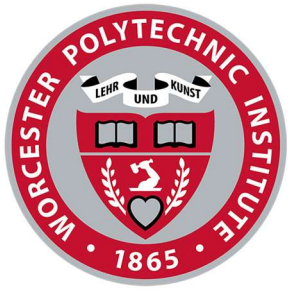
Analysis of More Efficient Methods for Operation Playhouse



WPI

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Authorship Page

Section	Author(s)	Revised by
Abstract	Matthew Breidenbach	Matthew Breidenbach
Executive Summary	All	All
1.0 Introduction	All	All
2.0 Background	Matthew Breidenbach	Myles Coakley
2.1 Operation Playhouse	Myles Coakley	Myles Coakley
2.1.1 Motivation for Operation Playhouse	Myles Coakley	Myles Coakley
2.1.2 Impact of Playhouse	All	Myles Coakley
2.1.3 Funding	Lain Zembek	All
2.2 Construction of a Playhouse	Lain Zembek	All
2.2.1 Materials Currently Used	Lain Zembek	All
2.2.2 Qualities of Desirable Materials	Lain Zembek	All
2.2.3 Current Construction Process	Matthew Breidenbach	All
2.2.4 Organizational and Waste Reduction Methods	Matthew Breidenbach	All
2.2.5 Current Waste in Operation Playhouse	All	All
2.2.6 Waste Reduction Method	All	All
2.3 Weather Conditions of Worcester and the Impact on Playhouses	Matthew Breidenbach	All
3.0 Methodology	All	All
3.1 Determining High Quality, Cost-Efficient Materials	Lain Zembek	All
3.1.1 Assess Current Materials	All	All
3.1.2 Interview Professionals	All	All
3.1.3 Vendor Evaluation	Lain Zembek	All

3.2 Reducing Construction Waste	Lain Zembek	All
3.2.1 Analyzing Dimensions	Lain Zembek	All
3.2.2 Observations	Lain Zembek & Matthew Breidenbach	All
3.2.3 How to Implement New Methods of Design	Lain Zembek	All
3.3 Identifying a Method to Reduce Build Time and Cost	Matthew Breidenbach	All
3.3.1 Observation	All	All
3.3.2 Interviewing	Matthew Breidenbach	All
3.3.3 Guideline	Matthew Breidenbach & Myles Coakley	All
4.0 Results	Matthew Breidenbach	All
4.1 Optimal Materials for Construction	Lain Zembek	All
4.1.1 Current Material Analysis	Lain Zembek	All
4.1.2 Finding Cost Effective Materials	Lain Zembek	All
4.2 Measuring the Amount of Waste	Matthew Breidenbach & Lain Zembek	All
4.3 Creating a Construction Guideline	Matthew Breidenbach	Lain Zembek
4.4 Discussion	All	All
5.0 Recommendations	Lain Zembek	Matthew Breidenbach
5.1 Waste Reduced Design	Lain Zembek	Matthew Breidenbach
5.2 Cost Effective Materials	Lain Zembek	Matthew Breidenbach
5.3 Organized Assembly Guideline	Lain Zembek	Matthew Breidenbach
5.4 Conclusion	Matthew Breidenbach	All

Abstract

The purpose of a playhouse is to provide a comfortable place for the veterans family to bond and play. The intention of our project was to develop a procedure for reducing waste, cost and production time to build a single playhouse. To achieve this, we determined high quality materials that are less expensive than those currently used, reduced material waste from each build, and identified a standardized construction method to reduce building time and cost. Completion of this project resulted in a blueprint with optional, alternative materials and dimensions, step-by-step assembly instructions, including videos, for Habitat for Humanity MetroWest/Greater Worcester and the volunteers to use, and a formal report outlining the results of the methodology.

Executive Summary

Habitat for Humanity International, a non-profit housing organization, was founded in 1976 by Millard and Linda Fuller. Their mission was to provide housing to families in need in exchange for their service in the building process, regardless of race, ethnicity or religion. Today the organization has built over 800,000 homes, serving over 100,000 families in a single fiscal year.

Habitat for Humanity MetroWest/Greater Worcester (HFHMWGW) affiliate's Operation Playhouse project requires a company, or group of people, to sponsor a playhouse. The money made from building these playhouses are applied to their bigger projects centered around helping veterans. However, HFHMWGW has identified problems with its playhouse design. The cost of the playhouse is much higher than desired. Along with the high cost, the playhouse creates a large amount of material waste.

Background

In our research, we described issues with the playhouse project, the impact of the playhouse project, the current materials used and possible techniques that will address the problem Habitat for Humanity MetroWest/Greater Worcester is facing. The current issue with high cost needed to be addressed with the materials purchased. In determining lower cost materials, we had to maintain the high-quality properties. The more important factors were strength, weight, and weather resistance. As for the waste in the design, a database needed to be set up to evaluate the quantity of waste and the areas of crucial improvement. Once the materials and design were examined, an organizational procedure was the next step in reducing time and increasing assembly efficiency.

Methodology

Our project objectives were:

- To determine high-quality materials that are less expensive than the ones currently used for construction.
- To reduce material waste from each build.
- To identify a standardized construction method to reduce building time and cost.

To determine high-quality materials, we needed to contact someone with a professional background in construction. We were able to contact a construction manager and determine which materials would work best for this project. The new materials required for a waste reduced playhouse would be available locally for HFHMWGW's convenience.

We visited the HFHMWGW warehouse and analyzed the material that they use for the playhouse assembly. We observed that forty percent of the lumber is wasted for the current design. HFHMWGW also purchases packages of hinges that come with screws. These screws are not used with the playhouse because they are the incorrect size. Since the screws are not the right size, HFHMWGW discards the screws and only uses the hinges. Based on the waste currently produced, we have resolved a method for reducing the waste to eight percent. To reduce the waste, we created a new design, a document of the waste comparison, and a list of new materials.

Our team documented a construction process by conducting interviews as well as an observation of the playhouse build. The interviews provided us with information about the current construction process from a volunteer's point of view. The observation validated the interviews data which allowed us to see what really happens at the build as well as what could be improved in the process.

Results and Conclusions

Our team found many different issues that ultimately influence cost, construction time, and material waste. From our visit to the HFHMWGW warehouse we were able to see the materials that are being used to create a playhouse. We identified three different types of wood being used in the current playhouse: plywood, oriented strand board (OSB) and pine boards. The plywood is used to make the walls of the playhouse, the OSB is used to create the roof and the pine is used for the trim and window stops.

Our team found it more cost effective if HFHMWGW switched to 19/32" sheathing plywood and 23/32" BCX pine plywood. As for the hardware, we concluded it would save money long term if HFHMWGW purchased their screws in larger quantities, as well as using a Philips head 1-⅝" screw instead of the 1-¾" T25 screw. By switching to these two types of lumber, and ordering screws in larger quantities, HFHMWGW can nearly cut their total price in half.

In chapter 5, we discussed the new design that we created. The new design we developed eliminates the need for six boards and instead requires only four. There are two sheets of each of the lumbers mentioned above. The sheathing plywood for the walls and the BCX plywood for the roof panels and trim.

From our findings, we recognized a few flaws in the current construction process. We noticed there was confusion about part location and use of equipment throughout the assembly, so by incorporating an assembly guide we can discard any disorientation with the steps for the trim, roof, shingles, etc. We built a 1:3 scale model of the new playhouse design that

HFHMWGW will be able to bring to different builds as a visual aid as well as expanding their playhouse project to other Habitat affiliates.

Acknowledgements

We would like to thank Habitat for Humanity MetroWest/Greater Worcester for the opportunity to improve this project and help influence the future success of Habitat for Humanity.

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Table of Contents

Table of Figures

1.0 Introduction

Habitat for Humanity (HFH) is a non-profit housing organization. Their mission is to bring people together to build homes, communities and hope (Habitat for Humanity, 2017). Homeownership gives families the opportunity to be financially stable, live in a safe environment, and to raise a family. Habitat for Humanity Greater Worcester, founded in 1985, later became affiliated with Habitat for Humanity MetroWest in 2007. To establish a better lifestyle for families in need, HFH MetroWest/Greater Worcester (HFHMWGW) affiliate constructs homes, using donation money, and sells them interest-free at a price near thirty percent of the family's income.

In 2014, Habitat for Humanity MetroWest/Greater Worcester adopted the concept of building playhouses for children of veterans from the HFH affiliate in Los Angeles. In doing so, they hope to bring the community closer together, raise awareness for this project, and offer thanks to veterans for their service. The program, called Operation Playhouse, can make a difference in veterans' lives, and establish serenity in their homes. In 2016, 28 veteran families in Worcester received a playhouse (Habitat for Humanity, 2016) and HFHMWGW plans to double this number by the end of 2018.

The goal of this project is to develop a procedure for reducing waste, cost and production time to build a single playhouse. HFHMWGW will be able to build more playhouses than before at a reduced cost and with less waste. Our objectives to meet this goal are:

1. To determine high quality materials that are less expensive than the ones currently used for construction.
2. To reduce material waste from each build.

3. To identify a standardized construction method to reduce building time and cost.

By observing the wood cutting and assembly practices on site, interviewing structure and lumber professionals as well as current Operation Playhouse volunteers and Habitat for Humanity staff members, a report, containing alternative designs and a precise construction guideline, can be developed that will allow HFHMWGW to build cost efficient playhouses for veterans' families.

2.0 Background

This chapter introduces the importance of the Operation Playhouse project for veterans' children. Additionally, it will identify the current materials used, the current construction process and possible techniques that will address the problem HFHMWGW is currently facing. The chapter concludes with the local weather conditions in Worcester and the impact on a playhouse.

