04 **Kiwi Prefab - Prefabricated Housing in New Zealand**
Master of Architecture Thesis
Pamela Bell, Victoria University of Wellington, 2009

MC This document is focused on the history and case studies of prefab housing in New Zealand, and projected outcomes for the future of prefab in New Zealand. The document is a solid reference for history of prefab / precedents (Levittown, Sears Homes) , definitions, system types, misconceptions / perceptions

Refer to the document for definitions and typology descriptions excerpted below:

"Prefabrication Terminology

There is significant confusion and misinformation surrounding the nomenclature of prefabrication which is why it is important to define the term early in this thesis. The prefabrication spectrum is extensive, and the industry is diverse and fragmented. Industry reports use differing terms which can lead to confusion (Gibb and Pendlebury). For the sake of clarity, the prefabrication term is used throughout this investigation, in preference to other industry terms such as 'offsite', 'modern methods of construction', 'non-traditional construction' and 'innovative construction'.13

In 1965, R.B. White described the nebulous nature of prefabrication:

Prefabrication could not be treated as a science; it is neither a single process nor a combination of known processes identifiable and measurable. It may sometimes be viewed in abstract and subjective terms, but it does not of itself provide a philosophy of design (White 298).

The prefabrication term is commonly misconstrued and suffers from historical misperceptions such as low-quality, flimsy and one-size-fits-all (Hart 123). These misperceptions have been a major historical impediment to consumer acceptance and subsequent commercial success

(Laing, Craig and Edge 81). Prefabrication is often confused with its associated terms, such as mobile, portable, standardized or industrialized. These terms are explained below and listed in the Glossary section.

Prefabrication has come to describe any manufacturing process that takes place within a factory-controlled environment. It particularly refers to any part of a building made away from the building site that is later assembled at the site (Brown). Other interchangeable historical terms include “ready-made” and “pre-assembly” (Marcel Duchamp qtd. in Colomina 68; Gibb). Kieran and Timberlake’s 2004 treatise Refabricating Architecture refers to prefabrication as both componentized and offsite construction. The latter term was taken up in the United Kingdom by the industry-wide campaigning organization, Build offsite. The United Kingdom’s industry has adopted the non-hyphenated offsite term in an effort to disengage from historical negative misperceptions.14 Today many terms abound, including pre-built, pre-configured, pre-designed, pre-planned and the abbreviation prefab. All indicate that work is done before reaching the final site. In this thesis, the definition of prefabrication is any component constructed away from the site and the abbreviated prefab term is used interchangeably.

Prefabricated housing can be categorized according to materials, technologies, market sector or extent of prefabrication. The extent, types, typologies or methodologies of prefabrication are described here. Prefab proponent and architectural historian Colin Davies set the scene:

Prefabricated buildings can be temporary or permanent, cheap or expensive, all the same or all different, small or large, traditional or Modern, well designed or badly designed (Davies 206).

Davies’ comment challenges the perception that prefabrication is synonymous with low-quality. Both United States and United Kingdom experts agree that prefabrication can be divided into four main types, or levels of extent. In the United States these are referred to as stick, panel, module or box-form (Arieff and Burkhart; Buchanan; Kelly).15 Leading British researcher Alistair Gibb defines these four primary categories as component sub-assembly, non-volumetric pre-assembly, volumetric pre-assembly and complete buildings. This thesis concurs with recent classifications that a fifth category of hybrid prefabrication is needed to describe systems that combine volumetric and panelized typologies (Alter “Acorn House”; Gaze et al). The five typologies of prefabrication referred to in this thesis are component (stick and sub-assembly), panel (non-volumetric), module (volumetric), hybrid (module-plus-panel) and complete buildings (box-form) (8).

Component

Component-based prefabrication includes stick and sub-assembly prefabrication. Stick refers to lengths of timber or steel that are pre-cut, pre-sized or pre-shaped puzzle-type pieces brought to site where they are assembled by a builder, as opposed to the traditional

construction process which cuts timber to size at site (9). Sub-assemblies include windows and doors which are assembled away from the site and installed into other elements once at the building site. This includes fixtures and fittings, and structural members such as pre-nailed roof trusses and wall frames. The use of pre-nailed components has become an accepted part of the traditional construction process by the full range of home building companies in New Zealand. A common form of component-based construction is known as kitset housing.

Panel

Panelized or non-volumetric prefabrication comprises manufactured panels that may include integrated building services and may be transported as a flat-pack (10). Panels can be classified as closed, complete with doors, windows, services and cladding or lining, or open as framing.16 Some architects refer to closed panel systems as cartridges or cassettes (Kieran and Timberlake, Loblolly House 83; Birkbeck and Scoones 40). Other elements include pre-insulated foundations and structurally insulated panels (SIPs). While panelized elements can be stacked flat for efficient transportation to site, they require more work for assembly at site than modular units.

Module

Modular, sectional or volumetric prefabrication refers to a three-dimensional structural unit being constructed away from the site and transported to site where it is combined with other units or systems to create a whole dwelling (11). In most cases, "a number of volumetric units are combined with additional onsite works such as an external…skin" (Cook 51). The three-dimensional object of prefabrication can be referred to as a volume, module, or section. Cores and pods are references to non-structural units used inside conventional buildings or modules (Birkbeck and Scoones 9). M.T. Gorgolewski offers this explanation of modular construction and its suitability:

Three-dimensional units are manufactured in the factory with a high degree of services, internal finishes and fit-out installed in controlled, factory conditions prior to transportation to site… This approach is particularly suited to highly serviced areas such as kitchens, bathrooms and plant rooms, which have a high added value, and cause disruption and delays on site, but may be less appropriate for other rooms which have less internal fit-out (Gorgolewski 122).

The term **modular home** was brought into common usage in the 1970s by the United States modular housing industry. It is a type of building that meets building codes, is factory assembled in full-dimensional units and then fixed onto a permanent foundation at site (Reidelbach Jr. 5). It is a more permanent type of building than the mobile or manufactured homes which also gained popularity during that era (refer to Associated Terms following).

Hybrid

Hybrid prefabrication will be used to refer to hybrid module-plus-panel or semi-volumetric systems (12-13). These systems use "volumetric units for the highly serviced areas such as kitchens and bathrooms and construct the remainder of the building using panels or by another means" (Gorgolewski 124). Hybrid prefabrication systems are regarded as combining the benefits of two prefabricated construction systems, while allowing for more flexibility and consumer choice. They can be used for additions and alterations in order to extend buildings with minimal disruption (Ross et al 1).

Associated Terms

Prefabrication is a system or process, not a product. This distinction is where much of the confusion and misperception about prefabrication lies. Prefabrication describes a way of construction rather than an aesthetic outcome. It can be viewed as an approach, a methodology, a mind-set, a tool, a pattern, or a philosophy. Non-physical elements such as services can also be clustered as David Gann points out:

Complete Buildings

Box-form or complete buildings are commonly known as portable, relocatable or transportable dwellings in New Zealand (14).17 They are a type of volumetric prefabrication where entire buildings are constructed in a factory or yard and then moved to site where they are attached to permanent foundations. These buildings may or may not incorporate prefabricated components, and standardized framing and sheet elements.

The growing demand for packaged products and service delivery is blurring the traditional boundaries between manufacturing, design, construction and service sectors (Gann 14).

In this way, prefabrication can be viewed as a system to bundle products and services and pre-package them for delivery to clients. It can be interpreted as both a literal construction process and as a systems-based approach for delivering housing.

The term prefabrication is often used interchangeably with associated terms such as mobile or portable, standardized or industrialized, pre-planned or pattern-book. These can be mistakenly substituted for prefabrication, so for clarity the following section identifies these terms. A dwelling may have one of these attributes without being able to be described as prefabricated.

Historically, standardized or pre-configured plans were compiled into pattern-books (15). While not technically prefabrication, concepts of efficiency are evident through the use of repetition, convenience for customers is offered in terms of communicated housing-plan options, and product reliability is enforced in using a singular brand name to deliver the housing system.

In America, the term mobile home has become displaced by manufactured home since 1974, due to a marketing effort by the United States Department of Housing and Urban Development (HUD) to dispel unattractive connotations of the trailer-home term (Mau and Institute without Boundaries 34). Formerly described as a travel-trailer or house-trailer, the manufactured home is wheeled to site on its own permanent chassis where it is mounted onto a permanent concrete slab foundation (16). Described as, “perhaps the most radical form of prefab housing”, it is designated as a vehicle, rather than a building (Rybczynski, “Prefab Fad”). This house does not need to conform to building-codes, which enables it to be delivered at a lower cost. This has led to its success as an industry in North America – despite negative social connotations resulting from relegation to cheaper land areas at the outskirts of urban centers. Manufactured housing may have suffered from a lack of

emphasis on aesthetic design, but its consumer-friendly marketing, distribution, and delivery systems are worth exploring in today's prefabricated housing (Ebong 17).

Terms of industrialization and standardization are often mistakenly used interchangeably with prefabrication. In 1972, Mary Mountier noted:

The essence of industrialized building, in contrast to simple prefabrication, is that it has an organizational structure similar to that of a manufacturing company (Mountier np).

As Mountier points out, the term industrialized refers to high-volume output and a large consumer market, while the term prefabricated can apply to small-scale production of any component or element of a building. In many instances, industrialized systems employ systems of prefabrication, but the terms are not necessarily interchangeable (Hay). Davies notes that:

Prefabrication does not necessarily imply either mass production or standardization. In fact, none of the three terms necessarily implies the other two. Standardization is not essential and mind-numbing monotony is not inevitable (Davies 205).

Standardization is the extensive use of components, methods or processes in which there is regularity, repetition and a background of successful practice. This may include standard building products, standard forms of contract, standard details, design or specifications, and standard processes, procedures or techniques (Gibb and Pendlebury 33). Standardization of processes is inherent for efficiencies of prefabrication, but it does not always result in a standardized product or outcome.

Mass-customization refers to the contemporary re-interpretation of mass production with the ability to incorporate change via new technology and web-based interfaces (17). Mass-customization is a way to deliver this. It is, "a process using standard components to produce a variety of end products" (Cook 50). In their 2004 treatise, Kieran and Timberlake comment:

Mass production was the ideal of the early twentieth century. Mass customization is the recently emerged reality of the twenty-first century (Kieran and Timberlake, Refabricating Architecture xii).

Post-World War Two economic, material and labor constraints developed the only real market for standardized housing products. Today the cultural context that consumers demand is more "choice, expression, individuality, and the ability to change [their] minds at the last minute", as well as a desire to have an active role in the design process (Kieran and Timberlake, Refabricating Architecture 133).

