IPRO 339/Shipping Container Housing

Final Project Report

7/24/2009

Abstract

Obtaining affordable housing is a serious problem for many Chicago residents. This IPRO aims to alleviate this problem by introducing affordable and sustainable housing options derived from novel ideas of converting shipping containers into livable housing units.

The Chicago bid for the 2016 Olympics has raised the issue of providing housing for the 17,000 athletes that the event will bring. This IPRO is planning on designing temporary housing for the 2016 Summer Olympics which can subsequently be transferred to the desired building lots for conversion into permanent housing units.

Maximizing efficiency for both purposes has been kept a top priority in line with the stated goals of showcasing sustainability.

Background

The target market for the project includes Chicago residents in need of more affordable housing, city aldermen, and 2016 Olympic officials. The key to succeeding with the project is to sell the idea to the Olympic Committee because this would facilitate acquiring the funds necessary to proceed with the project. Furthermore, once the housing units are installed in the Olympic Village, it will be much easier to convince any skeptically minded city officials who may be opposed to installing the units in their wards. The main argument from city officials has been that the units will be sub-standard and aesthetically displeasing. The finished Olympic Complex would help dispel any misgivings that may remain.

This IPRO is addressing several key issues. The primary issue is the shortage of affordable housing in Chicago. This issue has been coupled with the need to provide Olympic athletes with a temporary housing solution. We are proposing a temporary housing solution instead that can later be transported into allocated lots in Chicago. One key challenge is to design the housing units in such a way that they can be easily disassembled and moved to an alternate location. In addition, the design has to be such that the finished interior of each unit will not require much modification once it is moved to its permanent location. We also faced many challenges with respect to designing the housing to meet both Chicago Building Code and the International Olympic Committee requirements.

This particular IPRO has been in progress for several semesters. However, last spring the focus has shifted towards designing the dual purpose housing unit. Nonetheless, we are currently encountering some of the same issues in terms of applying building technology to shipping containers as those encountered in past IPRO's. A great deal of progress has been made researching construction options with shipping containers. Each semester additional technical problems are encountered and resolved. Examples include tackling the mechanical, plumbing, and electrical systems.

Objectives

The objectives of this IPRO were twofold. First was the goal to design housing for the athletes of the 2016 Summer Olympics. This had to be accomplished while minimizing the carbon footprint of the Olympic and Paralympics housing project by using existing shipping containers located at storage sites throughout the city. It was our objective that the housing units will be as environmentally friendly as possible.

The second goal was to find ways of transforming the temporary Olympic housing solution into a permanent affordable housing solution. After the completion of the Olympics and Paralympics, it will be necessary to transport the housing containers to various sites in Chicago so that they can be used as the backbone for the construction of affordable housing units.

Methodology

The tasks were tailored to the overarching need to design, create, and market affordable and sustainable housing for the city of Chicago by employing recycled shipping containers. This had to be accomplished with Chicago's local styles and tastes in mind.

Research was conducted to identify the most cost efficient and sustainable ways of incorporating plumbing, HVAC, and electricity into the homes. Additional site plans were produced that went to address site plans and individual floor plans. It was of paramount importance to ensure both housing projects are going to be structurally sound. It was also necessary to ensure the MEP and HVAC systems are going to be able to be implemented without issue. The design of the structures was checked against any necessary implementation of MEP and HVAC systems to prevent conflicts during construction. Design solutions were made to incorporate problems of solar gain minimization, water collection, optimizing site orientation, and enhancing thermal zones.

Several different plans were produced in order to determine the most optimal solution to the targeted markets. This was done keeping in mind the solution for both Olympic housing and the transition to an affordable Chicago housing structure.

This IPRO's research explored many avenues of viable and cost effective energy solutions. The structure was checked to ensure that the housing was compliant with Chicago fire code guidelines.

Options were explored for ensure civic and handicap accessibility, especially so with the Olympic housing given the fact that the Para Olympics are to follow regular Olympics. Attention was given to incorporate the climatic requirements of the Chicago region into the site design. These requirements varied from the Olympic Village to the permanent units due to the fact the Olympics are being held in the summer months.