2.1 Operation Playhouse

This section introduces why HFHMWGW is motivated to build playhouses, the impact Operation Playhouse has on the community and how volunteers can contribute to this project.

2.1.1 Motivation for Operation Playhouse

Worcester is currently home to about nine thousand veterans: approximately 6,000 serving from 2001 to now. Today, some of these veterans are still trying to adapt to civilian life. Having adequate medical, emotional, and transitional support are imperative for a successful transition into the workforce (Ruh, Spicer & Vaughan, 2009). Post-traumatic stress disorder (PTSD) affects one in ten Afghanistan veterans, and one in five Iraq War veterans (Dickerson, 2015). Such high rate of PTSD is not only caused by what happened during service, but also by the isolation and disconnection soldiers experience when they come back home. PTSD affects many soldiers' abilities to spend time with their children due to different sounds around them. The Department of Veterans' Services in Worcester, a State agency, is making an effort to provide eligible veterans and their families immediate financial aid, medical assistance and referral services on issues such as housing, employment opportunities, health and education (O'Connor, 2017). HFHMWGW presents an alternative service through Operation Playhouse.

Each playhouse provides a positive distraction for veterans, a place to bond with their children, and a way to give thanks to the veterans that served our country.

2.1.2 Impact of Playhouse

A playhouse is a small private space that gives a child a sense of security. It is undoubtedly true that the playhouse provides a place for children to play freely, which enlightens creativity and imagination in children. For veterans returning home to their families that they have not seen for years, a playhouse can bring them together by providing a place for parent-child activities while providing serenity for veterans.

The construction of a playhouse can bring people together by working as a team. This project offers more than a class or a volunteer opportunity. During the process of constructing playhouses, volunteers interact with one another, and build a closer community (Habitat for Humanity, 2017).

2.1.3 Funding

HFHMWGW provides volunteer opportunities for employees of corporations and local businesses, as well as individuals to build a playhouse. The volunteers also serve as sponsors; there are two sponsor levels for the expense per playhouse, one is the “Gold Hammer”, which is a price of $5,000, and includes press release, recognition on social media, lunch, 10 to 12 Operation Playhouse themed T-shirts for the participants, and an additional opportunity to assist with the Critical Home Repair Project: a movement by HFHMWGW to offer assistance to low income families so they can maintain their homes. The other sponsor level is the “Silver Hammer”, at a price of $2,500, including the same contents except for lunch and T-shirts. The

money received from the participants allows HFHMWGW to supply the materials, tools, and safety equipment to build a playhouse. The total cost of each individual playhouse is approximately seven hundred dollars. The profits made from the playhouse builds serve to fund other programs within HFHMWGW, like the Critical Home Repair Project. Participating in a playhouse build is a remarkable contribution to society.

2.2 Construction of a Playhouse

This section addresses the materials currently used, the methods in determining better quality materials, and the current construction process. In addition to the material selection and construction processes, the section discusses the current waste of materials as well as relatable organizational and waste reducing methods.

2.2.1 Materials Currently Used

These playhouses consist of basic four feet by eight feet plywood sheets, OSB (oriented strand board), additional pine lumber for trim, different sizes of screws, roofing shingles, and the roofing nails to hold the shingles in place. In addition to the actual materials the playhouse is composed of, other materials, such as paint brushes, tarps, and hinges, also affect the total cost to assemble each playhouse. The playhouse materials affect the amount of money collected from participants. If the total cost of the playhouse is reduced, HFHMWGW has the opportunity to decrease the required donations allowing more companies to participate.

Currently, playhouses are being assembled mainly using basic plywood and OSB board. The basic plywood makes up the four sides of the playhouse and the trim used on the outside. Plywood, an inexpensive but durable material, is commonly used for structural purposes. OSB is

a compilation of wood strands, usually pine, that is coated with glue and wax and then pressed into sheets. OSB, which is used for the roofing, is also an inexpensive material with similar durability properties to that of plywood. As for the asphalt shingles used on the roof, they give the look of an actual home. Shingles are not an expensive material but are a source of waste production in the project. Screw and nail prices vary with size. Screws are slightly sturdier and more expensive than nails, but equally as durable (T. Donovan, personal communication, November 22, 2017). Purchase volume affects the price of these materials. Plywood is not considered expensive in relation to more complex materials used in structuring actual buildings, but in order to decrease the cost of materials and potentially decrease participation price, a cheaper material would need to be used. For example, OSB is cheaper than plywood but has similar structural properties. OSB purchased in bulk would be significantly cheaper than plywood.

2.2.2 Qualities of Desirable Materials

In the pre-building phase, as seen in figure 1 below, an important factor to take into consideration is whether or not creating the desired material is producing pollution. Pollution prevention in the manufacturing process contributes significantly to the environment's sustainability. "Environmental friendly products may have an initial high cost but is worth the expense in regard to environmental protection" (Kim & Rigdon, 1998, p. 12). When using natural materials, like wood, they require less processing and are not as harmful to the environment. In addition to the manufacturing pollution concerns, pollution with material transportation must also be taken into consideration. "Materials that are local would be most beneficial for producing the least amount of air pollution" (Kim & Rigdon, 1998, p. 15).

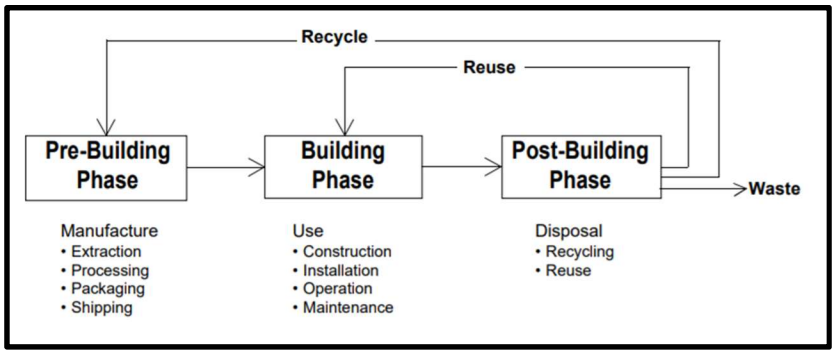

Figure 1. Three phases of building material life cycle (1998, Kim & Rigdon, p. 8)

The building phase part of the material selection process is about the effect of the material after installation. This includes the material's level of toxicity, if applicable. "Hazardous materials can be harmful to those using the materials in construction, as well as the occupants of the finished structure" (Kim & Rigdon, 1998, p. 18). An example of a potentially harmful material is OSB, which is currently used in the playhouse construction. Some types of OSB, depending on the manufacturer, contain a chemical called formaldehyde, which can possibly cause skin irritation to nearby people (T. Donovan, personal communication, November 22, 2017). Safety becomes an important assessment when implementing certain materials.

Another factor considered in construction is the lifespan of materials. Long lasting materials eliminate the need for maintenance costs as well as replacement material costs. Durability, in relation to lifespan, provides either a strong element with a long lifespan or weak features causing disintegration leading to additional materials being purchased. "In searching for materials with strong durability, higher costs of materials might become an issue, so weighing out options based on durability and cost would need to be decided" (Kim & Rigdon, 1998, p. 20).

In the post-building phase, the two biggest interests are reusability and recyclability of materials. For example, if a structure consisting of plywood boards was to collapse, are the boards able to be reconditioned and used again or made suitable for other uses? Reusability is a matter of the durability of the material. As for the recyclability, it depends on the condition of the materials and if it could be altered or processed for a different application.

2.2.3 Current Construction Process

Before the volunteers assemble the playhouse, high school students from four different schools cut the plywood sheets by tracing foam cutouts of the front (Figure 2), the side, and the back of a playhouse using a router. The router is a wood cutting tool used to hollow out an area in the face of a relatively hard workpiece. This tool creates a half-inch gap around the border of the windows and the door. The half-inch gap leaves no use for the cut-out wood. These pieces of wood are then disposed of, leading to waste of materials.

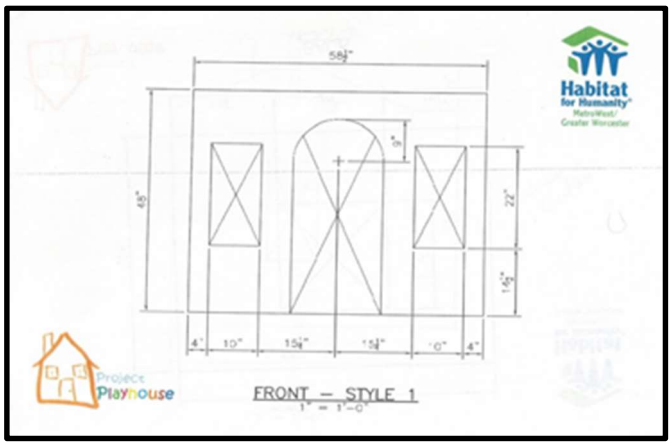

Figure 2. The front of playhouse (2017, permission granted from Habitat for Humanity)

HFHMWGW brings the cut plywood sheets to their warehouse, where the materials are stored until a group of volunteers are ready to build a playhouse. When ready to build,

HFHMWGW brings the materials for the playhouse to the predetermined site for the sponsor and volunteers to begin constructing the playhouse.

The whole construction process takes place over the course of one day, starting at 8:00 am and finishing at 3:00 pm. The participants go through an initial training, when they arrive, to learn how to correctly apply the shingles on the roof along with some other basic building information. The volunteers begin painting the materials from 8:30 to 11 am. While waiting for the paint to dry, the volunteers start assembling the roofing. After taking a lunch break for about an hour, the participants will finish assembling the roofing and begin putting the playhouse together. The construction process is finished at 3:00 pm where the participants start to clean up before HFHMWGW, and the sponsor dedicate the playhouse to the veteran and his/her family. HFHMWGW then brings the completed playhouse to the veterans home ending the day. HFHMWGW currently has no exact goal for time reduction.

