

# A Design and Communication Strategy for Crèche Construction in Informal Settlements

A MAJOR QUALIFYING PROJECT REPORT SUBMITTED TO THE FACULTY OF WORCESTER POLYTECHNIC INSTITUTE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE IN CIVIL ENGINEERING AND THE DEGREE OF BACHELOR OF SCIENCE IN PROFESSIONAL WRITING

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## Abstract

This project analyzed the challenges that face sustainable building processes in South Africa's informal settlements. A set of sustainability principles was created then transformed into tools informal settlement communities can use. Written guidelines and tools for planning collaboration and record-keeping were created for each process phase. The process and tools were tested and further refined by designing a sample crèche for a small community in the Philippi settlement (Cape Town). Potential obstacles in communication, resources, technical knowledge and legal requirements were identified and recommendations for refining the process and adding new tools were given.

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## The Challenge of Early Childhood Education in South Africa

Children demonstrate lower academic achievement and poor cognitive ability when they do not participate in adequate Early Childhood Development (ECD) programs. ECD is an umbrella term applying to the process by which children grow physically, mentally, emotionally, morally, and socially (DOE South Africa, 2010; Sayre et al., 2015). Neurologist Harold Chugani found that children between 4 and 10 exhibit twice as much learning capacity as adults (Chugani, 1987), yet only 40% of all children worldwide who live in poverty receive ECD care (Sayre et al., 2015) at that age. More specifically, UNICEF reported on recent educational opportunities in South Africa, revealing that in 2010 as many as 40% of the nation's children were not participating in Grade R, the equivalent of American 1<sup>st</sup> grade (2010).

In particular, it can be difficult to take advantage of ECD opportunities in South Africa's informal settlements. These informal settlements are areas where large groups of citizens and immigrants illegally squat in poverty on government lands. In these informal settlements, only 43% of children under the age of 5 are exposed to an early childhood development program either at home, a learning center or elsewhere. Informal settlements in the Western Cape Province – home of Cape Town – report that only 38% of their children below age 5 receive any type of early childhood education (ibid). Figure 1 shows that the settlements lack basic infrastructure, and these conditions make it difficult for residents to build ECD facilities and programs.

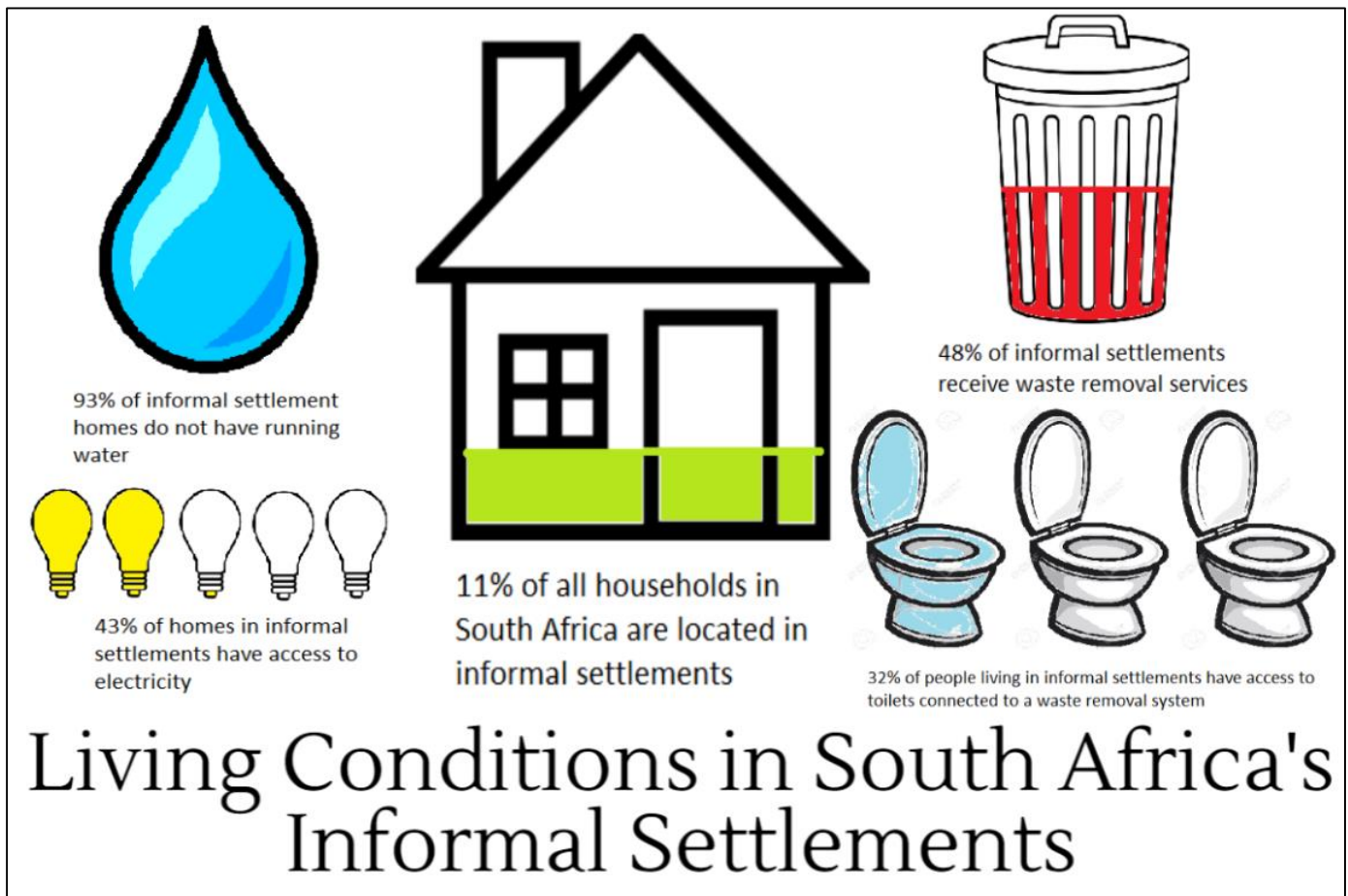


Figure 1 - Living Conditions in South Africa's Informal Settlements

The informal settlements, which offer little opportunity for social and economic advancement, began to form when Apartheid’s migration laws were lifted in 1994. Nonwhite citizens flooded South African cities looking for work, but were unable to find or afford suitable accommodations. High unemployment rates left these citizens with few choices, and many began to squat on government lands, creating housing backlogs which developed into informal settlements (Malinga, 2000). Even though Apartheid was abolished, racial disparities and violence linger in the country as a whole. BBC News Johannesburg reported South Africa as one of the most violent societies in the world, with approximately 18,000 murders per year, largely due to racial tension and poverty (Burdin, 2010). The poverty levels in the settlements are represented through the living conditions of the residents. Roads are narrow with trash and sewage overrunning them and people’s homes are largely made of scavenged boards and corrugated tin and plastic. The homes have dirt floors with few windows. Figure 3 to the left shows a typical family-sized home in these settlements. In an effort to help reduce these tensions and advance some of the nation’s poorest areas, South Africa’s government has developed educational support programs. Even with these programs, other challenges such as overcrowding and lack of resources prevent a lot of children in informal settlements from receiving the education they require. A large number of children combined with few resources to build schools leaves many settlements struggling to support their children. For example, one of Cape Town’s informal settlements, Monwabisi Park, offers only eight small crèches serving over 2,700 children in the immediate area (Barbour et al., 2010).

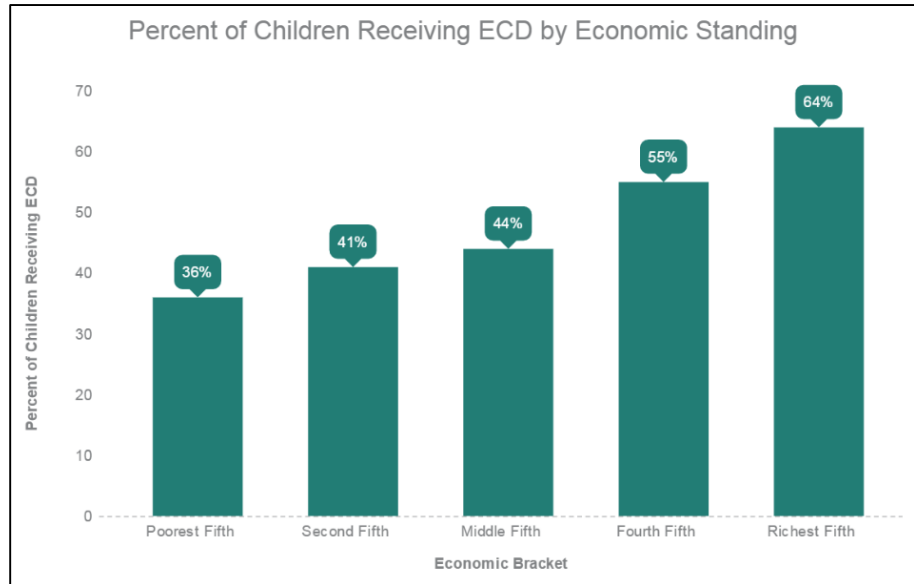


Figure 2 - Percent of Children Receiving ECD by Economic Standing



Figure 3 - Typical Informal Settlement Home

The homes have dirt floors with few windows. Figure 3 to the left shows a typical family-sized home in these settlements. In an effort to help reduce these tensions and advance some of the nation’s poorest areas, South Africa’s government has developed educational support programs. Even with these programs, other challenges such as overcrowding and lack of resources prevent a lot of children in informal settlements from receiving the education they require. A large number of children combined with few resources to build schools leaves many settlements struggling to support their children. For

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## Efforts to Increase ECD Opportunities for Children

The government offers subsidies of R150 (15 USD) per student per day to registered preschools which meet the South African Department of Social Development standards (City of Cape Town, 2003). It is difficult for the informal settlements to achieve these standards for a number of reasons. For example, limitations in space challenge the requirement that there should be 1.8 square meters of space for each child, lack of basic services make it difficult for communities to offer one toilet and hand-washing facility per every 20 children, and a lack of record-keeping typically means the community will not be able to provide the government with the proper documentation including a building plan or hand-drawn sketch of the building (Ervin et al., 2014).

No matter who is offering assistance, it is critical that the community becomes involved in ECD to help make it sustainable. Many have observed that attempts at improvement without involving the community are often temporary. California College for the Arts Professor Lisa Findley notes an example based on other community development projects: “The post-Apartheid government, after funding construction of plazas [in poor neighborhoods], usually failed to plan for maintenance and improvement. Most early projects are now derelict, and the trees that were planted with such hope for the future have been chopped down for cooking fuel” (Findley, 2011). Similarly, a team working to improve sanitation in the Langrug informal settlement, found that a lack of community involvement decreased the project’s longevity (Almeda et al. 2013). Chemical toilets that had been donated to the community were soon overrun with sewage. Community members were not involved in the process of choosing, securing, placing, and maintaining the toilets, so the toilets were abandoned and became a health hazard (ibid).

ECD programs and facilities within informal settlements require a planning and building method that will ensure their sustainability. Working with the communities rather than imposing construction plans on them creates an intrinsic value in a building, a value worth more than the building’s materials. Involving the community and its members in the process of planning, designing, and constructing a center creates community support needed for these facilities to become lasting. Developing relevant designs and processes from the bottom up involves making decisions tied to local resources and materials. It also involves hiring and training construction workers from the local area. A building process incorporating these factors in an informal settlement will more likely result in a sustainable product and be able to pass the formal government requirements for crèches, ensuring financial support in the future. **This project articulated a process for creating a sustainable crèche design and then tested that process by using it to design a crèche adapted to the available financial, material, and human resources of an informal settlement.**

This project is a first pass at tackling a complex process. I began by looking at the traditional construction process. I modified this process using a set of sustainability principles synthesized from goals and practices in the professional literature. I then began adopting and creating a series of literate tools (forms, checklists, process descriptions and other documents) to facilitate the implementation of the new process. I identify some of these documents here and illustrate how they might be used effectively with a sample community in South Africa. Others interested in creating a more sustainable construction delivery process for informal settlements can follow the steps I have outlined to further the tools here as well as create new tools that will help organize and address the multifaceted process of designing and building an ECD center in an informal settlement.

## Developing a Set of Sustainability Principles

Developing the framework for a sustainable building process requires a working definition of sustainability. At the simplest level sustainability means using natural resources in a way that they do not become depleted nor do they permanently damage the environment. This project requires a more comprehensive definition. As Robert Pojasek, an internationally renowned expert in process improvement, pointed out, “People will always need food, water, energy and shelter to survive. Yet to thrive will certainly take more than that” (Pojasek, 2009). His claim is a better representation of what this report will consider sustainable. A sustainable process will help maintain a decent quality of living, *and improve it over time.*

Researchers at the University of Colorado, Boulder developed “Principles of Sustainability” (Monday, 2002). This project synthesized these guidelines with other scholars’ interpretations of sustainability to create modified principles for building design and construction in informal settlements.