Merits of Prefabrication

The advantages or merits of prefabrication are potentials, rather than givens, as each individual example of prefabricated housing possesses its own particular systems and processes. Prefabrication can potentially offer **'more for less'**: more quality for less time at site, more known outcomes and less unknowns, and potentially more energy efficiency for less resource use (18). The importance of tangible outcomes in cost, quality and timeframe are evident through the consumer process of visiting a show-home, choosing from material samples, observing the factory manufacture, and watching the housing product arrive on the building site.

There is still confusion – mostly amongst end-consumers – that prefabrication will primarily deliver a more cost-effective housing solution, when the industry acknowledges that the main advantage is a potentially **higher quality** solution. In 2005, Brian Cook surveyed members of the United Kingdom prefabricated housing industry and noted:

Improvement in quality is regarded as the principal advantage of prefabricated housing (Cook 54).

This higher quality is achieved through closer coordination of labor, materials, machinery and sub-trades in factory conditions. Testing, evaluating and resulting remedial work can be carried out before the product leaves the factory floor. Further merits of prefabrication are grouped here into technical, social, economic and sustainability areas.

Technical merits include tight quality controls of workmanship and materials, increased speed of production through concurrent factory manufacture and site-based works, and the ability to test systems within the factory. This testing, together with minimizing joints, can reduce the level of defects and subsequent defect liability period post-occupancy.

Social merits include being able to work under cover during inclement weather, having tools and amenities close at hand, and improvements in health and safety (19-20). Investment in machinery and training leads to longer-term employment stability. Prefabricated homes are potentially aesthetically dissimilar from each other, and often indistinguishable from conventionally constructed homes.

Economic merits include the cost savings to customers and developers from a shorter period of financial borrowing as a result of shorter timeframes, and reduced defect liability periods. Time savings are potentially between thirty and sixty percent of a traditional construction process according to some modular manufacturers (Modtech Holdings) (21). Timeframes and costs will also be decreased by eliminating dependence on weather for site-based construction, easier coordination of trades in-house, and price advantages from bulk ordering. Michael Buchanan notes:

Given the cost savings inherent in the construction technique, a prefabricated shell will generally be less expensive than a site-built structure of exactly the same specifications, configuration, and quality (Buchanan viii).

Buchanan assures cost savings can be achieved. Time and money can also be saved by eliminating delays due to later material deliveries, non-appearance of sub-contractors, and

worker travelling time. Transport costs can be reduced to the carrying of fewer finished components or the single trip of the final housing product from factory to site. Costs can be further minimized by reducing overall floor area; often a prefabricated home can be a scaled-down size for scaled-down living needs (Elliston and Nafzgar 10).

Sustainability merits include reduced material waste through efficient ordering, indoor protection, pre-planning and cutting, and re-use (22-23). Material usage is thought to be saved by up to seventy-five percent for modular construction (Smith).18 Currently forty percent of our country's waste is created by the New Zealand construction industry so there could be great improvements made in the area of waste minimization (Wood "Govt3 and Sustainable Government Building"). Potential site benefits of prefabrication include less disruption, noise, pollution, effluence, ground-works, traffic, and fewer deliveries. It has been estimated that a complete building delivered to site uses less than half the energy in running costs compared with an average house (Elliston and Nafzgar 10).19 Factory testing and quality controls enable a tighter building envelope and better energy efficiencies for reduced running costs.

Together, these merits of prefabrication are well poised to tackle current construction industry challenges such as a low-skilled construction workforce, increasing market demands for higher quality, and increasing industry regulation (Gorgolewski 121).

05 The Social Acceptability of Prefabrication and Standardization in Relation to New Housing

Mr. Anthony Craig, Dr. Richard Laing, Dr. Martin Edge

MC This document is focused on housing in the UK.

"An important distinction to be made is that between process and product. Both standardization and prefabrication suggest not necessarily functionally or aesthetically distinct products from more conventional construction, but more routes toward the attainment of stated goals. With regard to housing, rather than viewing such processes as barriers to innovative and satisfactory design, providing the aims of any project are clearly stated it should be possible to work towards maximizing value for all concerned. "

"Demands set in the UK by the Government sponsored Egan (1998) have moved current thinking towards improving efficiency in construction and driving towards greater value and quality. Similarly, given the need for sustainability and the generally important consideration of environmental and social values in the longer term, it is essential that a long-term view be taken and that the consequent needs for flexibility, maintenance and eventual disposal (or re-use) be addressed at the design stage. It is clear that a wide range of short-term goals can be addressed through different levels of standardization, and that the prefabrication of components, or the use of modular building types, can provide the user with a flexible and personalized living space."

"Important past mistakes concerning a lack of quality, attention to detail, and consideration of the life cycle clearly must be recognized. The design team must also recognize where housing is constructed in large volumes, that a duty is owed to ensure that the resulting

buildings adequately address the needs of the householder, with regard to emotional satisfaction, function and economic performance. Prefabricated and standardized construction methods provide reliable, tested and flexible tools with which the design team must work to satisfy such demands."

"In Sweden for example, where timber is by far the preferred building material, the history of prefabrication is much more positive, and is based more on the promotion of self-building than on the philosophy of prefabrication (Vale, 1996)."

06 **Integration of Buildability Issues in Construction Projects in Developing Economies**

D. Tindiwensi

Department of Civil Engineering, Makerere University, Kampala, Uganda

MC This document defines the concept of "buildability". (In Revit-speak / BIM, this is where clash detection review happens with the contractor, subcontractors, engineers and architects). In the developed world, sequencing of the construction documents, CSI Format of the specifications, and then strict review and adherence to GC submittal schedule, and any GC sequencing and phasing requirements have been the traditional steps taken to provide this level of quality control.

"Definition

Buildability has been defined as 'the extent to which the design of a building facilitates the ease of construction, subject to the overall requirements for the completed building' (Gray, 1990). The definition has two major implications:

1. Buildability exists on a scale from good to bad. A design with good buildability takes close account of the way it is to be constructed and vice versa.
2. Each building has overall requirements which may necessitate the acceptance of less than good buildability

ACHIEVING DESIGNS FOR EFFICIENT EXECUTION

The design sets the pattern for all that follows. A 'good' design will mean that a 'good' project will follow but a good fabrication and installation cannot compensate for a poor design. It needs to be recognized that design goes through various stages, i.e. concept, scheme, feasibility, detail and production drawings. Furthermore, between each of these stages there is often a break in time, sometimes a change in responsibility and there can even be a change in philosophy and priorities. What has to be achieved therefore is a transition between these various stages without a break, or at the very least with strong links and ties, whilst clearly identifying the responsibilities within each stage. It is important to identify those areas, which, the design must take cognizance of if maximum efficiency is to be obtained.

Definition of good practice

Every industry will get what it deserves. If in this case it is considered that the designs are inconsistent and do not reflect good and economic practice, then it is the responsibility of the industry to rectify the matter. This can quite easily be achieved by developing coordinated industry specifications and standards on a national and/or regional basis. The specifications should reflect practical tolerances and 'fit for purpose' workmanship. Similarly, standards can be defined to cover all aspects of design and construction. These can be put together in authoritative guides which, will achieve not only a rationalization of the design process across the industry but will, in addition, provide the substance for those links between the various stages of design. The most important aspect in achieving this good practice is that it should be led by the industry but must fully involve all the stakeholders.

Communication and education

The major point here is to ensure that the professionals and academics adopt and apply this in design practice and not just in theory and research. The means to achieve this is by defining national and cross-industry training modules and to identify centers of excellence, which will take these modules as the basis of their programs. In addition, there is a need to develop and promote continuing professional development programs.

Definition of efficient execution

The previous discussion has highlighted the notion that the customer will purchase the product thinking that it has been designed for efficiency in execution and performance. It is at this point that a profit or loss is made. It is wrong to think that individual companies can achieve all of this by themselves. There has always been a large element of success in learning from each other. The Japanese, more than anyone else, have demonstrated this fact. In any event, industry-wide efficient construction motivates the preceding design into efficiency.

Benchmarking

Benchmarking lies at the heart of good practice and continuous improvement. There seems to be no other method of establishing whether efficiency is being achieved and improvements being gained from process and product development. There is however, a necessity to establish which activities should be measured. The methods available to undertake such a study are varied but one should choose those that are simple to understand. Gray (1990) suggests Method Productivity Delay Model (MPDM), Activity Sampling Model (ASM), Foreman Delay Surveys (FDS) and Network Processing Systems (NPS) as some of the possible techniques, but he however, singles out NPS to be the most effective.

Simplification and standardization

The basic point is to understand what leads to efficiency in operation, e.g. for a steel frame, the erection process is largely controlled by the attitude of the fabricator and welding productivity, is controlled by the efficiency and exactness of the way the components are assembled. The assembly process itself is influenced by the accuracy of the preparation and detailing by the draughtsman. It is, therefore, the standardization, simplification and planning of the previous activity, which is the major control of efficiency. Equally, it is

important that activities should be planned for completion once started. If the preparation of a piece of metal includes cutting, holing and shaping then this should be completed as a single operation and not a series of disparate activities. Each type of activity should go through this kind of analysis.

Before standardization is adopted, it is important to decide what it is that is being standardized. Is it the finished product itself or is it the basic formulation? For most general buildings it will have to be the standardization of the basic rules of design, detail, use of materials, which under the same circumstances will always lead to the same conclusion. Equally, however, more standard structures and especially in the single-story market lend them to standardization of the completed product.

Planning and control

Planning and control should not only aim at a disciplined sequence of works but also to reduce costs and time and to increase efficiency. It is the means by which the needs of erection (for example for a steel structure) are balance with the economies of fabrication. Each operative, section, or department needs plans that recognize their individual horizons. These plans should not only be based on achievable work packages but should ensure that only completed work can be passed forward.

The secret of success lies in not just providing this management discipline, but in starting with installation and working backwards to the design, i.e. construction led. This will amount to the much-required synchronization of the manufacturing and construction processes and each package will be on a just-in-time basis. One thing that should be noted is that we are in the business of designing, detailing, fabricating, and installing or constructing bespoke projects. We are not in the business of storing and stocking at any stage of our operations.