2.2.4 Organizational Methods

HFHMWGW lacks a detailed construction guideline for staff and volunteers that shows the complete assembly process of a playhouse. Without this guide, the construction process is longer than necessary. Using a written list of steps will prevent the instructor from lulling themselves into skipping steps even when they remember them (Gawande, 2010). The instructor may think that some concepts are not necessary to explain, but the volunteers building the playhouse may not exactly understand what to do since some lack any experience in building.

In addition to using written steps, the guideline can provide visuals that will help volunteers understand each step. Today, ninety percent of all information taken in by people is through visuals. People learn to read by adding words to their “visual dictionaries” (Briggs,

2015). Based on that information, visuals are more efficient when teaching new concepts. Forgetting one step of the instructions will cause the volunteers to ask more questions about how a certain task should be completed. Checklists provide protection against these potential misunderstandings and makes each step explicit. A checklist not only offers the possibility of verification, but also instills a discipline of higher performance.

2.2.5 Current Waste in Operation Playhouse

Current playhouse assemblies waste 40% of the plywood boards used. In one playhouse, HFHMWGW wastes about 51 square feet of the plywood sheets. Meanwhile, there is also other waste existing without quantification. Although some construction waste seems unavoidable, the potential cost reduction by reducing waste on site is an incentive for minimizing waste (Bossink & Brouwers, 1996).

2.2.6 Waste Reduction Method

There are three stages to validate the waste reduction model. First, we identify the causes of waste from the design phase. Second, we apply design strategies which lead to several alternative low waste producing materials. Finally, the potential source reduction levels can be quantified and discussed, as shown in figure 3 (Llatas & Osmani, 2016). Strictly following these three stages, we can find the cause of how waste is generated. Then we can either find alternative low waste producing materials, or substitute approaches to process the original materials efficiently. The waste reduction level can then be quantified, and a waste evaluation database can be built for Operation Playhouse.

Design wastes (DW) attributes, amounts, compositions and sources in building elements.

Building system (j)	N_i	U	Building element (i)/main conventional attributes l (o^n)	DW amount m^3	DW composition		Resulting onsite waste streams
					DW stream	%	
Foundation (01)							
	1.00	m^3	Cast in situ footings	1.538	Soil	96	Excavated soil
			Depth = 4.00 m		Concrete	2	Cast in situ concrete losses
			Formwork type = brick wall		Bricks	1	Broken bricks
			Packaging type = sacks of cement		Wood	1	Broken wooden pallets

Figure 3. Design Waste Quantification, (2016, Llatas & Osmani)

2.3 Weather Conditions of Worcester and the Impact on Playhouses

Worcester experiences warm summers averaging at about 72 degrees Fahrenheit and very cold winters averaging at about 33 degrees Fahrenheit. The city averages 48 inches of rain a year which is 9 inches more than the United States average. Along with 9 more inches of rain a year, Worcester averages 55 inches of snow a year—29 inches more than the United States average. The city, along with the rest of the New England region, experiences immense ice storms predominantly between December and March, typically lasting a few hours (Hellmer, Rios, Ouimet & Sibley, 2014). Ice storms occur in the area annually and causes damages of over 200 million dollars a year through ice accumulation on surfaces such as tree stems, branches, utility poles, power lines, etc (Hellmer, Rios, Ouimet & Sibley, 2014).

The high summer temperatures and the low winter temperatures of Worcester subjects the roofing to drastic changes in temperature. These drastic changes may cause the contracting membranes of the roofing to tear allowing water to pass through (Busching, 1979). The playhouse will have to be somewhat waterproof to prevent rotting of the walls and trimming. The roofing, along with the sides, must hold through rain and snow storms. Moisture intruding built up membranes of the roofing can increase the risk of the membrane splitting, wind blow offs, and blistering. These hazards can be caused by several moisture-produced effects: reduction in

membrane tensile strength, dimensional changes and creation of inter-ply mopping voids (Busching, 1979). The weather conditions must be taken into consideration so that the playhouses can withstand these harsh conditions for the expected 8-10 years without rotting or falling apart.

3.0 Methodology

The goal of this project was to develop a procedure for reducing waste, cost and production time to build a single playhouse. By assisting Habitat for Humanity, we can make it possible to build more playhouses. Reducing the cost of these playhouses allows Habitat for Humanity to allocate more money to their other housing programs. Our objectives are:

1. To determine high quality materials that are less expensive than the ones currently used for construction.
2. To reduce material waste from each build.
3. To identify a standardized construction method to reduce building time and cost.

HFHMWGWs current focus with Operation Playhouse is saving money and creating a more efficient construction process. Operation Playhouse commonly deals with groups of people from larger companies with intentions of creating a better teamwork atmosphere as well as giving back to the community. A group of company volunteers spend one day to build a playhouse. This is a year-round event that can take place inside or outside depending on the weather conditions of Worcester. The scope of our project is based on the time limitation of the seven-week term.

The structure of this chapter will include the methods for determining cheaper materials that are higher quality than the materials currently used in playhouse builds, the method for reducing the waste of materials, and developing an effective building method to reduce construction time and cost.

3.1 Determining High Quality, Cost-Efficient Materials

3.1.1 Assess Current Materials

To assess the current materials used by HFHMWGW, we visited their warehouse and inspected the materials they used for each playhouse. We then discussed with professionals the seven qualities mentioned in section 2.2.2 (cost, weather resistance, durability, weight, safety, production pollution, and low maintenance) as well as whether or not the current materials fulfill those qualities or if there are better solutions.

3.1.2 Interview Professionals

To find a more cost-effective material to use in constructing a playhouse, we interviewed individuals in the carpentry or construction industries as well as HFHMWGWs construction manager to determine which materials have the seven characteristics listed above. Prior to speaking with lumber retailers, we interviewed carpentry and construction professionals to know which materials work when implemented. We conducted our interviews in person and over the phone. When interviewing the professionals, we asked questions, in context to playhouses, like:

- What wall structuring material is most resistant to Worcester weather conditions?
- What should we be aware of when choosing materials in regard to safety?
- What method do you use to determine the most cost-effective materials?

3.1.3 Vendor Evaluation

During our communication with lumber vendors, we learned about the different types of lumber they currently carry. After speaking with the lumber professionals about material

properties, we were able to determine the materials that best suit this project. The vendors gave us stock numbers, shipping costs, and different size options. Based on this feedback, we were able to establish an estimate price for a year supply of sixty playhouses.

3.2 Reducing Construction Waste

3.2.1 Analyzing Dimensions

To eliminate the waste in each build, the dimensions of the playhouse can be altered, or completely revised, to fit the distributed size of lumber. By first analyzing the current dimensions of the playhouse and the size of the current lumber being purchased, we found the amount of waste.

3.2.3 How to Implement New Methods of Design

After we retrieved the dimensions of the new materials, we knew the new design modification limitations. After developing a new set of dimensions, we went through a trial and error period to see if our new design was a success. The trial and error period took place using the CAD programs so that materials were not wasted. The bigger parts of the playhouse, such as the walls, were drawn up first make the new dimensions a success, In addition to changing the dimensions of the walls, we used a better method of cutting wood that used the cut-outs from the window and door holes as the new window and door. Both the changing in dimensions and using a more resourceful way of cutting the wood allowed us to decrease the waste of materials.

3.3 Identifying a Method to Reduce Build Time and Cost

3.3.1 Observation

After we determined an alternative material that we will use as well to reduce waste, we identified a construction method that reduced the time needed to build each playhouse. We identified this construction method by observing the building of a playhouse, asking our sponsor questions on the details of the build as well as interviewing volunteers that have previously built a playhouse with HFHMWGW.

3.3.2 Interviewing

We first consulted with HFHMWGW to find previous volunteers that were able to answer questions. We contacted them by phone and email to set up semi-structured interviews in person or over the phone. We set up a semi-structured interview because it allowed us to ask additional questions that we didn't think of during the interview based on answers we were given. When interviewing the volunteers, we gathered more information about the current construction process from their point of view. We gained this information by asking them:

1. What information could have been useful before building the playhouse?
2. Did they know how to use the tools that were given to them?
3. Were the instructions clear to them?
4. What can be improved to reduce construction time?
5. What has and has not gone well?

By gathering a better understanding of the pros and cons of the current construction method, we were able to create our own guideline resulting in a quicker construction process.

3.3.3 Guideline

We created a construction guideline, that the volunteers will follow during the build of the playhouse, using the information we have gained from the observations and interviews. The guideline eliminates the need for instructions coming from a supervisor. The guideline provides steps needed to complete the playhouse with maximum efficiency.

One way to make a guideline for the playhouse is by making a video, using a design software, to show how the playhouse is assembled. The computer program that we used to model the build sequence was AutoDesk. The program shows each section of the playhouse, where the parts are connected, the material used for connection (a screw or nail), and the sequence in which the playhouse is assembled. The sequence first shows the installation of the shingles on the roof using roofing nails. Next, the assembly of the sides, the back of the playhouse, the front where the door is, and the roof was recorded. Once the sides of the playhouse are assembled, the installation process of trim is shown. Following that, the cut-outs of the door and windows are shown, and the actual window and door pieces replace the holes. The process of connecting the hinges on the door and windows is the final part shown in the sequence finishing the assembly.

The guideline, in addition to well written details, contains video instructions that state each tool needed for each part of the playhouse, as well as how to use the tool. This reduces the cost because some tools break if the volunteers use the tool incorrectly or the incorrect tool for a certain job. The breaking of the tools increases the cost by buying new tools or materials needed in the build. This is prevalent when the volunteers are using screws and drills in construction.