## Sustainability Principles for Building Design and Construction in Informal Settlements

*Sustainability Principles for Projects in Informal Settlements* lists the synthesized principles developed in this project. They can be used to help a project manager conform to the sustainability principles in a building project. The tool also works to develop potential goals to strive for in order to provide concrete examples to some abstract ideas.

Table 1 – Sustainability Principles for Projects in Informal Settlements

Sustainability Principles for Projects in Informal Settlements			
Sustainability Principles	Definition	Criteria	Reasoning
Identify a Community's Unique Needs	Talking to the community to find out what specific facilities can resolve the problems that community is facing	Initiating a pre-project meeting with community members for input and workshopping as well as mid project and close out follow up meetings	The pre-project meeting identifies what the community members want/need and the follow up meetings will provide follow ups to make sure the project is coming out the way they envisioned it
Maintain Intergenerational Dynamic	Creating a loop from older generations to younger ones so that knowledge can be handed down over time and the building can constantly be improving	Thorough documentation of all process initiatives as well as build plans, as-builts, and record of materials and all pertinent information	Keeping good documentation can help pass on information from one community to another. Thorough documentation helps find areas to improve on in future projects
Repair and Conserve the Environment	Looking at available resources and rationing their use in building and construction projects so that they are given adequate time to replenish and do not become depleted	60% of building materials are recycled or reusable	Using recycled or reusable materials in over half the building reduces the likelihood that resources will be overused without being replenished
Representing Shared Ideas	Involving a variety of community members when making large decisions so everyone can be a part of the process	Weekly meetings between project administrators and general population and involvement	Having regular meetings with the general population can help administrators get a good feeling for the public reaction to the project as well as keep as many minds as possible available to solve problems
Stimulating Local Economy	Adding features and capabilities to the building, such as a store, as well as hiring local workers to generate income which can then be put back into the community	2+ sources of revenue located in the building (tuition/donation/government grants, spaza shop)	Generating revenue will help provide more purpose to the building as well as provide a means to keep the building and its facilities in good, working condition. Having good revenue can also have a strong impact on the community as a whole
Anticipating and Planning for Natural and Operational Disaster	Anticipating future challenges and developing appropriate response tactics	4+ means of mitigation (fire, vandalism, administrator transition, O+M plans, etc.)	Having many means of disaster mitigation is key to maintaining the structural sustainability of the building. Many of these processes show good preparedness and will help reduce the threat of business discontinuity



## Identifying a Community's Unique Needs

The first step in this process is to work with the community to identify their unique needs and goals. One of the first steps WPI students take when planning intercultural projects is to set up interviews and focus groups between themselves, influential members of the community they are working with, local project coordinators, and translators as necessary. These collaborations ensure that community members want to actively participate in project planning and implementation. Students gain insight into the community structure and values that help them to co-develop relevant solutions. Project coordinators are able to begin designing projects to fit the community's unique needs. WPI prioritizes genuine community partnership. Shared Action Learning (SAL), a method developed by WPI Professor Justin Jiusto, is "a way to think about and engage in partnerships for sustainable community development. SAL emphasizes Sharing among partners of ideas, knowledge, resources, inspiration and compassion; Action that supports the creative impulses and growth of communities and partners; and Learning from research, action and critical reflexive practice" (Jiusto, 1995). The SAL approach is initiated in this needs analysis phase and continues to inform the rest of the process.

## Maintaining an Intergenerational Dynamic

University of Wollongong researchers argue that community members enacting change should not just maintain the standard of living through their actions but should improve it for future generations (Beder, 2002). They suggest keeping a connection between past, current, and future generations. The generational cycle is a continual loop, and it is important for older generations to provide information and resources to younger ones so that knowledge and advancements are not lost over time. In creating a design and constructing a building, those involved will need to communicate with and involve younger generations so they can improve upon it and care for it.

## Repairing and Conserving the Environment

The Environmental Protection Agency (EPA), a US organization tasked with securing environmental stability, has defined sustainability as an "interdependence between human societies and the natural environment" (Eason et al., 2012). They warn that humans' current pattern of economic and social development is placing an immense amount of stress on the planet's natural resources. The EPA cites the National Environmental Policy Act of 1969 which recognized a need "to encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man" (ibid). In other words, sustainability projects should make improvements to both the welfare of humans as well as the planet as a whole with each passing cycle.

In this project, local resources for building may be available in varying quantities. Some of the building materials may cause less damage to the environment, but may not be as readily available. As an alternative there may be recyclable materials that can be salvaged for use. As the researchers at the University of Colorado at Boulder point out, there may be instances where a community will need to allow time for depleted natural resources to replenish themselves (Monday, 2002). With proper care, these materials can make a comeback in the future to be used again with increased sensitivity and rationing.

## Representing Shared Ideas

Developing a sustainable structure requires input from the entire community. Including a diverse and representative group of planners and builders connects more people who can see the project's value, and it promotes equity and democracy. The diversity of these groups should transcend as many demographics as possible. Decisions about who should be involved in planning, design, and building should be made by considering a variety of age groups, racial backgrounds, economic standing, civic standing, and occupations or skills in order to expand the project's knowledge base and draw on existing skills. Inviting large portions of a community to a problem resolution discussion puts as many ideas on the table as possible and provides the greatest chance at reaching the best solution. Informal settlements, and South Africa as a whole, are incredibly diverse. There are also language differences; the country boasts eleven national languages (South African Government, 2015). Drawing on these differences is difficult but critical. Sustainable projects will attempt to represent shared ideas from a variety of ethnic groups.

## Stimulating the Local Economy

University of Colorado's principles suggest that sustainable projects will require a commitment of resources in the beginning, but they will provide long term benefits. Building a new early childhood development center in a small village will require funds and other resources (time, labor), but the community can get these back by utilizing a sustainable design.

For example, a community funded and run center provides its residents a safe place to leave children during the day for a small fee. Because parents have a safe place to leave children, they can focus on finding paid work elsewhere, or starting their own, self-run shops or maybe even being employed in the early childhood development center. Communities can even take this a step further by using buildings in multiple ways that bring in income; for example, including a small shop along the exterior of the building or involving students and parents in a small cottage industry as part of the learning process. This was illustrated in (Alameda et al., 2013), where a community bath house also included a store selling small hygiene products like soap, in order to generate income to pay for its maintenance and staff. If community members can view the center as an opportunity to generate jobs and income either for themselves or for the community at large, they will become much more invested in the design and build process as well as the building's overall life span.

## Anticipating and Planning for Natural and Operational Disaster

Disaster resistance and mitigation is important to sustainable development. It is imperative to create an emergency plan to deal with unexpected challenges, both natural and man-made. Physical destruction caused by fire or flooding could be mitigated with a plan. Most informal settlements do not even have running water, so choosing fire retardant materials, for example, would minimize damage to the infrastructure until a fire response team can take action.

Creating operation and maintenance plans early on can help to ensure the building is not damaged by theft or misuse. For example, some building materials, such as copper piping, are very valuable in informal settlements and, if left exposed, may invite theft. Developing a plan to secure materials, such as cementing the pipes in place, may not be normal protocol, but it could help make facilities safer and ensure longevity.

In sum, following these sustainability principles will increase inherent value in the building, help ensure protection of the environment, and enhance the quality of living. Involving community members in every step of the process is key; it creates investment. Community members will not want to see their hard work fall to ruin.

## Design and Construction Process for Sustainable Crèches

The typical construction process found in many of the world's developed regions would have to be adapted if used in South African informal settlements. The Gannett Fleming Engineering Design Company breaks down the typical process into five distinct phases: Project Initiation; Planning, Environmental Clearance & Real Estate Acquisition; Design; Construction; and Project Close Out (Gannett Fleming Inc, 2009). Their phases represent what is typical to many construction processes in developed nations, but they can be adapted for other contexts.

### Adapting the Typical Construction Delivery Process

Here, I incorporate the sustainability principles into the five-step, typical construction process. This new process in Table 2 contributes to the creation of a sustainable building. It also describes planning, documentation, and management tools in each phase to support these activities in a sustainable manner. *Tools for Creating a Sustainable Construction Delivery Process* shows the construction phase breakdown; important tasks to consider during each phase; the tools necessary to accomplish each task; and the reasoning for these tools.



Table 2 - Tools for Creating a Sustainable Construction Delivery Process

Tools for Creating a Sustainable Construction Delivery Process			
Construction Phase	Important Tasks to Consider	Tools	Rationale
Phase 1 - Project Initiation	Assess project manager capabilities	<b>Worker Description Page</b> - Help to locate, interviewing applicants or vote on, a reliable Project Manager. Document sets some minimum requirements and expectations	Finding a project manager who can be held accountable for their work will help maintain good communication between the stakeholders as well as ensure the project runs smoothly
	Determine and Secure a Budget	No Existing Tool Yet	The government does not want to fund start ups because the settlements are illegally on government lands and the people do not have a lot of extra funding to start it on their own
	Receive community permission/project authorization	<b>Project Agreement Page for Phased Collaborative Project Development</b> - Bring together each of the major stakeholders to establish responsibilities, payment methods, an anticipated start and end date, and signatures for investment	Establishing communication from the beginning shows the community that they are an intricate part of the process and their input will be heard and valued
	Select a delivery strategy	<b>Choosing the Most Sustainable Building Technology</b> - Interactive document to help stakeholders consider some building options and ask the right questions to determine which option will produce the most sustainable result for their community	Inviting the community to assist in choosing a building technology will ensure selection of the best available option for addressing the community's needs and using available resources
	Create a preliminary delivery schedule	<b>Project Management &amp; Administration Sheet</b> - Allows the project manager to space out what tasks should be completed and by what time	Keeping the project on time helps to prevent additional costs and loss of support from the community. This helps ensure all participants are completing the tasks they are responsible for during the project duration
	Complete supporting documents	<b>Determining Sustainability Criteria</b> - Some of the sustainability principles are abstract in nature. This document will help the project manager create tangible goals or targets to strive for in developing their project delivery process	Creating a plan that follows these criteria at the beginning of the project gives the management team something to refer back to so they can make sure the community stays involved through the whole process
Phase 2 - Planning, Environmental Clearance, & Real Estate Acquisition	Analyze the functionality of the planned building	<b>Choosing the Most Sustainable Building Technology</b> - If this document is adhered to, the finalized selection should best address community needs	Inviting the community to assist in choosing a building technology will ensure selection of the best available option for addressing the community's needs and using available resources
	Consider potential building and construction models	<b>Choosing the Most Sustainable Building Technology</b> - If this document is adhered to, the finalized selection should best address community needs	Inviting the community to assist in choosing a building technology will ensure selection of the best available option for addressing the community's needs and using available resources
	Select the project site	<b>Selecting a Site - Process Page</b> - A good process rather than a set document would be to create a general, somewhat scaled drawing of the community lay out. Make movable pieces so that different scenarios can be analyzed	Space is a commodity in the informal settlements, choosing a location as a group should prevent people from feeling like their land is being taken from them without their approval. It also helps provide insight to community dynamics that may not be evident to stakeholders who are not directly involved with the community
	Perform an environmental risk analysis	<b>Environmental Analysis - Process Page</b> - Prior to beginning any construction or environmental clearing it is important to ensure that any species will not be eradicated by construction. Other factors such as ground slope should be considered so if the area is cleared and there are heavy rains, there will not be a mud slide	Maintaining a safe work site is an ethical obligation project managers have to their workers and citizens in the area. Avoiding injury or disruption during the construction process will help keep support behind the project
	Appropriate proper legal building permits	<b>Creating a Creche Checklist</b> - This checklist provides information about the authority who will check the final creche if it going to be registered. Unregistered creches are most likely not held to this goal	Funding is a major challenge facing these communities, however the government will send subsidies to creches that meet a set of criteria, the checklist helps ensure that the creche will meet these criteria
Phase 3 - Design	Manage the project schedule to keep dates relative to the planned schedule	<b>Project Management &amp; Administration Sheet</b> - The document can provide a guideline for expectations, but should be updated and adjusted for any set backs	Creating and tracking a delivery schedule helps ensure that the project does not get drawn out over too long of a time period and helps ensure that the community receives everything they pay for
	Create the building design	<b>No Existing Document Yet</b> - This may be a job for a professional in the area. Any interaction with an organization like CORC would most likely accomplish this task. It will be important to incorporate community's requests as well as the requirements set forth in the <b>Creating a Creche Checklist</b>	Creating the design is a challenging task due to a variety of limitations including materials, resources, workers and funding. Developing a process to facilitate these challenges would be a huge benefit
	Perform a constructability review	<b>No Existing Document Yet</b> - This may be a job for a professional in the area. Any interaction with an organization like CORC would most likely accomplish this task	Safety is a major concern on all construction sites and ensuring the designed building will function safely is critical
	Monitor project schedule and cost against the project scope	<b>Project Management &amp; Administration Sheet</b> - The document can provide a guideline for expectations, but should be updated and adjusted for any set backs	Creating and tracking a delivery schedule helps ensure that the project does not get drawn out over too long of a time period and helps ensure that the community receives everything they pay for
	Keep close watch and record of materials	<b>Materials and Equipment Tracking Sheet</b> - Provides methods for tracking what day(s) materials arrive. Provides methods for tracking whether or not materials arrive.	Creating and tracking a delivery schedule helps ensure that the project does not get drawn out over too long of a time period and helps ensure that the community receives everything they pay for
Phase 4 - Construction	Locate qualified workers	<b>Worker Description Page</b> - Help to locate, interviewing applicants or vote on, a reliable Worker. Document sets some minimum requirements and expectations	Finding workers who can be held accountable for their work will help maintain good construction and help spike local economy by paying community members for their labor
	Regulate meetings to discuss safety procedures on or near the site for both workers and the general public	<b>Construction Worker Educational Plan</b> - Reviews what tasks are expected from the workers on a day-to-day basis as well as shows processes for developing relationships between stakeholders and workers as well as between workers and workers	Workers from the community may or may not have previous experience and developing good practice helps to keep people on site safe. It will also help give workers skills they can take with them after the project ends
	Ensure workers and contractors know what tasks they are responsible for having completed	<b>Phased Construction Drawings - Process Page</b> - Works to establish a visual representation of what expectations are to be met in correlation with the schedule. This will have to be drawn every time a new project gets underway. The original can be used as a basis for expectations as this tool is just a list	Showing phased construction can be beneficial for illiterate workers. It provides a visual goal of what tasks are to be accomplished and helps ensure clear communication between project management and workers
	Keep close watch and record of materials	<b>Materials and Equipment Tracking Form</b> - Provides methods for tracking what day(s) materials arrive. Provides methods for tracking whether or not materials arrive.	Creating and tracking a delivery schedule helps ensure that the project does not get drawn out over too long of a time period and helps ensure that the community receives everything they pay for
Phase 5 - Project Close Out	Final review of materials and equipment	<b>Materials and Equipment Tracking Form</b> - Provides methods for tracking what day(s) materials arrive. Provides methods for tracking whether or not materials arrive.	The project manager should review all of the materials and equipment that came and left the site to ensure there are no outstanding payments or materials that have not been accounted for
	Complete a final community walk through	<b>Project Agreement Page for Phased Collaborative Project Development</b> - Signing off that the project has been completed satisfactorily for future record	Walking through the final product with a representative from each stakeholder ensures that each groups unique needs were met
	Complete a government representative walk through	<b>Creating a Creche Checklist</b> - This checklist provides information about the authority who will check the final creche if it going to be registered. Unregistered creches are most likely not held to this goal	Coordinating with the local government to gain registration status will ensure that the creche receives funding for continuing its operation
	Transfer operation and maintenance plans	<b>Operation and Maintenance Plans - Process Page</b> - This page should provide steps explaining how to care for the building features to help ensure that it does not succumb to regular wear and tear over time	Providing the community with the necessary steps to take care of their building shows them care of the building is their responsibility and will increase the building's longevity