Continuous improvement and innovation

If the improvement or innovation does not, in the final analysis, reduce cost for at least one member of the construction team, then the value is probably debatable. The immediate measure of whether the improvement is a gain is to assess this against the established benchmark and then, once again is established, to raise the benchmark. Clearly, the construction process cannot be indefinitely shortened, but

07 **Performance and Perception in Prefab Housing**

Malay Dave, Bruce Watson, Deo Prasad

Faculty of Built Environment, UNSW Australia, Sydney, Australia

MC This document is specific to the perception of prefab housing in Australia; this document provides nothing relevant to our research that can be used.

08 **The role of a building's thermal properties on pupil's thermal comfort**

Despoina Teli, Mark Jentsch, Patrick A.B. James

MC This document is specific to the study of two schools in the U.K.

09 **School Design Matters! Reviewing design influences on Education Performance and the contemporary school's existence as a 'community asset', or 'development hub' in Africa**

Department for International Development

MC This document provides only general insights into school design in Africa. The document does provide brief histories of formalized education for several countries.

10 **FINAL REPORT: Efficiency Analysis of Classroom Infrastructure for Primary Education in Bangladesh**

MC This document is a report on the final determinations of conventional construction at (4) specific sights in Bangladesh.

11 **Prefabricated Housing, a Solution for Ghana's Housing Shortage**

Evans K. Essienyi

Submitted to the Program in Real Estate Development in Conjunction with the Center for Real Estate on 29 July 2011 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

MC This document is about prefab housing in Ghana.

"During the last five decades developing countries have made their first experiences with prefabricated, industrial building systems which they mostly imported (by transfer of respective production units) or systems which they developed on their own (sometimes copied from existing similar technical systems in the 'developed' world). In the majority of these countries, as experience shows, 'prefab' systems, usually heavy and large-scale, have been generally unable to cater for low-income housing, even in the cases where they were explicitly aiming at this target group. The most prominent aspects of their failure are:

1. high costs due to high fixed investments; high transport and assembly costs as the factory production is very centralized, heavy cranes are needed on site; the use of advanced technology and of imported inputs, especially expensive building equipment and high-energy-content building materials such as cement and iron rods are responsible for the production of prefabricated components resulting in high-cost housing far beyond the limits of affordability

2. Assembly problems which result in severe inaccuracies and even leakages of the assembled components

3. The physical unsuitability of buildings to later changes of use, as the large-scale, heavy components of certain prefab-systems are absolutely static and rigid against change; and lastly,

4. Cultural unsuitability as most building systems are only geared to produce some kind of international building type but never take reference to the local or indigenous building culture.

These factors have not made Prefabrication popular with the masses in developing countries and also undermined the success of prefabrication housing programs.

Presently some countries continue to use prefabrication and in particular large components and systems on a relatively large scale, as they are in the possession of well-equipped factories or as they still possess the economic resources to pursue such programs. Nevertheless, in the majority of the developing countries the use of large-scale prefab-systems has slowed down considerably and there exist many doubts whether any continuation is feasible. Generally, with regard to fabrication there exists a 'stalemate' and there rarely exist considerations for a redevelopment or revision of state policy and approach towards prefabrication which could lead to modified utilization of existing productive resources. Particularly there is little connection seen between the popular housing sector, which produces the majority of today's housing stock through self-help/mutual aid and/or the work of small-scale contractors and the need to readjust and adapt the technological policy of the construction sector towards the specific needs of the low-income population, their technical skills and economic capabi1ities.

One of the challenges of establishing and running economically profitably factories to mass produce prefab building components is the dilemma of whether the chicken first or the egg first. Whether the mass production of prefab components in factories first or the market first. We cannot have a satisfactorily run mass production factory unless there is a guaranteed and assured market for their products over the number of amortized years of heavy capital invested. There cannot be a guaranteed and assured market for such highly innovative new product unless structures built by their use are found economical and satisfactory. Economy cannot be achieved unless the factories are operated to their full rated capacity. The factories cannot be run to the full rated capacity without continued adequate captive demand. Such demands cannot be there unless there is an assurance of continued major mass housing and time bound finance, backed by housing programs; therefore, this becomes a complete vicious and evil cycle. This is the root cause of housing shortage problem remaining unsolved.

12 **Educational Infrastructure School Construction and Decentralization in Developing Countries Key Issues for an Understudied Area**

Alec Ian Gershberg, January 2014

MC This document may provide some information regarding policy issues; this document may be relevant to our research. Of particular interest may be Table 1: Education Infrastructure Decentralization Matrix. And Table 2: Arguments for and against decentralization or recentralization.

Table 1: Education Infrastructure Decentralization Matrix

Education	Administrative	Fiscal	Political
Deconcentration to Regional Government Offices and Regional MOE Offices	Move managerial decisions and managerial accountability to regional offices of central government and MOE.	Give regional managers greater authority to allocate and reallocate budgets.	Create regional, elected bodies to advise regional managers.
Devolution to regional or local governments	Education sector managers are appointed by elected officials at local or regional level.	Give subnational governments power to allocate education spending and, in some cases, to determine spending levels (i.e., through raising revenues).	Elected regional or local officials of general-purpose governments are ultimately accountable both to voters and to sources of finance for the delivery of schooling.
Delegation (and/or Devolution) to schools and/or school councils	School principals and/or school councils empowered to make personnel, curriculum, and some spending decisions.	School principals and/or school councils receive government funding and can allocate spending and raise revenues.	School councils are elected or appointed, often with power to name school principals.
Delegation to NGOs, Contract Management Agencies (CMAs) and/or Social Funds	Government responsible for provision, but delegates operational autonomy to implement large-scale small construction programs, to be carried out by small contractors with local labor.	Funds provided by government (central, regional local, perhaps with community input) but handles largely by delegated agencies. Cost savings in some cases.	Elected officials of general-purpose governments are, ideally, ultimately accountable to voters and to sources of finance for the delivery of schooling. How this works in practice is key. Agencies may buffer officials
Implicit delegation to community schools and community based approaches	School principals and/or community school councils make key decisions.	Some self-financing or local inputs with some government subsidies, especially in remote areas where public schools are not present.	School councils are often popularly elected. Government is still usually responsible for service provision, though not the direct provider.

Table 2: Arguments for and against decentralization or recentralization.

Efficiency & Fiscal Resources Arguments for Decentralization & Recentralization		
	Decentralization	Recentralization
Production Efficiency	1. Sub-national governments may choose input mixes and/or develop programs and policies more effectively than national governments. 2. Sub-national governments may manage resources more efficiently than national governments by: a) Reducing bureaucratic red tape; b) Implementing more appropriate/effective personnel management; c) Accounting more to stakeholders regarding how funds are spent	3. National governments must account for externalities and spillovers related to national goals. 4. National governments may have more expertise, particularly for evaluation and institution building in weak sub-national jurisdictions, and greater capacity for disseminating good practice. In addition, evaluation mechanisms must be comparable across jurisdictions and the national government must rely on comprehensive evaluation measures both for national planning and to hold sub-national jurisdictions accountable for use of national funds.
Allocative Efficiency	5. Sub-national governments know their constituents better than national governments and therefore provide services that more closely match citizen preferences. There may also be improved equity through more effective targeting of the poor populations. 6. If reforms improve services for disadvantaged groups, equity may improve despite regional disparities.	7. Central government has greatest capacity for inter-regional and inter-personal redistributive policies. 8. Centralized allocation may be less vulnerable to capture by local elites and interest groups.
Fiscal Efficiency and Fiscal Resources	9. National governments can use leverage from fiscal transfers to stimulate economically efficient and/or socially beneficial behavior by sub-national governments. 10. As with #5 above, sub-national governments can set some limited number of taxes and/or user fees in a more efficient and responsive manner with respect to the regional/local economy, households and other stakeholders. This *may* augment the public resource base.	11. Many important taxes (e.g., consumption [value added] taxes and income taxes) may be handled most efficiently and equitably at the national level. 12. Sub-national governments can run deficits that in extreme cases can threaten macro stability. 11. Importantly, greater sub-national fiscal responsibility may throw regions more to the mercy of their own endowments, thus increasing inequity nationally.
Democracy/Power Sharing Arguments for Decentralization & Recentralization		
	Decentralization	Recentralization
	12. If reforms allow true power sharing, then democratic political participation and/or political stability could be improved. Political equity may also improve.	13. Improved power sharing assumes functioning sub-national democratic institutions, which are notoriously weak in many countries in the region. (See #8 above).

13 GAO-09 Oversight of Relocatable Facilities

United States Government Accounting Office

MC This document is about relocatable (modular) military buildings only. This document may provide some insight on policy or construction process.

14 Infrastructure and Basic Facilities

Department for International Development

MC This document is the result of a search for other resources and provides links to other documents that may be relevant to our research. The subject matter is focused on elements of school infrastructure as the affect student achievement.

15 Assessing the degree of industrialisation in construction – a case of Uganda

To cite this article: Henry Mwanaki Alinaitwe , Jackson Mwakali & Bengt Hansson (2006) Assessing the degree of industrialisation in construction – a case of Uganda, Journal of Civil Engineering and Management, 12:3, 221-229

MC This document adds the term "industrialization" to be defined as part of our research

1.1. Definition

Foster [1] defines industrialisation essentially as an organisational process – continuity of production implying a steady flow of demand; standardisation; integration of the different stages of the whole production process; a high degree of organisation of work; mechanisation to replace human labour wherever possible; research and organised experimentation integrated with production. According to International Council for Research and Innovation in Building and Construction (CIB) TG57, (www.cibworld.nl), industrialisation involves the ration-alisation of the whole process of building (which includes the process of design, the forms of construction used and the methods of building adopted), in order to achieve integration of design, supply of materials, fabrication and assembly so that building work is carried out more quickly and with less labour on site and, if possible, at less cost. Industrialisation of construction deals with the rationalisation of the construction process through prefab-rication, extensive on-site use of forms, equipment, and advanced labour saving finish technologies (http://tx.technion.ac.il). Richard [2] defines industrialisa-tion as basically the aggregation of a large market to di-vide into fractions the investment in strategies and technologies capable, in return of simplifying the produc-tion and therefore reducing the costs.

2. Classification of industrialization

The existing strategies for industrialisation can be divided into on-site industrialisation and off-site industri-alisation. Another split in industrialisation strategies is between the product industrialisation and the process industrialisation.

2.1. On-site and off-site industrialisation

Off-site industrialisation is based on the assumption that buildings may also be made in factories. Prefabrica-tion is the production of construction components using factory mechanization. It refers to the manufacture and assembly of buildings or parts of buildings ahead of time that would traditionally be constructed in-situ on site and usually takes place at a manufacturing facility remote from the site. The factory setting enhances affordability through a combination of quantity purchasing of materials, mass production, assembly techniques and use of less skilled labour. The ultimate goal is a radical change that will lead to new buildings, fully constructed with prefabricated elements assembled on site, ready for use. In the housing industry some systems are already successful. Prefabrication may take one of these forms: prefabricated components, modular housing, and manufactured housing.