The creation of this guideline, along with the AutoDesk video, allows the volunteers to have an idea of what they will be doing beforehand, and allows them to move through the

construction process smoothly. Volunteers will know what they are expected to do prior to arriving at the site so that a Habitat for Humanity Supervisor will not have to guide each group through every step in the production of the playhouse. Instead of guiding every group through each step, the Habitat for Humanity supervisor can administer more playhouses being constructed as well as handling more questions the volunteers may have. In addition to the final instruction manual, a checklist comprised of each of the steps in the manual is useful for organizational purposes. The new checklist eliminates unintentional mistakes during construction.

4.0 Results

Our findings for this project focused on our goals to reduce the cost, waste and construction time needed to build a playhouse for HFHMWGW. Our team interviewed professionals, volunteers, and vendors. From these interviews we were able to extract opinions from those with experience in construction management, building playhouses, and prices of probable materials for a playhouse.

4.1 Optimal Materials for Construction

After observing a playhouse build on February 7, 2018 at Hanover Insurance, we noticed how easy plywood was to maneuver, paint, and drill into. The group of volunteers had little trouble using drills and screws which we also noticed. To determine cost effective materials, we first contacted the HFHMWGW construction manager to receive input on which materials could replace the current ones. The criteria of the new materials would need to maintain or exceed the current material durability quality. The construction manager first stated that he thinks plywood is most likely the best option but went on to recommend other materials such as Medium Density Overlay, or MDO, and Medium Density Fiberboard, or MDF. The issue with MDO was the price and how much it would cost to purchase multiple sheets of that wood. If we were to use MDO, the price would be upwards of sixty-five dollars per sheet, as opposed to the forty-dollar sheets used currently. The issue with MDF was the lack of tolerability with moisture levels due to MDF being used for indoor use only. From the interview and further research, we were able to determine that sheathing plywood is the best option. It has satisfying visual features, a cost-effective price, and high durability (Participant 5, January 25, 2018).

When speaking with the construction manager, the topic of fasteners for wood was brought up and he advised to use screws rather than nails because “screws are much easier for volunteers to use”. He also mentioned that a playhouse is a small-scale project which means not as many screws would be used in comparison to a house therefore there is not a large difference in price (Participant 5, January 25, 2018).

4.1.1 Current Material Analysis

During our visit to the HFHMWGW warehouse, our team observed the current materials used to build a playhouse. These materials consisted of douglas fir plywood, Oriented Strand Board (OSB), and pine trim board. The douglas fir plywood is a cheap, flimsy sheet of wood, OSB is a sheet of compressed wood chips using wax and adhesives, and the trim boards are smooth, thin pieces of wood used for framing around windows, doorways, etc. We observed that the OSB boards, used for the roof panel, are the correct thickness needed for the trim. This means that the remainder of the sheet of wood could be used for the trim reducing the cost of the playhouse. The problem with OSB is that it is not visually appealing. Since the OSB is heavy, visually unsatisfying, and cannot withstand moisture very well, we decided to use plywood for the roof. The HFHMWGW warehouse also contains the assembly kits needed for each playhouse build, which consist of paint kits, hardware/tool kits, roofing material and drill kits. Each team of volunteers gets one assembly kit for playhouse construction.

4.1.2 Finding Cost Effective Materials

When researching further for cost effectiveness, we found different vendors in the Worcester area that sell the plywood products we are looking for. We called each vendor, Home

Depot, Lowes, and Shrewsbury Lumber, about their products and received dimension information as well as quote prices for the lumber.

The plywood from Home Depot that would be suitable for the playhouse walls is RTD Sheathing SYP, which stands for Resistance Temperature Detectors Sheathing Southern Yellow Pine. It is suitable because it has long term durability and resistance to edge swelling. The Home Depot plywood suitable for the roofing and trim would be BCX Pine Plywood, which means the wood has a B rating quality for the front face, C rated inner layers, and an X for exterior rated waterproof adhesives. For further information on wood ratings, see Appendix B.

These two products are only sold at Home Depot in the Worcester area, so when looking at other retailers we had to find different plywood products with similar properties. The two plywood products chosen from Lowes are plytanium products, which have moisture resistance and high durability properties. The CDX plywood from Shrewsbury Lumber has a C rating front face, D rated inner layer, and X for exterior rated waterproof adhesive. This is the main plywood product sold by Shrewsbury Lumber. After receiving this information, we set up a bar chart showing the comparison of prices for the lumber required to build the redesigned playhouse with the price of lumber HFHMWGW currently purchases. The three color coordinated arrows at the bottom of the chart clarify which materials coincide with each retailer. This chart is shown in Figure 4.

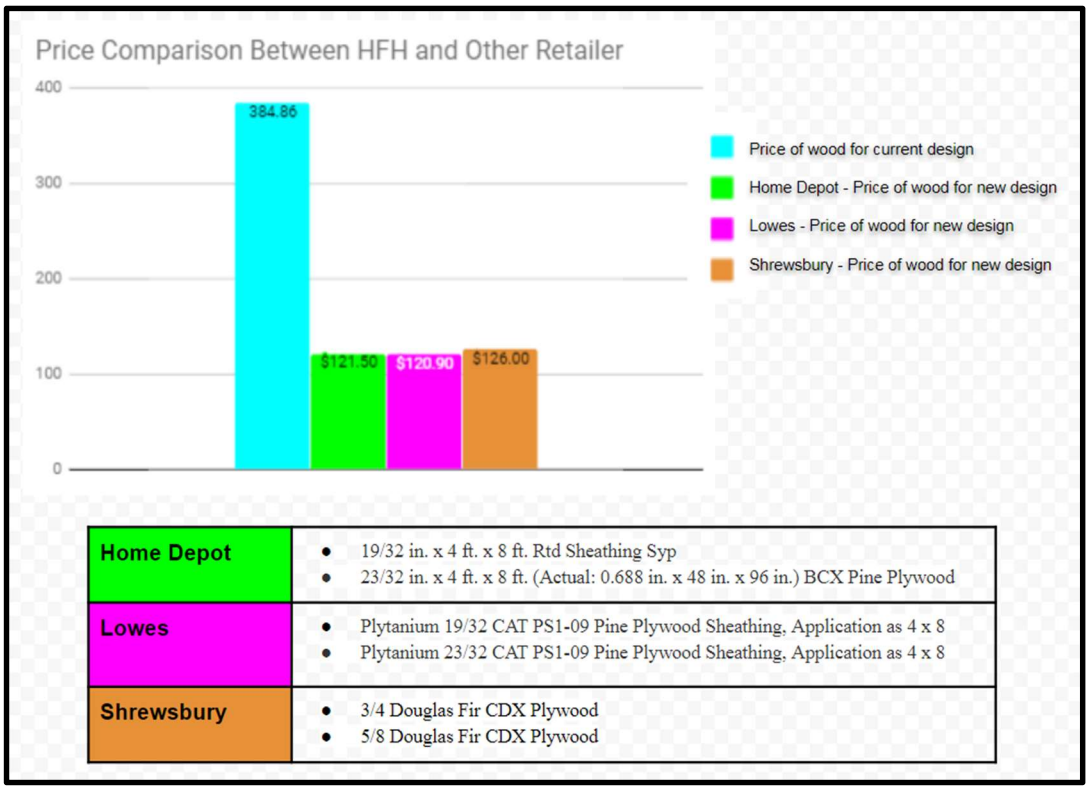

Figure 4. Price Comparison Chart

4.2 Measuring the Amount of Waste

At the HFHMWGW warehouse we were able to see what extra material was not being used from the OSB and plywood sheets. We found that HFHMWGW uses six 4(ft.) x 8(ft.) sheets of wood. Two of those sheets are OSB and four sheets are plywood. HFHMWGW uses the four plywood sheets for the walls and uses the OSB sheets for the roofing. When the roofing is cut, the extra OSB is sold in HFHMWGW's Restore. The result after cutting out all the walls and windows leaves about 40% of the wood to be discarded. Figure 5 shows the amount of material wasted in red.

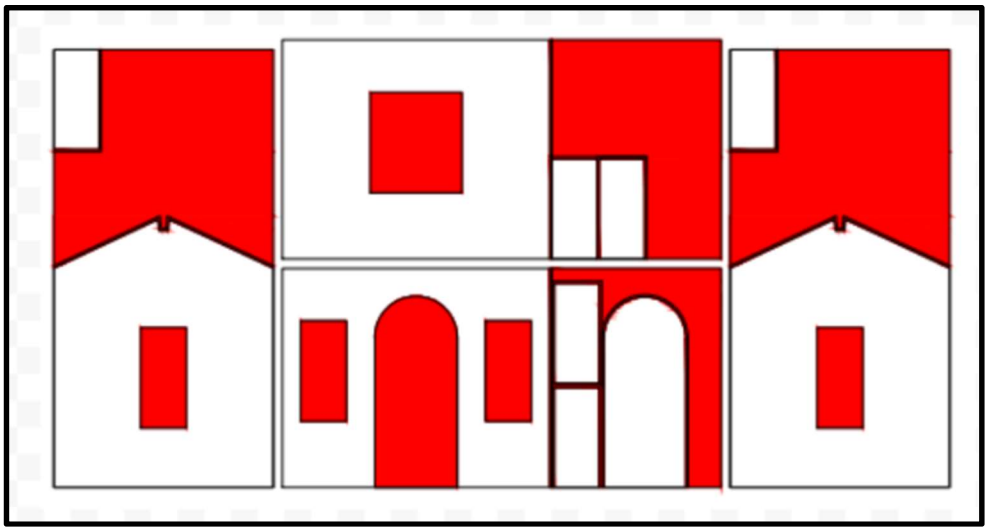

Figure 5. Material Waste of Current Design

When speaking with our sponsor, it was brought to our attention that HFHMWGW purchases packages of hinges that include screws. They end up throwing away the screws that come in the packages because they are not sizeable enough for optimum strength. We then researched retailers that sell individual hinges and found a vendor that sells just the hinges at a cheaper price. Another issue that occurred is the additional waste coming from broken equipment. Many volunteers will break drill bits because they are unaware of the proper procedure to drill a hole correctly. This incident was observed by our team at the playhouse build on February 7th, 2018. Another source of waste is the disposal of paint supplies. When the volunteers are painting the different playhouse pieces and are done using the paint rollers, they throw away the paint roller instead of the plush that spreads the paint.