## Testing the Framework

Below, I walk through the five phases of planning and designing a crèche that might be built in an informal settlement I visited in late 2014. This walk-through exercise illustrates how the process might work, and it identifies difficulties and gaps that will need to be addressed in further iterations of this process. Some of the tools I recommend will be highlighted during the discussion to show how they work. Using them helped me to identify difficulties and refine some of the tools. It also created examples for others to follow and expand upon.

The community I refer to in this exercise had, in reality, expressed a desire for a community crèche when I visited in 2014. I did not have all of the necessary conversations with the community that are stipulated in the process I created, conversations that would admittedly create a fuller picture of their needs and available resources, as the purpose of my time there was not to plan a crèche. We were able to have some conversations, however, that enabled me to create a hypothetical example, which is detailed below.

### The Community Background

This example focuses on a small community within one of Cape Town's largest informal settlements, Phillippi (Anderson et al., 2009), which is broken up into sub-communities, much like many of the world's major cities. Within one of these neighborhoods lies a shelter for women and children who are survivors of domestic abuse. The shelter houses 6 to 8 women and 8 to 12 children. They are the key stakeholders for this sample walk through. At the time, they also expressed interest in having some of the local neighborhood children participate in a crèche program they hoped to create; therefore, the surrounding neighborhood also comprises an important stakeholder group.

The shelter facility has running water and unreliable electricity; however, these amenities are not consistent throughout the neighborhood as a whole or throughout the Phillippi settlement. In addition, the safe house yard is surrounded by a wall approximately 10 feet in height, designed to keep unauthorized people from entering the grounds. This wall also protects their small garden, fountain, play area, and tool shed.

The safe house is owned by Cesvi, an Italian based non-profit that budgets a certain amount of money every year for food and clothing for the women who arrive with nothing. With each payment, the head of the safe house administration has opted to set aside for building a crèche. By 2014, they had accumulated approximately R 80000 or \$8000. Organizing funding is a major challenge for informal settlement communities. Having an invested, outside sponsor is a unique benefit specific to this community.

### Phase One – Project Initiation

The project begins when the women and children communicate the need for an onsite crèche to two safe house employees, known as house mothers, who are primarily responsible for the daily care of the safe house residents. This conversation is truly the beginning of the sustainable process because it expresses a desire in the community for the project to take place.

From here, the house mothers can communicate the residents' request to other safe house employees, including the administration and caretaker who is responsible for site upkeep. The conversation between these three groups is important for determining the feasibility of the project.

From an administrative perspective, it is important to consider if there is funding for this type of project, if there is permission to undertake this kind of project, and if not, where the community might get these things. The caretaker’s perspective focuses on how the available space will be used and maintained. This caretaker previously held employment with a construction company, and conceivably could apply for the role of Project Manager. The administration team and house mothers would use the [Worker Description Page](#) to determine whether or not the caretaker has basic qualifications for this job. Finding trained construction workers is not always easy in this context; sometimes a participating non-governmental organization (NGO) partner might provide training or mentoring to local project managers.

The administration has access to R 8,000 provided by Cesvi, but they might determine they require additional assistance in coordinating the project. Using their connections, they might reach out to a local NGO for support in evaluating the cost, space, in providing some training seminars, and in organizing local labor for this type of project. Many NGOs will require that the community itself show buy-in by agreeing to contribute money and labor in some form to the project.

If the administration decides to expand their operation to include some local children not enrolled in the safe house, it would need to bring the neighborhood into the process. They might hold an open meeting where any women with children in the immediate neighborhood can attend. From the meeting, they might learn there are an additional 4 families, totaling 10 additional children, who would be willing to commit a small tuition cost and some labor time, for their children to be able to attend the school. The parents might be invited to attend a “project agreement meeting” with each of the major stakeholders to discuss how the crèche will come to be. If they determine that the crèche will enroll as many as 22 children, they might then use the [Creating a Crèche Checklist](#), to establish the minimum required square footage in accordance with the South Africa Department of Social Development. The relationship between each of the major stakeholders is shown in Figure 4.

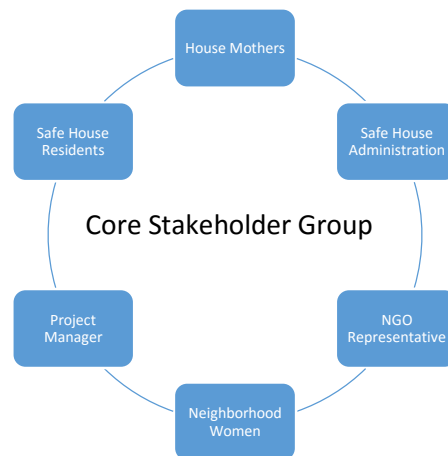


Figure 2 - Stakeholder Relationships

The stakeholder meeting will accomplish several tasks. Each of the major stakeholders agrees upon a series of tasks they will be responsible for throughout the crèche development process. This helps to divide the responsibility and allows each participant’s concerns to be addressed. Figure 5 outlines the major stakeholder responsibilities. Some considerations of the core stakeholder groups are a result of the unique community. For example, only neighborhood women and not their husbands are considered

due to the sensitive nature of the safe house residents. The atmosphere of the safe house is based on a dominant female presence. Another consideration regards the neighborhood women contributing labor and tuition. One possibility might be to have the women’s labor translate to a credit of a proportional amount of time for their children to attend the crèche tuition-free. For example, if these women are to be paid R100 per 8 hours of work, working 8 hours would allow them to send a child to the crèche tuition-free for 10 weeks, or 2 children tuition-free for 5 weeks, and so on.

House Mothers	<ul style="list-style-type: none"> <li>•Monitoring the wellbeing of the safe house women</li> </ul>
Safe House Administration	<ul style="list-style-type: none"> <li>•Providing space for the project site</li> <li>•Main source of funding</li> </ul>
NGO Representative	<ul style="list-style-type: none"> <li>•Worker training and general project guidance</li> <li>•Design work/Locate registered designer</li> </ul>
Neighborhood Women	<ul style="list-style-type: none"> <li>•Funding through tuition (R10/child/week)</li> <li>•Additional Labor (as required or available)</li> </ul>
Project Manager	<ul style="list-style-type: none"> <li>•See <i>Worker Description Page</i></li> </ul>
Safe House Residents	<ul style="list-style-type: none"> <li>•Main source of labor</li> <li>•Completing tasks in an effective, time-efficient manner</li> </ul>

Figure 3 - Stakeholder Responsibilities

At the end of the stakeholder meeting, each of the participants would sign off on the [Project Agreement Page for Phased Collaborative Project Development](#) form indicating that they are aware of and agree to their responsibilities. The NGO representative can also help set a rough estimate of how long the project should take – in this case the representative might decide a conservative estimate for this project is approximately 90 days.

The next step is for all willing participants to gather again and review the [Choosing the Most Sustainable Building Technology](#) form. This form allows the stakeholder team to choose which of available building technologies is best suited for their situation. They could accomplish this task by reading through the questions and answering “yes” or “no” to each of the questions. If the answer to the question is “yes” then a tally should be put in the On-Site Construction column. If the answer is “no” then a check should be put in the Prefabricated Modular Construction column. This form makes clear the differences between the two technologies. The negative forms of the questions are included to develop the alternative option in a positive light, rather than having a community feel as though they cannot have one of the options because they had to answer “no” to a question, it shows they can still have the other option by answering “yes” to the next question. Once the form responses have been tallied, the technologies can be directly compared by developing a value index. The value index takes the overall tallies and divides them by a common factor – cost. The NGO representative could provide

cost estimates for each type of building technology based on the NGO's previous experiences. A completed form might look like Table 3.

Table 3 - Choosing the Most Sustainable Building Technology

Choosing the Most Sustainable Building Technology				
Applicable Sustainability Principle	On-Site Construction	Consideration	Prefabricated Modular Construction	Applicable Sustainability Principle
Identifying a Community's Unique Needs	X	Building can fit into available space		Identifying a Community's Unique Needs
	X	Community will be present for the building process		
	X	Building allows for alternative or accessory uses		
	X	Community members are available to help with design and construction		
		Community members are not available to help with design and construction	X	
	X	The community has time and space to commit to construction		
		The community does not have time and space to commit to construction	X	
Maintaining Intergenerational Dynamic	X	Produces replicable and distributable plans for future projects		Maintaining Intergenerational Dynamic
Repairing and Conserving the Environment	X	Uses durable materials for weathering as well as wear and tear		Repairing and Conserving the Environment
	X	Building materials are easily replaceable		
	X	Building materials are easily accessible		
		Building materials are not easily accessible	X	
	X	The community has a method to transport materials		
	The community does not have a method to transport materials	X		
Representing Shared Ideas	X	Community members wish to participate in the process		Creating an Integrated Public Mindset
		Community members do not wish to participate in the process	X	
	X	Community members can see the process develop		
	X	Community members can deal with noise pollution and spacial disruption		
	Community members do not want to deal with noise pollution and spacial disruption	X		
Stimulating the Local Economy	X	Community members need jobs		Stimulating the Local Economy
	X	Community members want to learn marketable skills		
Anticipating and Planning for Natural and Operational Disaster	X	The community can provide safe storage for materials		Creating Disaster Resistance and Mitigation
		The community cannot provide safe storage for materials	X	
	X	Disaster resistant materials are locally available		
		Disaster resistant materials are not locally available	X	
	X	The community can provide area to store materials on-site		
		The community does not have area to store materials on-site	X	



As filled out, the form suggests that an onsite construction project would be most sustainable for this community. After the meeting, the project manager could meet separately with the NGO representative to discuss an anticipated project delivery schedule. Although a general time period for the project was established earlier, knowing the building technology can provide the NGO representative with a better idea of the pace at which the project will be moving as well as establish a time window through which the NGO can coordinate with a designer to ensure that they will be available to work on the project once the community has outlined their specific needs for the building. All of this information could be logged into the *Project Management & Administration Form*, leaving space to add more details as they become available.