On the other hand, on-site industrialisation refers to the application of advanced tools and technologies on building sites. Some examples are Ground Positioning System (GPS), assembly of big prefabricated units, identification of elements with bar codes, just is time deliveries, self-climbing formwork, self-levelling concrete, robotic finishing etc. (http://tx.technion.ac.il).

2.2. Product industrialisation and process industrialisation

Product industrialisation focuses on the techno-logical aspect of building. On-site and off-site are both examples of product industrialisation. On the other hand, process industrialisation is concerned with how parties are cooperating, contractually and informally. It deals with Design and Build contracts or with more advanced strategies like Private Finance Initiative (PFI), Design Build Market and Operate (DBMO).

4. Advantages and disadvantages of industrialisation in construction

4.1. Advantages

The advantages of pre-assembly and standardisation include speed of construction, lower cost, reduced need for skilled labour, high technical quality, independence of weather, reduction in manufacturing costs, fewer inter-face and tolerance problems, shorter construction periods, and more efficient research and development of components [7, 9].

Prefabrication of the housing components such as windows, doors, and cabinets, has been a long main stay of the construction industry, keeping the costs down by reducing on-site, high-cost labour. Modular housing involves the prefabrication of sections of housing that are assembled on site, thereby reducing significantly on-site labour costs. The construction industry needs to make a greater use of prefabrication in undertaking projects in order to overcome manpower shortage [10].

Continued development of prefabrication provides a growing range of construction products that may further reduce construction costs. Industrialisation will lead to improved quality of the products. There is a greater precision and consistency in quality. Industrialisation enables production under controlled conditions, often inside a factory or specialised works, hence protecting products from bad weather.

`Industrialisation minimizes site activity. There is re-duction in construction hazards leading to improvement in the workers' site safety and health. Prefabrication can simplify temporary or permanent removal or replacement with minimum disruption. For example, modular plant rooms located on the roof of a building can be removed and replaced in one operation over a weekend shutdown.

Prefabrication optimizes the location of the work where it is more efficiently built in this way. Sometimes this is the only option. It allows suppliers and contractors to exploit special skills or specialised equipment. Expensive or specialized components can be kept secure till installation in final position. For projects on remote sites, relocating the work to workshops could mean a better access to the skilled labour.

Industrialisation and particularly prefabrication will lead to a big reduction in the overall duration of a construction project if well-planned in advance. Process industrialisation leads to transfer of risks from the clients to the suppliers and contractors. This in a way encourages innovation since the risk takers will be forced to find ways of creating and implementing change in the construction industry. Industrialisation taking into account mass production will lead to reduced costs, when the quantities of work are beyond the minimum economic order quantities.

4.2. Disadvantages

The use of machines to replace manpower reduces on the jobs available for human labour. In some countries where unemployment is high, this can exacerbate the problem. Therefore, the increased use of industrialisation might lead to higher levels of

unemployment. Care has to be taken to use appropriate levels of industrialisation. For optimum productivity, there has to be an optimal level of industrialisation.

Use of prefabrication in buildings has the following shortcomings: possibility of damage during transportation; normally it requires lifting equipment; monotony of design unless there are variations in the prefabricated units; and over designs to take care of the loading conditions.

The cost of the technologies and equipment is usually high at the beginning. It was found out that large volumes are required in the long run as the production volume must exceed the critical volume and this is not always the case [9].

16 (NOT USED)

17 **Offsite Manufacturing (Also known as Dry Construction) The way forward for Nigeria's Housing Industry**

Kolo, Shaba, Pour Rahimian, Farzad and Goulding, Jack Steven,

International Journal of Sustainable Tropical Design Research and Practice, (2014)

MC This document is in regard to offsite-manufactured housing in Nigeria, specifically. However, some general insights regarding offsite manufacturing can be extrapolated. This doc's bibliography may be useful for extended research.

Offsite Manufacturing (OSM). Globally, the OSM market uses several terms interchangeably, the most prevalent of which include: prefabrication, offsite production, industrialised building systems, dry construction, modern methods of construction etc.

Despite the myriad of benefits associated with OSM (e.g. speed of construction, improved quality, reduced risk etc.), there are various barriers identified in the course of adopting OSM; some of these barriers include: client resistance, lack of established codes and standards, negative perception etc.

Research findings highlight core OSM uptake barriers, including issues such as: reluctance to innovate, paucity of codes and standards, lack of guidance and information, high capital cost, supply chain integrations, skill requirements etc. Whilst many of these countries have now established strategies to offset these uncertainties, it was also observed that governmental support was pivotal in helping to establish OSM as a viable alternative to traditional approaches. From a Nigerian context, similar parallels are observed, most notably the need to encourage OSM through greater awareness, better government policies, and through skilled supply chain partners in order to help improve the problem of housing shortage.

Dry Construction is quite new to the Nigerian housing industry as about 90% of the industry still uses the conventional block (Ashkin, 2013). The use of OSM in Nigeria has also been affected by factors like: high capital costs, few factories for production of components, reliance on expatriate skills, negative perception etc. (Opara, 2011).

Since OSM involves moving some parts of the construction process to a controlled environment (factory), the construction project can achieve better quality, less time on projects, less cost, reduced risk etc. (Arif et al., 2012a; Gibb & Isack, 2003).

In Malaysia, OSM is referred to as Industrialized Building Systems (IBS) and it was first used in the 1960s (Goulding & Arif, 2013). Also, the adoption of IBS was seen as a way of reducing the influx of foreigners into the Malaysian construction industry (Azman et al., 2012). In Nigeria, Opara (2011), identified reliance on foreign expertise as a problem with the Nigerian construction industry. Based on the experience of Malaysia, this problem can be mitigated by adopting OSM.

BARRIERS TO THE UPTAKE OF OFFSITE MANUFACTURING

Review of seminal literature shows that there are myriad of barriers hindering the uptake of offsite manufacturing (e.g., Arif et al., 2012a; Goulding et al., 2014; Jonsson & Rudberg, 2013; Zhai et al., 2014).
Cost in usually seen as the main barrier to the uptake of OSM (Arif et al., 2012a; PrefabNZ Incorporated, 2013). On the contrary, Alistair and Pendlebury (2006) argued that savings from OSM can be achieved in the areas of cost certainty and reduced risk, less overall life cycle costs, better quality of building which will in-turn lead to reduced maintenance cost, reduced preliminaries and site overhead, reduced construction time which can result in cost benefit from early occupation of properties. Also, WRAP (2007) suggested that savings can be achieved in the use of OSM as a result of reduction in waste of building materials especially bricks/blocks.

Opara (2011) identified high cost as a barrier to the uptake of OSM in Nigeria. Arif et al. (2012b) suggested that, it is more important for the offsite industry to focus more on visualisation and simulation technologies as means of increasing awareness on OSM.

Furthermore, Scofield et al. (2009) identified manufacturing capacity as a barrier to the uptake of OSM. Countries that are more established in the use of OSM, for instance UK, US, Japan etc. have a good number of factories that are into the manufacturing of OSM components. In Nigeria, there a few factories involved in the manufacture of OSM components e.g. Nigerite, Nigeria Portable Cabins etc. Certainly, Nigeria needs to have more factories manufacturing OSM components to meet increasing and future demands. Another barrier hindering the uptake of OSM is the negative perception and few codes/standards (Arif et al., 2012a). In the opinion of Arif et al. (2012a), prefabricated housing was used in the U.K during periods of high demand, that is after the world wars and most of these buildings were of low quality and standard. As a result, there was a general notion that factory manufactured buildings are of low quality, but current research shows otherwise. Arif et al. (2012a) identified improved quality as one of the major drivers to the uptake of OSM. Opara (2011), also identified negative perception as a barrier to the uptake of OSM in Nigeria. Apart from that, currently there are no codes guiding the use of OSM in Nigeria.

Currently, the OSM industry in Nigeria is quite small, as such, there is too much reliance on expatriate skills (Opara, 2011). The construction sector needs to train construction professionals in the area of OSM. This training will create more awareness among professionals and also potential clients.

From the experiences of developed countries, these barriers hindering the uptake of OSM can be tamed; however, for this to be achieved, stakeholders need to put hands together. Since Nigeria is still gradually trying to incorporate OSM, so much can be learnt from countries that have long practiced the system.

In the case of Nigeria, the government and other stakeholders need to come together to set up a body to champion this change that is needed in the construction industry.

It is proposed that the government should facilitate the growth by establishing a body to create the framework, strategies and codes to guide OSM. This could perhaps reduce some of these barriers discussed such as high cost, negative perception, few factories, lack of codes and standards etc. It is also suggested that these barriers hindering the uptake of OSM can be managed using Building Information Modelling (BIM).

In the area of negative image with regards to OSM, BIM concepts and BIM-based preconstruction simulations could contribute to the acceptance of OSM, as this approach could make the process controllable before production and component assembly (Ezcan et al., 2013). BIM can also help with the transportation of building components manufactured offsite, especially through simulation and modelling (logistics) where manufactured components can be micro-managed from the factory (where they are manufactured) to the site where (they will be used); and can also be visualised to see how these components will be fixed or attached to the building (Ezcan et al., 2013). These opportunities were also supported by Sarno (2012).

18 **Delivering Cost Effective and Sustainable School Infrastructure**

Roger Bonner, P K Das, Ripin Kalra, Bill Leathes & Nigel Wakeham

MC This document provides some case studies of conventional constructed schools in sub-Saharan Africa and Asia. It also provides comparative costs per classroom

19 **Preparation of standard designs for low and middle-income housing, schools and other building needs**

Sarah Wigglesworth Architects

MC This document is a collection of projects. This document provides no relevant information for our research.

20 **Education for All EFA School Construction in Developing Countries: What Do We Know?**

Serge Theunynck, Sr. Implementation Specialist

UNESCO

MC This document provides some guidelines for donor agency policies. Some comparative classroom costs are provided. Theunynck gives his clear opinion on the consideration of prefab.

Serge Theunynck is a definitive resource on this topic, as his research is referenced frequently by others.