When speaking with HFHMWGW construction manager, he proposed the idea of finding a way to change the dimensions the playhouse to maximize the number of cuts from each piece of wood. Maximizing the number of cuts from each piece of wood results in more of the wood being used for various parts of the playhouse. For example, in Figure 6 below, the new design

incorporates the trim pieces into the thicker sheets of plywood, eliminating the need for additional lumber for the trim. By making more cuts in the wood, the wood then produces more parts for the playhouse, which results in reduced waste.

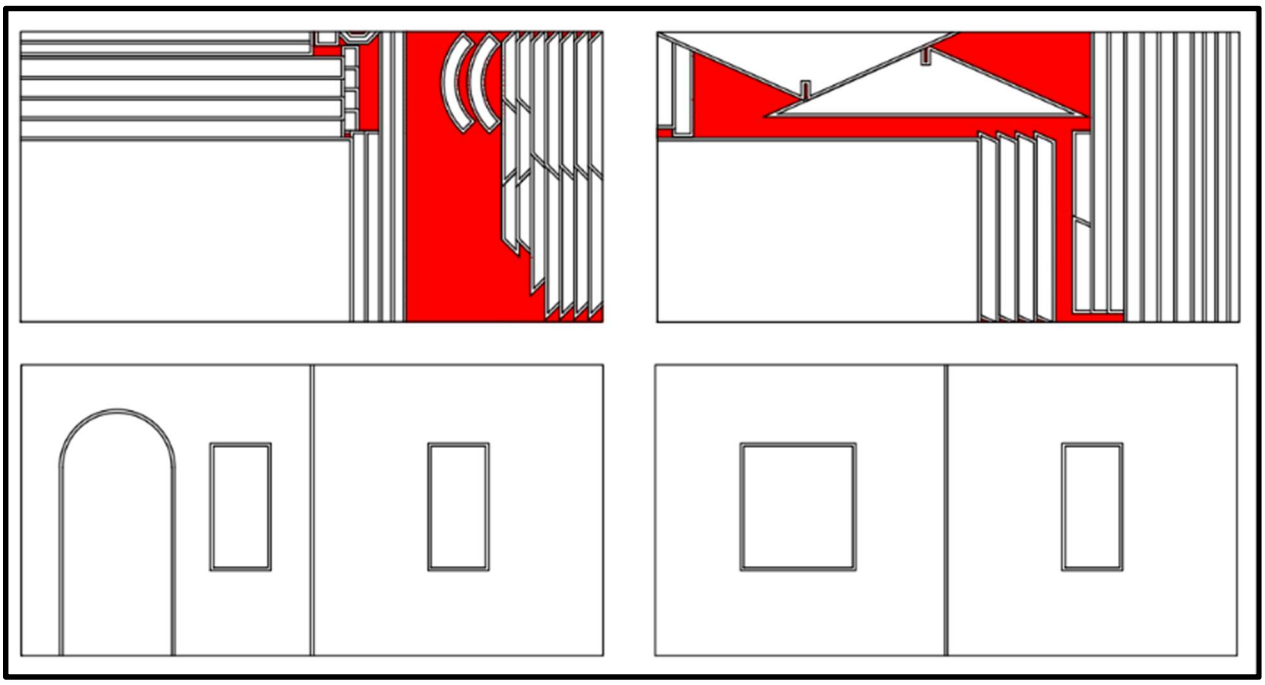

Figure 6. Material Waste of New Design

4.3 Creating a Construction Guideline

To build an efficient and accurate guideline, we needed to interview previous volunteers to get an understanding of the construction process from their point of view. We contacted our sponsor for previous volunteers that we could interview. We scheduled interviews with 4 volunteers that have worked on playhouse builds in the past. Our first interview was with a house captain for the playhouse program as well as a recipient of a playhouse. The second interview was with the President of the Board of Directors whose company has sponsored playhouse builds. The third interview was with a member of the Board of Directors whose company has also sponsored playhouse builds. The last interview was with a previous house captain. These

interviews are summarized in Appendix A. Along with interviewing volunteers, we observed three playhouses being built simultaneously. Through our interviews and observations, we concluded that each of the steps are not clearly stated which caused confusion. In addition to causing confusion, we concluded that giving the volunteers the information in advance will help with time management as well as the opportunity to prepare any decorations for the playhouse.

The confusion is caused due to the lack of a written checklist or guideline. The responses from our interviews show that misidentifying the pieces has a big effect on constructing a playhouse: “It’s probably the thing that is throwing most people off, like knowing which way each piece of wood goes” (Participant 1, January 17, 2018). Misidentifying a piece has a big impact on the construction process: “That [misidentifying a piece] is probably the most confusing because when going to screw two things together then you have extra holes in it and you’re trying to figure it out or rebuild the house” (Participant 1, January 17, 2018). What this response means is putting that misidentified piece in the wrong spot will cause the construction process to take longer. The construction process will take a longer time to complete because that piece will have to be detached, and then the correct piece will need to be applied. After the correct pieces are fastened, there will need to be touch ups to the playhouse to repair any holes that are showing.

The misidentification was not only seen in the responses from the interviews, but it was also seen when we observed the playhouses being built. Volunteers at the build had questions about what piece should be applied to the top/bottom of the back window trim and the side window trim. We observed that one of the groups started to use the top/bottom of the back window trim as the sides of the window trim. This piece would not work as the side window trim because the top/bottom trim for the back window is shorter than the pieces used for the side

window trim. While securing the walls and trim, volunteers had many questions about which screws are supposed to be used for each part. There are four different screw lengths so there are always questions about which one to use. The construction guideline would explain what parts are used for each step along with where and how they are applied to avoid confusion.

There is a lot of information that could be useful to the volunteers prior to the day of the build: volunteers are responsible for decorating the playhouse based on the theme they are given. The responses from our interviews show that it would be very helpful to have the information before the build: “there is a planning aspect that you really want to make sure that you plan out for your theme and your decorations” (Participant 2, January 17, 2018), “I think what would be helpful in the overall execution of a playhouse is to have the information in advance so that we could plan a design of what we are going to do” (Participant 3, January 24, 2018).

If the volunteers receive the information of the theme and design of the playhouse in advance this will speed up the painting step because the design will be pre-planned. In our observation of the playhouse, one of the groups created a military themed playhouse where the walls were painted camo. This group was the last to finish painting due to decorating the playhouse without pre-planning. The other groups from this build had down time between painting and assembling the roof. When they saw the other playhouse being painted camo, they decided to create some decorations of their own. If the volunteers had known in advance that they are required to decorate the playhouse, they would be able to plan out their decorations before the build.

To learn about the process leading up to the build we went with our sponsor to their warehouse where we walked through the details of the preparation steps and the current construction process. We went through each step of painting, shingling the roof and how the trim

and walls are to be assembled. Through our visit we found that there are no written instructions on assembling the playhouse as well as no order the assembly must follow.

In addition to walking through the instructions, we observed three playhouses being built simultaneously on February 7, 2018. At the build site we split up and each observed one playhouse. The findings from this observation are shown in the following order:

1. Arrival and Unloading
2. Painting
3. Roofing
4. Assembly of the Playhouse
5. Cleanup and Dedication to the Veterans

Upon arrival the volunteers had time to have some breakfast and socialize. When HFHMWGW was ready they had two people from each team set up two tarps, two tables and the four sawhorses to keep the worksite clean while the rest of the team started unloading the truck. The unloading process was disorganized resulting in some pieces missing from each team. The disorganization resulted in more time needed to make sure each team had all of the needed materials.

Once all the materials were unloaded, the teams began to paint the materials. The painting of the walls was done by placing the walls in the support stands. The trim was painted on the tables with the painters plastic on top to keep the table clean. Since each piece requires two coats of paint on all sides, the trim pieces got stuck to the plastic resulting in a messed-up surface and more time required to fix the paint job. One of the volunteers recommended the use of a rail-like system that the trim could be placed on while drying so that the paint on the trim

will not stick to the plastic on the table. During this time some teams had down time while another team had been painting a design on some pieces of the playhouse.

While waiting for the trim and walls to dry, a build captain explained how to assemble and shingle the roof. While explaining how to shingle the roof, the build captain forgot a step that is crucial before shingling the roof. It is rare for a build captain to forget a step needed to create a playhouse, but a checklist would prevent any errors. While assembling the trim for the roof, a volunteer drilled through the board at the wrong angle creating a hole in the trim. The volunteer then needed to re-drill a hole in a different spot slowing down the construction process. When shingling the roof, the volunteers asked if they were doing it correctly. A construction guide would reduce the questions asked as well as limit the mistakes made.