The project manager at this point could review the *Determining Sustainability Criteria* table for methods to keep the entire community involved throughout the process. The goal of this tool is to provide the manager with concrete targets or goals.

### Phase Two – Planning, Environmental Clearance & Real Estate Acquisition

By completing the *Choosing the Most Sustainable Building Technology* form, the community has already considered their options for a building technology and provided a general outline for the functionality of the building. Choosing the project site is the next task for the stakeholder team to accomplish. A suggested process can be found in the *Selecting a Site - Process Page*. Space is a premium luxury in the informal settlements, and while this is a unique situation where the safe house is contributing their available space, there still may be disagreements. When in the settlements, major disputes leading to violence have been caused by people encroaching on other's land. This tool can provide a contingency plan so these conflicts can be avoided before they become violent. In this case, the shelter already controls empty space in its yard that can be used, but in many cases, space in informal settlements is often scarce and creates disputes.

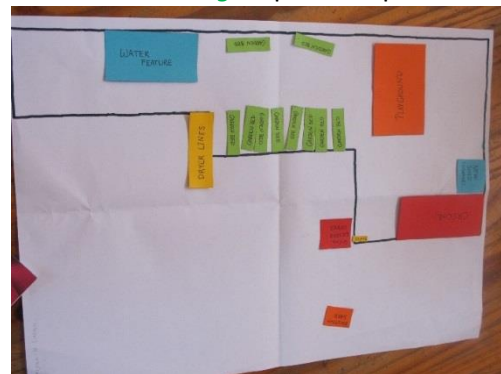


Figure - 4 Selecting a Site

The stakeholder team opts to create a scaled drawing of the safe house yard that includes different components of the yard including a garden, fountain, and trees. Yard features that are fixed in place are drawn directly onto the scaled drawing and features that can easily be relocated are scaled cut outs of colored construction paper. The team also includes a cut out of what the crèche might look like. The scaling is maintained with the anticipated sizing from the *Creating a Crèche Checklist* description above. The resulting process would create the site plan shown in Figure 6.

This process documents community input on the crèche orientation and location of the facilities, but it leaves room to adjust and move these items as necessary when creating the formal site plan. It also prevents ideas from becoming too concrete in participants' minds.

The project manager should meet again with the NGO representative to conduct the environmental risk analysis. An outline of the process they could follow can be found in the *Environmental Analysis – Process Page*. Some important factors they would consider in accomplishing this task include checking the selected site to be sure that clearing the area will not permanently deplete

any natural resources or create any hazards. For example, clearing vegetation in an area with significant grade can contribute to mudslides during rainy seasons because there are no roots to hold the soil in place. Another example would be choosing to build in an area closely surrounded by other, existing structures. Not only will this create a potential hazard for people using the adjacent buildings, such as being injured by construction equipment or materials, but there is also a much greater chance fires will be allowed to spread freely across multiple buildings, a very common problem in crowded settlements.

In the same time frame the project manager and NGO representative are meeting, the safe house administration could begin filing the forms with the local government to initiate the crèche registration process. The administration could use the *Creating a Crèche Checklist* to find which authorities need to be informed and which applications must be completed before the completed building can be inspected and granted registration. The community should not address the government about gaining registration until the crèche is ready to open because the government will neither sanction nor encourage new building on illegal land. However, following the checklist and locating the proper application materials is important because it will be less likely that the community will neglect to attain and fill out the proper forms. By locating the forms early in the process, the community can help keep their goal in mind and assure the work they are doing will be up to standards.

### Phase Three – Design

In order to begin the design process, the stakeholders must meet again to determine specific features that must be included in the final design. Including each of the stakeholders helps to gather the maximum input to ensure that all participants are satisfied with the final design. A final list of design requirements based on the stakeholder input might look like the list in Figure 7.

Stakeholder Design Requirements				
<p><b>Size</b></p> <ul style="list-style-type: none"> <li>•Holds 18-22 children</li> <li>•Per <i>Creating a Crèche Checklist</i> requirements approximately 50 square meters</li> </ul>	<p><b>Playing/Learning Space</b></p> <ul style="list-style-type: none"> <li>•Chairs</li> <li>•Tables</li> <li>•Sleeping Mats</li> </ul>	<p><b>Kitchenette</b></p> <ul style="list-style-type: none"> <li>•Cabinets</li> <li>•Double Basin Sink</li> <li>•Refrigerator</li> <li>•Stove/Hot Plate</li> <li>•Counter Space</li> </ul>	<p><b>Bathroom</b></p> <ul style="list-style-type: none"> <li>•One toilet per gender to accommodate some member's beliefs and customs</li> <li>•At least one sink to teach about hygiene</li> </ul>	<p><b>Passive Features</b></p> <ul style="list-style-type: none"> <li>•Metal roofing makes the space hot, we need a way to cool down the temperature</li> <li>•We require lighting, but can only offer unreliable electricity</li> </ul>

Figure - 5 Stakeholder Design Requirements

The NGO representative could contact the designer he/she contacted in Phase One. The designer could then implement these requests in addition to the requirements outlined within the *Creating a Crèche Checklist*. It is important this step is completed by a team member who has some experience with crèche building or building design to help ensure the requirements for crèche registration as well as the features specified by the community are adequately addressed.

In this specific example, I assumed the role of the designer and designed the crèche to fit the requirements specified above. Figure 8 is the resulting floor plan.

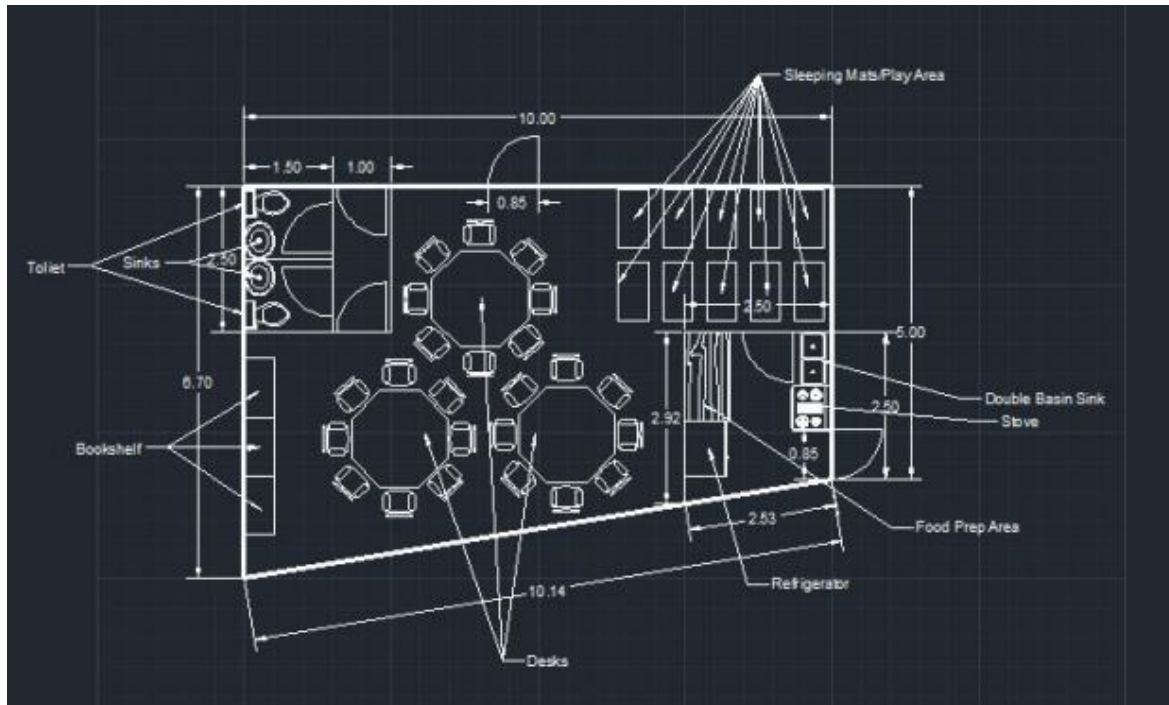


Figure 6 - Crèche Floorplan (CAD)

This design considers a variety of special and construction decisions to help facilitate the construction process and provide the most value for the available space. Some of the considerations can be found in Figure 9 below.

Figure 7 - Design Feature Considerations

Design Feature Considerations	
Design Feature	Rationale
Lumber for Framing	<ul style="list-style-type: none"> <li>• Free delivery from hardware store</li> <li>• Locally sourced materials</li> <li>• Easily manipulated dimensions</li> </ul>
Multiple Bathrooms	<ul style="list-style-type: none"> <li>• Located near local sewage and water line connections</li> <li>• Teach children proper hygiene</li> <li>• Ethical considerations to separate genders</li> </ul>
Corregated Metal Cladding and Roofing	<ul style="list-style-type: none"> <li>• Widely available, durable material</li> <li>• Easily recyclable - can be used from abandoned homes</li> </ul>
Kitchenette	<ul style="list-style-type: none"> <li>• Typical cooking method is fire over an open fuel source - hotplate is a much safer option</li> <li>• Sink located near municipal water line connection</li> </ul>
Overall Size	<ul style="list-style-type: none"> <li>• Registration requirements include 1.8m<sup>2</sup> per child</li> </ul>
Raised, Pitched Roof	<ul style="list-style-type: none"> <li>• Raised roof on all sides allows for passive ventilation (heat)</li> <li>• Roof overhang prevents precipitation entering the interior</li> <li>• Pitched, corregated sheeting allows for easy rain collection</li> </ul>
Footprint Shape	<ul style="list-style-type: none"> <li>• Irregular trapezoid maximizes available space community can offer</li> </ul>

The construction of the design above would be constrained to available materials. For example, the local hardware store only offers three sizes of construction grade wood. As a result, the design was reverse engineered so that joist and stud spacing was based upon the material size rather than choosing an appropriate size from a previously created design. Similarly, the loading calculations present the maximum limits that the building could sustain based on material sizes, whereas the traditional design process defines the material and member geometrics based upon anticipated design load combinations. The stakeholder team could rely on the NGO representative to coordinate with a secondary designer to check the corresponding design and calculations to verify the constructability of the design. For a more in-depth look at the design and calculations for this sample design, refer to the *Design Specifications Report*.

Once a design has been finalized and approved, the project manager could revisit the *Project Management & Administration Form* from Phase One to assure that, up to this point, the project is still on schedule. The project manager could also use the finalized design and some help from the NGO representative to begin filling out the *Material and Equipment Tracking Form*. This form is intended to help the project manager coordinate on what days and in what amounts materials should be arriving to the site. It could also help the project manager track the rental dates of any equipment that may be necessary during the construction phase of the project, which is outlined in the next section. The *Material and Equipment Tracking Form* could also be useful for determining how many workers are required to be on site to accomplish each of the tasks. It would be necessary for the project manager to keep close track of this form, updating it regularly to check tasks with workers and to ensure equipment is delivered and returned in a timely manner. It also provides a way to inventory materials, which must be securely locked up. Scarcity of building supplies and the value of these materials could easily invite theft.

#### Phase Four – Construction

In this scenario, we will assume that the safe house residents and neighborhood parents have committed to contributing the labor. They could draw on their experiences with building their own home, as many people living in the informal settlements have to do to put a roof over their head, using metal and wood scraps. They could accomplish tasks under the coordination of the project manager who would have experience with larger construction projects and materials. If the community were larger, the project manager could use the *Worker Description Page* to attract applicants. This process could also be used in this situation for specialized tasks, such as workers who will use hammers to complete the framing process, for example, or do cement mixing for floors.

The project manager might sign the *Worker Description Page* with the selected workers to ensure that they understand the expectations. Figure 10 shows the general requirements expected from the worker as well as how they would be compensated. The requirements provided here are a base-level set of rules. More explicit rules should be provided by the project manager during a worker orientation.

Construction Laborers
a. Report to Project Manager.
b. Work in a timely, efficient, and safe manner for the successful construction of the facility.
c. Work on all phases of construction as directed by the Project Manager, including earthwork, masonry, carpentry, finishing, etc.
d. Employment will be through _____ and will terminate at the end of facility construction or as otherwise determined by _____. Employment may or may not be organized through the Extended Public Works Program.
e. Work fulltime, at least 8 hours/day, five days/week until completion of construction or otherwise terminated.
f. Laborers will be compensated at a rate of R _____ for each full day of work completed.

Figure 8 - Sample Construction Laborer Requirements

It would be important for the project manager and the NGO representative to coordinate on organizing a safety training program to orient the new workers to site safety procedures. This orientation program would be mandatory for anyone who wanted to be paid for their work. It could include important safety features that may otherwise be overlooked, such as making sure to sign in and out when they come and go from the site. The project manager and NGO representative would use the *Construction Worker Education Plan* form to have a complete list of tasks that should be reviewed during the worker orientation.