The following findings are important for donors to consider: (i) demand-driven approaches are efficient; (ii) community-based approaches are cost effective, (iii) savings through bulk procurement are an illusion. (iv) well-defined partnerships are the keys to success, (v) simplified procurement procedures are needed to when working with community partnerships; (vi) focus needs to remain on local capacity and techniques, without useless experiments (vii) social funds and contract management agencies are efficient, (viii) new ideas for maintenance need to be addressed; (ix) sectoral and long-term approaches need improved donor coordination; (x) capacity building in monitoring and evaluation needs to be addressed.

II. Past and current practices

1.1. School Construction – the end of the nightmare. In the 1960s, most World Bank education projects focused on buildings. This "hardware" approach has given way over time to a "software" approach, with a much greater focus on teaching and learning issues and classroom processes. The share of World Bank funds for education going into civil works has fallen from almost 100% in the 1960s to about 45% (1995-98.) The nature of the civil works components has also changed considerably. Yet despite these important changes, civil works are still the single largest share of World Bank lending to education.

2.2 In spite of the focus on construction in the past, implementation was often extremely difficult. During the 1980s, for example, the number of classrooms planned in any given World Bank-financed education project was typically quite modest as compared to needs, and yet results were often poor. For example, in its 1984-91 WB-financed Primary Education Project, Peru planned 1,250 classrooms [1] when more than half a million school-age children were not enrolled. And only 493 had been built by 1991, at a rate of 70 classrooms per year [2]. In the 1980s, the average Sahelian country needed 1,000 additional classrooms per year, whereas construction during this decade averaged 75 classrooms per year [3]. During the 1970s and the 1980s this issue was mainly addressed through efforts on the "technical" field – i.e. technology, architectural design, construction engineering -- which provided little results.

2.3. During the 1990s, efforts to improve in-country construction "technical" capacity shifted towards the "organizational" field -- i.e. implementation and procurement arrangements, decentralization -- with positive results. By the end of the decade, the EFA programs in Senegal and Guinea provided for the construction of 2,000 classrooms annually. Based on the positive improvements of the last decade, one can be optimistic that every country should be able to produce the required number of classrooms to reach EFA by 2015.

Construction technology

2.11. The non-replicable local materials experiments. Beginning in the 1970s, in developing countries around the world, a host of projects sought to lower construction cost by use of local materials produced through "appropriate" [33] technologies. The movement started in Latin America with soil-cement technology. In Africa, such efforts reached their peak in the 1980s and have declined throughout the 1990s. Secondary objectives of these efforts were to : (i) reduce foreign exchange component of costs; (ii) reduce non-renewable energy-consuming materials such as cement [34] by promoting, for instance, compressed earth blocks, (iii) save scarce natural resources (i.e. Sahelian wood) by promoting traditional

architectural forms such as vaults for roofing, (iv) use labor-intensive construction techniques to decrease high unemployment levels in poor areas, (v) improve community ownership through participation in financing and labor. This approach was formally endorsed by the UN system [35] which supported several National or Regional Centers for the Research and Promotion of local materials. [36] Support was also given by some European universities [37]. Experiments were implemented by Governments mainly through NGOs and supported by a large range of donors including the World Bank [38] and involved significant international expertise. The United Nations Center for Human Settlements (UNCHS) created a Center for Adapted Technologies (Centre de Technologies Adaptées – CTA) in Bamako (Mali). UNESCO financed a large number of school prototypes built in local materials (BREDA and UNESCO Sudan Bureau). However, as early as the late 1970s (i.e. the WB-financed Education project in Brazil) [39] the absence of replicable results of these experiments was identified. Actually, these experiments always required large and costly technical assistance (international experts, UNESCO experts and staff form international consulting firms), and failed to survive after this assistance ends with the promoting project. However, tests continued for another decade with same results, as in WB-financed Education project in Niger (1986-95) [40]. By the late 1980s, after two decades of effort, the local materials approach was generally recognized as unsustainable, was generally abandoned. Reviewing Sahelian experiences, a 1993 World Bank Discussion Paper stated: "This research very quickly reached its limits, running into difficulties in transferring the know-how both to the formal and informal construction sectors" [41]. Compared to costs in the modern informal construction sector, local materials have not proven to be less expensive than modern technology, nor have they succeeded widely in reducing cement consumption, and leading to increased local ownership [42].

2.12. The failure of full pre-fabrication attempts. During the 1980s, some countries attempted to launch a process of classroom industrialization. The idea is attractive: classrooms are very standardized items, to be built in large numbers (Philippines 10,000 per year). Industrialization seems like a promising way to reduce costs and delays and to improve quality, providing at the same time a unique opportunity to contribute to the modernization of the national construction industry. Two countries tried full classroom prefabrication: Pakistan in 1985 [43] and the Philippines in 1994 [44]. With prefabrication, Pakistan expected to decrease its unit cost from an average of $4,500 per classroom [45] to less than $3,500 [46]. Bids came in even lower than expected, at $2,700 per classroom, but contractors were unable to carry out more than 5% of the contract, due to difficulties to transport prefabricated classrooms through existing low standard routes and paths, and to set-up them on school lands with inadequate topography. At the end of the project, actual classroom costs were double and frequently triple the $3,500 initially planned [47]. The Implementation Completion Report notes the disconnect between reliance on a sophisticated factory-made product, which was supposed to be suitable for all geographic and climatic conditions, and the local technological, administrative and social conditions in which the high-tech technology would be implemented [48]. The Philippines, with experience building more than 10,000 classrooms per year, made its attempt at pre-fabrication in 1994-95 with the objective of lowering costs from US$10,000 to US$9,200 and simplifying procedures by reducing the number of contracts. However, cost savings were reduced by the cost of site preparation by LGUs, and more than 25% of the prefabricated classrooms could not be transported to or assembled on the sites due to road or land conditions. Prefabrication was quickly abandoned by both countries [49] which returned to previous classic technologies. In addition to the actual implementation failure, the sophisticated technology of industrialized classrooms generates communities' frustration since the investment has no impact on local employment, requires unavailable

high-tech technology for maintenance, and cannot be a model for other communities' investment. The failure of classroom full-prefabrication in developing countries is consistent with similar experience in developed countries where small construction projects are still built by small and medium contractors at competitive prices compared to prefabricated buildings. Based on experience to date, classroom industrialization does not appear to be a promising solution in the EFA context.

Procurement Arrangements

2.18. Large vs. small contracts. Because classroom needs are large and predictable, they were considered, in the past, as a good basis for large packaging of works to be executed through large contracts. In the 1970s, most of the education projects in Africa financed by IDA, AfDB, UE, among others, were based on large contracts which were characterized by: (i) centralized procurement leading to International Competitive Bidding [74], (ii) simplification of procurement procedures by governments with limited procurement capacity and donors favoring prior review of procurement processes, (iii) reliance on large contractors with strong financial and technical capacity where Government of donor monitoring capacity was limited. Large contracts often resulted in: (i) an inadequate distribution of schools due to centralized planning resulting in empty new schools co-existing with unmet needs nearby, (ii) construction delayed by cumbersome public procurement procedures [75], (iii) high construction costs up to $17,000 (Mauritania 1984) to $20,000 per classroom, due to a low level of competition between the few large contractors (sometimes forming a cartel) able to fulfill formal administrative requirements for bidding, dividing between themselves a small public construction market. At the end of the 1980s, most Governments and donors shifted from supporting large contracts to smaller contracts. Small size of contracts, geographic dispersion of sites, and competitiveness of the local construction industry appeared to be favorable conditions for lowering construction cost, resulting in lower-cost schools, managed either by: (i) central Government Agencies (or local branches of such agencies), (ii) NGOs, and (iii) Contract Management Agencies (CMAs). By the end of the 80s, most World Bank-financed projects shifted to small contracts awarded through NCB procedures (Bangladesh [76], India [77]). In the 90s there were no ICB procedures in any projects financed by the World Bank or the other principal donors.

B. Construction costs: the promises of the "organizational" approach

2.19. After two decades of experimentation and disappointingly modest results, the 1990s and the 2000s have already seen a large array of organizational innovations.

Implementation Arrangements

2.20. Central vs. decentralized governmental planning and procurement. Until the 1980s, in most developing countries, governments' central agencies were responsible for school construction, from planning to construction contract management. In some countries, central directorates in Ministries of Education attempted to carry out the full range of activities: from construction planning, school design, to works procurement and site supervision. In other countries, the MoE delegated this responsibility to the ministry over civil works. World wide experience shows that Government management of the school building program either centrally or regionally, results in: (i) inadequate classroom allocation, (ii) weak monitoring capacity of the implementation agency, and (iii) low construction quality [78]. Since the 1980s, several Governments started transferring procurement responsibilities from the central level of the Ministry to sub-level entities of the

same Ministry through decentralization, such as the Philippines. Not much of a cost savings was seen as a result of the decentralization.

2.21. Devolution to Local Governments. Throughout the 1990s, there has been considerable pressure within countries and the international community to modernize governments by reducing the role of the central government to one of primarily policy and norm setting, while devolving service delivery and infrastructure to regional and local levels, or even private entities. Expectations were that this would result in lower costs and improved construction quality through better site monitoring by local government engineers. Devolution to local government is also expected to produce the following improvements: (i) closer monitoring leading to better work quality, (ii) local bidding, with increased use of local labor, lower costs and heightened community ownership leading to a greater commitment to maintenance, (iii) better integration of municipal investment between sectors expected to result in more active support of education.

2.23. The disappointing combination of partial community-based approaches and partial centralized procurement. The World Bank has supported community construction of school buildings in several projects in Africa and South Asia. Many of these projects met difficulties because the designs called for construction techniques unfamiliar to local craftsmen and could only be implemented by providing intensive supervision and training. In response, alternative solutions were tried. For instance, community participation was limited to site preparation and foundation building, while the remainder of the building was constructed by an experienced contractor. This design adaptation also proved too complex. The cost of providing technical support often exceeded any savings associated with community construction.

2.24. Positive results from delegation to NGOs. Many countries have delegated school construction to NGOs at some point to promote community participation and reduce construction costs. NGOs often have better access to the poor and can mobilize local resources, stimulate participation, and generate innovative solutions to local problems. NGOs are playing an important role in promoting education through school construction. Many NGOs are able to build low-cost classrooms with their own funding, but the scale is usually too small to have a national impact. In a few countries, the government has fully delegated its national school construction program to NGOs.

