Manufacturing System Design For Low Income Panelized Housing Market

A Major Qualifying Project

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Industrial Engineering

Omran Alomran

Danielle Kennon

Advisor: Professor Walter Towner PhD

March 1, 2019

ABSTRACT

Panelized building manufacturing has been popular in Scandinavia for years; however, it's just now beginning to emerge in the United States. Originally developed to increase construction efficiency, it dominates the traditional stick-building method by using prefabricated panels that reduce lead times. Therefore, DextTrust Industries and Mr. Erik Hodin are interested in pursuing a venture to manufacture low-income housing using panelized designs, under the brand name Scandinavian Panel Systems (SPS). The goal of this report was to assess the feasibility of the project from a financial and manufacturing point of view.

As the costs of building a home are on the rise, more and more people are losing the ability to purchase or even, in some rare circumstances, rent a home. As a result, SPS aims to lower the cost of building from an average of $150 per Sqft to the low to mid hundreds. By doing so, SPS will have an upper hand and advantage in the mid to low income housing market. To make their dream a reality, SPS had to use ground breaking technology that would enable them to reduce one of the highest costs, labor. By using RANDEK's Zero Labor System and its accessories, SPS would be able to reduce the labor it needed; hence, allowing them to sell at a lower rate.

To assess the feasibility of the project, we had to first understand how the system functioned; therefore, our firsts step were to contact RANDEK and research the process of panelized building. After getting the basic tools we needed that enabled us to understand the industry "Lingo", we attended conferences to meet other manufactures and users, as well as, reach out to industry leaders in both the sell and buy side of the industry. Next, we built an Axiomatic Design Matrix to determine all of the manufacturing requirements that SPS needed. Finally, to determine the feasibility of the project, we used the Yarmouth project as a base case for our analysis. After estimating the Yarmouth project lead time and cost, we were able to get an estimated total yearly output. To verify the results of our model, we used the output of each machine per panel in the Arena input analyzer to enable us to build a accurate Arena model.

After concluding our analysis, we reached the following results. The Monson plant will be able to generate a theoretical output of 160K Sqft per year; however, after accounting for inefficiencies and unexpected issues we believe that the output will be closer to 120K Sqft per

year. Next, the financial analysis gave us a base case NPV of about $3.5 million with an IRR of 7.94%. Therefore based on the data we have generate and the requirements provided to us by SPS, we are not recommending that DexTrust and Mr. Erik Hodin proceed with the project, in the current form, as the expected results don't go in line with their expectations.

ACKNOWLEDGEMENTS

We would like to offer special thanks to our Academic Advisor, Walter Towner for his valuable and constructive suggestions throughout, and providing us with the opportunity to explore this project.

We would also like to acknowledge Charles Robson and Tymothy Kennedy of DexTrust Industries, as well as Erik Rhodin of Line Company Architects, for their patience and assistance as we progressed through this project.

Lastly, we would like to thank Jonas Anderson of RANDEK, for continuous communication and assistance in data acquisition.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

DexTrust Industries, a local start-up aiming to become a community leader in economic development and sustainability, is considering the possibility of establishing a subsidiary - Scandinavian Panel Systems, SPS - to manufacture panelized homes. Before beginning development, DexTrust needs to know how their subsidiary would realistically operate, so that they can determine whether the expected profits outweigh the initiative's required investment. Our MQP team has partnered with DexTrust Industries in order to determine whether it makes sense to pursue the SPS initiative.

While complexities such as risk profiles, long-term corporate strategy, and market volatility are involved in these types of decisions, the scope of our project considers the SPS initiative from a strictly monetary perspective. In addition, we consider the attainment of a single project and ignore the intricacies associated with securing future projects. Our paper assumes that SPS will be developing their plans for a 3-story, multi-family apartment complex in Yarmouth, MA.

In order to estimate the initial investment and expected pay-off of SPS, cost estimations that encompass all aspects of production associated with the firm are developed. Our paper discusses technical subject matter related to the project, including materials management, production scheduling, and the development of a manufacturing system. A thorough financial analysis has also been included to determine whether or not it makes fiscal sense to develop Scandinavian Panel Systems.

CHAPTER 1: MATERIALS MANAGEMENT

The following section details the determination of material requirements that will be associated with the attained construction project. A technical breakdown of the building is included to determine the amount of construction panels required, and a determination of the various panel types and specifications is completed to assess the requirements for each panel type. Finally, the constraints and limitations associated with the materials to be used has been discussed.

1.1 PANELIZED BUILDING DECOMPOSITION

Figure 1. Yarmouth Project Preliminary Design

The construction project under consideration is a 54-apartment, 3 story, low-cost housing development that will be located in Yarmouth, MA (Figure 1). The building will be constructed using prefabricated panels that have been shipped to the site from the SPS manufacturing facility. While our project details the construction of the facility's main housing, SPS has future plans to develop the property even further with the latest technologies in renewable energy and facility waste management.

The building is comprised of three identical floors, each with 18 identical 600 square foot, one bedroom units (Figure 2). Because the units within the building are identical, the requirements to construct a single unit can be analyzed and multiplied to determine the requirements of the entire building.

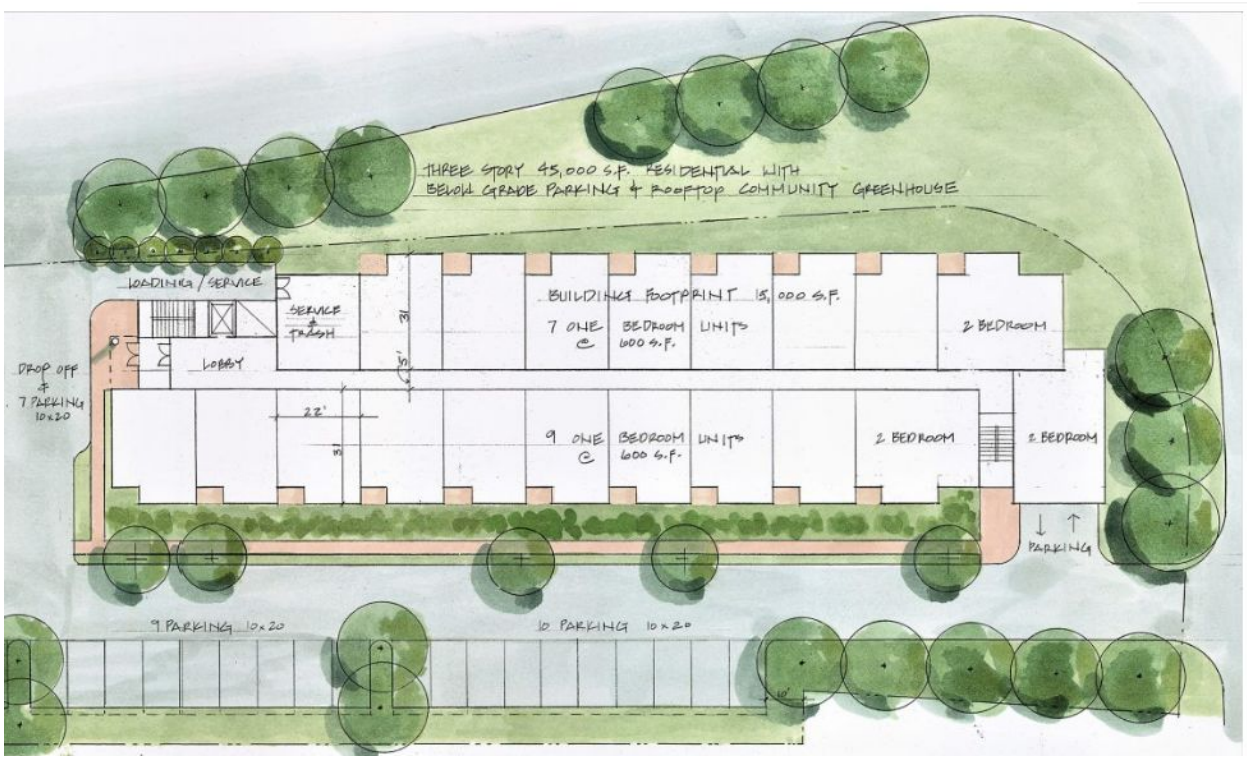

Figure 2. Yarmouth Project Floor Plan

1.2 PANEL SPECIFICATIONS

Each unit consists of several panels that differ in their design based on their functional purpose and location in the unit. To simplify and organize a unit's panel requirements, the panels were categorized by function - including floor panels, wall panels, and roof panels. This is an important step of understanding the building's design because the panels in each category are subject to different loads. The difference is forces equates to a difference in panel strength which is directly correlated to each panel's design and material requirements.

Beyond categorizing the panels by purpose, the panels were further identified by their dimensions. While all panels of the same category consist of the same structural design, many of their lengths and heights differ. After reaching out to Mr. Rhodin, we were able to secure additional schematics labelling the wall, floor, and roof panels required for each one bedroom unit. These schematics have been included in Appendix 8.

Mr. Rhodin was also able to provide us with an excel spreadsheet that detailed the dimensions of every panel required for each unit, and specified the quantity of windows and doors required for each panel type. Additional specifications such as frame thickness were provided as well.

Ultimately, the schematics and excel spreadsheet provided described the quantity of each panel type required for each unit. Because the preliminary project design schematic shows a total of 18 units per floor, and reports the existence of 3 identical floors, we know there will be a total of 54 units in the building. We then multiplied the quantity of panel types per unit by 54, to get the total number of panels by type in the entire project. These panel totals were organized in a table which has been attached in Appendix 4.

To ensure the accuracy of our work, we turned to Mr. Rhodin for verification of our panel totals. However, Mr. Rhodin did not agree with our calculated totals, and provided us with a different list of building totals. Because Mr. Rhodin designed the project and has extensive experience as an Architect, we chose to move forward with his numbers and they were likely more accurate. The total quantity of every panel type required for the project has been included in the table below (Table 1).

Table 1a. Building Panel List - Floor and Roof Panels

PANEL ID	QUANTITY	DIMENSIONS
Floor Panels		
FP 1	20	8x8
FP 2	34	5X14
FP 3	120	6X22
FP 4	34	7.5X22
Roof Panels		
RP 1	18	7X11
RP 2	18	7X11
RP 3	18	8X6
RP 4	46	6X22
RP 5	18	7.5X22

Table 1b. Building Panel List - Wall Panels

PANEL ID	QUANTITY	DIMENSIONS
Wall Panels		
WP 1	42	8X8
WP 2	102	8X5
WP 3	51	8X14
WP 4	51	8X23
WP 5	17	8X14
WP 6	18	3x22
WP 7	18	8x24
IWP 1	51	8X5
IWP 2	51	8X3
IWP 3	51	8X10
IWP 4	51	8X12
IWP 5	51	8X9
IWP 6	51	8X4
IWP 7, 9, 11	153	8X2
IWP 8	51	8X6
IWP 10	51	8X6
IWP 12	51	8X22
IWP 13	51	8X5
IWP 14	51	8X5
IWP 15	51	8X2

1.3 MATERIAL REQUIREMENTS

The material requirements of each panel were then realized by using Table 1, in combination with research and further consultation with Mr. Rhodin. Each panel consists of an initial frame made from solid lumber, and a layer of plywood used to cover the frame.

The panel frames begin as long beams of lumber that must be cut down to size and positioned together to shape the frame. The beams of lumber are laid on a flat surface, and nails are used to attach the beams together to form the frame (Figure 3).

Figure 3. Unity Homes - Open Panel Frame

After the frame has been fully assembled, pieces of plywood are used to completely cover one side of the frame (Figure 4).

Figure 4. Unity Homes - Closed Panel Frame

With plywood on one side of the frame, the panel can then be filled with insulation or utility piping, before the remaining side is also covered with plywood "closing" the frame. In our case, the panels will not be filled, and remain covered by plywood on only one side. This decision was made to comply with the Massachusetts residential utility laws and regulations.

A graphic was made to better understand the material requirements for each panel as shown below (Figure 5).

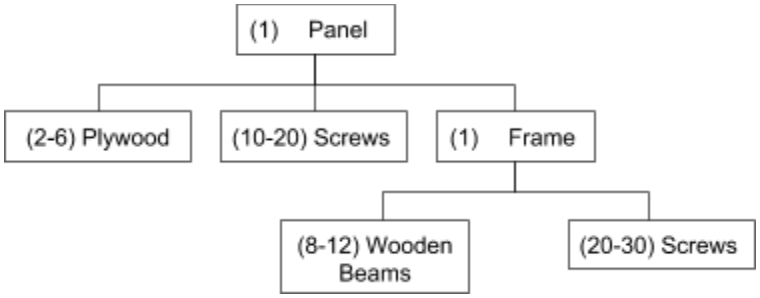

Figure 5. Material Requirements per Panel

Each panel consists of a single frame, and anywhere between 2-6 pieces of plywood depending on the panel's dimensions. Each frame is built using anywhere between 8-12 beams of lumber, depending on the panel type and the specific frame style.

Because the various panel types have different specifications, each panel type required its own material requirements graphic. These graphics have been included in Appendix 9. The graphics were used to determine the material requirements for the entire building.

CHAPTER 2: MANUFACTURING SYSTEM DESIGN

The following section discusses the supplier selection process. The necessary manufacturing equipment is realized, and both material and equipment suppliers are determined.

2.1 IDENTIFYING EQUIPMENT REQUIREMENTS

In order to design the most efficient and effective manufacturing system using RANDEK equipment, we developed an impressive understanding of the possibilities associated with each of RANDEK's machines. Our initial understanding indicated that RANDEK's ZeroLabor system would be placed in our facility and produce the entirety of the Yarmouth project's panels on its own. In an attempt to learn more about the dimensions and expected throughput of the ZeroLabor System, we searched RANDEK's website for relevant information. It was during this investigation that we realized the ZeroLabor System does not have the capabilities required to manufacture a complete panelized building on its own. While the ZeroLabor system is able to produce wall, floor, and roof panels, the panels can not be lifted or moved without the help of additional RANDEK machines or other third-party transportation equipment.

After learning this, we considered possibility of purchasing additional equipment from either RANDEK, or another supplier. We determined that the best combination of products could only be found if we acquired a strong understanding of the ZeroLabor System's exact capabilities and requirements. We further explored RANDEK's website in an attempt to accomplish this, but the website did not include any information on machine specifications (ie. dimensions, utility requirements, estimated production rate, etc) or pricing. This type of information was vital for determining the cheapest combination of machines that could accomplish our desired goals.

In order to obtain the specifications and pricing of the ZeroLabor system, we knew that we were going to need to contact RANDEK. Before reaching out, we assembled a list of questions which we felt would provide all necessary information if properly answered. We emailed the list of questions to a RANDEK sales associate, and received a wealth of information in return. However, upon closer inspection, we realized that the information provided was not

comprehensive enough for our needs. We immediately compiled a new list of additional data and specification inquiries, and promptly contacted RANDEK to gather answers.

While waiting for RANDEK's response, we began to further dissect other areas of the project such as raw material (wood) limitations, unexpected labor requirements/costs, and expected construction sequencing/methods. Ironically, the more we worked on the project, the further we felt from the solution. The question-asking and answering process continued throughout the next several weeks, and project work dependent on these answers was hindered. Coordinating communication of between several different stakeholders was challenging due to obstacles like varying schedules, miscommunications, and international time differences. To remedy this situation, we immediately began looking for other ways to gather the necessary data required to make educated assumptions and continue work on our project.

2.2 IDENTIFYING MATERIAL SUPPLIERS

After discussions with RANDEK, DexTrust, and Hodin, it became clear that due to the difference in grade between American and European lumber SPS will have to import its lumber from Europe. The reason behind the need for European wood is due to the fact that American wood has a high level of inconsistencies, which causes issues in the robotic system. Based on the quotes we received from Hodin, we believe that SPS should use multiple suppliers as identified in table 2. The following suppliers are US based companies that supply European wood. A full list of quotes is available in Appendix 6

	Jackson Lumber (Per unit)	National Lumber (Per unit)	Riverhead (Per Unit)
2X4/16"	$12.87	$10.65	$10.38
2x8/24"	$21.84	$19.70	$21.71
2x12/16"	$29.53	NA	NA
TJI 560/24"	NA	NA	$4.75
Plywood	$23.48	NA	$21.33
Screws	$50.12	$76.80	$47.19

Table 2. Lumber Suppliers and Prices

2.3 ACQUIRING RELEVANT EQUIPMENT DATA

Due to our analytical nature, we did not feel comfortable making decisions without first having access to all relevant data. In order to expedite project progress and continue work before receiving responses from others, we began to look for data independently.

2.3.1 INDUSTRIALIZED WOOD-BASED CONSTRUCTION CONFERENCE

After some research and communication with RANDEK, we learned about an opportunity to attend the IWBC conference, in Boston. The IWBC conference highlights the latest and greatest in the modular and panelized wood construction sector. Not only did this conference directly pertain to our project, but we soon heard that RANDEK would be sending representatives to the US to attend the conference as well. We chose to attend the conference in hopes of gathering some relevant information, as well as to meet with the RANDEK representative to clear up some questions in person.

At the conference, we participated in the sessions that we felt might provide us useful data during our project. We attended the following:

1. "Evolutions and Solutions; MGA and Katerra's explorations, systems and typologies in mass timber" By Michael Green
2. "If it's Not a System; It's Not a Solution" By Gerry McCaughey
3. "Marriott's Modular Program; Franchisor Perspective" By David Walsh

In the first session, we learned that Katerra is currently one of the largest panelized building manufacturers in the world. Green stresses that getting Katterra to where it is today was a difficult task. What helped them succeed is the backward integration they developed. Currently, Katerra depends on outside supply sources for a minimal range of products. In the future, Katerra hopes to be able to build an entire building using only materials from its subsidiaries. Green also highlighted the fact that we should not only focus on the production

aspects, but also provide the design team with the required materials to engineer new techniques to make buildings more affordable, safer, and more environmentally friendly.

The second session introduced us to Gerry McCaughey, the founder and CEO of Entreka. Entreka was founded after he had successfully built Century Homes Ireland, which currently supplies over 30% of new builds in Ireland. Due to the success he had seen in Ireland, McCaughey decided to start a new venture in the US under the brand name, Entreka. During his presentation, McCaughey focused on the importance of using automation, lean processes, and continuous innovation to be able to survive in such a brutal environment.

In the third and final session, Dave Walsh talked about how the Marriott Group is utilizing modular buildings. According to Walsh, the Marriott group has decided to use modular buildings for their lower tier hotels. The reasons they chose this route include affordability, time savings, and noise reduction. During his presentation, Walsh walked us through the process the building modules go through after they leave the factory. Each module is a single room, and before leaving the factory, each of these rooms is fitted with all the items that will be in the room when a hotel guest arrives. Since every module is a room, the rooms now have double wall insulation to decrease the noise transmitted between rooms, hence increasing comfort. Once the modules arrive at the site, it is only a matter of placing them in the right spot and connecting the electrical and water supplies before it is virtually ready to be rented. By doing so, the Marriott Group was able to secure substantial savings, and by building the hotel more quickly, they were ready to start generating revenue quicker. Walsh pointed out that by using the modular system, the Marriott Group was able to cut construction time in half.

Following the sessions, we met with RANDEK to go over some of the questions we had with regards to the manufacturing cell dimensions. While we were able to get a few basic questions answered, RANDEK did not have the time to sit down with us and provide the necessary data we had hoped for. As an afterthought, it might have been better to try to schedule a meeting with RANDEK outside of the conference while a representative was in the United States. It is understandable that RANDEK chose to attend the IWBC conference with their own agenda in mind, and did not allocate time to discuss specific equipment metrics with us. After trying to communicate with them on line, we decided that it would be more efficient to fly to

Sweden and meet them in their facility. The outcome of the trip will be discussed in a later section.

2.3.2 BENSON WOOD & UNITY HOMES

While the IWBC conference provided a significant amount of insight in regards to panelized construction and manufacturing, we still had a limited amount of data on the reality of penalized manufacturing. That is why we chose to attend a public tour at Benson Wood's manufacturing facility.

Benson Wood was established in 1974 after, the founder, Ted Benson recognized the cost savings he could achieve by transforming his existing contracting company into a panelized building manufacturer. Since it was established, Benson Wood focused on the production of high-end homes. However, in 2017 Bensonwood opened a state-of-the-art, automated factory to serve a new untapped market. With the opening of their new facility, Benson Wood established a subsidiary under the brand name Unity Homes. Unity Homes enabled Benson Wood to enter the low-cost housing sector (Bensonwood, 2019).

Designing a facility for panelized construction, with little knowledge of building panel manufacturing systems is a daunting task. Therefore, we decided to visit the automated Bensonwood/Unity Homes facility during one of their publicly advertised tours. By the conclusion of our tour, we were able to gain a better understanding of how panel manufacturing works, as well as things to look out for, and areas to avoid. We were also able to gain a better understanding of the size and shape of the space necessary to produce building panels.

2.3.3 RANDEK SITE VISIT

In an attempt to gain a better understanding of the RANDEK equipment and the company it self, we decided to visit Randek at their production facility in Falkenberg, Sweden on the 7th of January 2018. From our visit, we expected to gain a better understanding of capabilities and limitations of the Randek machinery in more detail than we were able to obtain over the phone.

In addition, the opportunity to see the machines in action will help us envision how SPS's manufacturing facility might operate.

During our visit, we were granted access to a senior sales representative, who would help us get the data we needed, and provide us with a tour of the facility. During our meeting, we were able to discuss the operating capabilities of the equipment they manufacture, specifically what to expect during the manufacturing stage. Furthermore, we were offered industry insight with regards to what current users of RANDEK equipment are experiencing. In the end, our visit to the RANDEK facility has been an insightful experience; however, we are not able to share more to comply with RANDEK's request.