In order for the workers to have a clear understanding of the work that must be completed in each construction phase, the NGO representative and project manager could create a generic drawing scheme. This drawing scheme would show a series of steps with sketch drawings to illustrate how to complete a task. A process for creating these drawings can be found in the *Phased Construction Drawings – Process Page*. The project manager would distribute these pages to the workers before each major task or phase to ensure the proper steps are followed for proper completion.

The project manager would also refer back to the *Materials and Equipment Tracking Form* he/she started during Phase Three of the project. This would be beneficial, as previously mentioned, in ensuring that all of the materials and equipment come and go from the site as intended and are collected and stored at the end of each day. It is important to note, however, that checking on this form regularly reduces the chances that a mistake goes unnoticed. This form, with project manager notes, might look like Figure 11.

Materials and Equipment Tracking Form						
Task	Phase Description	Materials budget	Labor budget	Expected timeframe	Actual timeframe	End date
Clearing + Grading Lot	3 workers to remove all vegetation	R 250.00	R 150.00	4 hours	4 hours	Day 4
Digging Post Holes	2 workers to dig out 9 holes (0.5m Diameter)	-	R 50.00	2 hours	3.5 hours	Day 5
Setting + Backfilling Posts	4 workers (1 hold posts, 2 fill; 1 keep pole straight)	R 1500.00	R 100.00	2 hours	2 hours	Day 5

\* Stamping dirt before putting post worms better than packing around the hole  
 note: ordered 9 gumposts, only 8 showed up. receipt to cash build.  
 Themba did not show up for work. No pay on 3/28 (take R 100 off budget)  
 need to talk to her b/c we will need her for skill saws next week.

Figure 11 - Sample Materials and Tracking Form

## Phase Five – Project Close Out

Once it seems as though the project has been completed, the project manager should go through the *Material and Equipment Tracking Form* that was established during Phase Three. By keeping track of the materials, equipment, and services as they arrived, he/she could highlight two very important close out factors. The project manager could look through the notes that were written on the sheet to check that there are no outstanding materials that never arrived and that there was no equipment left over that still needed to be returned. These checks would enable the project manager to conclude whether or not there were any incomplete contractor items left over. The form would also show any outstanding charges that would need to be paid before the final cost of the project is recorded.

There could be a final walkthrough after the construction is completed. It is important that a representative from each of the major stakeholders be present for the walkthrough. This way, all of the participating parties can approve of the final product and ensure that all of the unique needs were met. Each of the participating parties can then return to the *Collaborative Project Agreement Form* and sign off, indicating that the project was finished and is complete.

Following the community's final walkthrough, the safe house administration could coordinate again with the government to have the proper inspectors complete a walkthrough to confirm that the crèche meets the current registration requirements and all the appropriate forms have been completed on both the crèche and government sides. However, it should be noted that completing this task is much easier than it sounds. As previously mentioned, the informal settlements are illegal. Though Philippi is a well-established informal settlement and the land of this particular instance is owned by Cesvi, informal settlements that are small or still forming would likely face significantly more opposition from the government as the government would not want to encourage further illegal expansion. It is important that the crèche be functioning well before this task is completed. Ability to show that the crèche is performing at a high level can provide good cause for government support. As mentioned earlier, achieving government support and recognition in the informal settlements is a difficult task and the community must be sure the crèche is fully operational before applying for registration, but they also must not lose sight of this end goal.

Once the building is complete, as the shelter begins to develop an operations plan, the project manager would provide the community with a series of operation and maintenance (O+M) plans. These plans would clarify the kinds of care that are required to keep the building running after the project has been completed, and responsibilities for this care and procedures could be developed. These will help reduce the overall wear and tear on the building and thus increase its longevity.

## Conclusions and Recommendations

This project produced a series of tools and adapted tools from Jiusto's work to support a process by which a community might deliver themselves a sustainable crèche (Jiusto, 1995). It also began to "test" the process by applying it to a hypothetical situation rooted in my experience with a woman's shelter in Philippi. Table 4 shows a complete list of the finalized tools that were created to guide the above process.

Table 4 - Table of Finalized Sustainability Tools

Table of Finalized Sustainability Tools	
Tool	Goal
<a href="#">Worker Description Page</a>	Helps identify qualified team members and outline what responsibilities they will hold
<a href="#">Project Agreement Page for Phased Collaborative Project Development</a>	Helps identify qualified team members and outline what responsibilities they will hold
<a href="#">Choosing the Most Sustainable Building Technology</a>	Helps stakeholders consider building technologies and ask the right questions to determine which option will be most sustainable for their community
<a href="#">Project Management &amp; Administration Sheet</a>	Allows the project manager to identify what tasks need to be completed and when they will take place
<a href="#">Determining Sustainability Criteria</a>	Assists the project manager in creating tangible goals or targets for developing a sustainable project delivery process
<a href="#">Selecting a Site - Process Page</a>	Facilitates communication between stakeholders to avoid conflicts of community dynamics
<a href="#">Environmental Analysis - Process Page</a>	Helps identify qualified team members and outline what responsibilities they will hold
<a href="#">Creating a Creche Checklist</a>	Helps identify qualified team members and outline what responsibilities they will hold
<a href="#">Materials and Equipment Tracking Sheet</a>	Helps stakeholders consider building technologies and ask the right questions to determine which option will be most sustainable for their community
<a href="#">Construction Worker Educational Plan</a>	Allows the project manager to identify what tasks need to be completed and when they will take place
<a href="#">Phased Construction Drawings - Process Page</a>	Assists the project manager in creating tangible goals or targets for developing a sustainable project delivery process
<a href="#">Operation and Maintenance Plans - Process Page</a>	Facilitates communication between stakeholders to avoid conflicts of community dynamics

Some of the tools referenced in this table were refined based on the above application to the shelter community, but many need further development, and parts of the construction process might require other tools to help overcome combat some of the larger obstacles facing these communities including organizing a fundraising process. Due to time considerations, this process currently compares the potential benefits of on-site construction versus pre-fabricated modular construction. Technological and process advancements expand the possibilities for consideration when choosing a building delivery process. Continually updating these tools, specifically the *Choosing the Most Sustainable Building Technology* tool, makes this process applicable to even more communities. One example of a building technology that should be evaluated in the future is origami building. The technology is gaining popularity as people are beginning to investigate the numerous unique features it can offer. Making more options available in this process will only help increase the likelihood that the community is choosing the most sustainable technology for their specific situation.

It is important to remember the context of the area where these tools will be utilized when creating new tools. There are a number of dynamics that vary by community, and it is critical the tools be adaptable for anyone to use. There are political and social complexities that must be considered and there are others which will not apply to every project. For example, as mentioned, this community is unique in its ability to be able to receive funding from an outside source which circumvents a major obstacle that almost all other communities will face. All communities will face challenges within the larger political context of dealing with the South African government. The government does not formally approve of the informal settlements, but by working with NGOs, some communities have been able to undergo a re-blocking process which reorganizes them into a formal layout resembling a small town. The re-blocking process helps the community build a level of stability that raises their standing in the government's eyes. While this process can help move the communities forward, this is only a small step in overcoming a complex societal problem and there is still a lot of work to be done.

## Appendix A – Design Specifications Report

### Introduction to the Informal Settlement Building Design Process

The first step is for all stakeholders to gather and review the *Choosing the Most Sustainable Building Technology* form. This form helps the stakeholder team choose which of the available building technologies is best suited for their situation, based on their responses to a series of questions. Once the responses have been tallied, the technologies can be directly compared by developing a value index. The value index takes the overall tallies and divides them by anticipated cost. The figure below is intended to represent the decisions of the sample community for which this design was created.

Choosing the Most Sustainable Building Technology				
Applicable Sustainability Principle	On-Site Construction	Consideration	Prefabricated Modular Construction	Applicable Sustainability Principle
Identifying a Community's Unique Needs	X	Building can fit into available space		Identifying a Community's Unique Needs
	X	Community will be present for the building process		
	X	Building allows for alternative or accessory uses		
	X	Community members are available to help with design and construction		
		Community members are not available to help with design and construction	X	
	X	The community has time and space to commit to construction		
		The community does not have time and space to commit to construction	X	
Maintaining Intergenerational Dynamic	X	Produces replicable and distributable plans for future projects		Maintaining Intergenerational Dynamic
Repairing and Conserving the Environment	X	Uses durable materials for weathering as well as wear and tear		Repairing and Conserving the Environment
	X	Building materials are easily replaceable		
	X	Building materials are easily accessible		
		Building materials are not easily accessible	X	
	X	The community has a method to transport materials		
		The community does not have a method to transport materials	X	
Representing Shared Ideas	X	Community members wish to participate in the process		Creating an Integrated Public Mindset
		Community members do not wish to participate in the process	X	
	X	Community members can see the process develop		
	X	Community members can deal with noise pollution and spacial disruption		
		Community members do not want to deal with noise pollution and spacial disruption	X	
Stimulating the Local Economy	X	Community members need jobs		Stimulating the Local Economy
	X	Community members want to learn marketable skills		
Anticipating and Planning for Natural and Operational Disaster	X	The community can provide safe storage for materials		Creating Disaster Resistance and Mitigation
		The community cannot provide safe storage for materials	X	
	X	Disaster resistant materials are locally available		
		Disaster resistant materials are not locally available	X	
	X	The community can provide area to store materials on-site		
		The community does not have area to store materials on-site	X	

Figure 9 - Choosing the Most Sustainable Building Technology



The responses to these questions came after careful considerations to resource availability as well as what the community was willing to contribute from what they had saved. Using prices [approximately R 86000 or \$8,600] from previous, similarly sized projects showed that On-Site Construction had a better value than Prefabricated Modular Construction for this specific community (Brousseau et al., 2014).

## Design Development

Designing structures for on-site construction in South African informal settlement is much different than the typical design process used in developed areas. The typical design process identifies a loading scheme based on a series of forces the structure will be required to uphold (ASCE, 2013). Local building codes, which are typically published by the state government, work to impose these requirements on all new construction or renovations by setting minimum values for the building's design strength. Possible loading forces to consider include dead loads – static loadings that are inherently part of the building such as weight of materials, live loads – dynamic loads such as the number of people standing on a floor, wind loads, seismic loads, flood loads, and precipitation loads such as rain or snow. The second chapter of the 2010 Edition of ASCE 7 describes how each of these factors is put into a loading combination to determine the required strength of the final design (ibid). The design team calculates the appropriate size of a selected material to provide the desired level of strength. In the United States, there are a variety of tools available to determine sizing requirements depending upon the material. These tools include the AISC Steel Construction Manual, ACI Specifications for Structural Concrete, and the AWC National Design Standard. The design team balances ethical responsibilities to the public and to the project owner by ensuring that the final product is structurally safe for its intended use, but also not over-designed so that it remains economically feasible.

However, in the informal settlements, there are severe resource limitations such as funding and material availability. For example, the structure designed as part of this MQP was based in a community which only had access to three different sizes of structural lumber. The same community, albeit a small one, had been working for a few years to save the equivalent of about \$8,000. As a result, the design for the crèche (a small preschool), had to be reverse engineered based on the available funding and materials. The following process describes in detail how the resulting design considers the major factors of structural design as well as considerations that were made to address the limitations of this project.

## Establishing the Building Footprint

The first step in determining the design process was to consider the parameters surrounding the project. These design parameters can be found in the table below.

Table 5 - Design Considerations

Design Considerations	
Design Parameter	Considerations
Available Space in the Community	Finding available space in the community can be difficult because of the large number of people living on a small plot of land. The high population density could create challenges regarding clearance distances from other structures, building on space a community member has claimed as their own, and limited access roads for material delivery.
Available Materials in the Area	The local hardware store will deliver materials to any site within 1 km of the store for free. However, the store only offers structural lumber in 3 sizes (38mmx38mm; 38mmx114mm; 50mmx76mm). The store also offers support posts, corrugated metal sheeting, and bags of cement mix. The limited availability means building strength will be determined by number and layout of members, rather than member size.
Available Number of Workers	The community can guarantee 6 workers per day, and if necessary, up to 10 workers. Their experience with construction is not extensive with the exception of two workers who served previously on a construction team.
Available Funding	Funding is limited to approximately R 80,000 (\$8,000). Once the building is complete, the school will charge a small tuition fee. In the meantime, producing the most economical solution is a major component of the design. This will be a challenge as the building strength will be determined from the number and layout of members rather than the member size. Increasing the number of members can quickly increase the project cost.
Building Functional Requirements	Stakeholder requirements for the building include preschool accessories (sleeping area for students, learning area, bathrooms, and kitchenette). There are space requirements that must be considered for the number of children the crèche will serve.