2.26. Delegation to Contract Management Agencies (CMAs). Since 1990, many countries in Africa have worked through Contract Management Agencies. Following the non-profit AGETIP model (Agence d'Exécution de Travaux d'Intérêt Public – Public Works and Employment Agency) created in Senegal in 1989 [94] subject to ex-post monitoring by the government, 11 AGETIP-type agencies [95] were created in West Africa (Benin, Burkina Faso, Gabon, Gambia, Guinea-Bissau, Madagascar, Mali, Mauritania, Niger, Senegal and Togo). These agencies were given operational autonomy to implement large-scale small construction programs, to be carried out by small contractors with local labor. These institutions were relieved of the burden of public procurement and disbursement procedures and enjoy quick procedures described in public operation manuals. They are staffed with skilled professionals recruited from the private sector. They select, pay and supervise contractors and architectural/ engineering services for site supervision. Their mandate is to promote small and medium enterprises (SME) by allowing them to bid for contracts. These agencies have changed the "rules of the game" and have contributed to the growth of the construction industry [96].

2.28. The increasing role of Social Funds. Social funds were initially developed in the 1980s to mitigate the effects of the structural adjustment crises and designed to provide employment. By the 1990s, they had become almost ubiquitous instruments in the fight against poverty. In 2000, social funds existed in 50 countries in the World Bank's LAC region, 24 in Africa, some in the World Bank MENA Region, and were rare in Asia [100]. Social funds have gradually moved from using construction to promote temporary employment, to longer-term poverty reduction and community participation. Like the AGETIPs referenced above, social fund agencies are generally exempt from public procurement and civil service rules. The main characteristic of social funds is that they are demand-driven with projects generally originating in communities and NGOs. Most projects funded by Social Funds are not community-based and are implemented by the social fund agencies themselves, which act as contract management agencies, managing contracts with private firms and varying degrees of community involvement. Some social funds, such the Zambian one, are community-based (see below). Others, such as is the case for Angola's FAS, are in the middle, with communities taking decisions and hiring labor teams while the Agency manages funds and pays invoices [101].

2.31. Delegation to communities: a success story. Community-based approaches are of two types: (a) demand-driven as in the Mauritanian and Indian examples below, and (b) targeted, as in the Malian example below. However, results are all positive.
Africa. In 1989, Mauritania was the first country to fully delegate its national classroom construction program to communities (Parents' Associations) under the World Bank-financed Education Sector Restructuring Project (see Case Study) through community-based, demand-driven process. Unit costs were cut from $18,000 (1984) to $5,600 in 1991 (for lower architectural standards, but same size and similar life expectancy) [121]. The demand-driven community-based approach established a dynamic that boosted demand for education and helped mobilize additional donors (AFD). Communities built about 1,000 classrooms instead of the 250 initially planned by the project. By the end the subsequent WB-financed Education project [122] which continued this best practice, communities had built about 2,600 classrooms. Unit costs stood at about $4,600 per classroom in 2000 [123], one third of the cost (US$13,200) of the same type of classroom built by a contractor hired by Amextipe (Agetip-type MCA) under NCB [124]. Gross primary enrollment reached 86% in 1998/99 compared to 47% in 1989-90. Mali undertook in 1998 a successful community-based demand-driven approach with the Grass-roots Initiative Project in the Mopti region which built classrooms at US$6,600, 13% cheaper than similar constructions built by Agetipe at US$7,600 [125]. A similar approach was developed by Zambia in 1991 by the EU and WB through a Social Fund [126] and adopted in 1999 by the WB-financed Education Project [127]. In both projects, community-built classroom unit cost was $8,800-9000, less than half the cost of classrooms built over the same period using classic NCB procurement [128]. It is estimated that 40% of the cost difference is attributable to higher architectural standards, and 60% to the implementation and procurement arrangements [129]. The Social Fund created in Malawi in 1996 also adopted the community-based demand-driven approach. The Education Ministry in Chad decided in 2001 to follow a similar approach, using the Mauritanian engineers as technical assistants to set up their project.

2.32. Strategies for the success of community-based construction include the following: (i) only locally available materials are used, (ii) only construction techniques familiar to villagers and local craftsmen and contractors are used, (iii) design improvements are limited to those necessary to ensure standard durability and safety, (iv) duties and responsibilities of partners are well defined. Regular technical supervision will help in ensuring that quality standards of construction are met but does not substitute to close monitoring by

communities. The Mauritanian experience, based on result-oriented technical supervision combined with appropriate advices to local builders by supervisors, provides good results since supervision is regular and supervisors accountable. In the South-East countries, authorities tended to consider supervision as money wasted since weak supervision resulted in some proportion of classrooms of poor quality. Community pride in ownership of a well-built school, combined with appropriate technical advice to local builder is the main factor of quality construction.

2.33. Finally, community-based approaches are likely to be successful in countries where community involvement is a tradition. Community-based approaches in places where community participation it not the norm needs to be introduced carefully as a social change experiment.

B. The General Failure of Maintenance

2.34. The unsolved problem. Classroom maintenance is still an unsolved problem. For Governments, maintenance of investment is an economic duty. In addition, good or bad maintenance of educational facilities has an impact on educational outputs since decrepit and inadequate facilities make schooling a less attractive product to children, parents and teachers. This well-known issue has not been correctly addressed. The composition of national classroom stocks to be maintained, result from the combination of communities' and Government construction efforts. Classrooms built by communities, often with local non-permanent materials request a permanent high level of communities' efforts, just to keep them operational, consuming a large part, if not all, communities' maintenance capacity. In the opposite, government-built classrooms are most often legally Government-owned and considered by communities to be maintained by the owner, while the latter, in most developing countries, have never budgeted adequate resources nor set up adequate implementation arrangements. In many countries, poor Governments have simply shifted this responsibility to communities, also poor and heavily burdened by all other education costs. In addition, communities' reluctance to maintain Government-owned school buildings increases when the quality of construction is low, thus requiring……

21 **Army Relocatable Buildings**

Michael Dean, Bill Allen, Anthony White, 2008

MC This document shows various relocatable (modular) building types used by the Army.

22 **22 ufc_1_201_01_2013 Unified Facilities Criteria**

MC This document is not specifically relevant to our research. This UFC may however provide requirements or general guidelines to be followed for construction of "temporary and semi-permanent" buildings.

23 **Prefabricated Construction for Mass Housing in Mumbai**

Krish Villaitramani, Dhruv Hirani, 2014

MC This document provides no relevant information for our research.

24 **South Sudan Education Programme Construction & Rehabilitation of Education Facilities**

Nigel Wakeham

DFID, March 2012

MC This document is a compilation of field reports from the construction of school buildings. None appear to be prefab. This document may be of some use for conventional construction in South Sudan.

25 **Kingdom of Morocco, Education and Training Sector Survey (In Six Volumes)**

Volume II Investment in Education and Training

The World Bank, 1983

MC This document is specifically on prefab schools built in Morocco with emphasis on girl's education. However, there is very little provided on the prefab aspect—as they found the prefab construction to be a complete failure.

Methods of construction. Construction under the Project relied on prefabricated materials. This method should be avoided in the future. The materials did not adequately meet the needs of users, and because communities were opposed to their use, community involvement in the education process was lukewarm.

26 **Implementation Completion Report Kingdom of Morocco Rural Primary Education Project**

The World Bank, 1997

MC This document is a summary evaluation of the financial and educational outcomes for schools financed from 1989 through 1996 in the Kingdom of Morocco. The document concludes that prefabricated construction is to be "avoided in the future". (The conclusions are synonymous to those from the previous reference document, which evaluates projects preceding the dates of this document.)

The document may be of additional value in its summary conclusions and its identification of critical issues important to educational infrastructure development

27 **Education for All; Building the Schools**

The World Bank, August 2003

MC This document is a simple summary of principles that should be basic to new school buildings

28 **Assessing the Thermal Performance of Temporary Shelters,**

Ying Yu, Enshen Longa, Yuan Shen, Hongxing Yang, 2016

MC This document is not specifically relevant to our research topic, as it is about thermal issue in China. But there may be some applicable lessons.

29 **Analysis of costs and benefits of panelized and modular prefabricated homes**

MC This document is about prefab housing costs. The information contained in the document does not bear useful relevance to our research.

30 **Application of wind engineering research in the developing countries; Lessons from the Caribbean and India**

Frederick, C. Cuny

MC This document is specifically not relevant to our research topic.

31 **Construction Technology Diffusion in Developing Countries Limitations of Prevailing Innovation Systems,**

Emilia van Egmond-deWilde de Ligny, Journal of Construction in Developing Countries, Vol. 13, No. 2, 2008

MC This document is on the general concept of social acceptance of "new" construction technologies. There is a prefab case study, but it is not relevant to our research topic as it is about housing.

32 **Manufactured Housing - Efforts Needed to Enhance Program Effectiveness and Ensure Funding Stability**

MC This document is not relevant to our research topic.

33 **Housing industrialization success and failure universal and local - Limits for housing globalization,**

A. Lopes Correia, V. Murtinho, L. Simões da Silva, Structures and Architecture: Concepts, Applications and Challenges, 2013

MC This document is about prefab housing and is not specifically relevant to our research topic.

34 **Secondary Education in Ethiopia Supporting Growth and Transformation**

MC This document has no specific refences to buildings, but it does have some reference to policy.

35 **Child-Friendly Schools Infrastructure and Guidelines; Primary and Tronc Commun Schools,** Rwanda Ministry of Education, 2009

MC This document has no specific refences to prefabricated construction. The document is a literal design guide that identifies the standards and requirements for all school buildings built in Rwanda. ("Tronc commun" is the French term for "common core" studies.) The target audience of the document extends from "Ministry staff, District staff, International agencies, NGOs, Faith Based Organisations, School community, PTC, Private sector, building professionals and contractors. This document is to be referenced by all who are involved in the planning, monitoring, designing, procuring, constructing and rehabilitating school infrastructures."

36 **Prefab Content Versus Cost and Time Savings in Construction Projects: A Regression Analysis,**
Wajiha Shahzad, 2014

MC This document analyzes 30 commercial construction projects in New Zealand and provides comparative review for cost and time savings when prefab is used. While the construction sector and location make extrapolation of the findings unusable for our research, within the proper context, this document confirms that cost and time savings can be attained when prefab is used.

37 **School Construction Strategies for Universal Primary Education in Africa; Should Communities Be Empowered to Build Their Schools?** Serge Theunynck, 2009

MC This book is the most comprehensive and detailed analysis of nearly all the relevant data points to be considered for providing schools in developing countries—and particularly those in Sub-Saharan Africa. As pertains to prefab, the author concludes that the assumed "faster, cheaper, better" aspects of prefab simply don't bear true when applied to providing schools (or housing) in the developing world.