2.4 CREATING AN EFFICIENT MANUFACTURING FACILITY LAYOUT

Before we could begin deciding how the system's equipment would be arranged, we needed to understand the constraints of our facility. Our first course of action was to reach out to DexTrust and inquire about the dimensions of the space that was secured for our manufacturing purposes. We received a quick response, and were informed that the space was rather large with a length of over 250' and a width of roughly 145'.

Our next task was to figure out how much of that space would need to be dedicated to storing raw materials and finished goods. To do this, we reached out to architect, Erik Rhodin, to inquire about the quantity and size of the panels involved in the Yarmouth project. Mr. Rhodin was hesitant in his decisions of how to panelize the Yarmouth design, because he was unsure that panels with lengths of 30' or 40' would fit in the manufacturing space. In fact, he remarked that the entire space was likely not much longer than 50' by 50'.

We quickly realized that DexTrust and Mr. Rhodin had very little communication with regards to the facility dimensions, so we decided it would be best to visit the facility ourselves. After obtaining the address from DexTrust Industries, we arrived at a currently operating distribution center. The facility was very large, but we determined it would be best to take our own measurements of the floor space.

Without a tape measure on hand, we measured the facility in shoe-lengths by walking toe-to-toe in straight lines from one location in the facility to another and recording the number

of steps. We also noted several columns which were dispersed in a regular pattern throughout the facility, and we were sure to measure the number of shoe lengths between the columns and the wall, and between the columns themselves. The dimensions of other items which could not be moved, including utility equipment, office spaces, bathrooms, and walls, were measured as well. Of the six loading docks that were present along the facility's right side, only three were in working condition, which we were sure to make note of.

After leaving the facility, we converted our shoe-length measurement into feet, and created a digital blueprint of the facility's floor plan to help use visualize the space. The floor plan has been included in Appendix 3 of this document.

Our next task was determining how to place the necessary equipment within the confines of the Monson facility. We reached out to RANDEK to obtain the dimension of their ZeroLabor system and other components of the production line. We received a document with the required items to build a full system; however, we were only given the dimension of the Butterfly Table.

After a second unsuccessful attempt in getting the required dimensions we decided to take matters into our own hands. We used a computer software that enables us to calculate the dimensions of the other equipment based on the scale of the Butterfly Table. The results are shown in Figure 6.

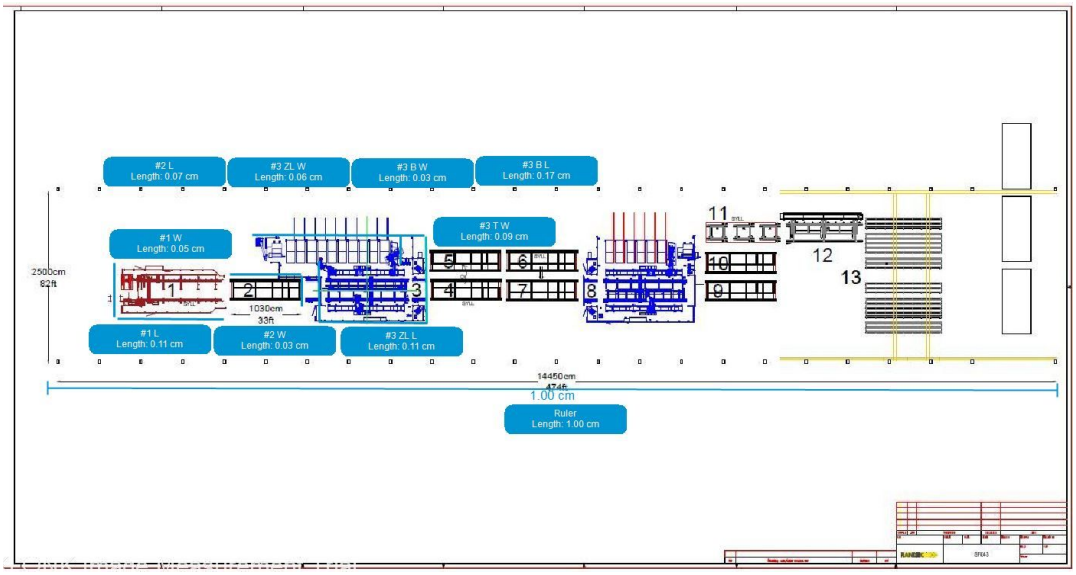

Figure 6. Production Line Dimensions

Next, we converted the numbers we obtained from the software to feet and quickly realized how tight the space would be. We drew the facility layout on Autocad and started to experiment with ways to fit the most machines, to reach the desired output desired by SPS, while being able to safely operate the factory.

After estimating the dimension of the machines we created an Autocad model and tested different layouts. Through the different iterations we started to notice that there isn't much room for creativity and opted for a simple system that laid the equipment in sequence. As a result, we arrived at two options. The options are identical except for an additional CNC machine which can be seen in the diffrence between Figures 7 and 8. The additional CNC machine was added because it was causing a bottleneck in the system and SPS would like to reach the highest level of efficiency possible.

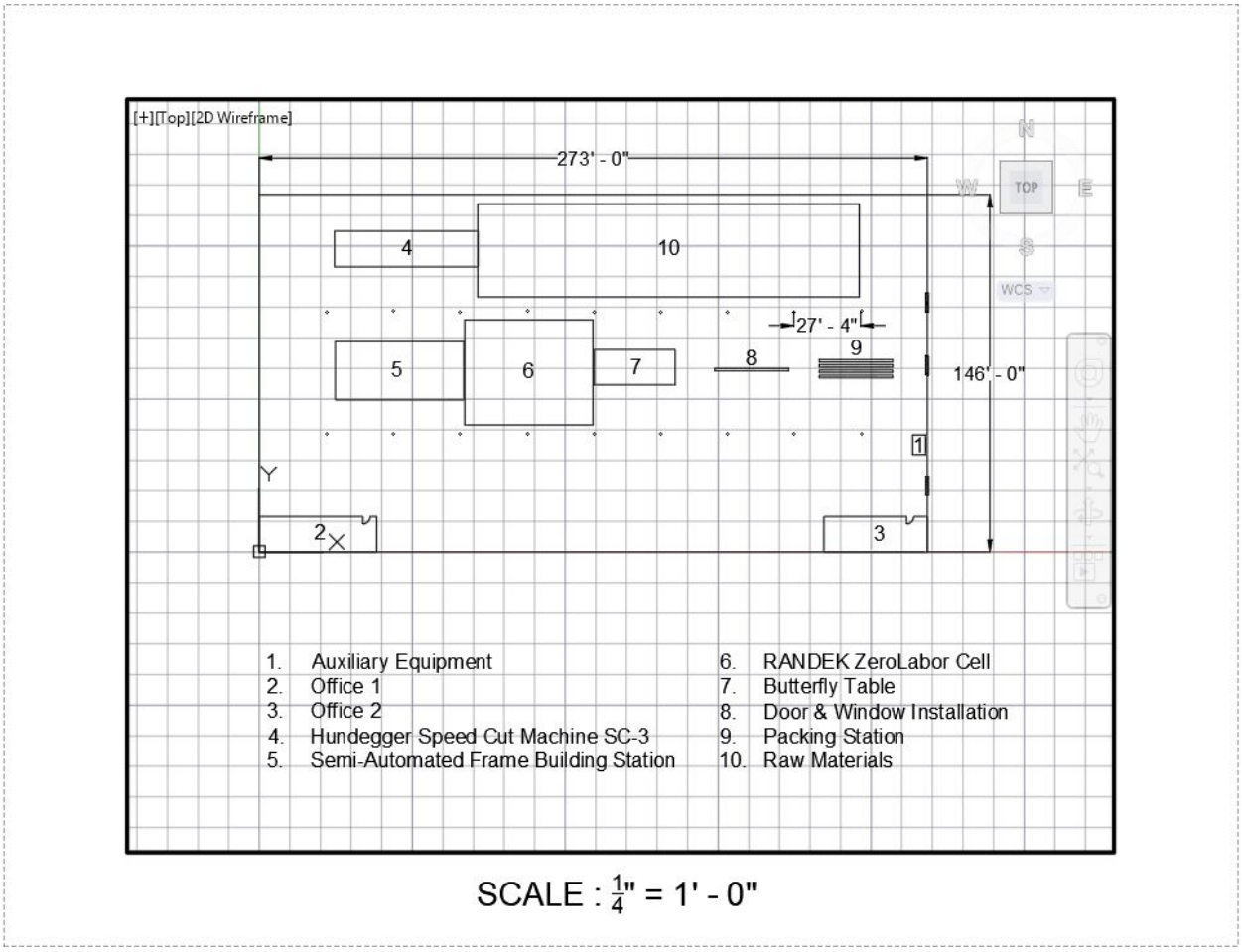

Figure 7. Suggested Monson Facility System Layout I (Not to Scale)

CHAPTER 3: PRODUCTION SCHEDULING

3.1 ACQUIRING RELEVANT EQUIPMENT DATA

3.1.1 IWBC CONFERENCE

Following the IWBC sessions discussed earlier, we looked to gather some data on processing times from RANDEK. However, as mentioned previously, RANDEK did not have the time to sit down with us and provide with new data. It might have been better to try to schedule a meeting with RANDEK outside of the conference, to gather the processing data we required. After trying to communicate with them on line, we decided that it would be more efficient to fly to Sweden and meet them in their facility. The outcome of the trip will be discussed in a later section.

3.1.2 BENSON WOOD & UNITY HOMES

While the IWBC conference provided a significant amount of insight in regards to panelized construction and manufacturing, we still had a limited amount of data on the actual processing times associated with penalized manufacturing. That is why we chose to attend a public tour at Benson Wood's manufacturing facility.

Upon arrival to the Bensonwood/Unity Homes facility, we quickly noticed that not all of the machines and equipment were being utilized around the clock, suggesting that the facility is not being utilized to its fullest capabilities. When we asked the facility manager for an explanation, he stated that they are currently operating at one-third of their capacity. After a little more questioning, we concluded this may be due to consumer sensitivity to price changes in the housing industry because of the increasing interstates. On the other hand, the market may simply be saturated with a large number of suppliers. A third and equally viable possibility is that Bensonwood/Unity Homes might have a weak internal control structure. While all, none, or a combination of these three may affect the production schedule, we are convinced that production is most greatly hindered by the company's single facility, which works to produce both luxurious Bensonwood homes and low-cost Unity Homes panels. With that, the factory employees find it hard to identify who they are; are they a high-end manufacturer or a low-cost supplier.

At the conclusion of our tour, we were able to gather some rough estimates for processing times which we utilized to forecast the expected throughput for SPS.

3.1.3 RANDEK SITE VISIT

In an attempt to gain a better understanding of the RANDEK equipment and the company it self, we decided to visit Randek at their production facility in Falkenberg, Sweden on the 7th of January 2018. During our visit, we hoped to gather some data relevant to cycle time for specific RANDEK machinery, in order to provide SPS with a more accurate estimate. Finally, getting the ability to see the machines in action will help us get a feel for the processing times SPS's manufacturing facility might experience.

During our visit, we were granted access to a senior sales representative, who would help us get the data we needed, and provide us with a tour of the facility. However, we are not able to share more to comply with RANDEK's request.

3.2 FORECASTING EXPECTED THROUGHPUT

After compiling and processing all the information we gathered, table 1 shows the required lead time per step in the production process.

Tabel 3. Production System Lead Times

Time required by item (sec)		
Door	1020.00	Per Door
Window	1800.00	Per Window
Frame	6.00	Per ft
Wood Cutting	48.00	Per Sqft
Transportation & Clamping between cells	40.00	Per Panel
Sheet stapling	22.50	Per Sheet
Sheet Handling	37.70	Per Sheet
Door Milling	109.00	Per Door
Window Milling	65.00	Per Window
Transportation out of cell	30.00	Per Panel

After seeing the time savings two machines would produce, we looked at the possibility of adding additional machines in general; however, due to the limited size of the facility that will not be possible.

We then used these processing times to estimate the time to produce all of the panels in the Yarmouth project. We organized the results in a table shown below in table 4.

Tabel 4 - Panel Total Times

Total Panel Times				
Panel code	Time per Panel (s)	Time per Panel (min)	Total Time per Panel Type (min)	Total Time per Unit
FP 1	3410.40	56.84	1136.80	56.84
FP 2	3854.80	64.25	2184.39	64.25
FP 3	6999.20	116.65	11898.64	349.96
FP 4	8583.20	143.05	4863.81	143.05
FP3	6999.20	116.65	2099.76	116.65
RP 1	4172.80	69.55	1251.84	69.55
RP 2	4172.80	69.55	1251.84	69.55
RP 3	2642.40	44.04	792.72	44.04
RP 4	6999.20	116.65	4199.52	233.31
RP 5	8583.20	143.05	2574.96	143.05
RP 4	6999.20	116.65	1166.53	116.65
WP 1	7140.40	119.01	4998.28	119.01
WP 2	3387.40	56.46	5758.58	112.91
WP 3	9600.80	160.01	8160.68	160.01
WP 4	11366.20	189.44	9661.27	189.44
WP 5	5870.80	97.85	1663.39	97.85
WP 6	3650.60	60.84	1095.18	60.84
WP 7	13621.20	227.02	4086.36	0.00
IWP 1	3387.40	56.46	2879.29	56.46
IWP 2	1490.40	24.84	1266.84	24.84
IWP 3	4310.80	71.85	3664.18	71.85
IWP 4	6219.80	103.66	5286.83	103.66
IWP 5	5049.80	84.16	4292.33	84.16
IWP 6	3003.40	50.06	2552.89	50.06
IWP 7,9,11	1106.40	18.44	2821.32	55.32
IWP 8	2642.40	44.04	2246.04	44.04
IWP 10	2642.40	44.04	2246.04	44.04
IWP 12	11369.20	189.49	9663.82	189.49
IWP 13	3387.40	56.46	2879.29	56.46
IWP 14	2258.40	37.64	1919.64	37.64
IWP 15	1106.40	18.44	940.44	18.44
SUM	166028.00	2767.13	111503.51	2983.41
SUM in hours	2767.13	46.12	1858.39	49.72
Sum in days	115.30	1.92	77.43	2.07

As per our current calculations, the Yarmouth project can theoretically be built in the factory in roughly 78 days if production continues uninterrupted for 24 hours, 7 days a week. However, we know that those conditions are not feasible due to unavoidable issues like equipment failures, outages, quality control, etc. In addition, it should be noted that the processing and manufacturing times considered were taken from a fully matured system and will not reflect what SPS is likely to see during their first year of operation. For this reason, we

estimate that the project will take at least 100 days to complete, although the calculations suggest otherwise.

We also examined the system's capacity by looking at processing times per processing step (work cell). A table was used to organize these times as well, which can be seen below in table 5.

Processing Times by Machine

Panel code	CNC (Hundegger)	Framing	Zero Labor	Door & Window
FLOOR PANELS /ONE BED UNIT				
FP 1	3072.00	48.00	120.40	0
FP 2	3360.00	84.00	240.80	0
FP 3	6336.00	132.00	361.20	0
FP 4	7920.00	132.00	361.20	0
CORRIDOR - FLOOR PANELS				
FP3	6336.00	132.00	361.2	0
ROOF PANELS				
RP 1	3696.00	66.00	240.80	0
RP 2	3696.00	66.00	240.80	0
RP 3	2304.00	48.00	120.40	0
RP 4	6336.00	132.00	361.20	0
RP 5	7920.00	132.00	361.20	0
ROOF CORRIDOR PANEL				
RP 4	6336.00	132.00	361.2	0
WALL PANELS / ONE BED UNIT				
WP 1	3072.00	48.00	250.40	3600
WP 2	1920.00	48.00	229.40	1020
WP 3	5376.00	84.00	370.80	3600
WP 4	8832.00	138.00	426.20	1800
WP 5	5376.00	84.00	240.80	0
WP 6	3168.00	132.00	180.60	0
WP 7	9216.00	144.00	491.20	3600
IWP 1	1920.00	48.00	229.40	1020
IWP 2	1152.00	48.00	120.40	0
IWP 3	3840.00	60.00	240.80	0
IWP 4	4608.00	72.00	349.80	1020
IWP 5	3456.00	54.00	349.80	1020
IWP 6	1536.00	48.00	229.40	1020
IWP 7,9,11	768.00	48.00	120.40	0
IWP 8	2304.00	48.00	120.40	0
IWP 10	2304.00	48.00	120.40	0
IWP 12	8448.00	132.00	579.20	2040
IWP 13	1920.00	48.00	229.40	1020
IWP 14	1920.00	48.00	120.40	0
IWP 15	768.00	48.00	120.40	0
Min	768.00	48.00	120.40	0.00
Max	9216.00	144.00	579.20	3600.00
AVG	4168.26	81.68	266.13	669.68
SUM	129216.00	2532.00	8250.00	20760.00

Tabel 5 - Processing Times by Machine

The system and processing times was then verified through the use of Rockwell Arena Simulation Software (Figure 8).

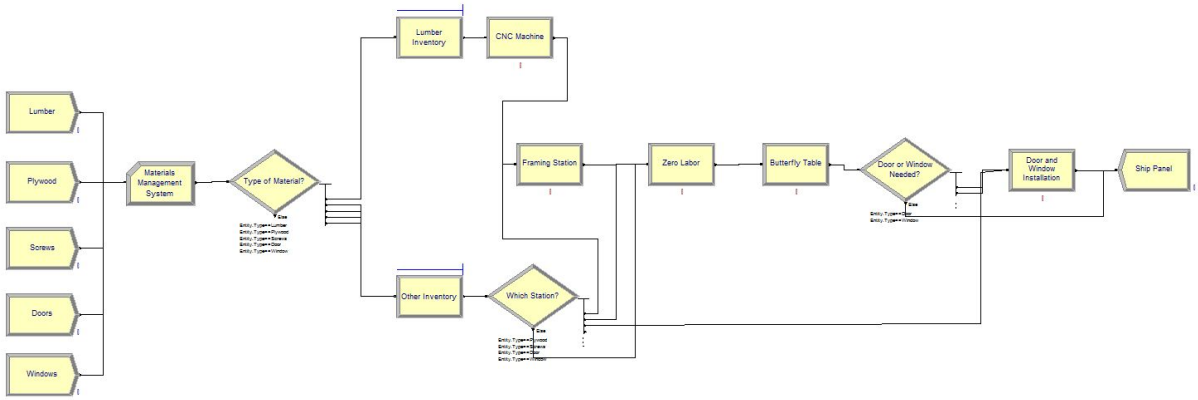

Figure 8: Monson Factory, Arena Simulation

It was determined that the CNC machine, which is responsible for cutting the wall studs to size, is the bottleneck of the system (Figure 9). The graph explains that the CNC machine is utilized virtually 100% of the time, and its average utilization is far greater than any other machine.

Usage

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Butterfly Tabel	0.02611111	0.00	0.02222222	0.02916667
CNC machine	0.9919	0.01	0.9714	1.0000
Framing Station	0.01815793	0.00	0.01362969	0.02156947
Installer	0.1486	0.04	0.07521208	0.2669
ZL machine	0.05825328	0.01	0.04234553	0.07087483

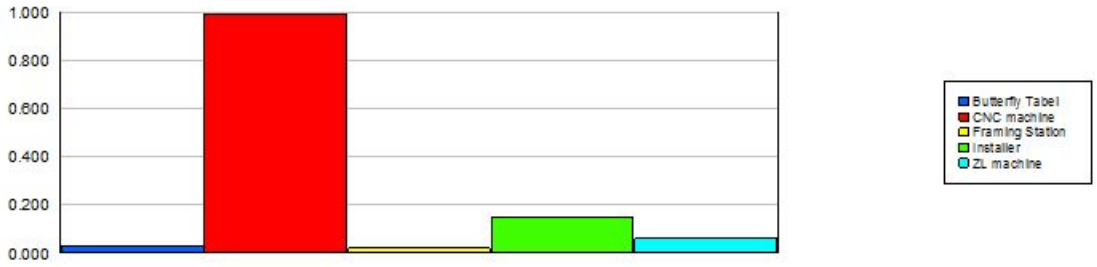

Figure 9: Arena Utilization Results

Furthermore, the Arena model provided similar figures to what we have unveiled through the Excel model. The excel sheet suggests that we can produce roughly 18 panels per day, and ARENA suggests 19. This difference can be expected since the machine processing times were fit to a probability distribution in ARENA, instead of assumed to remain constant. For this reason, the ARENA model will likely be more accurate than the Excel spreadsheet.

It should also be noted that the average processing time of a single panel is approximately 1.5 hours (based on the ARENA model), but the average time that a panel and its materials spends in the factory is roughly 8.3 hours (Figure 10).

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	1.5343	0.11	1.3363	1.7486	0.3318	3.6193

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	8.2963	0.91	6.5610	10.7297	0.4858	17.3839

Figure 10: Arena Time Results

This explains that the materials spend a lot of time queued at the CNC machine. Therefore, the production capacity will be limited by this machine (assuming all machines work properly, and exhibit no differences in quality, maintenance, etc). If SPS would like to increase panel lead time in the future, it is recommended that they start at this step of production, and consider purchasing an additional or more efficient CNC machine. It is important to note that this excessive queue time comes at a price and effects inventory and carrying costs that contribute to the company's net profit.

3.3 DEVELOPING A PRODUCTION SCHEDULE

One of the benefits of a panelized building is the ability to get it weathertight in a short span of time. However, this benefit is only realized when construction is completed unit by unit. For this reason, we decided to divide the building into five separate construction phases, where

each phase consists of 3-4 units (Figure 9). This decision was based on information provided by stakeholders within SPS and best practices realized through independent research. The colors on the figure indicate the phase number, and the numbers within each block indicate the apartment numbers per cell. Each block has three numbers because it consists of three different apartments on the building's three floors - stacked one on top of the other. By using a phased construction plan, we will protect the interior from the weather, but also save time by allowing for interior finishes to be performed continuously. For a detailed list of the production schedule refer to Appendix 4.