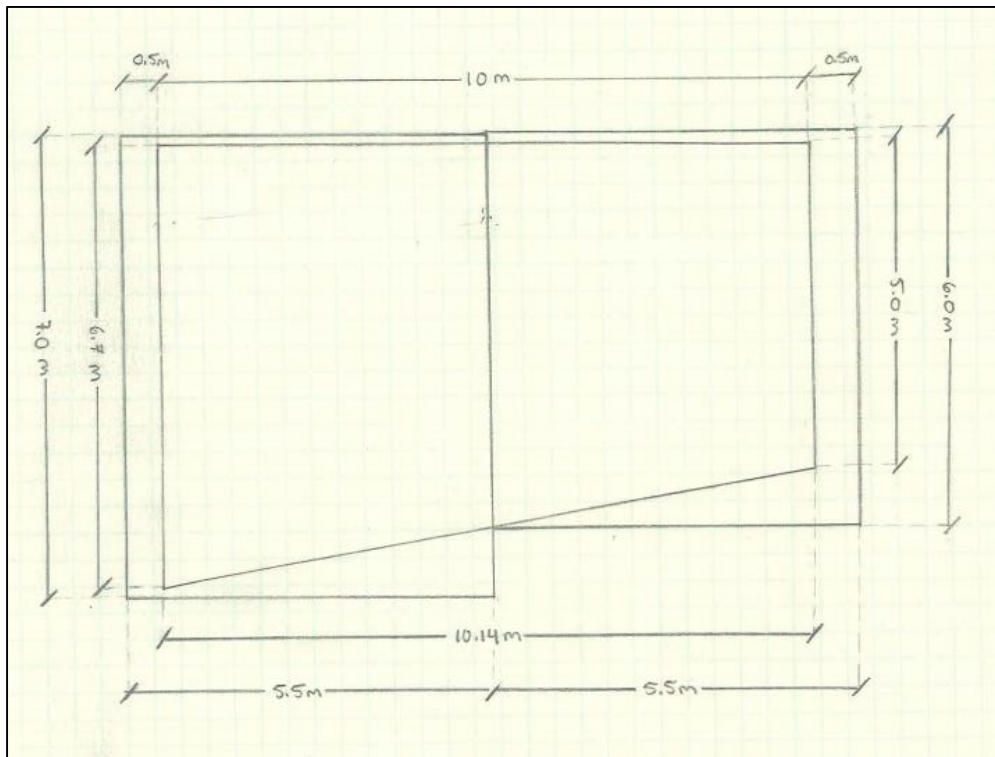


Figure 10 – Crèche Footprint Design

The resulting footprint and floor plan were developed based on the Building Functional Requirements and the South African Department of Social Development requirements and can be found below.

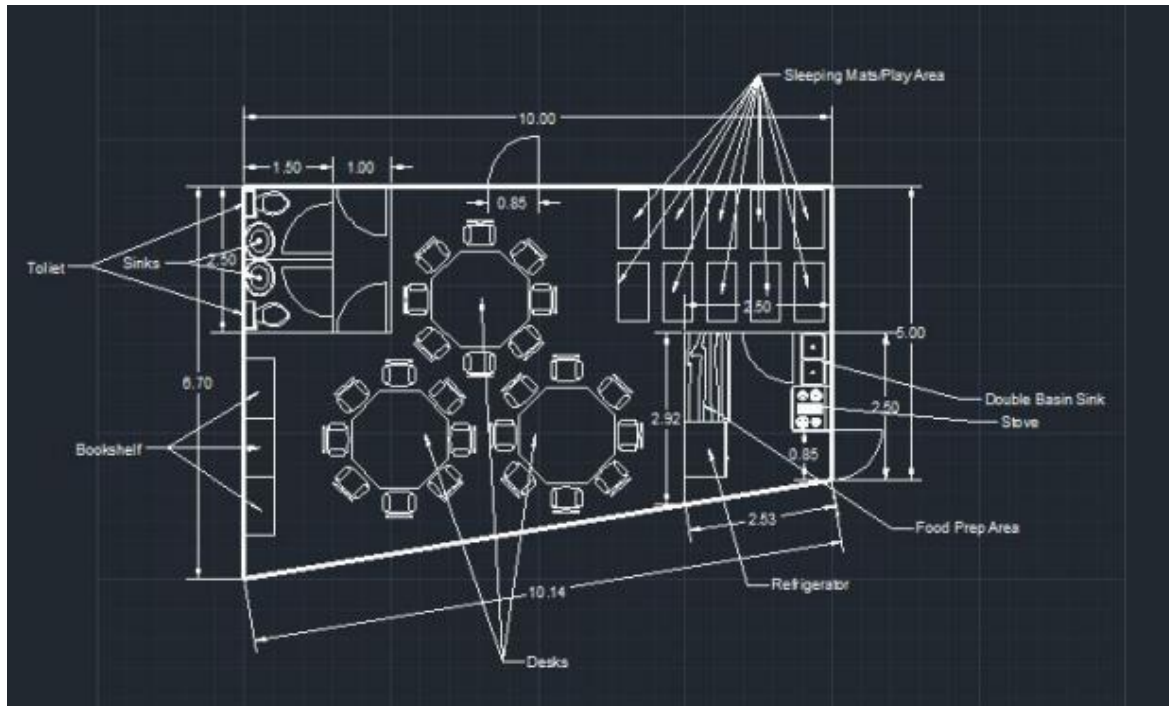


Figure 11 - Crèche Footprint (CAD)

Two of the key considerations for the general design and floor plan can be found in the table below. These requirements can be found in the *Creating a Crèche Checklist*. These requirements are set forth by the local registration board, which serves a purpose similar to the local building codes in the typical design and construction process.

Table 6 - Design Feature Considerations

Design Feature Considerations			
Consideration	Requirement	Result in Design	Design Value
Maximum of 22 Children	1.8m <sup>2</sup> /child of interior play space	39.6 m <sup>2</sup>	45.48 m <sup>2</sup>
Gendered Restrooms	1 for each gender	2 bathrooms	2 bathrooms

When designing the building floor plan layout, there were other considerations to be made. These considerations were founded in the specific needs requested by the project stakeholders and in the interest of ease of construction. These considerations and the reasoning behind them can be found in the table below.

Table 7 - Design Feature Considerations (B)

Design Feature Considerations	
Design Feature	Rationale
Lumber for Framing	<ul style="list-style-type: none"> <li>• Free delivery from hardware store</li> <li>• Locally sourced materials</li> <li>• Easily manipulated dimensions</li> </ul>
Multiple Bathrooms	<ul style="list-style-type: none"> <li>• Located near local sewage and water line connections</li> <li>• Teach children proper hygiene</li> <li>• Ethical considerations to separate genders</li> </ul>
Corrugated Metal Cladding and Roofing	<ul style="list-style-type: none"> <li>• Widely available, durable material</li> <li>• Easily recyclable - can be used from abandoned homes</li> </ul>
Kitchenette	<ul style="list-style-type: none"> <li>• Typical cooking method is fire over an open fuel source - hotplate is a much safer option</li> <li>• Sink located near municipal water line connection</li> </ul>
Overall Size	<ul style="list-style-type: none"> <li>• Registration requirements include 1.8m<sup>2</sup> per child</li> </ul>
Raised, Pitched Roof	<ul style="list-style-type: none"> <li>• Raised roof on all sides allows for passive ventilation (heat)</li> <li>• Roof overhang prevents precipitation entering the interior</li> <li>• Pitched, corrugated sheeting allows for easy rain collection</li> </ul>
Footprint Shape	<ul style="list-style-type: none"> <li>• Irregular trapezoid maximizes available space community can offer</li> </ul>

Once the footprint and a concept were developed, the structural designs were created. These include the building foundation, building frame, structural column support system, roof system, exterior wall system and its connection to the framing.

### Material Selection

Given the limitations in available materials, structural lumber was selected for the primary material in designing the building's support system. The design of wood structures in the United States is dictated through the American Wood Council's publication, the *National Design Standard* (NDS). NDS outlines a series of calculations that must be performed to ensure a design will be structurally sound. The NDS helps determine the dimensions of the structural lumber so that it can provide adequate strength. However, as previously mentioned, limitations in material choices required a reverse approach. The wood sizes and layout were selected first and then the NDS equations were used to calculate the maximum loading the members can bear before failure. These values were then compared to the design loading. If the member arrangement was unable to provide enough capacity, additional members were added to provide more support. NDS calculations are based on the mechanical values of different species of wood. The mechanical properties of the wood used for the frame construction and support are summarized in the table below.

Table 8 - Structural Lumber Mechanical Properties

Structural Lumber Mechanical Properties				
Wood Species	Compressive Strength	Modulus of Elasticity	Modulus of Rupture	Source
Rose Gum	36 MPa	13 GPa	79 MPa	<a href="#">Source</a>
South African Pine	22.8 MPa	9.6 GPa	15.8 MPa	<a href="#">Source</a>

Given the atypical method of creating the design, the safety factor for each of the calculations is considered by dividing the design load into the calculated capacity. The resulting frame and post system is shown in the figures below.

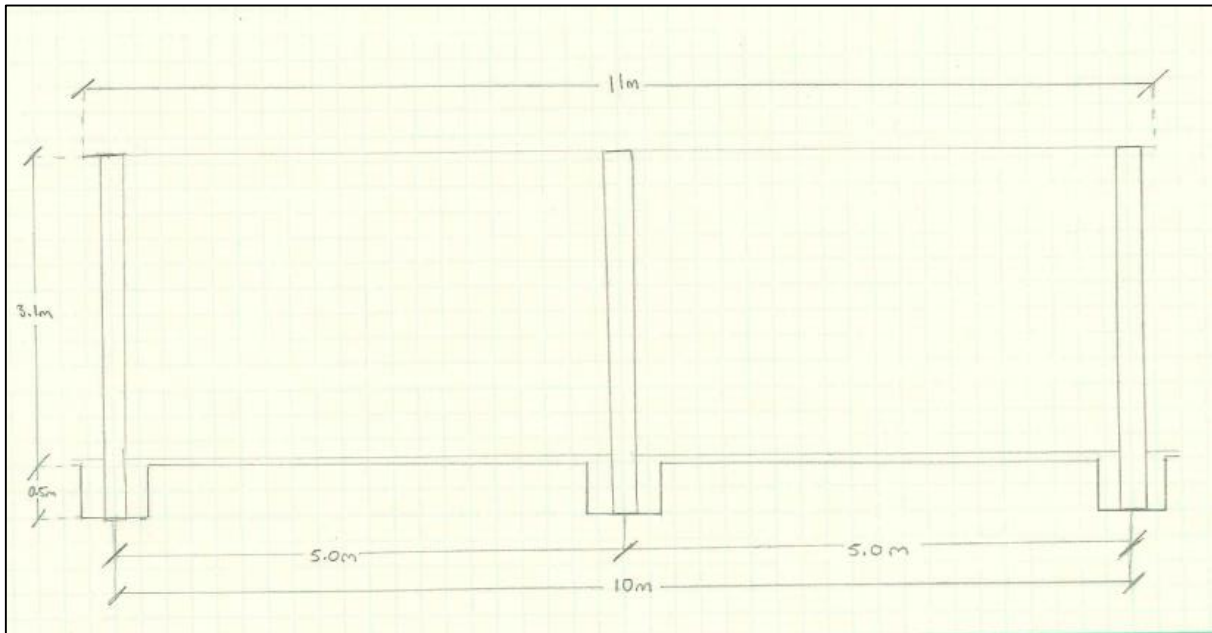


Figure 12 - Crèche Post Spacing & Foundation (Front View)

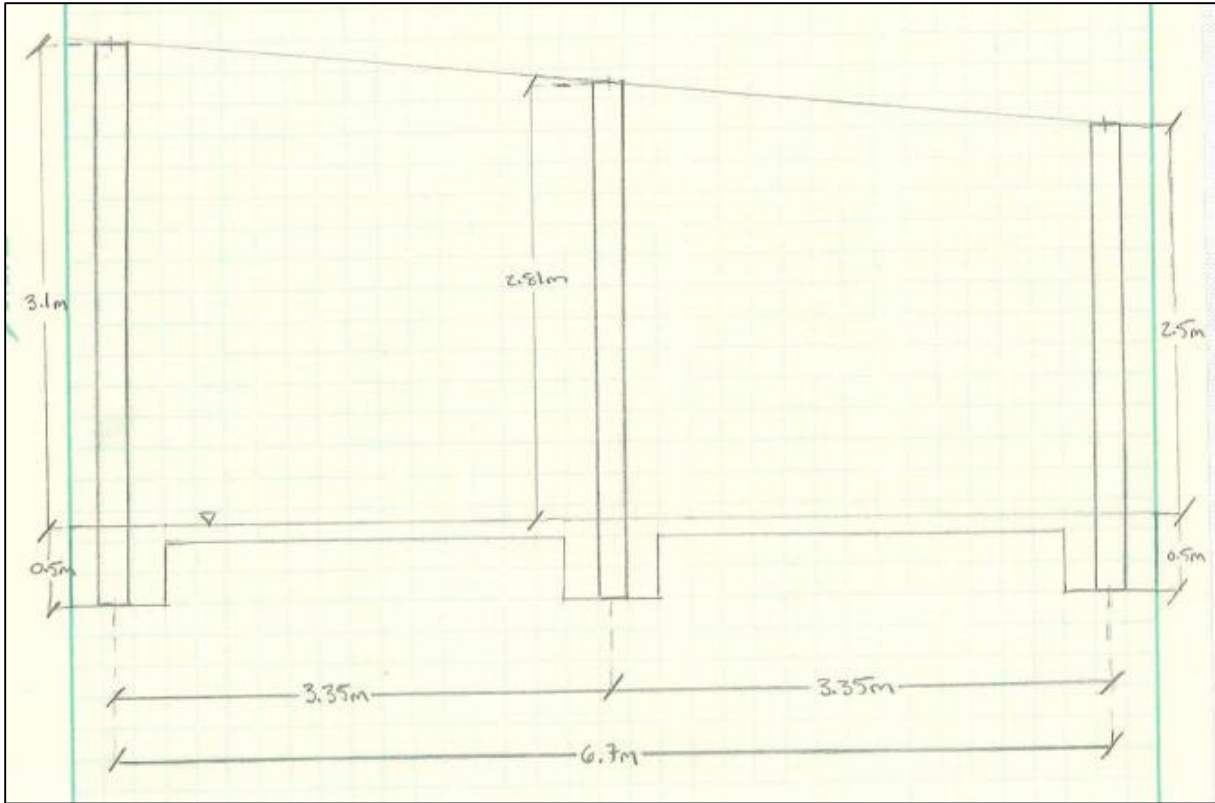


Figure 13 - Crèche Post Spacing & Foundation (Left View)