When assembling the playhouse, there was no set construction process so each team was building the playhouse a different way. Volunteers were often confused about what trim was supposed to be used– mainly the difference between the side window trim and the top/bottom trim of the back window. In addition to the trim, volunteers often asked which screw should be used to secure different parts of the playhouse. We observed that some volunteers were not using the right screw for certain parts of the trim. The documentation of the assembly process would limit this confusion leading to a faster build. We observed that the most efficient way of construction was when the volunteers assembled trim first before putting the walls up. Since this way was the fastest of the three, the assembly process will follow this order. One of the volunteers recommended that we created a schedule of the day so that the volunteers know how long each step should take. This schedule would help with time management.

Once the playhouse was assembled, the volunteers were responsible for cleanup and setting the playhouse up for the dedication. The dedication of the playhouse showed why HFHMWGW is doing this project and how the playhouse makes a difference in someone's life.

4.4 Discussion

From the data collected, we recognized three important key factors impacting the cost, the waste produced and the efficiency in building a playhouse: the size of the playhouse, an unclear procedure and lack of organization.

This is prevalent during the playhouse dedication when veterans come to pick up the playhouse and it does not fit into their vehicle. Due to the size of the playhouse, the current material is not being used as efficiently as possible. Based on the dimensions of the walls, only a small amount of material is being used while the rest is discarded causing waste. A modification of the design may create less waste than the current design. The lack of a standardized procedure, like a construction guideline, leaves the volunteers asking questions about part location, correct tool use, assembly steps, etc. It is unlikely that every volunteer will understand the concepts of construction and how each tool works. Based on our research, the instructions will lower the amount of questions that the volunteers have while also decreasing the time needed to construct a playhouse.

The lack of organization for the volunteers results in confusion as to what pieces their team is supposed to have for each playhouse. Each team is unaware of the required materials, so unless told otherwise they have no way of confirming which materials they need.

5.0 Recommendations

From the information gathered through interviews, research, and connections, we were able to produce cost saving recommendations, a waste reduced design, and an effective guide for constructing a playhouse. These recommendations will help HFHMWGW with saving money and efficiently producing more playhouses.

5.1 Waste Reduced Design

After looking at the waste production of 40% and the dimensions of the current playhouse, we found a way to use more of the sheets of wood already purchased instead of buying more sheets. Once we evaluated the current measurements of the playhouse, we found it was easiest to cut the four feet by eight feet sheets in half, so that the four walls would all be the same size. This will result in using two sheets of wood for the walls instead of four.

The roof and trim on the playhouse would both come from the thicker four feet by eight feet sheets of wood. The roof panels are currently cut from four feet by eight feet sheets of OSB but leave some scrap that is then sold in the HFHMWGW Restore. Even though they sell the scrap pieces, we decided to make it so the extra material is used for the trim instead of purchasing additional, smaller pieces of wood. The new design is shown below in Figure 7.

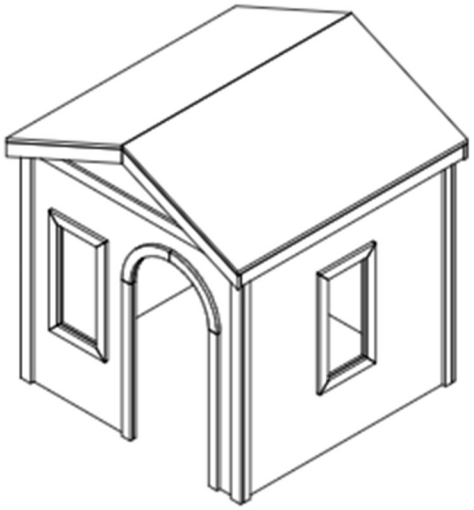

Figure 7. New Design

With the new design, all dimensions were made so the screw sizes used currently did not have to change. Our deliverable of the new design is presented on blueprints showing every needed dimension to understand the design. The blueprints include a view of the front, back, side, top and bottom of the body of the playhouse. There are also multiple views of the roof pieces. In addition to the blueprints, there is a document showing the layout of pieces on the sheets of wood for them to be cutout. We delivered a ⅓ scale model of the playhouse made from foam board. The model includes the windows, doors, and removable roof panels. We made the panels removable for easier transportation. We made this model so that HFHMWGW can show potential sponsors what they will be building as well as bringing the model to the build site as a visual aid.

By reducing the number of sheets of wood from six to four and using the extra material from the thicker sheets for trim, there would then be 7.86% of waste.

5.2 Cost Effective Materials

The current cost of lumber materials for a playhouse is about $380. Once we had redesigned the playhouse, the next objective was to find materials that had similar physical properties but were cheaper. After contacting the HFHMWGW construction manager, visiting the playhouse build, and speaking with retailers in Worcester county, we concluded 19/32" RTD Sheathing Plywood for the walls and 23/32" BCX Pine Plywood for the roof panels and trim would be the best option for the new design. These products have the best physical properties for the appropriate cost, as well as the best appearance for the satisfaction of the veteran recipient. The retailer we are recommending for these products is Home Depot. The reason being that Home Depot is HFHMWGW's current retailer as well as a donator to Habitat for Humanity. In addition to donating, Home Depot gives HFHMWGW cost for anything over $1,500 as well as free shipping since HFHMWGW is a non-profit organization.

For the hardware products used with the playhouse, we researched the quantity of screws per box. Currently HFHMWGW purchases the appropriate size screws in boxes of 100, with the exception of the 1-¾" T25 screws which is approximately 1,500 screws per box. When looking for an acceptable quantity, we were able to find ½", ¾", and 1" screws in boxes of 1,000. We also recommend these three screw sizes be purchased from Home Depot. As for the 1-¾" screws used for the corners and roofing of the playhouse, we were able to find 1-⅝" screws for $0.008 each from Customer Service Hardware, which would mean 1,500 screws is twelve dollars; eighteen dollars cheaper than the current pail of T25 screws. This also eliminates the need for purchasing the T25 drill bits, saving even more money. The slight difference in dimension of both screws would not hinder the performance of the playhouse.

In addition to the quantity changes for screws, we are also recommending Customer Service Hardware for the 1-½" x 1-½" hinges for the windows. Customer Service Hardware exclusively offers the hinges for as low as $0.29, which would mean for one new design playhouse the window hinges would cost $2.90. The current playhouse design requires $11.82 for window hinges and includes screws that are discarded due to the incorrect size. By purchasing the individual hinges, HFHMWGW would not only save money but eliminate that additional waste. As for the door hinges, Home Depot sells individual 2-½" by 2-½" hinges for $1.45, so for each playhouse it would cost $2.90 as opposed to $4.22 with the current design.

The cost of the current hardware and lumber materials for one playhouse is approximately $430. The lumber and hardware required for the new design gives an approximate total of $130 per playhouse.

Our deliverable to the sponsor included a list of materials stating the dimensions of each piece, the cost, quantity it can be purchased in, model number, and any additional notes for the sponsor's convenience. We also delivered price comparison charts, so the sponsor can have a visual perception of the true cost savings.

5.3 Organized Assembly Guideline

During our visit to the playhouse build, we noticed a lot of disorganization in the procedure to complete the playhouse. Although there were three HFHMWGW captains there to help, individuals were still making simple mistakes that could be eliminated with further instruction, like a manual.

Based on interviews with past volunteers and seeing the process of a playhouse build, we developed a simple, step-by-step instruction guide explaining the process for a playhouse to be

complete. The guide starts with details regarding the paint, then moves on to the assembly of the roof and the application of the shingles and finishes with the correct alignment of the trim pieces. This guide also includes a checklist for the process, so the participants can mark which steps they have completed and eradicate any skipped steps.

In addition to the guideline, we created a blueprint, previously mentioned in section 5.1, of the new design. The blueprint is a document that HFHMWGW will be able to send to all the volunteers before the day of the build. Volunteers will be able to draw out their own designs to scale on the blueprints as well as prepare any decorations that may go with the theme.

5.4 Conclusion

With each of these recommendations HFHMWGW will nearly divide their cost per playhouse in half, reduce the waste to 7.86% and efficiently speed up the assembly process. This will allow HFHMWGW to create more playhouses while still fulfilling the goal of reducing the cost, waste and assembly time.

The recommended design offers a slightly smaller playhouse which would be more conveniently transferable for veterans. The new design is also made of lighter materials, making the transfer process even easier. Despite the lighter materials, the playhouse is still as durable as the current design. Plywood is a paintable material, has the durability to survive northeast weather conditions, and will have a clean, smooth appearance.

With these recommendations we hope to increase Habitat for Humanity's cost savings and escalate the activity of Operation Playhouse in other areas of the country. We believe this will correlate with their success in other programs and help in taking a step towards a better

community. We would like to thank Habitat for Humanity for this opportunity and we wish their organization luck in their future endeavors.