Figure 11: Yarmouth Project, Construction Phases

CHAPTER 4: ANALYSIS AND RECOMMENDATION

4.1 PROOF OF CONCEPT

Knowing that the concept of panelized construction is operational feasible from the sell side, we decided to view it from the buyers perspective. As we discussed in Chapter 3, during the IWBC conference in boston, David Walsh explained how the Marriott Group is using modular buildings to reduce building costs and time. However, that wasn't of much use to us because they were using modular and the building are still new. Therefore, we reached out to the Dammam Hotels Company , located in Saudi Arabia, regarding their Dammam Hotel (Shown in figure 10).

Figure 12: Dammam Hotel

The Dammam Hotel was built in 1970 using panels manufactured in Sweden. According to the management, the total time from signing of the contract to having the hotel operational took less than 6 months. Furthermore, since inception the building has required very minimal maintenance. After further discussions with the management team, they have indicated that they credit a big part of their success to the affordability and speed of such a system, which enabled them to continuously offer competitive prices.

4.2 RISK ANALYSIS

After developing SPS's output capacity, we obtained a reasonable estimate of their future projected cash flows for the coming years. From there, we projected SPS's Income Statement, Balance Sheet, and Cash Flows Statement. Once we have the financial statements in place, developed a Discounted Cash Flow valuation model to project their future profitability. Currently, SPS plans to produce 500k SF during year one and double production on a yearly basis for the first 3 years. Furthermore, SPS plans to run the factory continuously at maximum output, starting from day one.

However; after working on this project for several months, we strongly believe these targets are not achievable with the acquired facility space, the chosen equipment, and the capital constraints. From the data we produced, the maximum output that can be produced in Monson will be far less than 500k SF. Assuming no downtime, no maintenance, no learning curve, and no unexpected issues, the RANDEK machines that will be used in the Monson plant can only produce 160K SF per year. Knowing that uninterrupted, continuous production is not feasible, we predict that the facility will be able to produce 120K SF per year. Therefore, unless SPS finds a much larger facility and additional capital, production will realistically be limited to 120K SF per year, assuming that the process is highly automated and very little downtime occurs (again, not a very realistic assumption). Doubling capacity every year following will, likewise, be virtually impossible to achieve in the Monson facility. We expect the increase in production rate to be far more gradual. Every system large or small has a learning curve which greatly affects its ability to operate at full efficiency. We strongly believe that SPS cannot assume that such a complex system in the hands of a startup will be able to achieve the best case figures in the first year.

4.3 FINANCIAL ANALYSIS

The end goal of the project is to have a successful venture that will generate profit; therefore, we needed to identify the factories output, costs, and the owner's expectations. After developing the finalized facility layout and deciding on the equipment that will be used, we will use the Yarmouth project as the stepping stone for SPS's profitability analysis. During our

feasibility analysis, we will treat the plant as a separate entity. Costs of shipping and construction will not be included in the analysis. In other words, we will be assuming a Free on Board (FOB) Shipping Point.

The first step we took was calculating the factories maximum output. For us to be able to accurately determine it, we built a possible facility lay out to determine the processing times. We then used the decomposed building plan provided to us by Erik Hodin to calculate the required time to manufacturer the Yarmouth project. From the numbers we received, we simulated the factories output on Arena to calculate the output.

After receiving the panel specifications and the lumber quotations he received, we calculated the amount of wood by type, windows, doors, and nails needed to build the Yarmouth Project. We then calculated the cost of raw materials, and derived a per SF cost to be used in the cost projection of future projects(Table 6).

Item	**Cost per unit**	**Units required**	**Total Cost**
2x12/16"	$32.48	412	$13,383
TJI 560/24"	$5.23	983	$5,136
2x8/24"	$23.19	1197	$27,760
2x4/16"	$12.43	3717	$46,202
Screws	$1.28	111594	$142,484
Plywood	$24.65	4732	$116,623
Door	$56.56	459	$25,961
Window	$150	273	$40,950
		Total	$418,499
		Total per SF	$9.51

Tabel 6. Yarmouth Project Raw Material Quantity and Cost

Next, based on the data we have generated and the figures obtained from SPS, we built a financial model to assess the feasibility of the project. To build the model, we forecasted SPS's financial statements, which have been built based on our knowledge of SPS's target capital structure, our estimated output, and costs. From the financial statements, we were able to calculate the net-debt free cash flows. Next, we calculated the companies expected WACC and exit multiple using other competitors in the industry. Using the values we have, we projected and discounted the net-debt free cash flows and the exit multiple.

Knowing that SPS will be operating at full capacity and that there is no space to further expand in the Monson facility, we assumed a constant output for the duration of 5 years. (As shown in table 7) Based on the data we have the expected NPV of the project is $3.49M, with and IRR of 7.94% and a ROE of 6.66%.

Fiscal Year Ending ($)	12/31/19	12/31/20	12/31/21	12/31/22	12/31/23
Revenue	**$7,200,000**	**$7,200,000**	**$7,200,000**	**$7,200,000**	**$7,200,000**
EBIT	$758,638	$758,638	$758,638	$758,638	$758,638
Less: Taxes	$153,803	$153,803	$153,803	$153,803	$153,803
Debt-Free Earnings	**$604,835**	**$604,835**	**$604,835**	**$604,835**	**$604,835**
Less: Capital Expenditures	-$10,000,000	$0.00	$0.00	$0.00	$0.00
Less: Working Capital Requirements	-$600,000	-$600,000	-$600,000	-$600,000	-$600,000
Add: Depreciation and Amortization	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000
Total Net Investment	**-$9,600,000**	**$400,000**	**$400,000**	**$400,000**	**$400,000**
Net Debt-Free Cash Flows:	**-$8,995,165**	**$1,004,835**	**$1,004,835**	**$1,004,835**	**$1,004,835**
Discount Period	0	1	2	3	4
PV of Net Debt-Free Cash Flo	**-$8,995,165**	**$895,733**	**$798,478**	**$711,782**	**$634,500**

Key Assumptions

Discount Rate and Tax Rate Assumptions	
Discount Rate	12.18%
Tax Rate	35.00%

Terminal Value Assumptions	
Terminal Year EBITDA	$1,758,638
EBITDA Multiple	8.51
Terminal Value	**$14,959,359**
Discount Period	4
PV of Terminal Value	**$9,446,040**

Feasability Figures	
NPV	$3,491,368
IRR	7.94%
ROE	6.66%

NPV - Sensitivity Analysis

		Price per SF					
		$50.00	$55.00	$60.00	$65.00	$70.00	$ 80.00
% of Total Adjusted Capacity	55%	$(22,250,810)	$(19,725,469)	$(17,200,129)	$(14,674,788)	$(12,149,447)	$(7,098,765)
	65%	$(18,571,006)	$(15,586,512)	$(12,602,018)	$(9,617,525)	$(6,633,031)	$(664,043)
	75%	$(14,891,201)	$(11,447,554)	$(8,003,908)	$(4,560,261)	$(1,116,616)	$5,770,678
	85%	$(11,211,396)	$(7,308,597)	$(3,405,798)	$497,002	$4,399,801	$12,205,400
	100%	$(5,691,690)	$(1,100,161)	$3,491,368	$8,082,897	$12,674,425	$21,857,483

Tabel 7. SPS DCF and Sensitivity Analysis

Even Though the NPV is positive, we ask you to refer to the sensitivity analysis on table 7. For SPS to be a feasible investment, SPS will either have to produce at high prices with a low output or at high prices and high output. Knowing that the goal of SPS is to produce low income housing, SPS will not be able to charge a premium for its products. Moreover, after discussions with people in the industry, we believe that the market is currently over saturated and that SPS will not be able to sell all of its capacity at a profitable price. Therefore, based on the data we have generated and the outcomes required by Dextrust and Erik Hodin, we are unable to recommend this project going forward.

CHAPTER 5: CONCLUSION

CONCLUSIONS

This section of our paper describes the key learning outcomes, for the two industrial engineers, that were experienced throughout this project.

C.1 IDENTIFYING AND ARTICULATING A PROJECT OBJECTIVE

This particular MQP did not begin with a clearly structured goal. After becoming partners with DexTrust Industries, an initial meeting was conducted to discuss the company's objectives and discuss the scope of our project. During the meeting, DexTrust presented a company structure which included themselves, their partners, and a number of possible subsidiaries with various economic, environmental, and social intentions. The discussion moved from one broad goal to the next with talk of renovating Native American reservations, constructing sustainable smart cities, and fostering ecological community development. We quickly learned that our partners at DexTrust were visionaries, easily excited by the possibilities of the future. We made a mental note to contribute a critical voice to our discussion with DexTrust in order to keep our team grounded and control the scope of our project.

After the meeting was adjourned, we carefully considered DexTrust's plethora of goals for Scandinavian Panel Systems, and were able to determine a single overarching objective: DexTrust wanted to make money by manufacturing low-cost panelized housing. This marked the establishment of our project's objective - to design a system for manufacturing low-cost panelized housing, and to determine whether it is likely to turn a profit.

We also learned the value of using the Axiomatic Design Methods (AD). To develop our FR's, DP's, and PV's, we had to understand the system truly and completely. While completing

our AD coupling matrix, we learned the importance of being clear in our writing, and to make sure anyone could understand it without us explaining it. This is critical to both our project, and any project. Ensuring that all team players are solving the same problems and reaching for the same goals is critical.

C.2 MAKING PARTIALLY-INFORMED BUSINESS DECISIONS

Eventually, due to strict deadlines and to avoid scope creep, we decided to make the necessary assumptions needed to proceed with the project, rather than wait for responses. We know that data-driven solutions, supplemented with knowledge from those familiar with the project and its various components, will produce the most accurate results. However, it is often the case in business that all of the information needed to make a perfectly informed decision is not available, and a decision must be made based on any available data and educated assumptions. This was a key learning point for our team that we were fortunate enough to realize after working on real problem in industry. While our time at WPI equipped us with highly analytical backgrounds, we were not accustomed to making decisions without fully understanding every aspect of the problem and thoroughly analyzing all relevant data. We now understand the importance of making business decisions with confidence, even when a lack of information prevents us from finding the “perfect” solution.

C.3 COMMUNICATION IS KEY

During A-term, we realized that communication skills between the members SPS team did line up with doing this type of work, and that key elements like the capabilities of manufacturing equipment, the size and condition of the proposed manufacturing facility, and the amount of details in the panelized designs, had been miscommunicated. It became clear that all members of this organization were not on the same page. As a result, we stressed heightened

communication and trust during B-term by scheduling weekly meetings with all members of the SPS team. We also began gathering information directly from the source, rather than through other team members which had lead to some inaccuracies in the past, due to poorly understood assumptions.

Furthermore as time progressed, we saw our role evolve into one where we could protect the new company from assumptions that might be changing after they system is installed. We wanted to provide an informed contrarian view to balance the exuberante and excellence of the company founders.

C.4 INDUSTRY PERSPECTIVE

Additionally, our perspectives relating to operations in industry were drastically changed during A-term, and continued to develop throughout B-term. The biggest obstacle we faced this term is the difference between communicating with external sources in industry vs in an academic environment. At WPI, professors want students to succeed, and are ready and willing to communicate with them in an effort to help. In industry, companies are often focused on their own agenda and do not make it a priority to provide help to us for the completion of the project. In other words, unless a business recognizes the situation as something that will benefit them in the future (building a network, generating profits, etc), it will provide little to no contribution to the success of the initiative.

APPENDICES

APPENDIX 1: AXIOMATIC DESIGN MATRIX

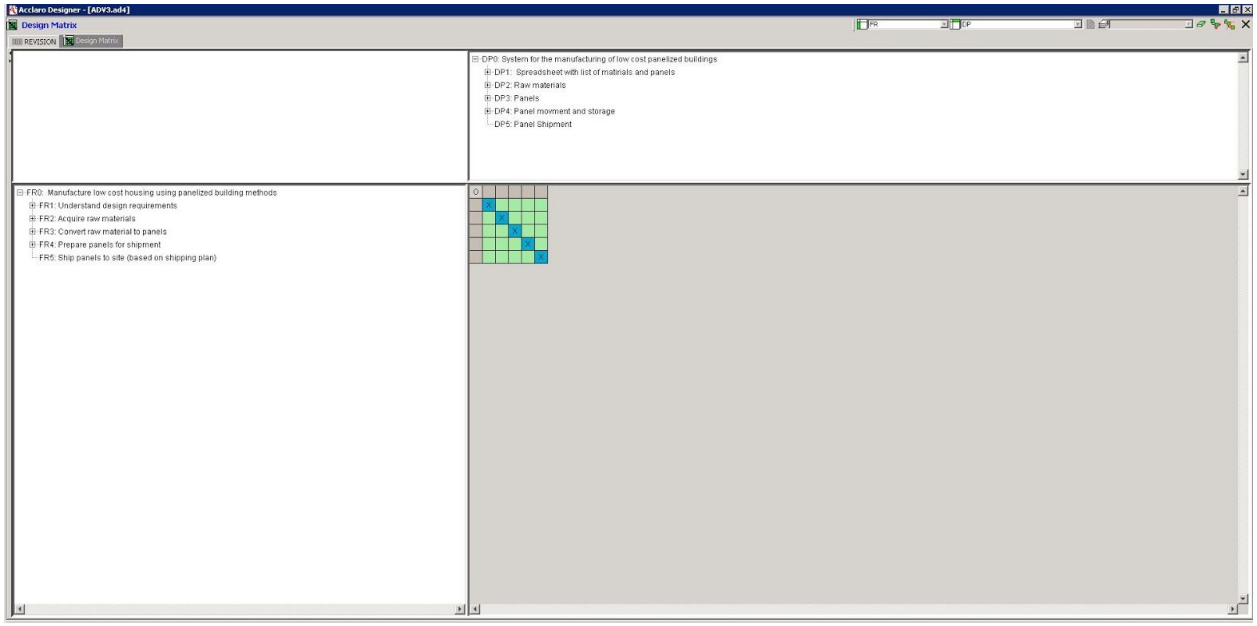

Figure 13. Axiomatic Design, Upper Level Matrix

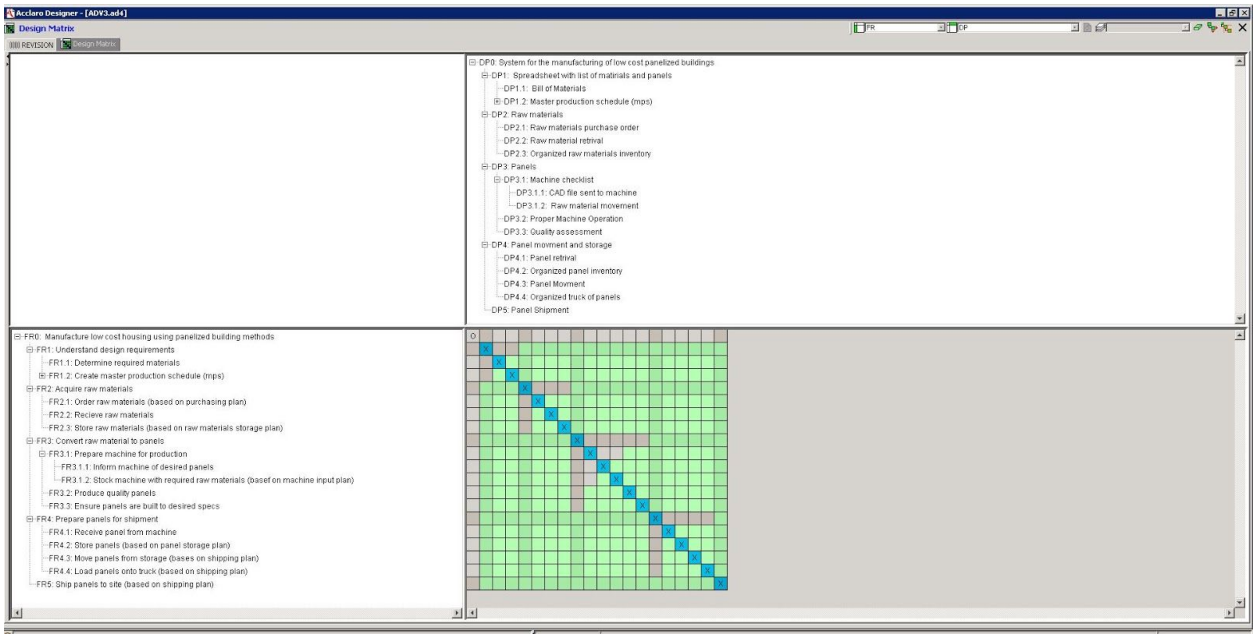

Figure 14. Axiomatic Design, Mid-Level Matrix

APPENDIX 1 (CONTINUED): AXIOMATIC DESIGN MATRIX

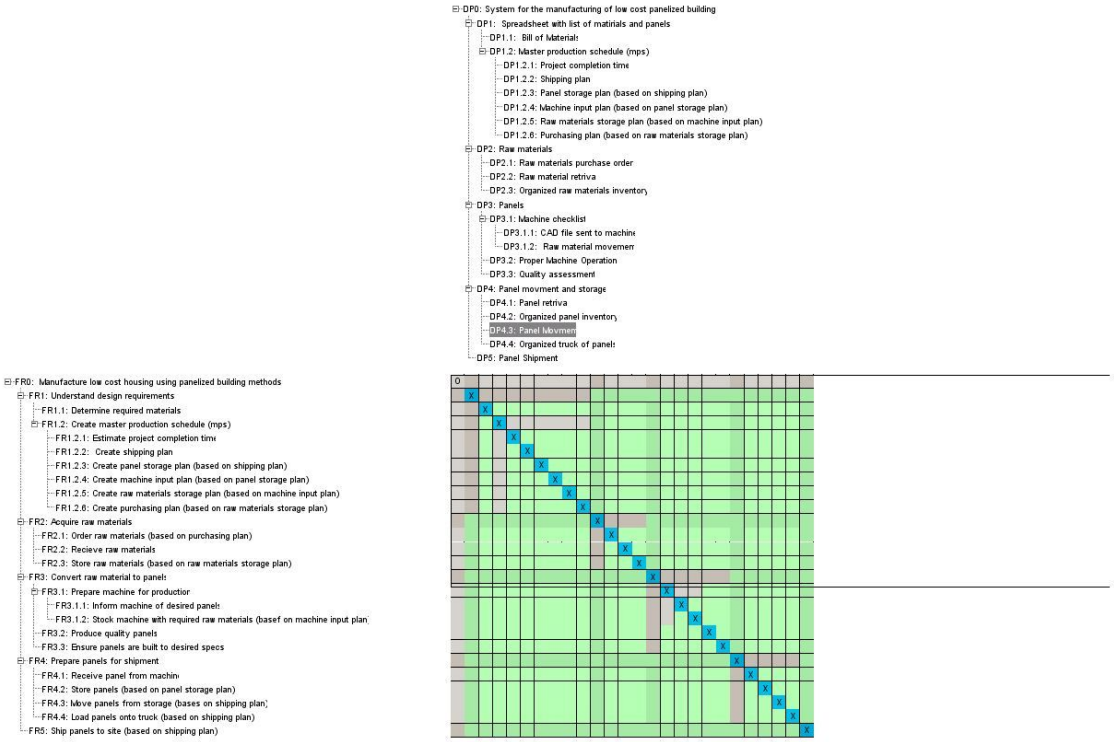

Figure 15. Axiomatic Design, Full Matrix

APPENDIX 2: ZEROLABOR INQUIRIES, RANDEK CORRESPONDENCE

Kennon, Danielle Jaqueline

Fri 10/5, 10:44AM

To: Jonas Andersson <Jonas.Andersson@randek.com>

Cc: Omran Mosa Alomran <omalomran@wpi.edu>

Hello Jonas,

Thank you for taking the time to call us. Below you will find our list of questions.

1. What are the machines dimensions ?
2. Can we get the ZeroLabor system spec sheet ?
3. How many 20ft panels/roofs can it produce per hour ? what about 30ft? Or 40ft?
4. How does the system conduct quality control? How do we know the panels are always built to specification?
5. Are there any specific material or utility requirements to operate the ZeroLabor system?
6. How many bays of wood can be used, and how high can the wood be stacked?
7. Aside from wood, how much raw material can it hold (ex: nails, glue, etc)?
8. On average, how often does the system require maintenance?
9. Can we decide the order in each type of panel is produced? Or does the system make this decision based on the CAD file?
10. Does the system require a short down-time to switch from producing roof panels to wall panels to floor panels?