Calculations were made to test the structural integrity of the Olympic housing against wind loads as well as force-modeling to get an accurate picture of what will be happening, and the necessary limitations were passed over to the architecture subgroup. Foundation calculations were made and correlated with the soil information to see if the soil can handle the dead load. Wind load testing was done with force-modeling. The results of testing and calculations were documented with the calculations and results. The analysis of the test results is simply seeing what type of connections will be required to tie the units together and how much of the outside walls will have to be continuous, untouched wall.

To go about solving the above subtasks of the overall problem, our team was divided into groups to work on individual tasks. The individual tasks were categorized and one category was given to each subgroup. All design goals should be completed within the given timeframe, but the ultimate construction of the housing unit will require additional time and resources. Potential solutions were tested using computer-aided design software and mathematical computation which was performed by the appropriate subgroup. All findings were transparently posted using the IGroups system and reviewed by other members of the subgroup as well as the overall design team.

Results are subject to professional review by outside sources, such as licensed professionals and government officials. These third-party individuals need to be contacted by members of the subgroups before the finalization of the design to ensure all project requirements have been met.

Team Structure and Assignments:

This IPRO was divided into 4 subgroups: Engineering, Architecture, Presentation, and Quality Control.

The Engineering subgroup dealt with the more technical aspects of the project including structural integrity, insulation, installation of appropriate heating and cooling systems, installation of electrical systems, and so forth. The perspectives of this subgroup focused more on feasibility and sustainability.

The Architecture subgroup collaborated very closely with Engineering subgroup on many of the same issues but from more of a design perspective that incorporated the marketability of the options explored.

The Presentation subgroup tackled the issue of marketing the idea to potential sponsors. They played a critical role in showcasing the goals and needs of the IPRO and took the lead in fundraising efforts.

The Quality Control subgroup dealt with ensuring that the appropriate documentation and reports were produced in a timely fashion. They ensured that deadlines were met and that the work put forward was of professional quality.

Individual Contributions

Saad Ahsan - Saad participated in the quality control team. His direct responsibilities included aiding the production of the project plan and the final report. He also helped compile the midterm and final presentations and held speaking roles at both events. HE also spent a lot of time personally communicating with various team members in order to coordinate efforts in accomplishing the aforementioned deliverables.

Aaron Anderson - Aaron did calculations for heat transfer in the Olympic housing, both uninsulated and insulated, as well as calculations for radiant floor cooling. He helped design HVAC system which included ventilation requirements per unit, exhaust fan for bathroom, and A/C unit requirements for every other area. He researched insulation options for Olympic and permanent housing and helped Jennifer Gibbons with presentation/communication each week.

Rajiv Bais - Rajiv called up potential sponsors for our project and met with the ones who were interested. He also helped with various PowerPoint presentations throughout the semester and brochures for mailing out to potential sponsors. Rajiv

researched potential lots where we could build our units on IIT campus and the costs involved.

Ronald Chan - Ronald worked on the configuration of the shipping container houses. He designed the walkway and stair systems. He also helped design the master plan of the Olympic village.

Michael Dunn - As part of the Quality Control subgroup, Michael helped prepare the project plan document. He designed the poster and brochure. He also wrote our ethics statement and coordinated volunteer scheduling for our IPRO Day table.

Jennifer Gibbons - As a member of the Engineering sub-group of the Design Team, Jennifer checked her teammates' calculations and researched prospective materials and building components to use in the Olympic housing units. As the communications leader of the Design Team, she was in close communication with the Architect sub-group. She also created all meeting presentations, which updated the whole IPRO team on her sub-team's progress and outlined the goals for each upcoming week.

Nicole Gregory - Nicole designed the foundation for both Olympic and permanent housing units and did the appropriate calculations. She also worked out the budget for the foundations, as well as, the labor required. She referenced pictures and provided information for the various presentations throughout the semester.