As pertains to policy, the author emphasizes that centralized planning and decision-making lead to inefficiencies and isolate local owners and end-users from deeper involvement at the initial project planning stages, which then leads to lesser investment and sense of personal ownership of facilities.

38 **Primary School Buildings Standards, Norms and Design;** Jean De Spiegler, 1986

MC This document does not address prefab. The document is a graphical design guide for schools in Bhutan.

39 **Investigation on the Effective Usage of Prefabricated Elements in Construction Projects and Developing a Module to Reduce Time and Cost;** K. V. Vinoth Kumar, 2016

MC This document analyzes cost and time savings for prefabricated concrete panels construction in India. The data compiled does not appear to be based on a particular construction sector, and therefore, may not be able to be extrapolated for relevance to our research on schools.

40 **Industrialized Construction Chronology the Disputes and Success Factors for a Resilient Construction Industry in Malaysia;** Ali Rashidi, 2017

MC This document identifies various systems and terminology associated with industrialized building (prefabricated construction). The document identifies critical success factors essential to implementation.

41 **Transitional Shelter Guidelines;** DFID 2012

MC This document is the culmination of years-long study that identifies essential requirements for the planning design and construction of transitional shelter/housing. This design guide does not explicitly address prefab. The key information this document provides to our subject research is the form and structure to the planning, design, and construction of any construction project that addresses relief or aid in developing countries.

42 **Forced Migration Review: Shelter in displacement,** University of Oxford, 2017

MC This document is a journal that specifically addresses the issues of populations in forced migrations, and their housing needs. The article written by Irit Katz emphasizes that the *architecture* of prefab structures doesn't usually create conducive environments for permanence. He suggests that when inhabitants create "free-fab" structures, more organic shelters are formed that generate a sense of place where cultural, social and emotional connections may be fostered—even in a temporary setting.

43 **Developing a Framework for Prefabrication Assessment Using BIM,** C. Fernandez, 2014

MC This document provides an analysis of how Building Information Modelling (BIM) can be utilized in the design and manufacturing of prefabricated construction components.

44 **Open System Platform for Open Building Manufacturing,** J. Maseda, 2010

MC This document introduces the concept of "open building" construction. Essentially, the concept is that prefabricated construction systems can be designed to be generically flexible. This document specifically addresses the (conceptual) "Open Manubuild System

Platform" which would allow the design and manufacture of such systems specific to a project.

45 **CE2045 Prefabricated Structures,**
M. Dinagar, 2012

MC This document is the course curriculum of a civil engineering class on prefabricated construction. The document may be useful in its simple outlining of various systems and critical issues relevant to employing the systems.

46 **Comparative Study on Prefabrication Construction with Cast In-Situ,**
N. Dineshkumar, P. Kathirvel,

MC This document is a study of conventional versus prefabricated precast concrete residential buildings in India.

47 **Open Building Concepts,**
Stephen Kendall, 2006

MC This document provides little more than a very broad overview of the open building concept.

48 **Prefabrication in Developing Countries: A Case Study of India,**
R. Smith, S. Narayanamurthy,

MC This document looks at prefabrication in general as it is applied in India.

"The role of prefabrication in architecture has been lauded for its potential to increase productivity and efficiency while not sacrificing quality. The values of better, faster and cheaper are applicable to developed countries such as the U.S., Japan, and Europe, whose middle class continues to demand this equation in buildings that range from the remarkable to the prosaic. Developing countries, including China, India, Africa and many parts of South America, that are beginning to rely on prefabrication have the potential advantages of realizing housing quickly and affordably; however, greater reliance on manufactured production has possibly more disadvantages than advantages for these cultures.

With prefabrication, improved working conditions would seem to be agreeable to everyone: instead of building in the weather, international fabricators supply controlled environments with ergonomically considered equipment – and yet in many fabrication environments, reliance on minimal skills, and a disconnect with the community in which workers live, leaves little room for continued fostering of personal and collaborative skills, culture, tradition and community building. The potential for prefabrication to be used to create a bland, monotonous landscape is an issue that developed countries' construction professionals must grapple with. Countries such as India are undoubtedly suffering a greater banality in the built environment by embracing prefabrication. Prefabrication is touted as offering a more sustainable solution to building, but developing counties already

rely on vernacular practices for design and construction that require relatively low life cycle energy.

Developing countries continue to embrace technology from their developed country allies. This trend does not seem to see a slowing. The following paper will address this growing trend through the example of India, a country that is transforming quickly by adopting digital, material, and construction technologies from around the world and rapidly transforming its landscape. This paper will illustrate the advantages and disadvantages of prefabrication adoption in this culture and suggest ways in which developed countries architects and local building professionals may take a leadership role in fostering both culture and technology.

Technology transfer can affect the government, economy, and culture of both the transferring and the receiving nations. It opens too many ethical dilemmas." Prefabrication will continue to grow in India as the demand for fast affordable housing increases. However, technology transfer of prefabrication process, including materials and digital tools, can affect the environment, economy and culture of the receiving country negatively. There are risks associated with the transfer of prefabrication technology. The host country may not have the infrastructure, the manufacturing and/or professional prowess to accept it. The negative effects can be social, environmental and/or economical."

49 **Offsite Manufacturing in Developing Countries: current Situation and Opportunities,**
S. Mostafa et. al.,

MC This document introduces "lean" and "agile" methods of manufacturing as regards to prefabricated construction.

50 **Marginal Productivity Gained Through Prefabrication Case Studies of Building Projects in Auckland,**
W. Shahzad, et. al., 2015

MC This document may provide additional definitions, but referenced data is specific to Auckland, New Zealand. Also, the cost data is reviewed through advanced mathematic formulas--

51 **Performance of Modular Prefabricated Architecture: Case Study-Based Review and Future Pathways,**
F. Boafo, et. al., 2016

MC This document summarizes various concepts related to prefabricated construction and analyzes performance of projects in China.

52 **Merriam-Webster Online Dictionary**
copyright © 2015 by Merriam-Webster, Incorporated

53 **Harrison, Melvin. "The Crystal Palace Foundation."**
Crystal Palace Aquarium Co Ltd - The Crystal Palace Foundation, www.crystalpalacefoundation.org.uk/History/.

54 **“Sears Archives, History.”**
Sears Archives Home Page, www.searsarchives.com/homes/index.htm.

55 **“Homage.”**
Habitat 67, www.habitat67.com/en/homage/.

56 **Rossen, Isabella. “La Maison Tropicale: From Failure in Niamey to Masterpiece in NYC.”**
Failed Architecture, 19 Apr. 2013, failedarchitecture.com/la-maison-tropicale-from-failure-in-niamey-to-masterpiece-in-new-york/.

ANNEX 6. EVALUATION METHODS AND LIMITATIONS

EVALUATION METHODOLOGY

The evaluation methodology is based on literature review, a series of Key Informant Interviews (KIIs) with engineering and international development experts and end users and the analysis of the use of prefab construction in an international development context through a comparison of existing prefabricated and conventional construction projects. The analysis is focused on construction of education and health-related facilities.

The purpose of this analysis is threefold:

1. To evaluate the effectiveness of the use of prefab construction in the USAID development context;
2. To validate common perceptions regarding the merits of prefab construction versus conventional construction; and
3. To establish evidence for when prefabricated construction may be appropriate to facilitate decision-making regarding the selection of prefab construction versus conventional construction solutions.

This analysis considers prefabricated construction through the following elements:

- Usability
- System meets Local Code/Building standards
- Environmental Compliance
- Site Conditions
- End-user Acceptance
- Sustainability
- Constructability
- Local Labor (& Skillsets)
- Cost (including cost of logistics)
- Schedule
- Quality
- Material Life Cycle
- Procurement (Including overall acquisition approach)
- Policy

The following graphic describes the stepwise process used in this analysis:

In addition to a comprehensive literature review, the analysis includes an assessment of USAID policies, Federal Acquisition Regulations and other US government and international development agency practices as they relate to prefabricated construction.

This analysis has been conducted to:

1. Gain an understanding of the impact of USAID policies on the selection and use of prefab construction; and
2. Identify policy gaps that impact construction program decision-making and implementation, particularly related to the use of prefab versus conventional construction.
3. Understand policies that other organizations have developed to respond to the strengths and weaknesses of prefabricated construction.

Key Informant Interviews were performed as an indispensable method for documenting and understanding others' experiences with prefabricated construction in a development context and within the context of US government procurement regulations. The interviews provided a way to gauge of the strengths and weaknesses of prefabricated construction. The interviews further provided a way to understand the organizational drivers when considering prefabricated construction.

Among those interviewed are facility owners, such as the Ministry of Health personnel, and facility end-users. These interviews provided their experiences with prefabricated facilities. This information qualified owner experiences using the facilities, particularly with regards to comfort, size and sustainability.

The evaluation includes a SWOT analysis that is to be used to identify the strengths, weaknesses and risks in using prefabricated construction as well as potential opportunities. Key informants were also asked about their recommended prefabricated best practices, which are consolidated herein.

The following table, which is aligned with the Project Scope, elaborates the Data Collection Methodology.