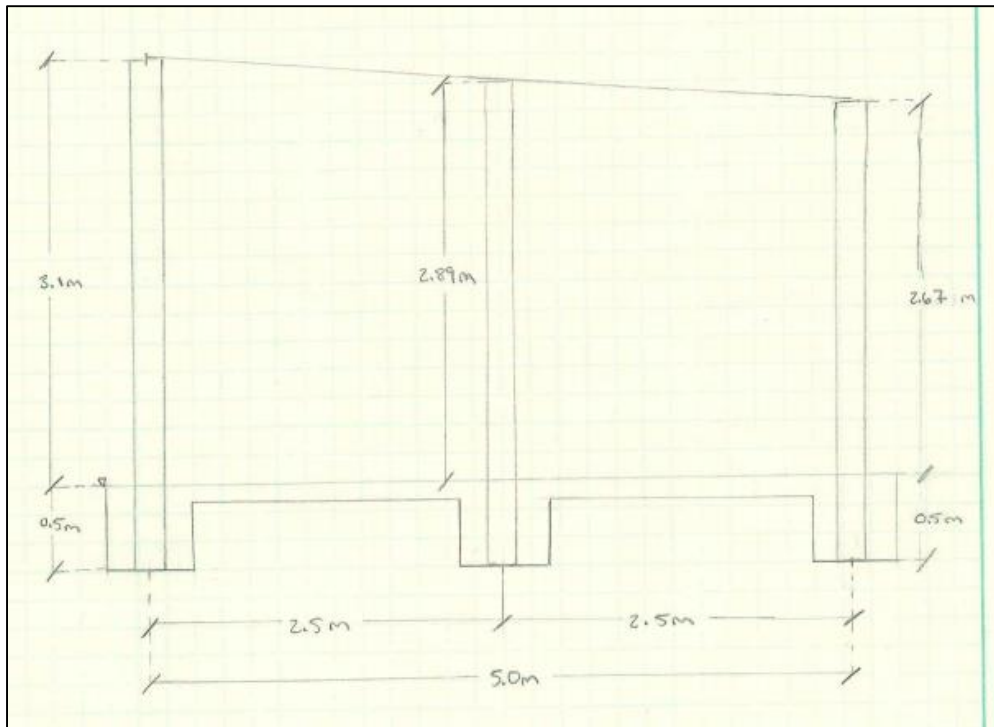


Figure 14 - Crèche Post Spacing & Foundation (Right View)

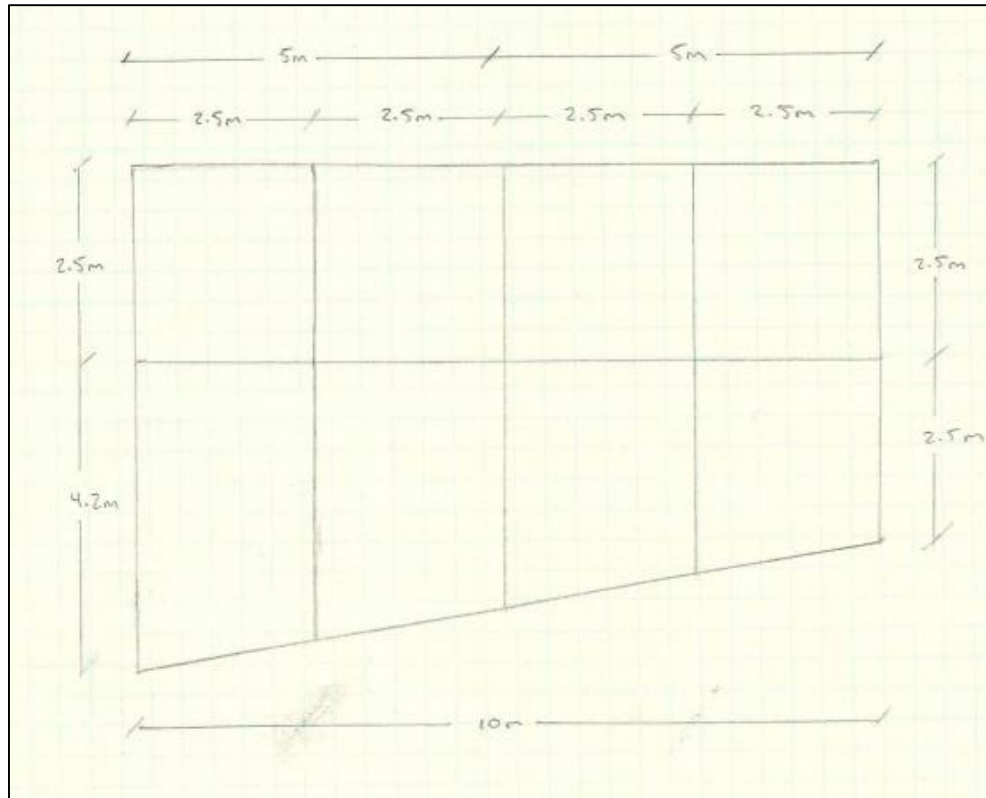


Figure 15 - Crèche Roof Frame Design

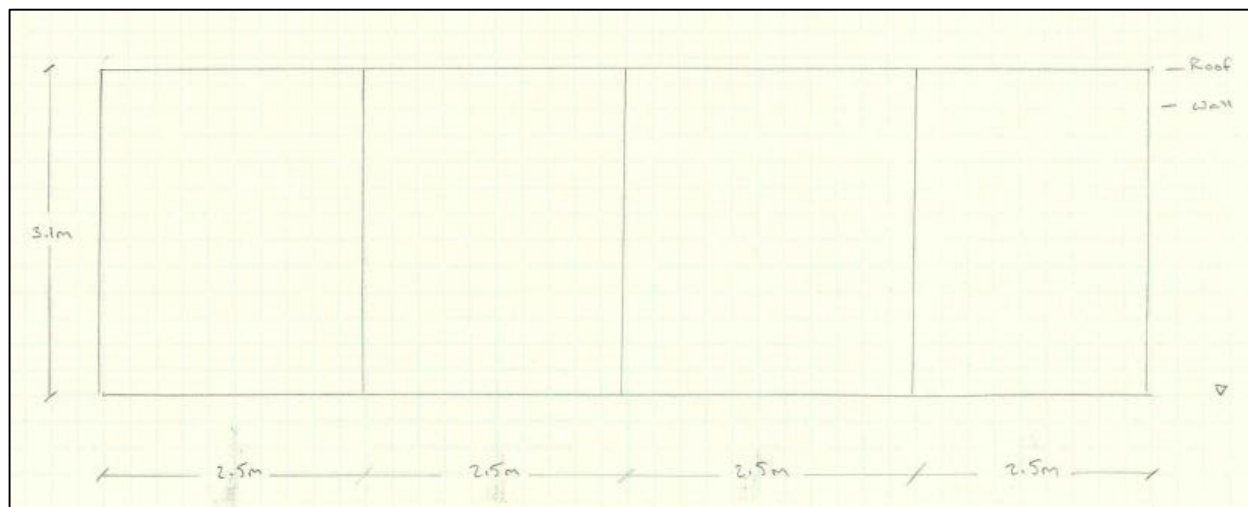


Figure 16 - Crèche Wall Frame Design (Front View)

### Roof System

The roof system is a simple beam and girder system supporting a thin, corrugated metal sheeting. The roof system is supported by a set of wooden columns. The beams and girders are all created from South African Pine wood of the lowest structural grade, and the posts are Rose Gum wood. Three considerations were made in the design calculations for the roof. The checks that needed to be performed were that the beams and girders must support the design loading combination without

exceeding the maximum deflection set forth by the NDS. The columns must support the design loading exerted by the roof and its components without being crushed or collapsing due to a flexural buckling. The final checks determined that the connections are able to withstand the potential pressure or suction caused by wind loads on the roof and the metal sheeting will not shear off at the connection-sheeting interface.

### Wall Framing System

The framing system creating the four walls is a simple stud and post system. The wall frames are intended to be built separately and then connected to the grounded posts mentioned above. The additional force applies a combined bending and axial loading effect. These posts are Rose Gum wood, and the framing is South African Pine wood. At the completion of the product, a layered cladding system would be attached to the stud framing. The cladding would consist of an interior layer of plywood, then a layer of insulation, and an exterior layer of sheet metal. The checks that were performed are if the posts can resist the bending force enacted on them by the wind loading and whether or not the studs in the wall can resist the total deflection set forth by the NDS for a wall to resist wind loads. For the deflection calculation, the additional rigidity provided by the cladding was not factored into the calculation.

### Foundation and Flooring System

To limit costs while providing the necessary structural stability, the floor will be a slab-on-grade system. The Rose Gum wood posts will be back filled with a cylindrical anchorage of concrete mixture and above that, an approximately 4-inch thick layer of concrete will be placed. A thin mesh covering around the edges of the concrete slab will help reduce the likelihood of vegetation growing around the slab edges over time. There were two checks that needed to be completed for this system. The first was to comply guidelines to ensure the minimum depth for a specific span of slab-on-grade concrete that was provided by ACI 360 and reiterated by D. Matthew Stuart in his lecture *Slab on Grade Reinforcing Design* (Stuart, 2013). The second check was to ensure that the concrete can resist the counter-moment created by the wind load on the wooden posts.

### Connections

The connections were determined using the [Connection Calculator](#) an online tool published by NDS. This tool allows users to select a species of wood, the lumber dimensions, the connection type and size as well as the loading scenario. It then performs the calculations to determine the maximum forces that can be placed on the wood before the connection yields. The yield mode with the lowest resistance was used as the determining factor when outlining the allowable loadings for the building.

### Results and Discussion

Table 5 below shows both the actual and allowable loadings for the resulting design. The calculations for these examples can be found in the *Crèche Structural Analysis* document located in the Appendix. Appropriate sources can be found in the actual calculations documents.



Table 9 - Checking Design Values

<b>Checking Design Values</b>		
	<b>Allowable Value</b>	<b>Actual Value</b>
Column Crushing	603,000,000 N	26,617 N
Euler Buckling	530,853 N	26,618 N
Girder Deflections	0.0278 m	0.2094 m
Beam Deflections	0.0174 m	0.0325 m
Girder Deflections (w/o maintenance)	0.0278 m	0.0049 m
Beam Deflections (w/o maintenance)	0.0174 m	0.0008 m
Moment Due to Wind on Columns	1,333,125,000 Nm	24,745 Nm
Slab-on-Grade Maximum Spacing	5.5 m	5 m
Concrete Resistance to Column Pressure	17,000,000 N/m <sup>2</sup>	73,867 N/m <sup>2</sup>
Combined Bending and Axial Compression	81,850 N	38,531.83 N
Connection Spacing (assuming connections along framing lines)	15.08 m o.c.	1.5 m o.c.
Metal Sheeting Shearing at Connection	330,000,000 N/m <sup>2</sup>	11,763,394 N/m <sup>2</sup>

The sample design described above was limited by a lack of available materials. For example, the local hardware store only offers three sizes of construction grade wood. As a result, the design was reverse engineered so that joist and stud spacing was based upon the material size rather than choosing an appropriate size from a previously created design. Similarly, the loading calculations present the maximum design loads that the building could sustain based on material sizes, whereas the typical design process requires materials to be selected based upon anticipated design load combinations.