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Appendix A: Interviews

Participant 1 - Volunteer - 1/17/18	
Question	**Response**
How many years of experience/projects have you worked on with Habitat for Humanity MetroWest/Greater Worcester?	First project, habitat home owner, no experience with even a screwdriver.
How many playhouses have you helped Habitat for Humanity MetroWest/Greater Worcester build?	N/A
Were the instructions on how to build the playhouse clear? If not, what was unclear?	At first they were not very clear but once you got the hang of it, it is pretty clear once you know what you are doing. It was just when I came in so honestly at first you don't know it was pretty confusing but now it's pretty clear now that everyone knows what they are doing.
Did you know how to correctly use the tools that were supplied to you?	Yep, I was given good instructions.
If not, were explanations thorough on how to use them?	N/A

What do you think has gone well with the playhouse construction?	We had a very good group that day so it was probably seeing how the teamwork comes together and stuff because when out on the build you're like “were never building a house today” and then it does come together if everyone works together well so that went really well that day, it came together well. Even though team stressing didn’t really help that day, but yeah probably the team work was probably the coolest thing and the best part.
What in the current construction process can Habitat for Humanity MetroWest/Greater Worcester improve? How could Habitat for Humanity MetroWest/Greater Worcester improve the current process?	Each build is different and each group is different. Maybe knowing, I guess the big thing probably is misidentifying parts of the house. It’s probably the thing that is throwing most people off, like knowing which way each piece of wood goes. So that’s probably the most confusing because once they screw two things together then you have extra holes in it and you’re trying to figure it out or rebuild the house. That’s probably the confusion that adds most interest to the building. It’s fun but it could be clear what parts go to what.
What information would be useful for new Operation Playhouse volunteers to know before starting to build a playhouse?	Probably the identification of the pieces so that they see the big picture instead of learning on the fly, and then really the biggest thing that helps or hurts some one is you really have to be able to time management and have to be able to direct like, I mean some of the people there, like we’ve had people that know how to build things, they can probably build a better playhouse than you can, and then there’s people that are afraid of the staple gun. You have to know

	how to direct certain people with certain talents and how to like make them feel better or to know if they are really scared, don't let them touch it. There are some people that are just afraid and there's other people that are like "maybe there's a reason you're that scared" so the best thing would probably be is just time management and how to lead them how to do it so maybe just having knowledge of how to better do that so they are identical because you want it to be fun and you also want a playhouse built by a certain time so that would probably be the most helpful thing for one of the crew leaders to know how to do.

Participant 2 - Volunteer - 1/17/18	
Question	**Response**
How many years of experience/projects have you worked on with Habitat for Humanity MetroWest/Greater Worcester?	I serve as the president of the board but I am also president of the Holliston Housing Trust (HHT), which is how I got involved with Habitat. It's coming up on 4 years now. I sought out Habitat because I thought the HHT would want to sponsor a project so we've found town owned land in the town of Holliston so we secured that at town meetings so

	that we could build habitat projects. So I have been working on that for 4 years or so and have been very active in the board and etc. So that has kind of been my involvement. I became president of the board about a year after I joined the board and have been president ever since. I have about a year left in my term as president. As part of the housing trust we also, in addition to building the two homes in holliston, the housing trust as a demonstration has sponsored for the last three years a playhouse and last year 2 playhouses at celebrate Holliston in September so we as a housing trust group seek volunteers to build a playhouse.
How many playhouses have you helped Habitat for Humanity MetroWest/Greater Worcester build?	Let's see so I've done 2 at my company, we've done 4 with celebrate Holliston and I have also participated in 2 years of the metrowest build-a-thon so we've built 2 more there so a number of them with different managers because we had Seth before we had David but we've always had kits that we were provided with etc. The same kind of methodology each time.
Were the instructions on how to build the playhouse clear? If not, what was unclear?	Generally, yes, I mean there's no written instructions obviously but it's fairly self explanatory if you will. You know, it's very important to have somebody like David there or in the past we had Carl there to help us out.

	Someone who has built a few of them so they can tell the group where to spend their time and how to stay on track so you can finish by the end of the day, you know, with the basic idea of finish all your painting and start the roof before lunch and put everything together after lunch and dedicate it at the end of the day. It's all just by guidance you know what should I do next, if you didn't have that person there you couldn't just say follow the instruction sheet.
Did you know how to correctly use the tools that were supplied to you?	Yes, and if you didn't they'd explain it to you so its not an issue.
If not, were explanations thorough on how to use them?	N/A
What do you think has gone well with the playhouse construction?	I think the whole purpose of doing a playhouse at a company or with a group is to actually develop team building so that is always a positive aspect of the experience so that's why everyone signs up to do these things and they also sign up to do the dedication to the family and see the look on their faces and the look on their kids faces and usually a heartwarming story to go along with it so I think that is the positive aspect of the build. I think that is what makes everybody feel good at the end of

	the day even if there's bumps in the road during the build the positive experience always overrides it and you just work through it and keep going.
What in the current construction process can Habitat for Humanity MetroWest/Greater Worcester improve? How could Habitat for Humanity MetroWest/Greater Worcester improve the current process?	A couple of things on the last few playhouses that I have constructed. There has been a little bit of issue in the quality of the kits in terms of how the trim fits on windows in particular and how you put that together to look good at the end of the day. I think we had gone to a program where these things were being cut out by machine which worked really well and then we had to go back to having schools and trade schools cut them out and the quality of the kits has been a little bit less than perfect. I mean at the end of the day it doesn't matter much, its a playhouse so if there is a gap in the trim because you're trying to make it work its really not the end of the day and it looks cute and it looks fine at the end of the day but if you're kind of a stickler in

	terms of how you want that thing to look at the end of the day that has been a little bit of an issue in terms of how that goes together and there is an imperfect thing with respect to the roof in my view and that it's designed to come apart so that you can put it on the truck and haul it away etc. but in the end of the day I dont think its really waterproof so I don't know how families deal with that after they get it home to their site because if done right you'd have a row of shingles go over the top so that you would be able to keep the water out. Right now that is an imperfection I think in the way that the playhouse is designed but you might actually be able to talk to a family or two about their experience with it and what worked and didn't work from their perspective as a user of the playhouse to kind of get a sense of what the problems might be as a user of the playhouse and how it holds up over time.
What information would be useful for new Operation Playhouse volunteers to know before starting to build a playhouse?	You are a little pressed for time on the decorations end of things especially if you don't have a good drying day for the paint so for instance there has been a few instances where we've built a playhouse and we've had decals and things that had to go on it and it wasn't in an ideal world the paint would cure for a few days before you put them on

	but you're trying to get to the end and you're trying to put the whole thing together so you give the whole experience for the family. So there is a planning aspect that you really want to make sure that you plan out for your theme and your decorations, ideally you wouldn't have things that are affixed to it in an adhesive way. Although it looks really good when you put it together that day I am not sure those things stay on there very well over time so decorations that are painted on or decorations like wood that is affixed to it. Those kind of things might hold up better as a product verses decals and things like that so there is a design element of planning and depending on how much time someone wants to spend on it you have to plan to have time to do that at the end of the day before the veterans family shows up.

Participant 3 - Volunteer - 1/24/18	
Question	**Response**
How many years of experience/projects have you worked on with Habitat for	I want to say either three or four years.

Humanity MetroWest/Greater Worcester?	
How many playhouses have you helped Habitat for Humanity MetroWest/Greater Worcester build?	I've personally been involved in three.
How was your experience building the playhouse(s)?	I loved it. It was fun, it was manageable, I enjoyed it, I already support habitat and its mission and it was fun bringing other people in who maybe have never been on a build site before and seeing their excitement. It was just a great joy especially at the end of the day to be able to give it to veterans family and see the kids enjoy it. I have also been part of two group playhouse builds, one in worcester and one in MetroWest and those added a whole other dimension to it and made it that much more fun to see the different teams of people and what everybody came up with
Were the instructions on how to build the playhouse clear? If not, what was unclear?	I might not be the best person to ask that because I come with a bit of a construction background so I didn't necessarily need that instructions that other people might have. If you were building it by yourself which we were largely left to do because I have built them and I have usually other people from construction companies on my

	team. It wasn't clear which way the interior pieces go to hold the boards up. That wasn't clear and we had to ask for some help but we certainly got help the second we asked for it so if you were trying to build it independently it would be helpful to have some more instructions but the way habitat does it there's always someone there so when we had one or two questions someone was right there to answer them.
Did you know how to correctly use the tools that were supplied to you?	N/A
If not, were explanations thorough on how to use them?	N/A
What do you think has gone well with the playhouse construction?	I think it's a great product, it is easy to do. There was a time where the pieces were being cut by a machine and they would stick together perfectly and you've got nice angles for the windows and that's great. That is what I really like about the construction when it comes together and all the pieces are done perfectly. I've never had a problem with missing pieces or missing tools or inadequate resources so I think they always package up the product and onsite we have absolutely everything we need so that's always gone well when I've built with them.

What in the current construction process can Habitat for Humanity MetroWest/Greater Worcester improve? How could Habitat for Humanity MetroWest/Greater Worcester improve the current process?	I'm not sure that there's much that needs to be done to improve the construction process. I think what would be helpful in the overall execution of a playhouse is to have the information in advance so that we could plan a design of what we are going to do and I go and mock up my own drawings so I could figure out where the design will be and what it will look like. If there was a blank set of drawings that you could look at, this is the dimensions and size of what a completed playhouse looks like so that you could plan the color scheme and the decorations and things like that, that might be helpful. Other than that I don't think there is any improvements that need to happen to the actual construction process of the house.
What information would be useful for new Operation Playhouse volunteers to know before starting to build a playhouse?	I think it would be helpful to know in advance that the team is responsible for design and that they can do what they want to in terms of design and they should come with a plan I think it would be helpful to know that a certain part of the day is designing and a certain part of the day is

	building so that people could allocate their resources the right way, but other than that letting people know they certainly have the capacity to do the project. I don't think that is so much of an issue with the playhouse because it is smaller and manageable but I feel like sometimes people have a hesitation when they go on a jobsite and not thinking they know how to do construction work. If that is a concern at all certainly you can tell people that they can do whatever is put before them because it is not difficult to construct them.