Table 1: Data Collection Methodology and Response Analysis

Process	Scope of Work	Data Collection Methodology and Response Analysis.
Policy and Procurement Assessment	The Contractor will identify and review policy and regulation guiding the selection and implementation of prefab vs. conventional approaches for building at USAID. What influence do the existing USG/USAID policies, contracting, and procurement procedures have when deciding between conventional and prefab construction? When and how are prefab buildings not construction?	Discussions were held with the USAID infrastructure team to review the USAID project development protocol through project procurement. This review was performed to verify the process and identify policy and procedures that may impact prefabricated construction. USAID and other procurement-related documents were then reviewed to identify how they are to be used when prefabricated construction is selected for use. RFP documents were also reviewed where construction was being undertaken in order to

		understand how these systems were being procured.
	What regulations and policies dictate the use of prefab infrastructure in certain programmatic settings? Is current internal programmatic guidance limiting construction to PREFAB/pre-fabricated approaches supported by policy and regulation? What gaps and/or inconsistencies exist in the policy that would support selection of the best and most appropriate approach?	The USAID infrastructure team reviewed procurement practices with contracting personnel in order to understand the regulations and to inform how contracting personnel understand construction. This information was also used to verify some of the findings (e.g. prefabricated facilities can be procured as supplies rather than as construction). Other US Government documents and policy were reviewed as they related to prefabricated construction. DoD organizations in particular encountered issues with prefabricated construction and had developed specific prefabricated construction standards and policies in order to address these issues.
	This analysis will be supported by examples of USAID construction contracts and procurements.	Although the intent was to review prefabricated projects with USAID staff and implementers, this could not be coordinated during the assessment period. In addition, the Contractor was unable to get approval to review actual contract documents for two projects in which prefabricated construction had already been implemented.
Technical Considerations	What are the real strengths, weaknesses, opportunities and threats for prefab infrastructure and how do these aspects differ from the common preconceptions? The contractor will provide an analysis of the technical realities of prefab infrastructure and how those realities relate to the experiences of USAID staff and its beneficiaries. This analysis will be illustrated by examples of prefab	**Hypothesis** *Proponents of pre-fabricated facilities claim that such systems are faster, cheaper, provide a better product (use), and last longer.* *However, the Contractor postulates that pre-fabricated projects are often deployed without the same level of care in design, procurement planning and oversight as conventional projects.* **Hypothesis Testing**

	construction supported by USAID and other development organizations. The analysis under this task should consider discussion of advantages, disadvantages and limitations for the following general criteria: • Timeliness • Cost • Quality • Design • Sustainability	The hypothesis is tested in three ways: 1. Literature review of other prefab facilities in a development context; 2. Questionnaire/Interview with implementors experienced with deploying prefabricated systems. 3. Field results comparison of a conventional and pre-fabricated program Since only a small number of projects were available to be sampled, the data analysis is qualitative in nature. **Literature Review (General Comparison)** In this analysis, prefabricated systems were evaluated in comparison to conventional systems through the 9 elements. Their strengths, weaknesses, threats (major failure considerations) and opportunities were evaluated. **Implementor Experience** USAID and the Contractor identified experts who engaged in managing prefabricated construction projects. Interviews were conducted in a discussion format based upon the different elements. This process was used to fully assess and understand system strengths and weaknesses, as well as other potential limitations. Experts were also asked to comment on a recommended set of implementation best practices. **Implementor Cost / Schedule Comparison** Comparative cost data and schedule data were gathered

		instead of detailed cost information, given the sensitivity of such data. **Project Comparison (Results Comparison)** Two locations were identified in which PREFAB projects and traditional projects have been constructed. Field staff were provided with a checklist to evaluate 2-3 projects of both types in order to assess project outcomes. The Contractor also interviewed project teams, as available, to understand how programs had been delivered. USAID had conducted field assessments in Malawi and those results were utilized.

EVALUATION LIMITATIONS

Given the small data-set and the conditions of this analysis, there are several factors that limit the thoroughness of the evaluation. These limits include:

1. Lack of input from USAID activity managers
   The assessment of how Missions were performing prefabricated infrastructure is based upon RFP documents, inputs from USAID contracting staff and discussions with a limited number of implementors instead of direct conversations with USAID activity managers and procurement staff who have experience implementing prefabricated construction projects. This limited the Contractor's ability to fully assess how prefabricated construction was being implemented by USAID

2. Difficulty of comparing projects in dynamic environments
   The evaluation attempts to compare constructions that are as similar as possible in all regards except that some projects relied on pre-fabricated construction and others relied on traditional construction. However, all construction projects exist in highly dynamic environments and their success is subject to a wide range of variables, such as proximity to a local supply chain and qualified labor, quality of design preparation, quality of management and oversight, importance to a population or authorities, changing environment, changing regulations, access to new technologies, and many other dynamic parameters. While the evaluation does attempt to control for these variables by looking at results from a similar context, this could lead to exaggerated or understated findings.

3. Inability to directly compare cost and schedule
   The Contractor did not review actual cost or schedule data from infrastructure projects for purpose of comparing differences cost and schedule variances between methods of construction (i.e. traditional stick built vs. prefabricated). For this analysis the Contractor relied on literature research and implementor expert opinions to draw general conclusions regarding cost and schedule impacts of various construction methods.

4. Small number of projects
   The evaluation assessed programs that have utilized pre-fabricated construction. Visiting these programs gave the Contractor a broad overview of the utility of pre-fabricated construction in specific contexts. However, given the small number of planned project site visits, this may have caused exaggerated or understated findings which limited the applicability of lessons learned from these visits.

5. Sample Selection
   The qualitative data collection employed by this evaluation relies on convenience sampling, meaning that the Contractor spoke to whomever had proper technical expertise or experience and was willing to serve as a respondent to interviews and the survey. While the qualitative data collection certainly creates a narrative around the evaluation's criteria, it also suffers from particular biases.

6. Reliance on USAID for Guidance
   The Contractor relied on USAID for access to evaluation stakeholders and for assistance in identifying USAID infrastructure projects to consider in this evaluation. Even with the best of intentions this type of reliance has potential to create biases in the final report. To mitigate this, Perez also considered information gathered from key informant interviews with industry stakeholders and experts not identified by USAID.

ANNEX 7 COMPARISON OF 11 CASE STUDIES FROM LITERATURE REVIEW

Author	Title	Publisher	Paper Overview
Evans K. Essienyi	Prefabricated Housing, a Solution for Ghana's Housing Shortage	Submitted to the Program in Real Estate Development in Conjunction with the Center for Real Estate on 29 July, 2011	This reviewed a prefabricated housing in Ghana. The government was looking for ways to provide a large quantity of affordable housing and hired a Dutch firm to build prefabricated factories to help meet the local housing need. The project was abandoned as costs for each unit were significantly higher than planned given that set-up and production costs were greater than expected.
Kolo, Shaba, Pour Raiman, Farzad and Goulding, Jack Steven	Offsite Manufacturing: The way forward for Nigeria's Housing Industry	Alam Cipta Vol 7 (1) June 2014	This article assumes that prefabricated construction is an effective option for some of the construction challenges in developing countries, particularly with regards to a lack of skilled labor. The paper does describe some barriers to implementation in developing countries to include high initial set-up costs for manufacturing, lack of standards, and the perception of poor quality by potential housing buyers.
Theunynck, Serge	School Construction in Developing Countries: What Do We Know?	https://www.humanitarianlibrary.org/sites/default/files/2014/02/Theunynck%2520%282002%29%2520School%2520Construction%2520in%2520Developing%2520Countires.pdf	This article identified two large school construction projects that attempted to use prefabricated construction and issued large contracts - Pakistan in the 1980s and Philippines in the 1990s. Both projects were significantly over budget and construction was difficult in remote areas. Both reverted to conventional construction. Overall Mr. Theunynck makes the case that established modern building methods are most appropriate for school construction.
Theunynck, Serge	School Construction Strategies for Universal Primary Education in Africa: Should Communities Be Empowered to Build Their Schools?	World Bank 2009	In this paper, Mr. Theunynck identified and provided a review of 5 prefabricated school construction programs. The school buildings cost more than conventional construction in every case. The major issue was transportation and the need to engage expensive international contractors given the large sizes of the awards (who then used local subcontractors with an additional overhead). The main benefit was the reduction in labor, which actually frustrated local communities since outside labor and materials are brought in.

World Bank	Implementation Completion Report, Kingdom of Morocco, Rural Primary Education Project	World Bank 1997	The report explicitly states that prefabricated construction should not be used for school construction in the future. It did not meet the needs of the users, communities did not think they were good quality and they were not engaged in the design or construction process. Overall end-quality was poor with sagging ceilings, falling panels and problems with heating/cooling systems.
Cuny, Frederick	Application of wind engineering research in the developing countries: Lessons from the Caribbean and India	Publisher N/A c.1980	This paper reviewed shelter options for disaster victims. The paper did not recommend prefabricated construction as it was not perceived well by the victims, often did not meet wind requirements due to poor detailing and overall quality of the buildings were poor. The only benefit was its potential for a reduced implementation schedule.
A. Lopes Correia, V. Murtinho, L. Simões da Silva	Housing industrialization, success and failure, universal and local: Limits for housing globalization	Taylor & Francis Group, London 2013	This paper reviews why prefab has not necessarily taken hold in developing markets. The author discusses the importance of infrastructure meeting local conditions, which makes technology transfer difficult in the housing sector. The prefabricated systems that work are generally flexible, easy to construct, uses understood/safe technology and has an effective marketing program. The inverse for poor systems.
Isabella Rossen	La Maison Tropicale: From Failure in Niamey to Masterpiece in NYC - Failed Architecture	https://failedarchitecture.com/la-maison-tropicale-from-failure-in-niamey-to-masterpiece-in-new-york/ Downloaded 10 Aug 2018	This paper reviewed the iconic prefabricated concept developed in France for its Western African colonies in the 1940s. Although well thought through with regards to its design and usability, in the Congo and Niger the people were fearful of the building. In the end only 3 concept houses were constructed, and the large-scale plan was never implemented. One of the concept homes recently sold at an auction for $7M.
Ryan E. Smith, Shilpa Narayanamurthy,	Prefabrication in Developing Countries: a case study of India	International Journal of Advanced Engineering Research and Applications Volume – 2, Issue – 2, June – 2016	This paper reviews prefabricated construction in India. Smith and Narayanamurthy state that prefabricated construction is seen in India as providing better quality outcomes given its production in the factory. The problem that the authors see as limiting prefabricated construction in India is that it is difficult for investors to recoup their initial prefabricated factory set-up cost with the current housing rates. Also building prefabricated construction requires more advanced processes and it is often difficult to re-train a conservative construction market to support this new construction.

Sherif Mostafa, Jantanee Dumrak, Nicholas Chileshe, and Jian Zuo	Offsite Manufacturing in Developing Countries: Current Situation and Opportunities	Conference: 5th International Conference on Engineering, Project, and Production Management (EPPM 2014), At Port Elizabeth, South Africa	This paper starts with the assumption that prefabricated construction and central manufacturing provides a cheaper and better-quality product. The paper acknowledges that there was often a disconnect with the existing supply chains that impact prefabricated construction outcomes. The paper did provide some evidence that prefabricated construction is cheaper and faster product in India and Tanzania. However, the paper noted that prefabricated acceptance was uncommon in the developing world. Many places, such as Nigeria, did not have sufficient codes in place.
Nuzul Azam Haron, Ir. Salihuddin Hassim, Mohd. Razali Abd. Kadir and Mohd Saleh Jaafar	Building Cost Comparison Between Conventional and Formwork System: A Case Study of Four-Story School Buildings in Malaysia	American Journal of Applied Sciences 2 (4): 819-823, 2005	This paper tested the assumption that prefabricated construction cost was cheaper than conventional construction for 4-story education facilities (panelized prefabricated construction units). The authors found that the cost was higher for prefabricated construction. The authors attributed this cost difference to greater competition with conventional contractors providing more market options.


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