Thanks again,

Danielle Kennon

APPENDIX 3: MANUFACTURING FACILITY FLOOR PLAN

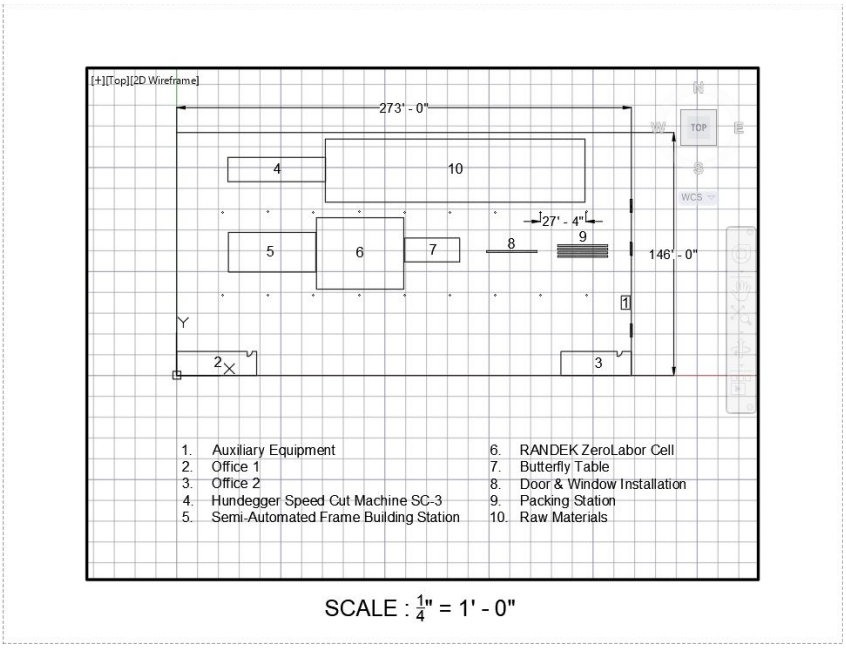

Figure 7. Suggested Monson Facility System Layout I (Not to Scale)

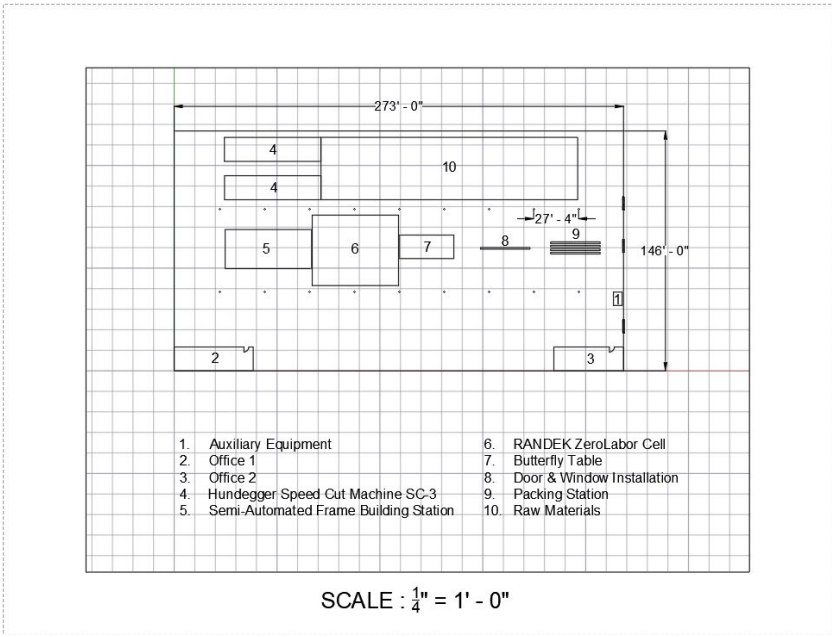

Figure 8. Suggested Monson Facility System Layout II (Not to Scale)

APPENDIX 4: YARMOUTH PRODUCTION SCHEDULE, PHASES, & TIMES

Production Schedule for Phase 1 & 5 (Per Phase)		
Production Sequins	Panel Code	Quantity
1	RP 1	3
2	RP 2	3
3	RP 3	3
4	RP 4	9
5	RP 5	3
6	IWP 1	3
7	IWP 2	3
8	IWP 3	3
9	IWP 4	3
10	IWP 5	3
11	IWP 6	3
12	IWP 7	3
13	IWP 8	3
14	IWP 9	3
15	IWP 10	3
16	IWP 11	3
17	IWP 12	3
18	IWP 13	3
19	IWP 14	3
20	IWP 15	3
21	WP 1	3
22	WP 2	3
23	WP 3	3
24	WP 4	6
25	WP 5	3
26	WP 6	3
27	FP 2	3
28	FP 3	9
29	FP 4	3
30	FP 3 (Hall way)	2
31	FP 1	3
32	IWP 1	3
33	IWP 2	3
34	IWP 3	3
35	IWP 4	3
36	IWP 5	3
37	IWP 6	3
38	IWP 7	3
39	IWP 8	3
40	IWP 9	3
41	IWP 10	3
42	IWP 11	3
43	IWP 12	3
44	IWP 13	3
45	IWP 14	3
46	IWP 15	3
47	WP 1	3
48	WP 2	3
49	WP 3	3
50	WP 4	6
51	WP 5	3
52	WP 6	3
53	FP 2	3
54	FP 3	9
55	FP 4	3
56	FP 3 (Hall way)	2
57	FP 1	3
58	IWP 1	3
59	IWP 2	3
60	IWP 3	3
61	IWP 4	3
62	IWP 5	3
63	IWP 6	3
64	IWP 7	3
65	IWP 8	3
66	IWP 9	3
67	IWP 10	3
68	IWP 11	3
69	IWP 12	3
70	IWP 13	3
71	IWP 14	3
72	IWP 15	3
73	WP 1	3
74	WP 2	3
75	WP 3	3
76	WP 4	6
77	WP 5	3
78	WP 6	3
79	FP 2	3
80	FP 3	9
81	FP 4	3
82	FP 3 (Hall way)	2
83	FP 1	3

Production Schedule for Phase 2,3 & 4 (Per Phase)		
Production Sequins	Panel Code	Quantity
1	RP 1	4
2	RP 2	4
3	RP 3	4
4	RP 4	12
5	RP 5	4
6	IWP 1	4
7	IWP 2	4
8	IWP 3	4
9	IWP 4	4
10	IWP 5	4
11	IWP 6	4
12	IWP 7	4
13	IWP 8	4
14	IWP 9	4
15	IWP 10	4
16	IWP 11	4
17	IWP 12	4
18	IWP 13	4
19	IWP 14	4
20	IWP 15	4
21	WP 1	4
22	WP 2	4
23	WP 3	4
24	WP 4	8
25	WP 5	4
26	WP 6	4
27	FP 2	4
28	FP 3	12
29	FP 4	4
30	FP 3 (Hall way)	2
31	FP 1	4
32	IWP 1	4
33	IWP 2	4
34	IWP 3	4
35	IWP 4	4
36	IWP 5	4
37	IWP 6	4
38	IWP 7	4
39	IWP 8	4
40	IWP 9	4
41	IWP 10	4
42	IWP 11	4
43	IWP 12	4
44	IWP 13	4
45	IWP 14	4
46	IWP 15	4
47	WP 1	4
48	WP 2	4
49	WP 3	4
50	WP 4	8
51	WP 5	4
52	WP 6	4
53	FP 2	4
54	FP 3	12
55	FP 4	4
56	FP 3 (Hall way)	2
57	FP 1	4
58	IWP 1	4
59	IWP 2	4
60	IWP 3	4
61	IWP 4	4
62	IWP 5	4
63	IWP 6	4
64	IWP 7	4
65	IWP 8	4
66	IWP 9	4
67	IWP 10	4
68	IWP 11	4
69	IWP 12	4
70	IWP 13	4
71	IWP 14	4
72	IWP 15	4
73	WP 1	4
74	WP 2	4
75	WP 3	4
76	WP 4	8
77	WP 5	4
78	WP 6	4
79	FP 2	4
80	FP 3	12
81	FP 4	4
82	FP 3 (Hall way)	2
83	FP 1	4

Tabel 8. Yarmouth Project, Production Schedule

APPENDIX 4 (CONTINUED): YARMOUTH PRODUCTION SCHEDULE, PHASES, & TIMES

Phase 5			Phase 4		Phase 3		Phase 2		Phase 1	
			8	7	6	5	4	3	2	1
			26	25	24	23	22	21	20	19
			44	43	42	41	40	39	38	37
18	17	16	15	14	13	12	11	10	9	
36	35	34	33	32	31	30	29	28	27	
54	53	52	51	50	49	48	47	46	45	

Figure 11: Yarmouth Project, Construction Phases

APPENDIX 5: EXAMPLE OF AXIOMATIC DESIGN WALKTHROUGH

FR 5. Ship Panels to Site

Ask yourself: What needs to happen before you can ship the panels to the site?

Answer: Prepare Panels for Shipment (FR. 4)

FR 4. Prepare Panels for Shipment

Ask yourself: What needs to happen before you can prepare the panels for shipment?

Answer: Convert Raw Materials to Panels (FR. 3)

FR 3. Convert Raw Materials to Panels

Ask yourself: What needs to happen before you can convert raw materials into panels?

Answer: Acquire Raw Materials (FR. 2)

FR 2. Acquire Raw Materials

Ask yourself: What needs to happen before you can acquire the raw materials?

Answer: Understand the Design Requirements (FR. 4)

FR 1. Understand Design Requirements

APPENDIX 6: LUMBER PRICES

JACKSON LUMBER & MILLWORK:

Jackson
LUMBER & MILLWORK

Quote

215 Market Street	10 Industrial Drive	67 Haverhill Rd	10 Jefferson Ave
Lawrence, MA 01843	Raymond, NH 03077	Amesbury, MA 01913	Woburn, MA 01801
Phone: (978) 686-4141	Phone: (603) 895-5151	Phone: (978)-388-0366	Phone: (781)-933-0057

Billing Fax: 978-687-5841

Transaction # 242749
Price Date 02/16/2018
Location LAWRENCE
Sales Representative JOHN HANCOCK

MAIL TO: Jackson Lumber & Millwork Co. Inc.
PO Box 449, Lawrence, MA 01842

Bill To:
NICK MONAHAN
** CASH ACCOUNT **
554 WASHINGTON STREET (617)406-8700
DEDHAM, MA 02026

Ship To:
7OL 7 OAKMONT LANE
BELMONT, MA 02178

Customer #	Quote #	Quote Date	Oper	Purchase Order	Terms	Ship Via
64010	242749	02/16/2018	057		CASH	UNKNOWN TBD

LN#	Item Number	Ordered	Description	UM	Price/Unit	Extension
1	SPR268	10	2 X 6 X 8 K/D SPR STUD	EA	4.72	47.20
2	SPR268	60	2 X 6 X 8 K/D SPR STUD	EA	4.72	283.20
3	ACQ2416	4	2X4X16 #1 GC TREATED W/WAX	EA	12.87	51.48
4	SPR2416	4	2 X 4 X 16 K/D SPR #2&BTR	EA	7.48	29.92
5	SPR21010	10	2 X 10 X 10 K/D SPF #2 & BTR	EA	12.78	127.80
6	CDXF4812	12	4 X 8 X 1/2 CDX FIR 4PLY	SH	23.48	281.76
7	DOWSILL	8	5-1/2" X 50' FOAM SILLSEAL	RL	4.29	34.32
8	OUT2816	24	2 X 8 X 16 #1 GC TREATED	EA	19.92	478.08
9	SPR2816	24	2 X 8 X 16 K/D SPR #2 & BTR	EA	15.42	370.08
10	5091	4	LUS26Z ZMAX SNGL JOIST HNGR100	EA	0.92	3.68
11	5175	4	LUS210-2Z DBL 2X10 HANGER (25)	EA	2.46	9.84
12	OUT21010	17	2 X 10 X10 #1 GC TREATED	EA	15.24	259.08
13	OUT21020	3	2 X 10 X 20' #1 GC TREATED	EA	35.55	106.65
14	OUT468	1	4 X 6 X 8 #2 GC TREATED	EA	15.84	15.84
15	ABW46Z	2	4X6 ADJ POST BASE HYBRID ZMAX	EA	20.04	40.08
16	THD50600HMG	2	SIMPS TITAN ANCHOR 1/2X6 EA	EA	3.63	7.26
17	5093	17	LUS210Z ZMAX SNGL HNGR 50	EA	1.33	22.61
18	34OSB	92	4X8 X 3/4 T&G OSB	SH	24.46	2250.32
19	O0264507	12	DYNAGRIP ADV SUB ADH 28OZ7000	EA	4.60	55.20
20	SPR2820	25	2 X 8 X 20 K/D SPR #2 & BTR	EA	21.84	546.00

Amount:	74,745.37
Tax:	4,671.59 *
Total:	79,416.96 *
Paid:	0.00
Due:	79,416.96

This Quotation is valid thru 4/18/2018. After that it is subject to review by Jackson Lumber and Millwork. Special Order and Manufactured merchandise is Non-Returnable.

Page 1 of 5 4/11/2018 9:39:53AM

Jackson LUMBER & MILLWORK

Quote

215 Market Street	10 Industrial Drive	67 Haverhill Rd	10 Jefferson Ave
Lawrence, MA 01843	Raymond, NH 03077	Amesbury, MA 01913	Woburn, MA 01801
Phone: (978) 686-4141	Phone: (603) 895-5151	Phone: (978)-388-0366	Phone: (781)-933-0057

Billing Fax: 978-687-5841

Transaction # 242749
Price Date 02/16/2018
Location LAWRENCE
Sales Representative JOHN HANCOCK

MAIL TO: Jackson Lumber & Millwork Co. Inc.
PO Box 449, Lawrence, MA 01842

Bill To:
NICK MONAHAN
** CASH ACCOUNT **
554 WASHINGTON STREET (617)406-8700
DEDHAM, MA 02026

Ship To:
7OL 7 OAKMONT LANE
BELMONT, MA 02178

Customer #	Quote #	Quote Date	Oper	Purchase Order	Terms	Ship Via
64010	242749	02/16/2018	057		CASH	UNKNOWN TBD

LN#	Item Number	Ordered	Description	UM	Price/Unit	Extension
21	SPR2810	400	2 X 8 X 10 K/D SPR #2 & BTR	EA	9.74	3896.00
22	SPR2816	80	2 X 8 X 16 K/D SPR #2 & BTR	EA	15.42	1233.60
23	SPR249	240	2 X 4 X 104 5/8 K/D SPR	EA	3.84	921.60
24	SPR2416	20	2 X 4 X 16 K/D SPR #2&BTR	EA	7.48	149.60
25	CDXF4812	100	4 X 8 X 1/2 CDX FIR 4PLY	SH	23.48	2348.00
26	RSPR18	20	1 X 8 X 16 RGH SPRUCE (240)	EA	9.27	185.40
27	SPR21014	20	2 X 10 X 14 K/D SPF #2 & BTR	EA	17.68	353.60
28	FOIL481	6	4X8X1 R6.2 FOIL BOARD 4.8LBS	SH	20.25	121.50
29	LUC210Z	1	SIMP CONCEAL FLANGE JH 2X10	EA	1.73	1.73
30	5093	18	LUS210Z ZMAX SNGL HNGR 50	EA	1.33	23.94
31	LSSU210	7	LSSU-210 SLOPED HANGER (25)	EA	9.99	69.93
32	LSSU210	1	LSSU-210 SLOPED HANGER (25)	EA	9.99	9.99
33	SDW22634R50	1	SIMPS 6-3/4 SCREWS 50PK	EA	50.12	50.12
34	SPR21012	54	2 X 10 X 12 K/D SPF #2 & BTR	EA	14.67	792.18
35	5093	54	LUS210Z ZMAX SNGL HNGR 50	EA	1.33	71.82
36	OUT21010	17	2 X 10 X10 #1 GC TREATED	EA	15.24	259.08
37	OUT21020	3	2 X 10 X 20' #1 GC TREATED	EA	35.55	106.65
38	5093	17	LUS210Z ZMAX SNGL HNGR 50	EA	1.33	22.61
39	34OSB	100	4X8 X 3/4 T&G OSB	SH	24.46	2446.00
40	O0264507	12	DYNAGRIP ADV SUB ADH 28OZ7000	EA	4.60	55.20

Amount:	74,745.37
Tax:	4,671.59 *
Total:	79,416.96 *
Paid:	0.00
Due:	79,416.96

This Quotation is valid thru 4/18/2018. After that it is subject to review by Jackson Lumber and Millwork. Special Order and Manufactured merchandise is Non-Returnable.

Jackson LUMBER & MILLWORK

Quote

215 Market Street	10 Industrial Drive	67 Haverhill Rd	10 Jefferson Ave
Lawrence, MA 01843	Raymond, NH 03077	Amesbury, MA 01913	Woburn, MA 01801
Phone: (978) 686-4141	Phone: (603) 895-5151	Phone: (978)-388-0366	Phone: (781)-933-0057

Billing Fax: 978-687-5841

Transaction # 242749
Price Date 02/16/2018
Location LAWRENCE
Sales Representative JOHN HANCOCK

MAIL TO: Jackson Lumber & Millwork Co. Inc.
PO Box 449, Lawrence, MA 01842

Bill To:
NICK MONAHAN
** CASH ACCOUNT **
554 WASHINGTON STREET (617)406-8700
DEDHAM, MA 02026

Ship To:
7OL 7 OAKMONT LANE
BELMONT, MA 02178

Customer #	Quote #	Quote Date	Oper	Purchase Order	Terms	Ship Via
64010	242749	02/16/2018	057		CASH	UNKNOWN TBD

LN#	Item Number	Ordered	Description	UM	Price/Unit	Extension
41	SPR21012	18	2 X 10 X 12 K/D SPF #2 & BTR	EA	14.67	264.06
42	SPR288	380	2 X 8 X 8 K/D SPR #2 & BTR	EA	7.73	2937.40
43	SPR2816	40	2 X 8 X 16 K/D SPR #2 & BTR	EA	15.42	616.80
44	SPR2492	340	2 X 4 X 92 5/8 K/D SPR STUD	EA	2.99	1016.60
45	SPR2416	30	2 X 4 X 16 K/D SPR #2&BTR	EA	7.48	224.40
46	SPR21014	6	2 X 10 X 14 K/D SPF #2 & BTR	EA	17.68	106.08
47	CDXF4812	70	4 X 8 X 1/2 CDX FIR 4PLY	SH	23.48	1643.60
48	SPR1316	400	1X 3 X 16 PREMIUM KD STRAPPING	EA	3.46	1384.00
49	SUL210R	18	2X10 RH SKEWED HANGER (10)	EA	11.37	204.66
50	SUL210L	20	2X10 LH SKEWED HANGER (10)	EA	11.37	227.40
51	SPR21010	62	2 X 10 X 10 K/D SPF #2 & BTR	EA	12.78	792.36
52	5093	150	LUS210Z ZMAX SNGL HNGR 50	EA	1.33	199.50
53	SPR21010	70	2 X 10 X 10 K/D SPF #2 & BTR	EA	12.78	894.60
54	CDXF4812	20	4 X 8 X 1/2 CDX FIR 4PLY	SH	23.48	469.60
55	34OSB	82	4X8 X 3/4 T&G OSB	SH	24.46	2005.72
56	SPR2816	20	2 X 8 X 16 K/D SPR #2 & BTR	EA	15.42	308.40
57	SPR288	120	2 X 8 X 8 K/D SPR #2 & BTR	EA	7.73	927.60
58	CDXF4812	25	4 X 8 X 1/2 CDX FIR 4PLY	SH	23.48	587.00
59	SPR21014	12	2 X 10 X 14 K/D SPF #2 & BTR	EA	17.68	212.16
60	34OSB	14	4X8 X 3/4 T&G OSB	SH	24.46	342.44

This Quotation is valid thru 4/18/2018. After that it is subject to review by Jackson Lumber and Millwork. Special Order and Manufactured merchandise is Non-Returnable.

Amount:	74,745.37
Tax:	4,671.59 *
Total:	79,416.96 *
Paid:	0.00
Due:	79,416.96

Jackson LUMBER & MILLWORK

Quote

215 Market Street	10 Industrial Drive	67 Haverhill Rd	10 Jefferson Ave
Lawrence, MA 01843	Raymond, NH 03077	Amesbury, MA 01913	Woburn, MA 01801
Phone: (978) 686-4141	Phone: (603) 895-5151	Phone: (978)-388-0366	Phone: (781)-933-0057

Billing Fax: 978-687-5841

Transaction # 242749
Price Date 02/16/2018
Location LAWRENCE
Sales Representative JOHN HANCOCK

MAIL TO: Jackson Lumber & Millwork Co. Inc.
PO Box 449, Lawrence, MA 01842

Bill To:
NICK MONAHAN
** CASH ACCOUNT **
554 WASHINGTON STREET (617)406-8700
DEDHAM, MA 02026

Ship To:
7OL 7 OAKMONT LANE
BELMONT, MA 02178

Customer #	Quote #	Quote Date	Oper	Purchase Order	Terms	Ship Via
64010	242749	02/16/2018	057		CASH	UNKNOWN TBD

LN#	Item Number	Ordered	Description	UM	Price/Unit	Extension
61	ACQ2416	8	2X4X16 #1 GC TREATED W/WAX	EA	12.87	102.96
62	SPR2416	8	2 X 4 X 16 K/D SPR #2&BTR	EA	7.48	59.84
63	SPR248	100	2 X 4 X 8 K/D SPR STUD	EA	2.99	299.00
64	FLRTRUSS	1	1ST FLOOR TRUSS PACK 7D QUOTE # 27577	EA	6,541.64	6541.64
65	FLRTRUSS	1	2ND FLOOR TRUSS PACK 7D QUOTE # 27577	EA	12,419.31	12419.31
66	RFTRUSS	1	ROOF TRUSS PACK 7D QUOTE # 27577	EA	15,704.67	15704.67
67	RFTRUSS	1	UPPER ROOF TRUSS PACK 7D QUOTE # 27577	EA	933.45	933.45
68	D	1	2X12 CHANGE GROUND FLOOR	EA		0.00
69	SPR21218	30	2 X 12 X 18 KD SPF/DF #2&BTR	EA	34.47	1034.10
70	SPR21216	25	2 X 12 X 16 KD SPR/DF #2&BTR	EA	29.53	738.25
71	SPR21214	12	2 X 12 X 14 KD SPR/DF #2&BTR	EA	25.93	311.16
72	SPR21212	15	2 X 12 X 12 KD SPF/DF #2&BTR	EA	22.27	334.05
73	SPR21210	28	2 X 12 X 10 KD SPF/DF #2&BTR	EA	18.48	517.44
74	D	1	2X12 CHANGE 2ND FLOOR	EA		0.00
75	SPR21218	27	2 X 12 X 18 KD SPF/DF #2&BTR	EA	34.47	930.69
76	SPR21216	35	2 X 12 X 16 KD SPR/DF #2&BTR	EA	29.53	1033.55
77	SPR21212	11	2 X 12 X 12 KD SPF/DF #2&BTR	EA	22.27	244.97

This Quotation is valid thru 4/18/2018. After that it is subject to review by Jackson Lumber and Millwork. Special Order and Manufactured merchandise is Non-Returnable.