Participant 4 - Volunteer - 1/24/18	
Question	**Response**
How many years of experience/projects have you worked on with Habitat for Humanity MetroWest/Greater Worcester?	I guess two years.
How many playhouses have you helped Habitat for Humanity MetroWest/Greater Worcester build?	Probably 8

How was your experience building the playhouse(s)?	Good
Were the instructions on how to build the playhouse clear? If not, what was unclear?	I think so.
Is there anything that was unclear?	Not that I can think of.
Did you know how to correctly use the tools that were supplied to you?	Yeah
What do you think has gone well with the playhouse construction?	I liked the enthusiasm of the volunteers that I've worked with and I liked the whole idea of what they're doing.
What in the current construction process can Habitat for Humanity MetroWest/Greater Worcester improve? How could Habitat for Humanity MetroWest/Greater Worcester improve the current process?	There is one part of it when assembling the window and the door frames where you need to go from the inside with the screws rather than the outside because the frame pieces are ¾" and the screws are only 1" or 1¼", so there's not much bite. We actually had one door fall of while we were loading it after the build. We had to repair it, put it back together, so what can we do to make that better? I think if we had a couple of clamps. I really like the dewalt clamps that you just squeeze them, the smaller ones that you can

	clamp those pieces and then stand it up and screw it in from the backside rather than fastening from the front. One other thing I wouldn't mind seeing them try lifting straps once the house is complete to make it easier to move it around. Sometimes we have to shift it off the tarp while we are cleaning up and everything when the house is done. Whether they would help that much in loading them in the trucks I'm not sure but I think it might make it easier to handle them.
What information would be useful for new Operation Playhouse volunteers to know before starting to build a playhouse?	I suppose that they have to be there early to help set up and be there through the cleanup process afterwards because we have to leave it like we were never there. There have been a few times we have been short. That's another thing in the importance of everybody getting there on time because David usually gives an orientation and safety talk and stuff so everyone needs to be there for that and listen so it's kind of disruptive when some of the people start coming in late and not showing up on time so it think that is the most important thing. Especially get there on time to help set up.

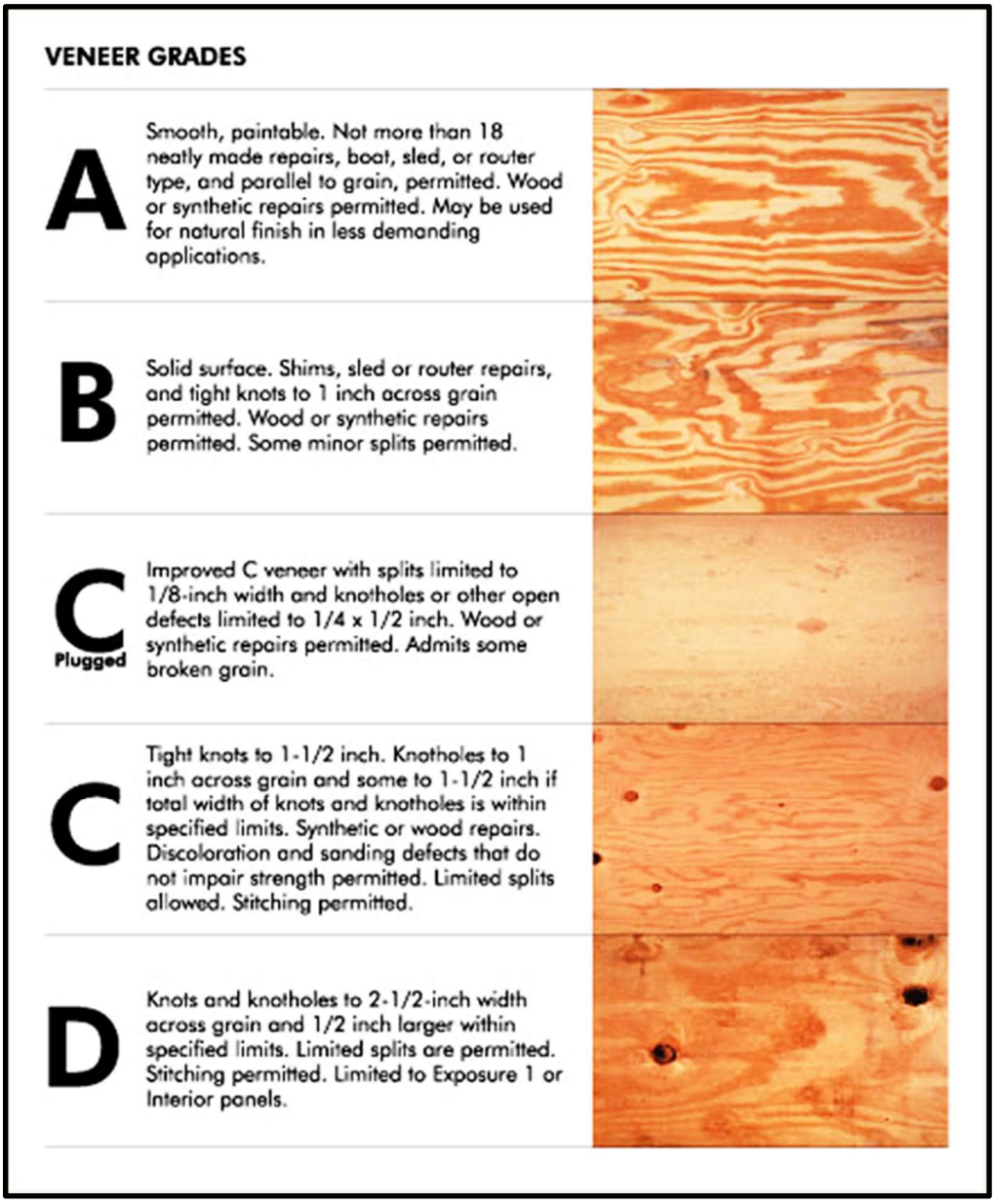
Participant 5 - Construction Manager - 1/22/18	
Question	**Response**
How many years of experience do you have working with lumber?	I've been working in construction for 18 years now, I've been working for Habitat affiliate for 5.
What projects have you been involved in? Was there use of plywood/OSB sheets?	Yeah, so all of the houses that we build use plywood and OSB.
What is the best method for determining cost effective materials?	I think that you have to figure out what the minimum quality is that you want and what lifespan you are looking for and then you can kind of match a material to that and figure out what the cost is of that material at that point. I think they have already started to do that, I think that when we first started the program we started using a pine plywood for the sides but it was warping. A pine doesn't hold up that well, so that's why they switched to the fir plywood which has held up well and that has worked and i think that's why they've continued with it. I think that there is some other products out there that they could experiment with and see if they like any of those better and compare the cost of those.

What materials best fulfill these qualities: low cost, weather resistance, high durability, low weight, safety, low pollution production, and low maintenance?	I think that the fir plywood is a good option I think that they could look at MEDEX which is like a MDS kind of like a fiberwood product for outdoor use. I don't know how that would compare in cost. MDO is another product that is used outdoors. You'll just have to experiment with it and see sort of how it holds up but it is the same product that they use to make highway signs out of so I think that would work well but again I don't know how that would compare in cost with the fir plywood but it would be something to look at.
You mentioned and alternative such as MDO and MEDEX?	MEDEX is spelt M-E-D-E-X and MDO is an abbreviation of medium density overlay.
Will these products need constant maintenance? Are there substitutes that have a greater life expectancy?	I think that you would need to paint them but they wouldn't need anymore maintenance than the fir plywood would.
Do you have any waste reduction methods that we could use on the playhouses that you may use on building homes?	I don't know how much waste there is with the trim that they are cutting, I don't know if they could zero in on what the best size pieces are for the trim. Another thing too is that they have been buying pre-primed lumber from the lumber yard or home depot. They might be able to get

	unprimed milt lumber from a sawmill, I don't know if they'd be able to get that any cheaper but probably not though because the stuff that they are using is finger jointed and the stuff from the sawmill will probably be solid. The only other thing too is if you could think about, I don't know if there is anyway to change the dimensions of the playhouse at all to maximize the amount of cuts they get out of each piece. One last thing too is weighing the MDO vs Plywood is MDO and MEDEX may be available in different sized sheets, plywood is generally only available in 4 by 8 sheets. But MDO and MEDEX might be available in 5 foot wide sheets or might be available in 10 or 12 foot long sheets. That'd be something else to research and figure out what's available out there
What is the most cost effective method for fastening wood?	Nails are cheaper than screws but i think where you're assembling them with volunteers screws are much easier for volunteers to use and the total number of fasteners that go into a playhouse is pretty small. If you were building something like a house or 2 houses you might see a significant cost difference if you use screws vs nails but building a playhouse you would be talking about a dollar or two or something like that difference. So I think you're

	mostly using screws and I think that’s the way to go.

Appendix B: Chart Representations



PLYWOOD GRADES				
Interior Grade	**Face**	**Back**	**Inner Plies**	**Common Uses**
A-A	A	A	D	Cabinet doors, built-ins, and furniture where both sides show.
A-B	A	B	D	Alternate for A-A. Face is finish grade; back is solid and smooth.
A-D	A	D	D	Finish grade face for paneling, built-ins, and backing.
B-D	B	D	D	Utility grade. One paintable side. Used for backing, cabinet sides, etc.
C-D	C	D	D	Sheathing and structural uses such as temporary enclosures, subfloor. Unsanded.
Underlayment	C-plugged	D	C,D	For underlayment or combination subfloor-underlayment under tile and carpeting.
Exterior Grade	**Face**	**Back**	**Inner Plies**	**Common Uses**
A-A	A	A	C	Outdoors, where appearance of both sides is important.
A-B	A	B	C	Alternate for A-A, where appearance of one side is less important. Face is finish grade.
A-C	A	C	C	Soffits, fences, base for coatings.
B-C	B	C	C	For utility uses such as farm buildings, some kinds of fences, base for coatings.
C-C plugged	C-plugged	C	C	Excellent base for tile, backing for wallcoverings, high-performance coatings.
C-C	C	C	C	Unsanded, for backing and rough construction exposed to weather.