Limited resources also challenged the calculation process when determining the maximum allowable loadings for the building based on the design. Typical building materials in South Africa are not common in the United States, so in order to follow the AWC NDS, a correlation had to be drawn

between the wood typical in South Africa to a wood found in the NDS manuals. Another challenge stemming from the NDS was the allowable design spacing. In some instances, the calculations based on typical procedure required a significant increase in the number of supports. One specific example is in the roof analysis. The typical process requires a live load on the order of 20psf in addition to the material dead loads. The resulting design included triple the number of beams and double the number of girders in the roof, even when using the largest wood size available. These additional members would cause a significant increase in the cost of materials. Money is scarce in the informal settlements and finding additional monetary support can be extremely difficult, which may cause the project to remain incomplete for years. As a result, the solution was to post signs in multiple languages on the site and the building itself restricting people from climbing onto the roof during the building's lifespan. Prohibiting people from walking on the roof allowed the additional live load to be discounted, resulting in a design value of approximately 1 pound per square foot based on the AWC NDS. Challenges like this one continue to plague the design and construction process in poverty ridden areas, but projects like this one can begin to find feasible solutions to these obstacles.

## Appendix to the Design Specifications Document

### Creating a Crèche Checklist

The team created the checklist below from altered from Entrepreneur SA's "How do I start a Child Services Business" and South Africa's department of social development (Department of Social Development, 2013; Entrepreneur Magazine, 2010). It includes the necessary steps and considerations to take when planning a crèche in South Africa. Each of the major turning points in the development process organizes the steps.

#### Considerations before you get started

- What type of center will you need?
  - Run from a home or a residence
  - Run from a commercial location
- What licensing will be required?
- What legal requirements must I comply with?
  - Zoning laws and regulations
- What are your financial needs?
  - Estimate start-up costs and sources of revenue
- Who will make up the staff?
  - Training and certification
- Is networking necessary?
  - Marketing/getting students for your crèche
- What health and safety issues could you face?
  - Plan for accident/illness prevention
  - Emergency procedures
  - Insurance for children and owner
- What equipment is needed and who will provide it?
  - Total cost
- What programs should you plan?
  - Schedule of activities

#### Structural and Health Requirements

- Indoor play area
  - At least 1.8 m<sup>2</sup> per child in size used for play, meals, and rest
- Kitchen
  - Suitable cooking and washing facilities that are separate from play area, inaccessible to children
  - Natural lighting and ventilation
  - Smooth finish wall surface
    - Coated with a washable paint
- Sanitary Facilities
  - One toilet and hand washing facility for every 25 children under 5 years of age, regardless of gender

- Two toilets and hand washing facility for 25 children over 5 years of age, one for each gender
- Separate toilet facilities for staff, according to National Building Regulations
- Potties for young children must be cleaned and disinfected immediately after use and stored in a suitable, clean place
- Supply of hot and cold running, potable water
  - If running water is unavailable, a minimum of 25 liters of potable water must be stored in a hygienically clean container on site
- Outdoor Play Area
  - Provide at least 2.0 m<sup>2</sup> per child
  - Provide shady or other cool areas
  - Fenced in with childproof gates
  - Free of holes and dangerous steps or levels
- General Health and Safety
  - Recorded health register
  - Maintain a safe play area
    - Regulated by local or city council
    - Recommendations by insurer or lawyer

#### Checklist to Apply for Registration as a Place of Care

- Weekly menu of food
- Daily program of activities
- Building plan/hand-drawn sketch of building
- Service/Business plan (application for funding)
- Copy of constitution, signed and dated (if funding is required)
- Financial report of the past year (for funding purposes)
- Contract with building owner (leasing agreement – funding)
- Application available at:  
[http://www.services.gov.za/services/content/Home/ServicesForPeople/Parenting/Childbenefits/ECDfacility/en\\_ZA](http://www.services.gov.za/services/content/Home/ServicesForPeople/Parenting/Childbenefits/ECDfacility/en_ZA)

#### Checklist for Complying with Council

- Approved medical officer of health
- Environmental health permit
- Crèche must have (for centers with 30+ children)
  - Office
  - Sick-bay
  - Staff room
- Insurance cover
  - Liability insurance
    - Accident and equipment
  - Play structure warranties
- Health by-laws for local municipalities

- Playground structures
- Certificate of compliance for food preparation

#### Registering with Local Municipality

- Apply to Health Department
- Contact Department of Health to find correct zoning area
- Register venue with local municipality
- Municipality follows regulations set by Department of Social Development in accordance with the Childcare Act, 1993 (Act No. 74 of 1983)
- Any other Council imposed regulations and restrictions it sees fit

#### Hiring Staff

- Age
  - 18-60 years old
  - Combination of ages
- Attributes and skills
  - Patience
  - Hygiene
  - Ability to understand young children
  - Administration/management
- Health
  - Medically examined
  - Those with infections or illness must refrain from working with children and food
- Culture
  - Knowledge and respect
- Training and experience
  - Completed or completing basic level training course
    - Recognized agency covering health, safety, nutrition, child development
  - Administration
    - Crisis management
- Language
  - Native tongue of students
  - Knowledge of others to introduce to children
- Staff/child ratios
  - House (mixed group)
    - 1:6
  - House with add on
    - 0 to 18 months – 1:6
    - 19 months to 3 years – 1:15
    - 3 years to 6 years – 1:25
    - After school center – 1:35

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## Appendix B – Professional Licensure Statement

Professional licensure is critical to developing high quality work in both the public and private sectors. Each state issues a special license to professionals who are able to demonstrate exceptional quality in their work. State licensing boards are assisted by the National Council of Examiners for Engineering and Surveying (NCEES). This group administers tests to ensure those seeking professional licensure have the appropriate work experience, have met specific educational qualifications, and have passed the proper examinations. All candidates must pass the NCEES requirements before they can apply to the state licensing board for final approval.

Engineers with professional licensure accreditation have proved their ability to ethically and technically interpret the numerous codes and standards that come into effect when the engineer is drafting or reviewing designs. Adhering to the proper codes and applying them effectively helps maintain a general minimum safe guard for all people who use the final product. Maintaining licensure and a respected name in the industry requires engineers to act responsibly and ethically with their authority.

The process for obtaining a professional engineering license takes a number of years of commitment. The first step usually takes place just before or not long after graduation from an ABET accredited engineering program. A candidate can take the Fundamentals of Engineering Exam. If the candidate scores high enough, they pass the test and become an Engineer in Training (EIT). EITs can then work under a Principle Engineer for five years, compiling their work for submittal to a state board of licensed engineers who will determine whether or not the EIT's work exhibits sufficient quality to become a Professional Engineer. To become a Professional Engineer, the EIT must also pass the Professional Engineering exam. A high enough score on that test in tandem with the board's approval grants the EIT licensure as a Professional Engineer (PE). The testing and requirements are different for each state. These variations in requirements are due to special considerations that must be given for numerous reasons, such as geographical location. For example, the state of California has additional requirements for testing knowledge on seismic design and safety. The PE license must be renewed every couple of years to maintain the licensure.

Professional licensure is important to the engineering profession, the engineer holding the license, and to the public as a whole. Licensure within the profession is important to uphold a certain level of qualification for maintaining strong work integrity. Their stamp on a design provides people with assurance that the design will safely perform its function.

It is also important to the individual because it provides a goal to strive for within the field. Obtaining licensure is a significant milestone in the career of an engineer. Earning the level is a major accomplishment that adds a lot of additional responsibility to the individual who holds it. Their work and review of other people's work is what will be put into effect. Their work and reviews on others' work has been highly regarded by other professionals in the field, but at the same time, they are held responsible for anything that may go wrong when the design is implemented. This may put a lot of pressure on the individual to succeed.

Professional licensure is also immensely important to the public as a whole. With regards to the public, the matter of professional licensure is based largely on ethics and safety. There is an inherent level of safety factored into final drafts of engineering design by helping to keep a high level of performance requirement for licensure. Engineers have an ethical responsibility to ensure that the designs they

create, which will be manufactured and implemented for daily use by the general public, are held up to code. Cutting corners to lower project costs or allowing contractors or laborers to provide sub quality work can be extremely hazardous to people using the facility. The professional engineer has the final say on what is acceptable and it is their ethical duty to make sure that not only their work, but everyone else's work on the project is acceptable.



## Appendix C – Capstone Design Statement

The first major deliverable for this project was a construction delivery process that had been adapted to increase sustainable construction in informal settlements. This process consisted of using literate tools to facilitate communication between the community and technical advisors. The goal of the process is to allow community groups to be able to take part in the entire design and construction process in a way that accounts for their specific talents and needs. The second major deliverable of this project is a building design that was created from using this process. The architectural layout and structural design were prepared.

A design of a crèche (early child-care center) was produced for construction in a Cape Town informal settlement. Limitations in space, funding, material resources, and work force combined with a wide array of social complexities including language barriers and limited educational backgrounds applied additional constraints that had to be considered in the final design. As a result, the design serves to facilitate the construction process by using a simple, efficient floorplan, as few building materials as possible to keep costs low and minimize the number of materials required for construction. The design was then checked against the minimum allowable values which were calculated by using the equations in the American Wood Council's National Design Standard. However, rather than selecting a structural lumber size based on these calculations, the maximum allowable dead and live loads were determined based on the size of available members. The wind loading, connection strength, and concrete slab-on-grade analysis were all checked by ensuring that the structure could withstand the calculated forces that came from using the NDS equations. Additional members were added if any part of the structure failed. Wind loading was considered due to the 50-year, 3-second gust maximum wind speed.

In producing this design, some of the real-world constraints set forth by the American Society of Civil Engineers as a part of the criteria for a capstone design experience were addressed. These constraints included economic, social, sustainability, constructability and health/safety factors. The following constraints listed by ASCE have been addressed in the scope of work for this project:

### Economic:

Severe poverty is one of the most prominent obstacles to construction in informal settlements. The design takes into consideration the economic implications of the building and construction process. In an attempt to keep costs down, a balance was sought between structural stability and fiscal caution. There are numerous examples throughout the design that express this balance. One of the most prominent examples is in the roof design. The roof support system initially included a live load of 20psf to account for maintenance work. In order to pass the deflection test of the NDS, the system would have required tripling the number of beams and doubling the number of girders to provide the required additional strength. As a result, the decision was made to post a sign on the site and on the building forbidding people from walking along the roof. This allowed the design to discount the additional maintenance load and thus did not require the additional members.

### Social:

The social implications of working in the informal settlements also required significant consideration. Space comes at a premium in these areas. The buildings are closely packed and cover hundreds of square miles. As a result, finding adequate space can be especially challenging. The irregular, trapezoidal footprint of the building is an example of how the design attempted to account for

some of these social considerations. While a rectangular shape would have allowed for an increased square footage, the surrounding area would not accommodate it. A second social consideration factored into the design was the inclusion of two bathrooms. While it may seem that, at the preschool level, having gendered bathrooms is unnecessary because the space could be used for increased learning area, it is important to consider the diversity of the settlement population. Numerous religions, tribes, immigrants and citizens co-exist in these areas, but some of their beliefs may require the use of separate facilities for male and female students.

#### Environmental Sustainability:

The entirety of this project attempts to factor in numerous aspects of sustainability. The design process incorporated environmental sustainability by using materials that are widely available throughout the informal settlements, rather than referring to new materials. The main example is the corrugated metal used for both the roof and the exterior wall cladding. This material can be found around abandoned shacks or in recycling plants all across the area. This not only prevents the community from having to purchase additional materials, but also prevents the exhaust created from the mechanical energy required to produce the sheeting.

#### Manufacturability:

The design fits a variety of manufacturability concerns the community would have. The design places the bathrooms along the far left wall of the design and the sinks for the kitchenette along the far right, in the bottom corner; the local sewage and water connection pipes for the area are set directly adjacent to the bathrooms and the city water lines are set directly adjacent to the sinks in the kitchenette. By organizing the footprint in such a way, the construction crew will have a much easier time laying the piping in because the distance they must cover is relatively short. Also, the building is required to have a certain square footage of useable space for the children. Thus a single-story structure with a large footprint was designed. This is far more accessible for the community to construct than a multi-story building with a smaller footprint. The community does not have the tools necessary to lift materials onto a second floor. Keeping the design to a single story helps to improve manufacturability by considering the tools and equipment the community has available to them.

#### Health/Safety:

Fires are a major challenge for informal settlements. Many people cook over open fuel sources and the buildings are tightly packed, allowing flames to quickly travel from one building to the next. The health and safety of the occupants was considered by incorporating fire resistive materials in its construction. The woods used in construction are slow burning and do not produce a lot of smoke. This will help maintain tenability long enough for the building occupants to safely exit. A second consideration was the use of sinks in the bathrooms. While they create extra connections to water sources and reduce the available space for the children, they help to teach the children proper hygiene. The purpose of the building is to support early childhood development, part of which includes healthy restroom practices. A final health consideration was the pitched roof. Having the raised roof allowed for a passive ventilation to keep the space tenable, otherwise the metal roof would have caused elevated temperatures inside the building, especially during the summer months.

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