Amount:	74,745.37
Tax:	4,671.59 *
Total:	79,416.96 *
Paid:	0.00
Due:	79,416.96

Jackson LUMBER & MILLWORK

Quote

215 Market Street	10 Industrial Drive	67 Haverhill Rd	10 Jefferson Ave
Lawrence, MA 01843	Raymond, NH 03077	Amesbury, MA 01913	Woburn, MA 01801
Phone: (978) 686-4141	Phone: (603) 895-5151	Phone: (978)-388-0366	Phone: (781)-933-0057

Billing Fax: 978-687-5841

Transaction # 242749
Price Date 02/16/2018
Location LAWRENCE
Sales Representative JOHN HANCOCK

MAIL TO: Jackson Lumber & Millwork Co. Inc.
PO Box 449, Lawrence, MA 01842

Bill To:
NICK MONAHAN
** CASH ACCOUNT **
554 WASHINGTON STREET (617)406-8700
DEDHAM, MA 02026

Ship To:
7OL 7 OAKMONT LANE
BELMONT, MA 02178

Customer #	Quote #	Quote Date	Oper	Purchase Order	Terms	Ship Via
64010	242749	02/16/2018	057		CASH	UNKNOWN TBD

LN#	Item Number	Ordered	Description	UM	Price/Unit	Extension
78	SPR21210	2	2 X 12 X 10 KD SPF/DF #2&BTR	EA	18.48	36.96

This Quotation is valid thru 4/18/2018. After that it is subject to review by Jackson Lumber and Millwork. Special Order and Manufactured merchandise is Non-Returnable.

Amount:	74,745.37
Tax:	4,671.59 *
Total:	79,416.96 *
Paid:	0.00
Due:	79,416.96

THE NATIONAL LUMBER FAMILY OF COMPANIES:

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber · Reliable Truss · Kitchen Views · National Millwork · Pro Insulators · Oxford Lumber · Babel's

QUOTE # 23119

Page # 1

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

We are pleased to be able to quote the following items for your use at the designated location. This quote is valid for fourteen (14) days. Substantial shipping must commence within twenty-one (21) days. Each shipment allows up to 4 hours, round trip, freight included. Quote is valid for shipments taking place within sixty (60) days from quotation date. This quote is an estimate.

Line	Pieces	Product	Description			Piece Price	Extension
001	10	420608	2X6X08 KD SPF/HF STUD			5.480	54.80
002	60	420608	2X6X08 KD SPF/HF STUD			5.480	328.80
003	4	520416	PT 2X4X16 #1 SYP			10.656	42.96
004	4	420416	2X4X16 #2+BTR KD SPF			7.627	30.75
005	10	421010	2X10X10 #2+BTR KD SPF/HF/DF			10.817	108.38
006	12	000143	ZIP SYSTEM 7/16" 4X8 WALL			25.888	310.66
			SHEATHING				
007	2	000139	ZIP SYSTEM TAPE 3.75"X90'			24.850	49.70
008	8	OCSILL	SILL SEAL 50LF 1/4" X 5-1/2"			4.990	39.92
009	24	520816	PT 2X8X16 #1 SYP			17.600	422.40
010	24	420816	2X8X16 #2+BTR KD SPF/HF/DF			13.973	335.36
011			1ST FLOOR SYSTEM				
012			----------				
013			PRECISION END TRIM FL SYSTEM				
			PLEASE ALLOW 48HR FOR DELIVERY				
			ON ALL EWP I-JOIST PACKAGES				
014	1348	0FLOOR	RAPID FRAME PREAPPLIED GLUE LF			.165	222.42
			BASED ON MANUFACTURERS				
			RECOMMENDED 3/8" CONT BEAD.				
015			1ST FLOOR BLOCKING				
016			----------				
017	23	B912B2	BCI 90 3.5" X 11.88" X B24			8.900	204.70
			THIS LENGTH IS NON-RETURNABLE				
018	2	B914B2	BCI 90 3.5" X 14" X B24			9.500	19.00
			THIS LENGTH IS NON-RETURNABLE				
019							
020			1ST FLOOR EWP HARDWARE				
021			----------				
022	4	0LUS26	LUS26 HANGER (DBL SHEAR)			1.310	5.24
			100PCS/BOX				
023	3	ITS412	ITS3.56/11.88			6.490	19.47
024	4	F3514T	IUS3.56/14 DBL FM W/TAB			5.890	23.56
025	4	F3510M	HHUS410 FM MED HVY 3-1/2			11.110	44.44
026	90	F3512T	IUS3.56/11.88 SNG.FM W/TAB			4.950	445.50
027							

This Quote expires on Feb.07/18

... Continue ...

*** Thank You ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE # 23119

Page # 2

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
028			1ST FLOOR FLUSH BEAMS				
029			----------				
030	5	LV1210	LVL 11.875" X 1.75" X 10'			54.500	272.50
031	2	LV1213	LVL 11.875" X 1.75" X 13'			70.850	141.70
032	4	LV1215	LVL 11.875" X 1.75" X 15'			81.750	327.00
033	6	LV1621	LVL 16" X 1.75" X 21'			163.590	981.54
034	3	LV1420	LVL 14" X 1.75" X 20'			139.800	419.40
035	3	LV1421	LVL 14" X 1.75" X 21'			146.790	440.37
036							
037			1ST FLOOR JOISTS				
038			----------				
039	1	B91203	BCI 90 3.5" X 11.88" X 03'			13.350	13.35
040	5	B91205	BCI 90 3.5" X 11.88" X 05'			22.250	111.25
041	1	B91206	BCI 90 3.5" X 11.88" X 06'			26.700	26.70
042	1	B91207	BCI 90 3.5" X 11.88" X 07'			31.150	31.15
043	18	B91210	BCI 90 3.5" X 11.88" X 10'			44.500	801.00
044	5	B91212	BCI 90 3.5" X 11.88" X 12'			53.400	267.00
045	7	B91213	BCI 90 3.5" X 11.88" X 13'			57.850	404.95
046	18	B91215	BCI 90 3.5" X 11.88" X 15'			66.750	1201.50
047	1	B91216	BCI 90 3.5" X 11.88" X 16'			71.200	71.20
048	20	B91217	BCI 90 3.5" X 11.88" X 17'			75.650	1513.00
049	14	B91425	BCI 90 3.5" X 14" X 25'			118.750	1662.50
050							
051			1ST FLOOR RIM BOARD				
052			----------				
053	7	FS1412	1.125"X14"X12' OSB RIM			28.320	198.24
054	16	FS1212	1.125"X11.875"X12' OSB RIM			23.880	382.08
055	17	521010	PT 2X10X10 #1 SYP			15.817	269.52
056	3	521020	PT 2X10X20 #1 SYP			38.500	115.50
057	1	540608	PT 4X6X8 #2 SYP			15.984	15.98
058	2	ABA46Z	ABA46Z ADJ POST BASE Z-MAX			18.810	37.62
059	2	004130	MF 04130 WEDGE ANCH 1/2X5 1/2			3.320	6.64
060	17	0210HZ	LUS210Z 2X10-14 JOIST H Z-MAX			1.980	33.66
061	92	0000DG	DRYGUARD 4X8 23/32 T&G			29.920	2752.64
			GEORGIA PACIFIC PREMIUM OSB				
062	12	ABM500	CONSTRUCTION ADHESIVE 28OZ VOC			4.990	59.88
			COMPLIANT				
063	25	420820	2X8X20 #2+BTR KD SPF/HF/DF			19.707	492.91
064	400	420810	2X8X10 #2+BTR KD SPF/HF/DF			8.920	3568.45
065	80	420816	2X8X16 #2+BTR KD SPF/HF/DF			13.973	1118.09

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE #

23119

Page # 3

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
066	240	420409	2X4X104 5/8"(8'8 5/8")KD SPF			3.393	814.40
067	20	420416	2X4X16 #2+BTR KD SPF			7.627	153.01
068	100	000143	ZIP SYSTEM 7/16" 4X8 WALL			25.888	2588.80
			SHEATHING				
069	17	000139	ZIP SYSTEM TAPE 3.75"X90'			24.850	422.45
070	20	0108RS	1X8X16' ROUGH SPRUCE LEDGER			7.669	153.87
071	20	421014	2X10X14 #2+BTR KD SPF/HF/DF			15.983	319.90
072	6	IA8000	INSULATION RIGID SE 1X4X8 R5			19.968	119.81
073							
074			2ND FLOOR SYSTEM				
075			----------				
076			PRECISION END TRIM FL SYSTEM				
			PLEASE ALLOW 48HR FOR DELIVERY				
			ON ALL EWP I-JOIST PACKAGES				
077	1004	0FLOOR	RAPID FRAME PREAPPLIED GLUE LF			.165	165.66
			BASED ON MANUFACTURERS				
			RECOMMENDED 3/8" CONT BEAD.				
078			2ND FLOOR BLOCKING				
079			----------				
080	34	B912B2	BCI 90 3.5" X 11.88" X B24			8.900	302.60
			THIS LENGTH IS NON-RETURNABLE				
081	12	B914B2	BCI 90 3.5" X 14" X B24			9.500	114.00
			THIS LENGTH IS NON-RETURNABLE				
082							
083			2ND FLOOR EWP HARDWARE				
084			----------				
085	1	HUC412	HUC412 FM CONCEALED HANGER			15.890	15.89
086	18	T2514S	ITS2.56/14 TF			6.230	112.14
087	18	0210HZ	LUS210Z 2X10-14 JOIST H Z-MAX			1.980	35.64
088	6	ITS412	ITS3.56/11.88			6.490	38.94
089	32	F3514T	IUS3.56/14 DBL FM W/TAB			5.890	188.48
090	4	ITS414	ITS3.56/14 TF			7.260	29.04
091	7	0TMU28	LSSU28 ADJ SLOPE/SKEW			14.780	103.46
092	1	0HU616	* HU616 FM HANGER			34.530	34.53
093	82	0LUS28	LUS28 2X8/10 FM HANGER			1.430	117.26
094	1	LSSU21	LSSU210-2 ADJ SKEW & SLOPE			20.850	20.85
095	4	F5510M	HHUS5.50/10 FM MED TRIPLE			25.040	100.16
096	4	F3512T	IUS3.56/11.88 SNG.FM W/TAB			4.950	19.80
097	1	SW634S	SDW 6-3/4" EWP-PLY SCREW 50CT			76.860	76.86
098							

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE # 23119

Page # 4

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
099			2ND FLOOR FLUSH BEAMS				
100			----------				
101	3	LV1621	LVL 16" X 1.75" X 21'			163.590	490.77
102	11	LV1630	LVL 16" X 1.75" X 30'			233.700	2570.70
103	2	LV1409	LVL 14" X 1.75" X 9'			62.910	125.82
104	4	LV1410	LVL 14" X 1.75" X 10'			69.900	279.60
105	3	LV1413	LVL 14" X 1.75" X 13'			90.870	272.61
106	4	LV1417	LVL 14" X 1.75" X 17'			118.830	475.32
107	6	LV1421	LVL 14" X 1.75" X 21'			146.790	880.74
108	12	LV1426	LVL 14" X 1.75" X 26'			181.740	2180.88
109							
110			2ND FLOOR JOISTS				
111			----------				
112	6	B91203	BCI 90 3.5" X 11.88" X 03'			13.350	80.10
113	1	B91205	BCI 90 3.5" X 11.88" X 05'			22.250	22.25
114	1	B91207	BCI 90 3.5" X 11.88" X 07'			31.150	31.15
115	1	B91208	BCI 90 3.5" X 11.88" X 08'			35.600	35.60
116	7	B91216	BCI 90 3.5" X 11.88" X 16'			71.200	498.40
117	14	B91218	BCI 90 3.5" X 11.88" X 18'			80.100	1121.40
118	3	B91404	BCI 90 3.5" X 14" X 04'			19.000	57.00
119	6	B91405	BCI 90 3.5" X 14" X 05'			23.750	142.50
120	1	B91410	BCI 90 3.5" X 14" X 10'			47.500	47.50
121	15	B91415	BCI 90 3.5" X 14" X 15'			71.250	1068.75
122	13	B91425	BCI 90 3.5" X 14" X 25'			118.750	1543.75
123	2	LV1425	LVL 14" X 1.75" X 25'			174.750	349.50
124							
125			2ND FLOOR RIM BOARD				
126			----------				
127	1	LV1202	LVL 11.875" X 1.75" X 02'			10.900	10.90
			THIS LENGTH IS NON-RETURNABLE				
128	1	LV1203	LVL 11.875" X 1.75" X 3'			16.350	16.35
			THIS LENGTH IS NON-RETURNABLE				
129	1	LV1207	LVL 11.875" X 1.75" X 7'			38.150	38.15
			THIS LENGTH IS NON-RETURNABLE				
130	2	LV1211	LVL 11.875" X 1.75" X 11'			59.950	119.90
131	11	FS1412	1.125"X14"X12' OSB RIM			28.320	311.52
132	3	FS1212	1.125"X11.875"X12' OSB RIM			23.880	71.64
133							
134			2ND WALL SYSTEM				
135			----------				

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber · Reliable Truss · Kitchen Views · National Millwork · Pro Insulators · Oxford Lumber · Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE #

23119

Page # 5

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
136							
137			DROPPED BEAMS				
138			----------				
139	3	LV1213	LVL 11.875" X 1.75" X 13'			70.850	212.55
140	2	LV1221	LVL 11.875" X 1.75" X 21'			114.450	228.90
141	3	LV1233	LVL 11.875" X 1.75" X 33'			179.850	539.55
142	4	LV1621	LVL 16" X 1.75" X 21'			163.590	654.36
143	9	LV0710	LVL 7.25" X 1.75" X 10'			36.500	328.50
144	2	LV1413	LVL 14" X 1.75" X 13'			90.870	181.74
145	54	421012	2X10X12 #2+BTR KD SPF/HF/DF			13.900	750.60
146	54	LUS210	LUS210 FM 2X10/14 HANGER			1.570	84.78
147	17	521010	PT 2X10X10 #1 SYP			15.817	269.52
148	3	521020	PT 2X10X20 #1 SYP			38.500	115.50
149	17	0210HZ	LUS210Z 2X10-14 JOIST H Z-MAX			1.980	33.66
150	100	0000DG	DRYGUARD 4X8 23/32 T&G			29.920	2992.00
			GEORGIA PACIFIC PREMIUM OSB				
151	12	ABM500	CONSTRUCTION ADHESIVE 28OZ VOC			4.990	59.88
			COMPLIANT				
152	18	421212	2X12X12 #2+BTR KD SPF/HF/DF			22.776	409.97
153			EWP COLUMNS				
154			----------				
155	2	160608	6X6X08 #2+BTR DOUG FIR			54.960	109.92
			MAY DEVELOP NON-STRUCTURAL				
			SURFACE CRACKS				
156	1	140610	4X6X10 #2+BTR DOUG FIR			29.900	29.90
			MAY DEVELOP NON-STRUCTURAL				
			SURFACE CRACKS				
157	4	V60607	VLAM 5.25" X 5.25" X 07'			82.950	331.80
			THIS LENGTH IS NON-RETURNABLE				
158	11	V60610	VLAM 5.25" X 5.25" X 10'			118.500	1303.50
159	1	V70708	* VLAM 7" X 7" X 08'			210.000	210.00
160	4	V70709	* VLAM 7" X 7" X 09'			236.250	945.00
161	3	V70710	* VLAM 7" X 7" X 10'			262.500	787.50
162							
163			EXT. WALL HEADERS				
164			----------				
165	1	LV1208	LVL 11.875" X 1.75" X 8'			43.600	43.60
166	9	LV0708	LVL 7.25" X 1.75" X 8'			29.200	262.80
167	3	LV1408	LVL 14" X 1.75" X 8'			55.920	167.76
168	1	LV1414	LVL 14" X 1.75" X 14'			97.860	97.86

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

NATIONAL LUMBER | RELIABLE TRUSS | KITCHEN VIEWS | NATIONAL MILLWORK | PRO INSULATORS | OXFORD LUMBER | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE # 23119

Page # 6

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
169							
170	380	420808	2X8X08 #2+BTR KD SPF/HF/DF			6.923	2631.05
171	40	420816	2X8X16 #2+BTR KD SPF/HF/DF			13.973	559.37
172	340	420492	2X4X92 5/8" KD SPF/HF STUD			2.960	1006.77
173	30	420416	2X4X16 #2+BTR KD SPF			7.627	228.80
174	6	421014	2X10X14 #2+BTR KD SPF/HF/DF			15.983	95.90
175	70	000143	ZIP SYSTEM 7/16" 4X8 WALL			25.888	1812.16
			SHEATHING				
176	12	000139	ZIP SYSTEM TAPE 3.75"X90'			24.850	298.20
177			LOAD 3				
178	400	910316	1X3X16' KD SPF STRAPPING			3.120	1248.00
179			CLESTORY ROOF				
180			----------				
181							
182			DROPPED BEAMS				
183			----------				
184	9	LV1413	LVL 14" X 1.75" X 13'			90.870	817.83
185							
186			EWP COLUMNS				
187			----------				
188	5	160608	6X6X08 #2+BTR DOUG FIR			54.960	274.80
			MAY DEVELOP NON-STRUCTURAL				
			SURFACE CRACKS				
189							
190			ROOF				
191			----				
192							
193			ROOF BEAMS				
194			----------				
195	5	LV1406	LVL 14" X 1.75" X 6'			41.940	209.70
			THIS LENGTH IS NON-RETURNABLE				
196	4	LV1407	LVL 14" X 1.75" X 7'			48.930	195.72
			THIS LENGTH IS NON-RETURNABLE				
197	3	LV1408	LVL 14" X 1.75" X 8'			55.920	167.76
198	4	LV1409	LVL 14" X 1.75" X 9'			62.910	251.64
199	6	LV1410	LVL 14" X 1.75" X 10'			69.900	419.40
200	1	LV1411	LVL 14" X 1.75" X 11'			76.890	76.89
201	4	LV1412	LVL 14" X 1.75" X 12'			83.880	335.52
202	3	LV1413	LVL 14" X 1.75" X 13'			90.870	272.61
203	8	LV1414	LVL 14" X 1.75" X 14'			97.860	782.88

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE # 23119

Page # 7

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
204	4	LV1415	LVL 14" X 1.75" X 15'			104.850	419.40
205	3	LV1416	LVL 14" X 1.75" X 16'			111.840	335.52
206	5	LV1417	LVL 14" X 1.75" X 17'			118.830	594.15
207	6	LV1419	LVL 14" X 1.75" X 19'			132.810	796.86
208	5	LV1420	LVL 14" X 1.75" X 20'			139.800	699.00
209	8	LV1425	LVL 14" X 1.75" X 25'			174.750	1398.00
210	2	LV1426	LVL 14" X 1.75" X 26'			181.740	363.48
211	3	LV1429	LVL 14" X 1.75" X 29'			202.710	608.13
212	3	LV1433	LVL 14" X 1.75" X 33'			230.670	692.01
213							
214			ROOF EWP COLUMNS				
215			----------				
216	3	V60709	VLAM 5.25" X 7" X 09'			143.550	430.65
217	9	V60607	VLAM 5.25" X 5.25" X 07'			82.950	746.55
			THIS LENGTH IS NON-RETURNABLE				
218	7	V60609	VLAM 5.25" X 5.25" X 09'			106.650	746.55
219							
220			ROOF EWP HARDWARE				
221			----------				
222	4	F1709M	HUS1.81/10 SGL. FM 5170#			11.110	44.44
223	18	LBV114	* LBV1.81/14 TF			21.110	379.98
224	20	SUR410	* SUR410 FM SKEWED RIGHT 45			24.440	488.80
225	18	00210R	SUR210 2X10 45 RIGHT SKEW			14.950	269.10
226	12	TMU175	LSSUI25 ADJ SLOPE/SKEW			14.530	174.36
227	55	F3514T	IUS3.56/14 DBL FM W/TAB			5.890	323.95
228	5	F1710T	* IUS1.81/9.5 FM W TOP TAB			3.580	17.90
229	6	F3510M	HHUS410 FM MED HVY 3-1/2			11.110	66.66
230	20	SUL410	* SUL410 FM SKEWED LEFT 45			24.440	488.80
231	154	0LUS28	LUS28 2X8/10 FM HANGER			1.430	220.22
232	1	F5510M	HHUS5.50/10 FM MED TRIPLE			25.040	25.04
233			Unusable (F1714T) Below				
234	5	F1714T	IUS1.81/14 FM W/TOP TAB			3.950	19.75
235	20	00210L	SUL210 2X10 45 LEFT SKEW			14.950	299.00
236	2	F3510T	IUS3.56/9.5 DBL FM W/TAB			4.690	9.38
237							
238			ROOF RAFTERS				
239			----------				
240	4	B91401	BCI 90 3.5" X 14" X 01'			4.750	19.00
241	4	B91402	BCI 90 3.5" X 14" X 02'			9.500	38.00
242	5	B91403	BCI 90 3.5" X 14" X 03'			14.250	71.25

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

QUOTE #

23119

Page # 8

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
243	5	B91404	BCI 90 3.5" X 14" X 04'			19.000	95.00
244	5	B91405	BCI 90 3.5" X 14" X 05'			23.750	118.75
245	7	B91406	BCI 90 3.5" X 14" X 06'			28.500	199.50
246	3	B91407	BCI 90 3.5" X 14" X 07'			33.250	99.75
247	8	B91408	BCI 90 3.5" X 14" X 08'			38.000	304.00
248	14	B91409	BCI 90 3.5" X 14" X 09'			42.750	598.50
249	6	B91410	BCI 90 3.5" X 14" X 10'			47.500	285.00
250	6	B91415	BCI 90 3.5" X 14" X 15'			71.250	427.50
251	14	B91416	BCI 90 3.5" X 14" X 16'			76.000	1064.00
252							
253	32	421008	2X10X08 #2+BTR KD SPF/HF/DF			8.733	279.69
254	30	421010	2X10X10 #2+BTR KD SPF/HF/DF			10.817	324.50
255	150	LUS210	LUS210 FM 2X10/14 HANGER			1.570	235.50
256	70	421008	2X10X08 #2+BTR KD SPF/HF/DF			8.733	611.77
257	20	000138	ZIP SYSTEM 1/2" ROOF/WALL			29.920	598.40
			COMBO PANEL				
258	3	000139	ZIP SYSTEM TAPE 3.75"X90'			24.850	74.55
259	82	0000DG	DRYGUARD 4X8 23/32 T&G			29.920	2453.44
			GEORGIA PACIFIC PREMIUM OSB				
260	20	420816	2X8X16 #2+BTR KD SPF/HF/DF			13.973	279.69
261	120	420808	2X8X08 #2+BTR KD SPF/HF/DF			6.923	830.72
262	25	000143	ZIP SYSTEM 7/16" 4X8 WALL			25.888	647.20
			SHEATHING				
263	4	000139	ZIP SYSTEM TAPE 3.75"X90'			24.850	99.40
264	12	421014	2X10X14 #2+BTR KD SPF/HF/DF			15.983	191.80
265	14	0000DG	DRYGUARD 4X8 23/32 T&G			29.920	418.88
			GEORGIA PACIFIC PREMIUM OSB				
266							
267			BASEMENT				
268	8	520416	PT 2X4X16 #1 SYP			10.656	85.91
269	8	420416	2X4X16 #2+BTR KD SPF			7.627	61.49
270	100	420408	2X4X08 KD SPF STUD			2.960	296.37
271							
272			ROOF IS FLAT RUBBER				
273			NEED TO CONFIRM KNEE WALL				
274			2X8 EXT.WALL STUDS CONFIRM				
275			CEILING HEIGHTS.. 2X4 INTER				
276			WALLS. USING ALL ZIP WALL				
277			SHEATHIGN W/DRYGUARD T&G				
278			NO TRIM NO SIDING NO RUBBER				

This Quote expires on Feb.07/18

... Continue ...

*** *Thank You* ***

THE NATIONAL LUMBER FAMILY OF COMPANIES

National Lumber | Reliable Truss | Kitchen Views | National Millwork | Pro Insulators | Oxford Lumber | Babel's

QUOTE # 23119

Page # 9

Quote Date	Quote Expires
Jan.24/18	Feb.07/18

Customer PO#

Remarks:

NATIONAL LUMBER
71 Maple St
Mansfield MA 02048
(508)339-8020 fax (508)339-3856

Re-Print

180124Q23119

Printed on Jan.24/18 3:29 PM
by aohaire on TSL
(M) MANSFIELD
Approvals Required:N

Bill to: HAVEN BUILDERS LLC
7 OAKMONT LANE
554 WASHINGTON ST
DEDHAM MA 02026

Ship to:
7 OAKMONT LANE
GPS: 47 GREENSBROOK WAY
BELMONT MA 02478

Customer #	Outside Salesman	Inside Salesman	Special Sales Person	Quote entered by	Project Type
6034610-09	ROB HARRIS	ALAN J. O'HAIRE	N/A	ALAN J OHAIRE	( )

Line	Pieces	Product	Description			Piece Price	Extension
279			ROOFING NO STANDING SEAM METAL				
280			ROOFING NO NASILS OR DECKING				
This Quote expires on Feb.07/18						SUBTOTAL:	$83,639.12
*** Thank You ***						MA Tax of 6.25%	$5,227.54
						TOTAL:	$88,866.66

RIVERHEAD BUILDING SUPPLY:

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™
Estimating Department
www.rbscorp.com
Phone: (401) 541-7400 — Fax: (401) 884-9966
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc
Q#k0210

Estimate Number: 83875
Estimate Date: 01/25/18

LN #	QTY	U/M	Description	Price	Extension
1	10	EA	2X6X8 SPF KD #2&BTR	5.430	54.30
2	60	EA	2X6X8 SPF KD #2&BTR	5.430	325.80
3	4	EA	2X4X16 #1 PRESSURE TREATED MCA	10.380	41.52
4	4	EA	2X4X16 SPF KD #2&BTR	7.930	31.72
5	10	EA	2X10X10 SPF KD #2&BTR	11.490	114.90
6	12	EA	4X8X1/2 CDX FIR PLYWOOD	21.330	255.96
7	8	RLL	ROLL 50' 5-1/2" STYRO SILL SEAL	3.990	31.92
8	24	EA	2X8X16 #1 PRESSURE TREATED MCA	16.140	387.36
9	24	EA	2X8X16 SPF KD #2&BTR	15.730	377.52
10			----------		
11			1ST FLOOR BLOCKING		
12	46	LFT	LFT 11-7/8 TJI 560 I-JOIST	4.460	205.16
13			TALLY: 23/2		
14	4	LFT	14" TJI 560 I-JOIST	4.750	19.00
15			TALLY: 2/2		
16			----------		
17	4	EA	ZMAX ACQ 2X6 SGL HNGR	1.050	4.20
18	3	EA	TM 11-7/8 TJI 560 SGL HANGER	4.550	13.65
19	4	EA	FM 14" TJI 560 SINGLE HANGER	3.990	15.96
20	4	EA	FM 9.5" MD ML DBL HANGER	8.550	34.20
21	90	EA	FM 11-7/8" TJI 560 SGL HANGER	4.050	364.50
22			----------		
23			FIRST FLOOR FLUSH BEAMS		
24	5	EA	1-3/4 X 11-7/8 X 10 LVL	48.200	241.00
25	2	EA	1-3/4 X 11-7/8 X 14 LVL	67.480	134.96
26	4	EA	1-3/4 X 11-7/8 X 16 LVL	77.120	308.48
27	6	EA	1-3/4 X 16 X 22 LVL	152.900	917.40
28	3	EA	1-3/4 X 14 X 20 LVL	120.600	361.80
29	3	EA	1-3/4 X 14 X 22 LVL	132.660	397.98
30			----------		
31			FIRST FLOOR JOISTS		
32	41	LFT	LFT 11-7/8 TJI 560 I-JOIST	4.460	182.86
33			TALLY: 1/3 5/5 1/6 1/7		
34	9	EA	11-7/8 X 20 TJI 560 I-JOIST	89.200	802.80
35			TO BE CUT FOR 10'S		
36	5	EA	11-7/8 X 12 TJI 560 I-JOIST	53.520	267.60
37	7	EA	11-7/8 X 14 TJI 560 I-JOIST	62.440	437.08
38	19	EA	11-7/8 X 16 TJI 560 I-JOIST	71.360	1,355.84
39	20	EA	11-7/8 X 18 TJI 560 I-JOIST	80.280	1,605.60
40	14	EA	14 X 26 TJI 560 I-JOIST	123.500	1,729.00
41			----------		
42			1ST FLOOR RIM		
43	12	EA	11-7/8" X 16' TIMBERSTRAND	43.350	520.20
44	6	EA	14" X 16' TIMBERSTRAND	50.900	305.40
45	17	EA	2X10X10 PRESSURE TREATED MCA	13.060	222.02
46	3	EA	2X10X20 PRESSURE TREATED MCA	30.860	92.58
47	1	EA	4X6X8 #2 PRESSURE TREATED S4S	15.050	15.05
48	2	EA	ABA46Z 4X6 POST BASE ZMAX	16.890	33.78
49	2	EA	1/2X5-1/2 WEDGE ANCHOR	2.150	4.30
50	17	EA	ZMAX ACQ 2X10 SGL HNGR	1.430	24.31

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™
Estimating Department
www.rbscorp.com
Phone: (401) 541-7400 — Fax: (401) 884-9966
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc
Q#k0210

Estimate Number: 83875
Estimate Date: 01/25/18

LN #	QTY	U/M	Description	Price	Extension
51	92	EA	4X8X3/4 TG EDGE GOLD OSB	29.970	2,757.24
52	12	EA	PL400 CONST ADHESIVE 28OZ -	4.920	59.04
53	25	EA	2X8X20 SPF KD #2&BTR	21.710	542.75
54	400	EA	2X8X10 SPF KD #2&BTR	9.990	3,996.00
55	80	EA	2X8X16 SPF KD #2&BTR	15.730	1,258.40
56	240	EA	2X4X104-5/8 SPF KD PRECUT	3.500	840.00
57	20	EA	2X4X16 SPF KD #2&BTR	7.930	158.60
58	100	EA	4X8X1/2 CDX FIR PLYWOOD	21.330	2,133.00
59	20	EA	1X8X16 ROUGH SPRUCE	10.970	219.40
60	20	EA	2X10X14 SPF KD #2&BTR	16.080	321.60
61	6	EA	4X8X1" T&G STYROFOAM PSI 25	24.380	146.28
62			----------		
63			SECOND FLOOR BLOCKING		
64	68	LFT	LFT 11-7/8 TJI 560 I-JOIST	4.460	303.28
65			TALLY: 34/2		
66	24	LFT	14" TJI 560 I-JOIST	4.750	114.00
67			TALLY: 12/2		
68			----------		
69			2ND FLOOR EWP HARDWARE		
70	1	EA	DBL LVL CONCEALED FLANGE HANGER	10.490	10.49
71	18	EA	TM 14" TJI 230/360 SGL HANGER	4.390	79.02
72	18	EA	ZMAX ACQ 2X10 SGL HNGR	1.430	25.74
73	6	EA	TM 11-7/8 TJI 560 SGL HANGER	4.550	27.30
74	32	EA	FM 14" TJI 560 SINGLE HANGER	3.990	127.68
75	4	EA	TM 14" TJI 560 SGL HANGER	5.470	21.88
76	7	EA	LSSU28 SLOPED SKEWED HANGER	10.990	76.93
77	1	EA	HU6X6 FM	34.530	34.53
78	1	EA	LSSU210	20.850	20.85
79	4	EA	FM 11-7/8" TJI 560 SGL HANGER	4.050	16.20
80	1	EA	6-3/4" INT FLUSH LVL SCREW 50PC	47.190	47.19
81			----------		
82			2ND FLOOR FLUSH BEAM		
83	3	EA	1-3/4 X 16 X 22 LVL	152.900	458.70
84	11	EA	1-3/4 X 16 X 30 LVL	208.500	2,293.50
85	6	EA	1-3/4 X 14 X 10 LVL	60.300	361.80
86	3	EA	1-3/4 X 14 X 14 LVL	84.420	253.26
87	4	EA	1-3/4 X 14 X 18 LVL	108.540	434.16
88	6	EA	1-3/4 X 14 X 22 LVL	132.660	795.96
89	12	EA	1-3/4 X 14 X 26 LVL	156.780	1,881.36
90			----------		
91			2ND FLOOR JOISTS		
92	38	LFT	LFT 11-7/8 TJI 560 I-JOIST	4.460	169.48
93			TALLY: 6/3 1/5 1/7 1/8		
94	7	EA	11-7/8 X 16 TJI 560 I-JOIST	71.360	499.52
95	14	EA	11-7/8 X 18 TJI 560 I-JOIST	80.280	1,123.92
96	52	LFT	14" TJI 560 I-JOIST	4.750	247.00
97			TALLY: 3/4 6/5 1/10		
98	15	EA	14 X 16 TJI 560 I-JOIST	76.000	1,140.00
99	13	EA	14 X 26 TJI 560 I-JOIST	123.500	1,605.50
100	2	EA	1-3/4 X 14 X 26 LVL	156.780	313.56

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™
Estimating Department
www.rbscorp.com
Phone: (401) 541-7400 — Fax: (401) 884-9966
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc
Q#k0210

Estimate Number: 83875
Estimate Date: 01/25/18

LN #	QTY	U/M	Description		Price	Extension
101			----------			
102			2ND FLOOR RIM			
103	3	EA	1-3/4 X 11-7/8 X 12 LVL		57.840	173.52
104	9	EA	14" X 16' TIMBERSTRAND		50.900	458.10
105	3	EA	11-7/8" X 16' TIMBERSTRAND		43.350	130.05
106			----------			
107			SECOND FLOOR WALLS			
108	3	EA	1-3/4 X 11-7/8 X 14 LVL		67.480	202.44
109	2	EA	1-3/4 X 11-7/8 X 22 LVL		106.040	212.08
110	3	EA	1-3/4 X 11-7/8 X 34 LVL		163.880	491.64
111	4	EA	1-3/4 X 16 X 22 LVL		152.900	611.60
112	9	EA	1-3/4 X 7-1/4 X 10 LVL		32.200	289.80
113	2	EA	1-3/4 X 14 X 14 LVL		84.420	168.84
114	54	EA	2X10X12 SPF KD #2&BTR		13.790	744.66
115	54	EA	ZMAX ACQ 2X10 SGL HNGR		1.430	77.22
116	17	EA	2X10X10 PRESSURE TREATED MCA		13.060	222.02
117	3	EA	2X10X20 PRESSURE TREATED MCA		30.860	92.58
118	17	EA	ZMAX ACQ 2X10 SGL HNGR		1.430	24.31
119	100	EA	4X8X3/4 TG EDGE GOLD OSB		29.970	2,997.00
120	12	EA	PL400 CONST ADHESIVE 28OZ	-	4.920	59.04
121	18	EA	2X10X12 SPF KD #2&BTR		13.790	248.22
122			----------			
123			EWP COLUMNS			
124	2	EA	5-1/4 X 5-1/4 X 10' PARALLAM		107.400	214.80
125	1	EA	3-1/2 X 5-1/4 X 10' PARALLAM		72.700	72.70
126	15	EA	5-1/4 X 5-1/4 X 10' PARALLAM		107.400	1,611.00
127	74	LFT	*NS 7" X 7" PARALLAM		18.320	1,355.68
128			TALLY: 1/8 4/9 3/10			
129			----------			
130			EXTERIOR WALL HEADERS			
131	1	EA	1-3/4 X 11-7/8 X 8 LVL		38.560	38.56
132	9	EA	1-3/4 X 7-1/4 X 8 LVL		25.760	231.84
133	3	EA	1-3/4 X 14 X 8 LVL		48.240	144.72
134	1	EA	1-3/4 X 14 X 14 LVL		84.420	84.42
135	380	EA	2X8X8 SPF KD #2&BTR		7.970	3,028.60
136	40	EA	2X8X16 SPF KD #2&BTR		15.730	629.20
137	340	EA	2X4X92-5/8 SPF KD PRECUT		2.990	1,016.60
138	30	EA	2X4X16 SPF KD #2&BTR		7.930	237.90
139	6	EA	2X10X14 SPF KD #2&BTR		16.080	96.48
140	70	EA	4X8X1/2 CDX FIR PLYWOOD		21.330	1,493.10
141	400	EA	1X3X16 S4S SPRUCE		3.250	1,300.00
142			----------			
143			CLESTORY ROOF			
144	9	EA	1-3/4 X 14 X 14 LVL		84.420	759.78
145	5	EA	5-1/4 X 5-1/4 X 10' PARALLAM		107.400	537.00
146			----------			
147			ROOF BEAMS			
148	58	LFT	1-3/4 X 14 LVL		6.030	349.74
149			TALLY: 5/6 4/7			
150	3	EA	1-3/4 X 14 X 8 LVL		48.240	144.72

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™
Estimating Department
www.rbscorp.com
Phone: (401) 541-7400 — Fax: (401) 884-9966
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc
Q#k0210

Estimate Number: 83875
Estimate Date: 01/25/18

LN #	QTY	U/M	Description	Price	Extension
151	10	EA	1-3/4 X 14 X 10 LVL	60.300	603.00
152	5	EA	1-3/4 X 14 X 12 LVL	72.360	361.80
153	11	EA	1-3/4 X 14 X 14 LVL	84.420	928.62
154	7	EA	1-3/4 X 14 X 16 LVL	96.480	675.36
155	5	EA	1-3/4 X 14 X 18 LVL	108.540	542.70
156	11	EA	1-3/4 X 14 X 20 LVL	120.600	1,326.60
157	10	EA	1-3/4 X 14 X 26 LVL	156.780	1,567.80
158	3	EA	1-3/4 X 14 X 30 LVL	180.900	542.70
159	3	EA	1-3/4 X 14 X 34 LVL	205.020	615.06
160			----------		
161			ROOF EWP COLUMNS		
162	27	LFT	*NS 5-1/4 X 7" PARALLAM	13.820	373.14
163			TALLY: 3/9		
164	16	EA	5-1/4 X 5-1/4 X 10' PARALLAM	107.400	1,718.40
165			----------		
166			ROOF EWP HARDWARE		
167	4	EA	FM 9.25" ML SGL HANGER	10.190	40.76
168	18	EA	LBV1.81/14 TF	21.110	379.98
169	20	EA	SUR410 FM SKEWED RIGHT 45 DEG	24.440	488.80
170	18	EA	2X10 SGL HNGER 45DEG R	15.990	287.82
171	12	EA	LSSU28 SLOPED SKEWED HANGER	10.990	131.88
172	55	EA	FM 14" TJI 560 SINGLE HANGER	3.990	219.45
173	5	EA	FM 9.25" ML SGL HANGER	10.190	50.95
174	1	EA	FM 9.5" MD ML DBL HANGER	8.550	8.55
175	5	EA	FM 14" - 16" ML SGL HANGER	16.500	82.50
176	20	EA	2X10 SGL HNGER 45 DEG L	15.990	319.80
177	2	EA	FM 9.5" MD ML DBL HANGER	8.550	17.10
178			----------		
179			ROOF RAFTERS		
180	135	LFT	14" TJI 560 I-JOIST	4.750	641.25
181			TALLY: 4/1 4/2 5/3 5/4 5/5 7/6		
182			+3/7		
183	4	EA	14 X 16 TJI 560 I-JOIST	76.000	304.00
184			CUT TO 8'		
185	7	EA	14 X 18 TJI 560 I-JOIST	85.500	598.50
186			CUT TO 9'		
187	3	EA	14 X 20 TJI 560 I-JOIST	95.000	285.00
188			CUT TO 10'		
189	20	EA	14 X 16 TJI 560 I-JOIST	76.000	1,520.00
190	62	EA	2X10X10 SPF KD #2&BTR	11.490	712.38
191	150	EA	ZMAX ACQ 2X10 SGL HNGR	1.430	214.50
192	70	EA	2X10X10 SPF KD #2&BTR	11.490	804.30
193	20	EA	4X8X1/2 CDX FIR PLYWOOD	21.330	426.60
194	82	EA	4X8X3/4 TG EDGE GOLD OSB	29.970	2,457.54
195	20	EA	2X8X16 SPF KD #2&BTR	15.730	314.60
196	120	EA	2X8X8 SPF KD #2&BTR	7.970	956.40
197	25	EA	4X8X1/2 CDX FIR PLYWOOD	21.330	533.25
198	12	EA	2X10X14 SPF KD #2&BTR	16.080	192.96
199	14	EA	4X8X3/4 TG EDGE GOLD OSB	29.970	419.58
200			----------		

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™

Estimating Department

Phone: (401) 541-7400 — Fax: (401) 884-9966
www.rbscorp.com
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc
Q#k0210

Estimate Number: 83875
Estimate Date: 01/25/18

LN #	QTY	U/M	Description	Price	Extension
201			BASEMENT		
202	8	EA	2X4X16 #1 PRESSURE TREATED MCA	10.380	83.04
203	8	EA	2X4X16 SPF KD #2&BTR	7.930	63.44
204	100	EA	2X4X8 SPF KD STUD	2.990	299.00

RIVERHEAD BUILDING SUPPLY
Build Smarter. Build Better.™

Estimating Department

www.rbscorp.com

Phone: (401) 541-7400 — Fax: (401) 884-9966
6000 Post Road — North Kingstown, RI 02852

Haven Builders Llc

Project:
Q#k0210

Estimate Number: 83875
Job Number: 0000000
Estimate Date: 01/25/18
Expiration Date: 02/08/18

Phone: (000) 000-0000
Fax: (000) 000-0000

Sales Rep: Ian Hysell
Email: ihysell@rbscorp.com

Thank you for giving Riverhead Building Supply the opportunity to supply this project. Your sales representative will be contacting you in the near future to assist you further in planning your project.

Material Estimate	$	79,811.90	
Less 5% For Qualified Accounts		3,990.59	
Total Estimate	$	**75,821.31**	(plus applicable sales tax)

The enclosed estimate is intended to be used as a reference only. The quantities and descriptions of material as well as all other aspects of the estimate reflect the best judgement and experience of the estimator. It is your responsibility to determine whether quantities and material specifications are sufficient. Please note that substitutions for stock materials may have been made and that some items may not be included in the total of the estimate. No warranty is expressed or implied as to the completeness of this estimate. Please review all quantities and material specifications before ordering.

Pricing

Prices are subject to change if the entire package is not purchased. Unit prices in this estimate will be held for 14 days from the estimate date and are based on the complete package/total items estimated. We will hold this pricing for an additional two (2) months provided that the purchasing of material begins within the 14 day period. Be sure to notify your RBS sales representative prior to your first order if you wish to take advantage of this option. Special order prices and lead times are current as of the original estimate date. These prices are based on the information available at the time of quoting and are subject to change at any time based on availability, quantities, or specifications. Confirm all special order prices and lead times with your sales representative before placing any special orders.

Terms of Sale

For House Accounts: 5% 10th of month, Net 25 **or** for qualifying Pro Accounts: 5% rebate issued quarterly.

Delivery

There is no charge for delivery within our normal delivery area (minimum order size may apply) Orders will be delivered from the RBS yard which serves your project location. Orders may be conveniently placed by calling our Customer Service Center at 800-874-9500. All early morning deliveries should be called in at least 24 hours in advance. Monday morning deliveries should be called in by the previous Friday morning.

Returned Material

Return of stock merchandise will be accepted provided that we are furnished with the original invoice number and the material is in original packing and in good condition.

Special order items: Returns of special order items must have prior approval by RBS and are subject to the conditions of the respective vendor. Any cost incurred will be the responsibility of the customer. Any item that has been cut to order or manufactured to order is not returnable.

Please refer to the back of your invoice for complete terms of sale.

APPENDIX 7: BACKGROUND

The following section provides context to the goals achieved in this project. DexTrust Industries and its Scandinavian Panel Systems initiative are explained in detail and with clarity. Panelized housing is discussed to provide a thorough understanding of what SPS must be capable of, and RANDEK's panelized-housing equipment is summarized so that different manufacturing options can be considered. A look at axiomatic design provides the framework necessary to understand our design decisions and decision-making processes.

DEXTRUST INDUSTRIES

DexTrust Industries was established in 2017 in response to the growing market demand for urban planning and economic development. Since its inception, Dextrust has provided its community partners with outreach and business coordination to develop strategies and capacity realignment for the purpose of increasing the rate of business creation and development opportunities. While its consulting efforts proved fruitful, DexTrust Industries wants to begin contributing to the physical creation of economical and sustainable communities. Its plan is to manufacture low-cost housing in the United States by using a panelized construction method that has been widely used in Scandinavia for years.

DexTrust's has created a unique network of partnerships and subsidiaries that collectively comprise their prospective manufacturing ecosystem. To illustrate the complexity of this network, the DexTrust Manufacturing Ecosystem has been included below.

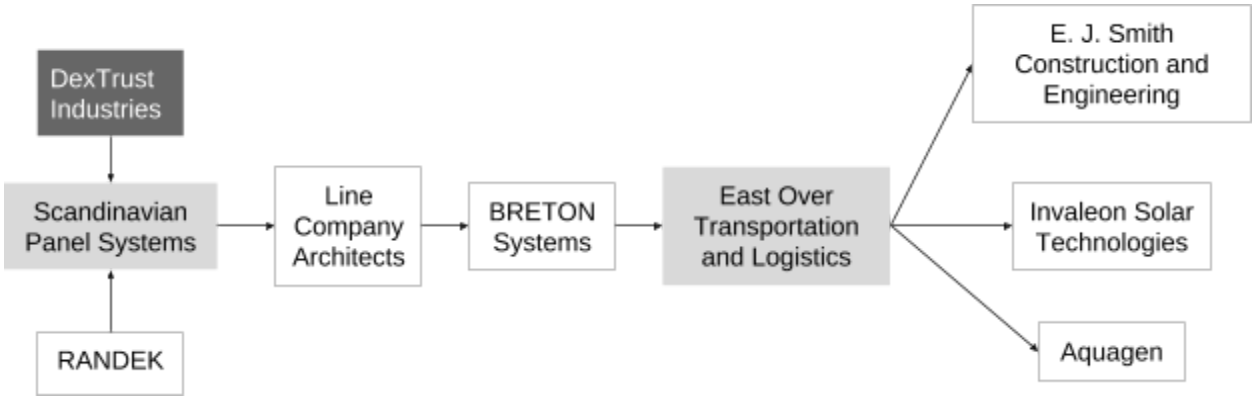

Figure 16. DexTrust Manufacturing Ecosystem

Partners of the firm are shown in white, and subsidiaries are shown in light grey. If the ecosystem is initiated, infrastructure projects will be secured by DexTrust Industries, passed to Scandinavian Panel Systems (SPS), and then evaluated by Line Company Architects. The remaining companies will be responsible for transporting materials and finishing projects on site.

THE SPS INITIATIVE

Scandinavian Panel Systems was established by Erik Hodin, Tymothy Kennedy, and Charles Robson to manufacture low-cost housing in the New England area. Each of the founders provides a unique skill set to the group that will help the project succeed. Erik Hodin is an architect that has had a previous venture in a similar industry, which provided him with the necessary experience to design the panels. Next, Tymothy Kennedy is a well-respected lawyer that has gained the ability and knowledge required to handle the political and regulatory barriers in the business. Last but not least, Charles Robson has experience working in supply chain management, which will be an integral part of the business as he will have to manage the company in times of limited capital.

DexTrust Industries and Hodin plan on collaborating with RANDEK, a Swedish-based equipment supplier, to establish the Scandinavian Panel Systems (SPS) manufacturing company. The current average price to build a single-family home in the New England area is between $215 and $150 per square foot; SPS plans on producing similar homes for around $100 per square foot and constructing them in only a fraction of the time (Home Advisors 2018). They hope to reach this goal using the ZeroLabor System built by RANDEK.

PANELIZED HOUSING

The process of manufacturing using panelized designs started in Scandinavia after the end of the Second World War. The goal of the panelized system was to minimize the time it took to rebuild the homes that were destroyed during the war. As time progressed, people acknowledged the potential upsides of using such a system and acted accordingly.

The key to the success of the panelized system was the ability to turn a construction project into a manufacturing system. By building in a controlled environment, all factors of productions are steered to maximize efficiency and reduce costs. When panelized buildings first started, panels were hand built on an assembly line, similar to what Henry Ford created, and were limited by size constraints. Furthermore, panelized buildings or prefabricated homes, in general, were viewed as low-quality building that were built for the lower social classes of society. As technology progressed, panels became stronger, and systems became more efficient, panel manufacturers gained the ability to manufacture building at a much higher quality. As a result, panel manufacturers were able to enter the untapped market of high-end buildings.

Currently, a modern panel manufacturing plant can produce panels for an entire building with minimal of labor. Limiting the number of required staff has a significant effect on the cost of building, not only due to the reduced number of staff, but also due to the increased efficiency and precision.

THE YARMOUTH PROJECT

SPS is currently considering the possibility of placing a bid on a 54 apartment, 3 story, low-cost housing building (Figure 2) in Yarmouth, MA. The building will be constructed using panels from the SPS manufacturing facility. Furthermore, SPS plans to collaborate with DexTrust's subsidiaries to achieve the highest level of efficiency while minimizing wastes. The project will include the latest technologies in renewable energy and facility waste management.

Figure 1. Yarmouth Project Preliminary Design

RANDEK EQUIPMENT

RANDEK opened its doors in the 1940's in response to an increasing demand for wooden panelized buildings in Sweden. RANDEK was the first dedicated panelized system machine manufacturer in the world. As time progressed, RANDEK continued to innovate and improve their equipment; providing customers with the ability to produce over 300,000 homes from 1950 to 1980. With such a massive and efficient operation, RANDEK was soon recognized by Sweden's neighbors. By the 1970's, RANDEK's customer range had spread across Europe from Germany to Russia, and soon after, to the rest of the world. (RANDEK)

Today, RANDEK produces top of the line machinery and systems for panelized building manufactures all over the world. RANDEK works personally with all of its customers to improve the building process by shortening time frames, improving quality, reducing costs, and much more. Furthermore, RANDEK's equipment is currently producing some of the most energy and labor efficient buildings in the world.(RANDEK)

RANDEK's latest project resulted in them developing the ZeroLabor System. The goal of the ZeroLabor System is to eliminate the need for highly skilled workers, hence reducing costs. The system is built using a cell design, meaning it could be used as a stand-alone piece, it could be incorporated into a current production line, or multiple cells could be connected to produce a full system. A 3D Rendering of a single ZeroLabor System cell has been included below.(RANDEK)

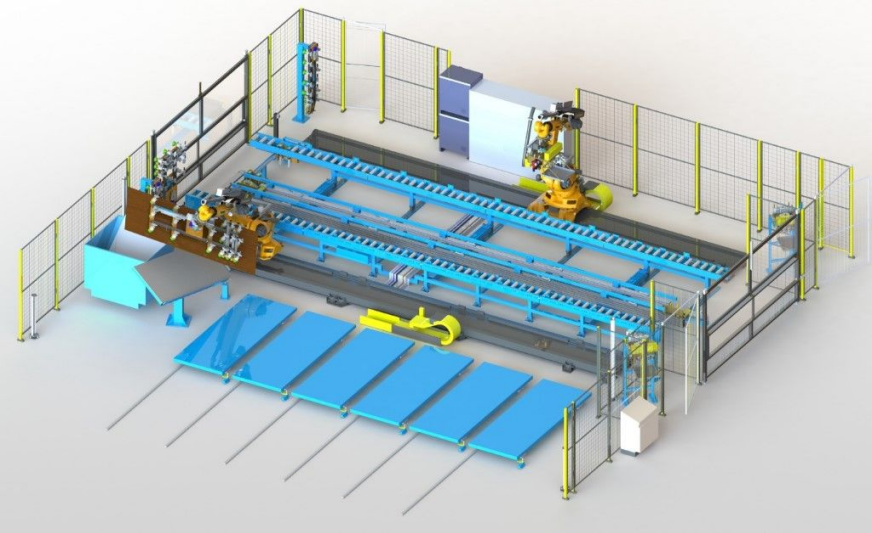

Figure 15. RANDEK ZeroLabor System Manufacturing Cell

The ZeroLabor System is unique as it is the only system that can produce walls, roofs, and floors without the need for any modifications. However, the system is typically implemented as a single step of production process that includes additional machines. The gates on the left and right of the cell open to allow the pre-manufactured frames to enter and the constructed panel to roll to the next station, where it is turned over, moved, stored, or further altered, depending on the production process.

AXIOMATIC DESIGN

Professor Suh Nam-pyo developed axiomatic Design during his time at Massachusetts Institute of Technology (MIT). The idea behind the design was to create a methodology to simplify systems design. The Greek root for the word Axiomatic is Axioma, which means "What is thought of fitting" The process of creating an Axiomatic Matrix involves defining Functional Requirements (FR's), Design Parameters (DP's), and Process Variables (PV's). Functional requirements are derived from asking the question of " What it does?" Design parameters are based on the question of " What the functional requirement looks like?" Process variable are obtained last after answering the question " How its made?" (Suh 1990)

APPENDIX 8: YARMOUTH PROJECT FLOOR PLAN AND PANEL DECOMP.

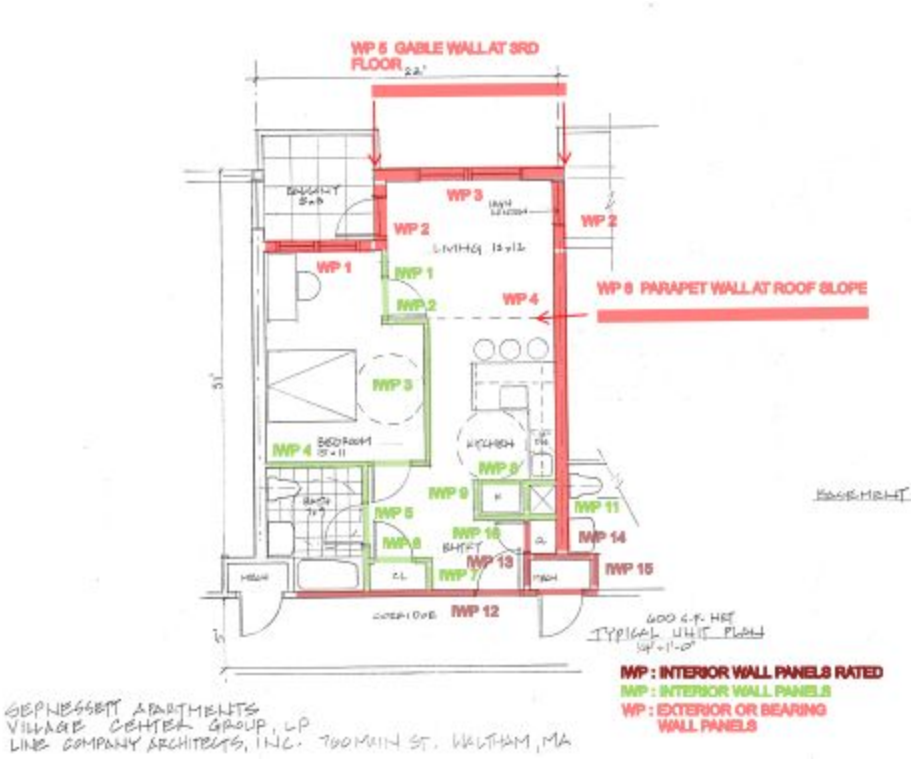

Figure 17. Yarmouth Project, Wall Panels Layout

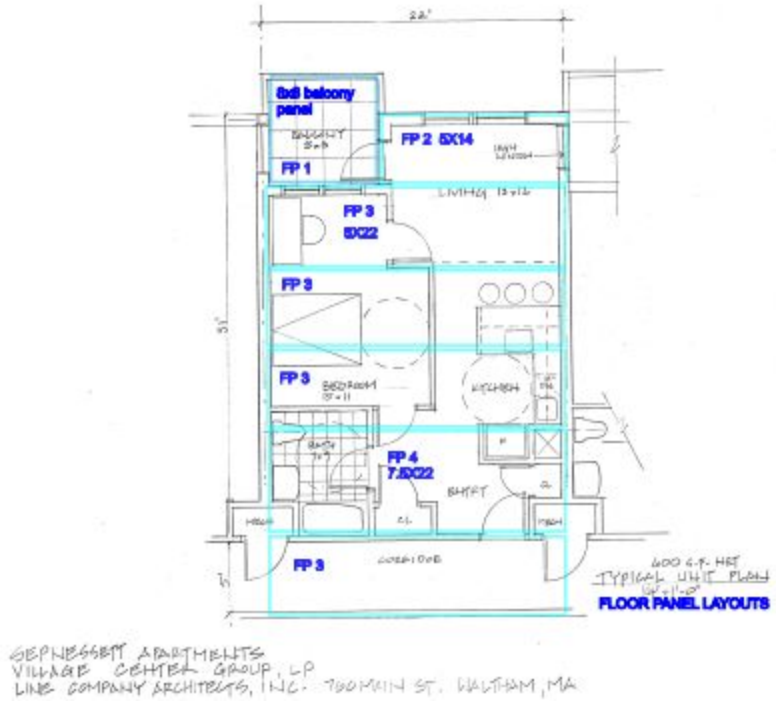

Figure 18. Yarmouth Project,Floor Panels Layout

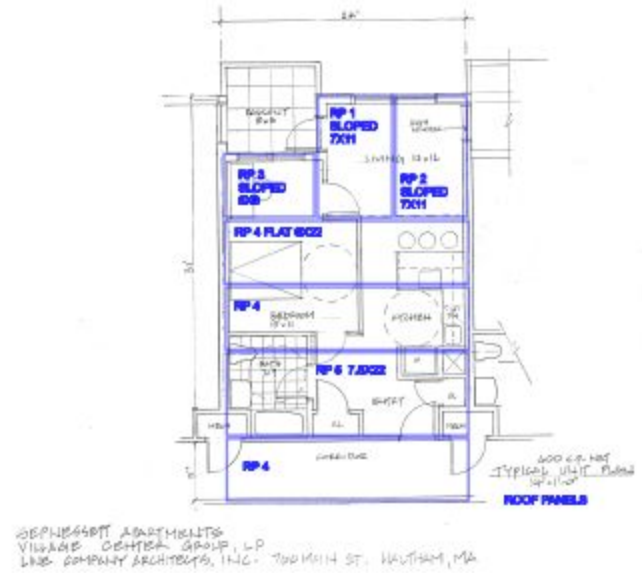

Figure 19. Yarmouth Project, Roof Panels Layout

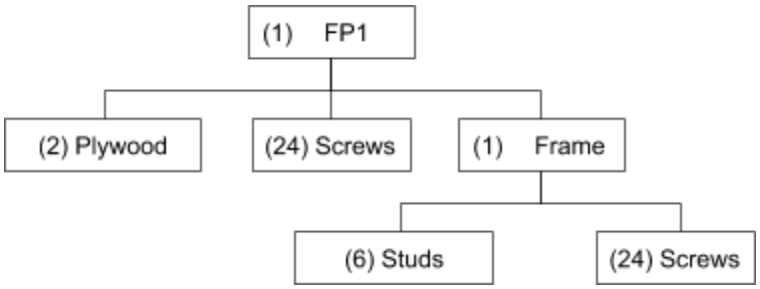

Figure 5. Material Requirements - FP1

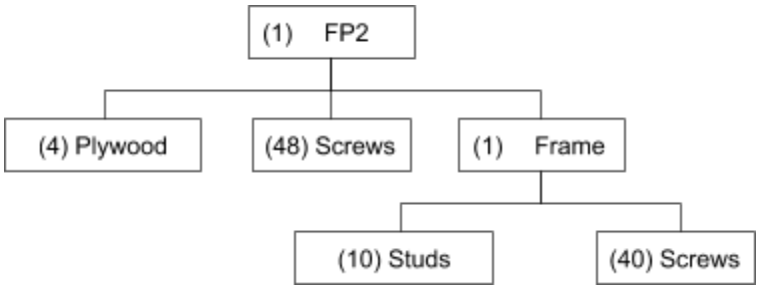

Figure 20. Material Requirements - FP2

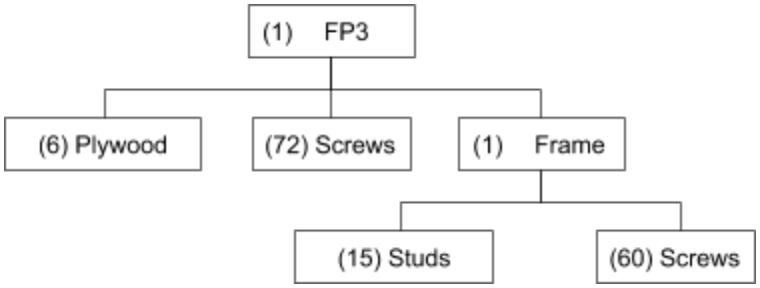

Figure 21. Material Requirements - FP3

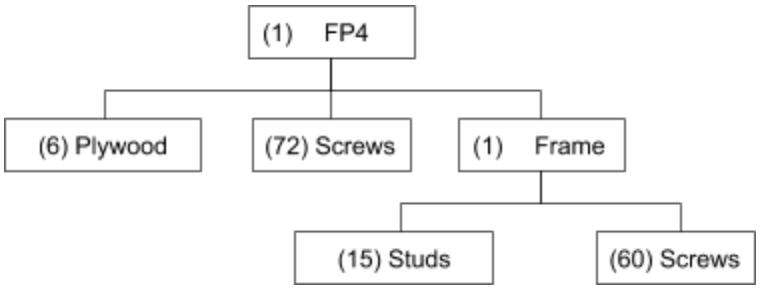

Figure 22. Material Requirements - FP4

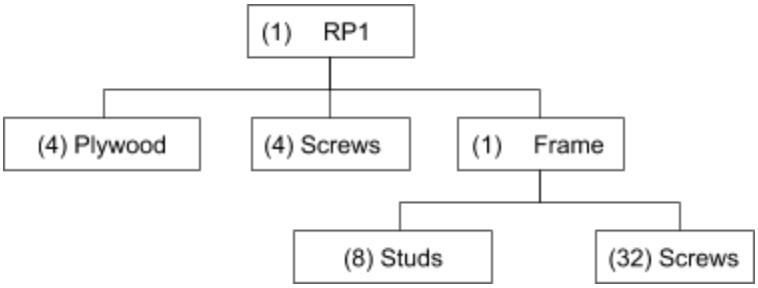

Figure 23. Material Requirements - RP1

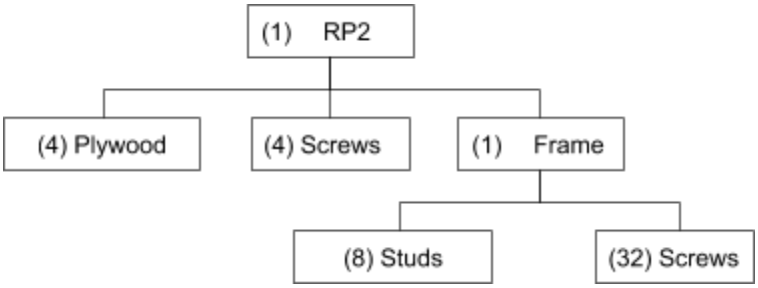

Figure 24. Material Requirements - RP2

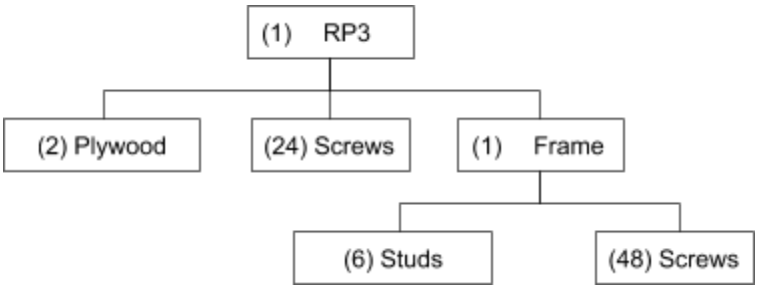

Figure 25. Material Requirements - RP3

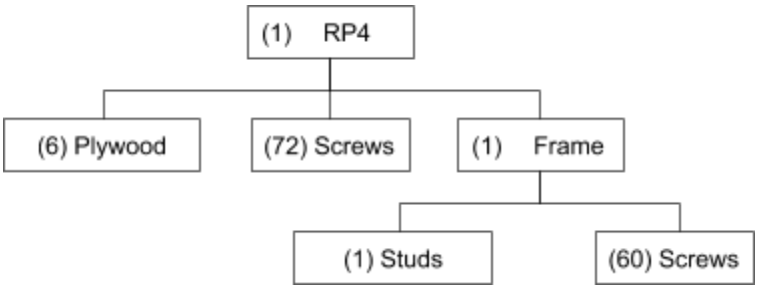

Figure 26. Material Requirements - RP4

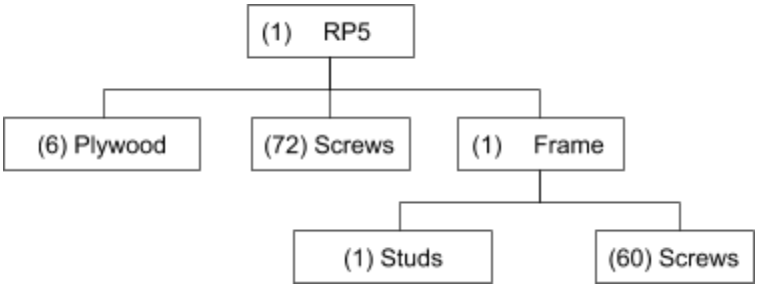

Figure 27. Material Requirements - RP5

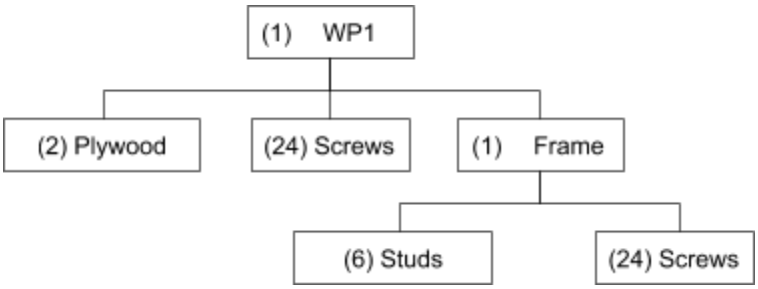

Figure 28. Material Requirements - WP1

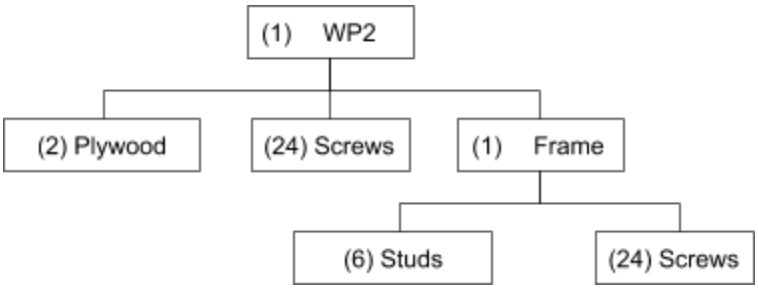

Figure 29. Material Requirements - WP2

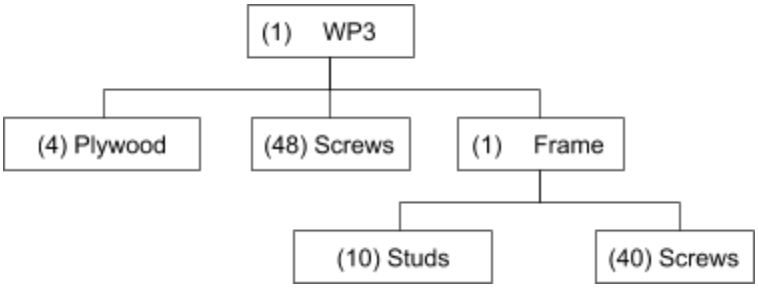

Figure 30. Material Requirements - WP3

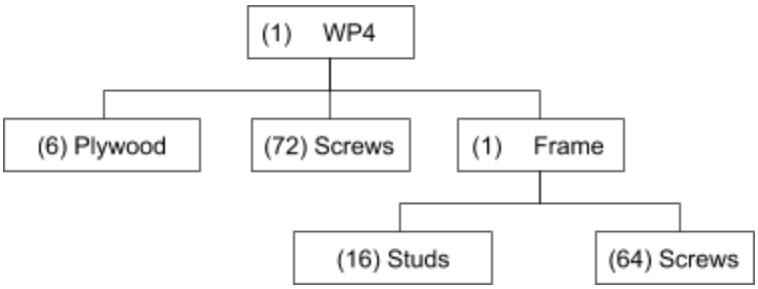

Figure 31. Material Requirements - WP4

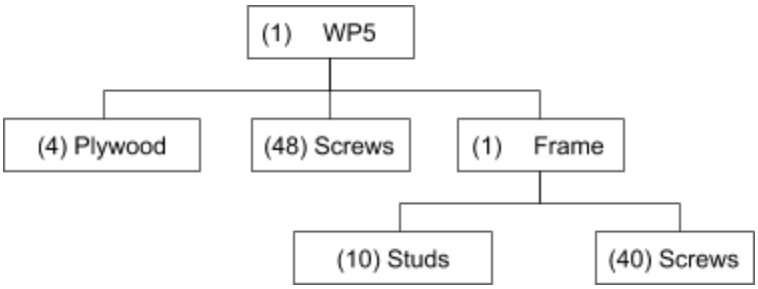

Figure 32. Material Requirements - WP5

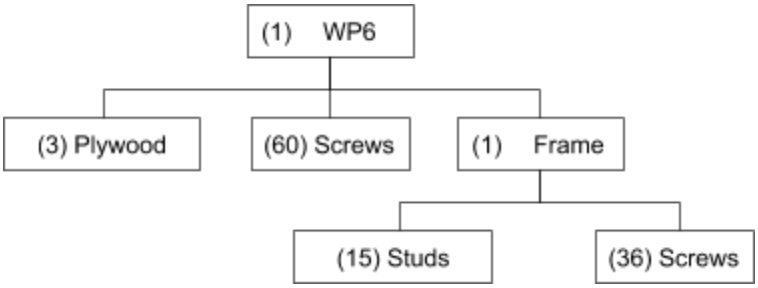

Figure 33. Material Requirements - WP6

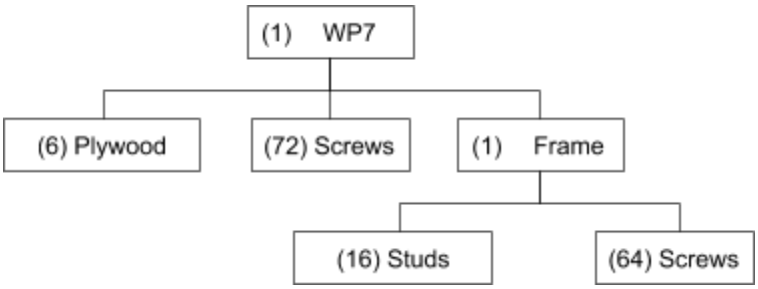

Figure 34. Material Requirements - WP7

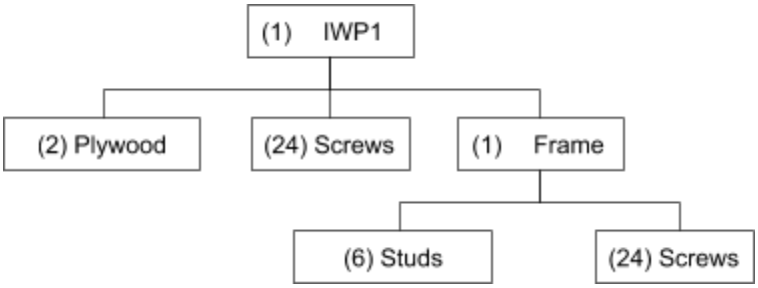

Figure 35. Material Requirements - IWP1

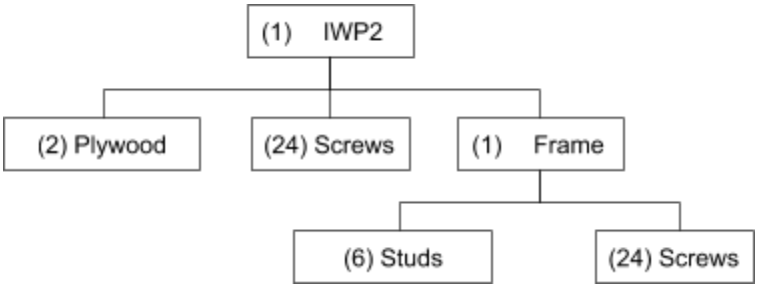

Figure 36. Material Requirements - IWP2

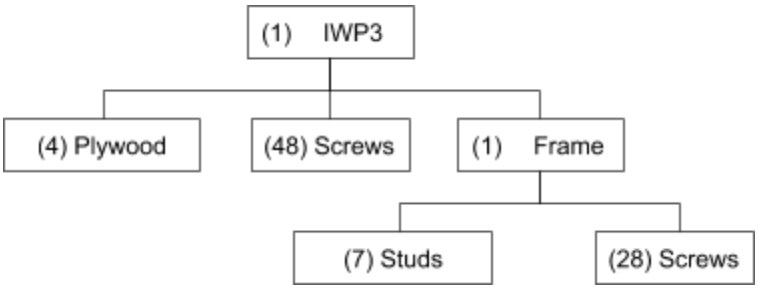

Figure 37. Material Requirements - IWP3

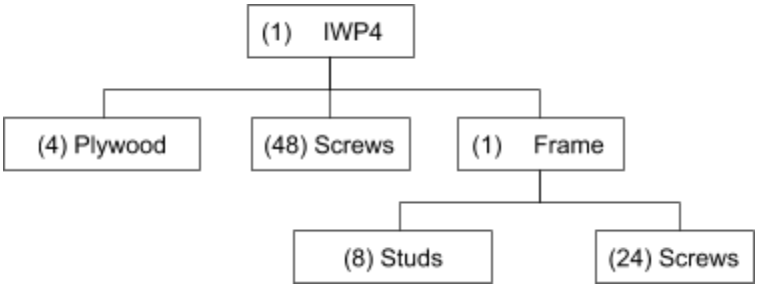

Figure 38. Material Requirements - IWP4

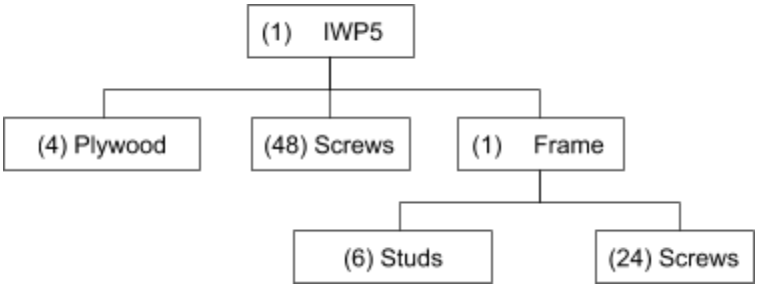

Figure 39. Material Requirements - IWP5

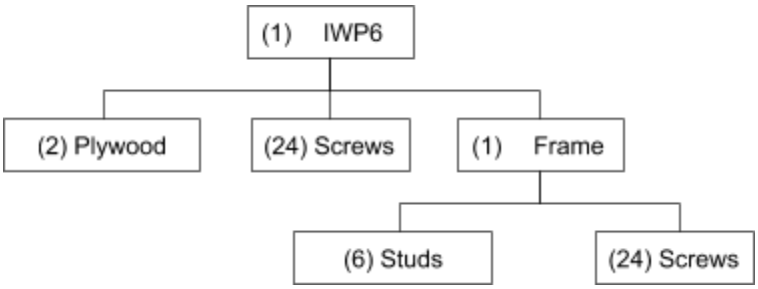

Figure 40. Material Requirements - IWP6

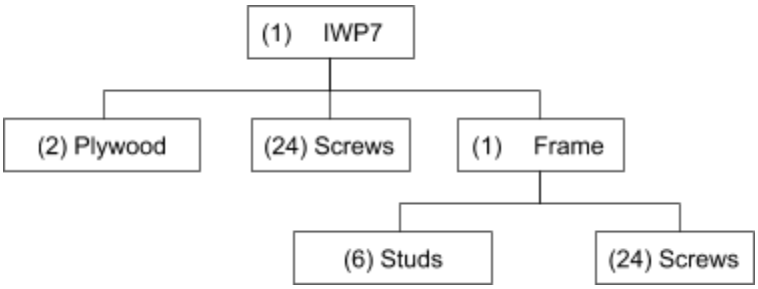

Figure 41. Material Requirements - IWP7

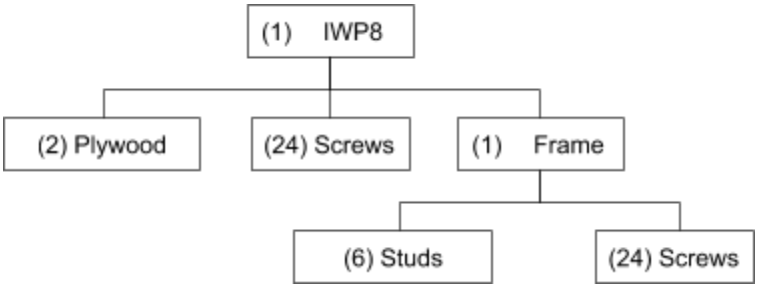

Figure 42. Material Requirements - IWP8

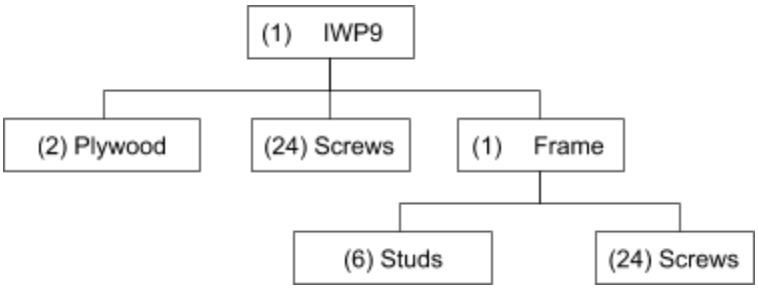

Figure 43. Material Requirements - IWP9

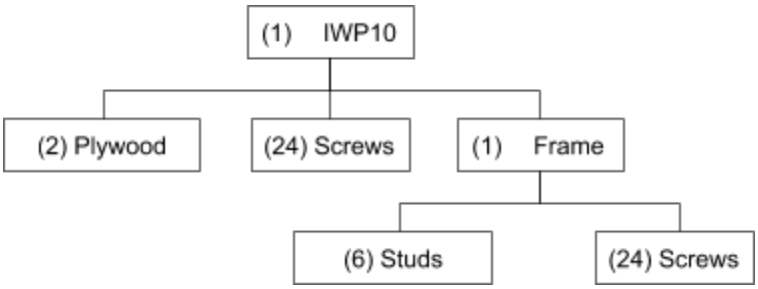

Figure 44. Material Requirements - IWP10

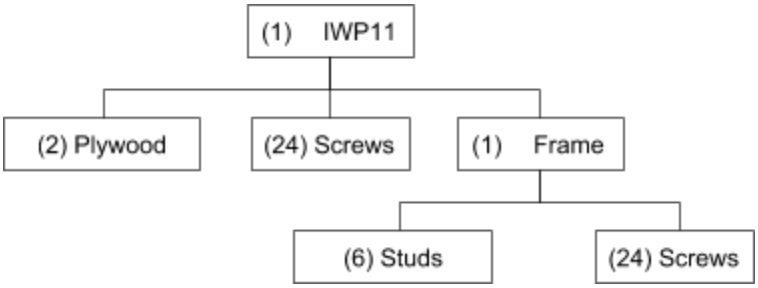

Figure 45. Material Requirements - IWP11

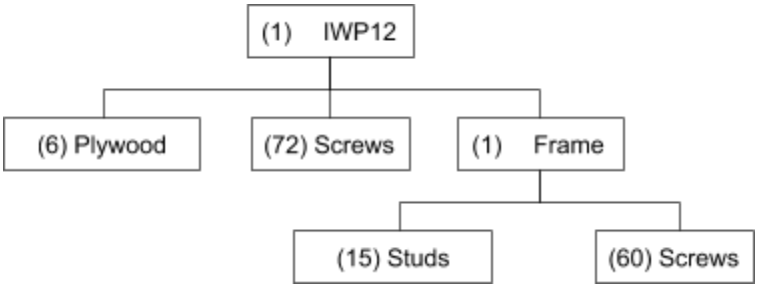

Figure 46. Material Requirements - IWP12

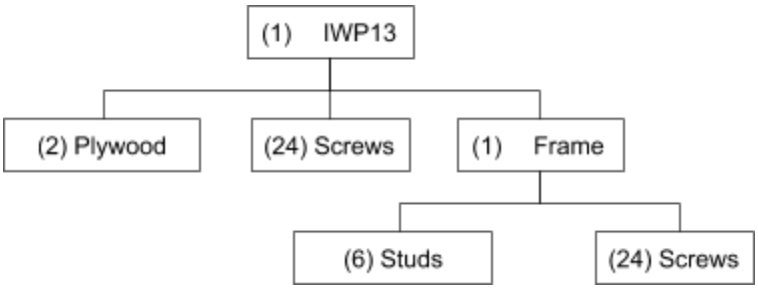

Figure 47. Material Requirements - IWP13

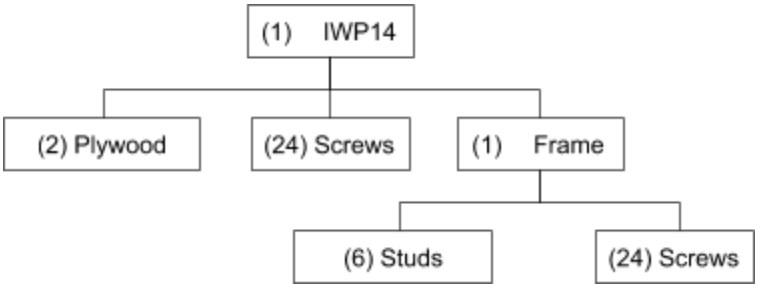

Figure 48. Material Requirements - IWP14

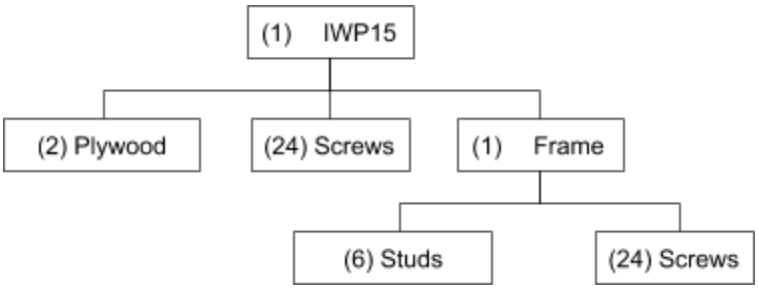

Figure 49. Material Requirements - IWP15

REFERENCES

Anderson, J. (2019). Personal Interviews with [RANDEK].

Eagle Logistics Group LLC. (2018). Personal Interview with [Eagle Logistics Group LLC].

Hansen, S. (2012, November 09). How Zara Grew Into the World's Largest Fashion Retailer. Retrieved from https://www.nytimes.com/2012/11/11/magazine/how-zara-grew-into-the-worlds-Largest-fashion-retailer.html

Home Advisors. Learn how much it costs to Build a House. Retrieved from https://www.homeadvisor.com/cost/architects-and-engineers/build-a-house/

Hundegger USA. (2019). Our Machines. Retrieved from: https://www.hundeggerusa.com/our-machines/

Green, M. (2018). *IWBC Conference, 2019*. "Evolutions and Solutions; MGA and Katerra's explorations, systems and typologies in mass timber" [Lecture].

Katerra. (2019). Our Vision. Retrieved from https://www.katerra.com/en/about-katerra/the-vision.html

Kennedy, T. (2019). Personal Interview with [DexTrust Industries].

McCaughey, G. (2018). *IWBC Conference, 2019*. "If it's Not a System; It's Not a Solution" [Lecture].

Merced, M. J. (2018, January 24). Katerra, a Construction Start-Up, Raises $865 Million. Retrieved from https://www.nytimes.com/2018/01/24/business/dealbook/katerra-softbank-vision-fund.html

New Bensonwood and Unity Homes Production Facility in Keene,NH. (2018, August 23). Retrieved from https://bensonwood.com/grand-opening-production-facility/

Randek. Building The Future. Retrieved from http://www.randek.com/images/pdf/Broschyr_210x297_EN_WEBB.pdf

Rempos Remodelling Professionals. (2019). "How long does it take to replace a front door?" Retrieved from: http://www.rempros.com/estimating-time/front_door_replacement.html

Rhodin, E. (2019). Personal Interviews with [Line Company Architects].

Robson, C. (2019). Personal Interviews with [DexTrust Industries].

Suh, N. P. (1990). *The principles of design*. New York: Oxford University Press.

Towner, W. PhD. (2019). Personal Interviews.

Walsh, D. (2018). *IWBC Conference, 2019.* "Marriott's Modular Program; Franchisor Perspective" [Lecture].

Window World Inc. (2019). FAQ. Retrieved from: https://www.windowworld.com/faq.php