Joel Jacobson - Joel helped research and organize weekly presentations. He researched sustainable building materials and construction costs. He was responsible for compiling and refining the final budget for the completion of the Olympic Village and permanent housing units. In addition, Joel modeled the shipping containers in 3-D using Revit.

Rostislav Kucher - Rusty calculated the wind load for the side walls and designed them appropriately for the load. He also checked seismic calculations, checked connections for upwards force, tension force, and shearing force. He served as a coordinating link between architecture and engineering. He provided a structural perspective for the budget. He also presented at both the midterm and final presentations.

Timothy LaBuda - Timothy's contribution to this semester's IPRO was the overall reworking of the site's master plan and urban design guidelines. This was a well-underachieved category coming into this semester's IPRO. He designed three separate schemes that would help connect our site to Burnham Park and the lakefront. Along with his designs is a list of guidelines that would help future IPRO classes in achieving a connected and thriving community. This should help set a new standard for the Olympic Village. He also spent countless hours in developing the urban design, 3-D

modeling of the site and Olympic Housing units both interior, exterior and overall, rendered and composed.

Nancy Lima - Nancy was part of the Presentation Team and was involved with contacting various companies in order to obtain donations in the form of funding, materials, or labor.

Jiae Park - Jiae researched the precedents of container buildings from general information to specific details. She was involved with designing the Olympic Village site and worked on the site model with Erin. She assisted in preparing weekly presentations for the Design Group. Furthermore, she helped the team leader create the final presentation file in graphic format.

Lucas Park - Lucas was the team leader of the Presentation Team. He organized the presentation group and delegated individual tasks to various team members. He attended several business engagements in an attempt to raise funds for our IPRO. He met an IIT professor as well as several agencies in order to obtain donations in the form of materials. He met with members of the Navy to determine if we can obtain donated labor to reduce the cost of construction. He applied for a long term construction grant based on research of implied green technologies directed toward low income housing from the Home Depot. In addition, he created the presentation that was used during the Presentation Team's business engagements.

Erin Pederson - Erin built the site model for the presentation group. She produced design drawings for the plumbing systems. She also started work on the electrical plan drawings. In addition, she assisted the team by conducting research in various areas.

Mark Pyciak - Mark was a member of the Quality Control Team. He was involved in coordinating with other teams to ensure that all necessary information necessary for the various deliverables was submitted. He worked on the Project Plan, Midterm and Final Presentations as well as the Final Report.

Raihan Rahman - Raihan contacted NGO's, specifically those that are active in community outreach programs in the south side of Chicago. He also reached out to local home building material stores such as Lowes and Home Depot. He attempted to schedule meetings with local TV, radio, or newspapers. He also tried to reach out to local builders that may be interested in providing funding to our project.

Anna Ribot - Anna started working on floor plans attempting to find new solutions quite different from previous semesters' IPROs. In addition, she worked on aesthetics designs of the affordable housing units. This included drawings and planar views of different proposals, materials and colors. Finally, she redesigned the details of the final facade.

Michael Roseen - Michael was involved with much of the preliminary research for the Engineering Sub team. He researched the specifications of containers and on the connections between the containers for tying the housing units together. He also worked on the final budget with Aaron Anderson. He also worked on the plumbing system which included the specifications on the plumbing in the bathroom.

Ivan Silvestre - Ivan was part of the Presentation Group and his contributions were the visualizations and renderings of the affordable housing. He was responsible for all the renderings of the affordable housing, as well as, the rendering of the sample container on the proposed IIT site. He worked closely with the architecture group updating the renderings whenever they updated the housing plans.

Cassandra Specht - Cassandra was involved with editing Floor Plans from previous IPROs. She performed administrative duties for the Design Team. She created the weekly PowerPoint presentations and was a presenter at both the midterm and final presentations. Additionally, she worked on the transition strategy from Olympic to Affordable Housing.

Budget

The amount of money spent on this IPRO was much less than anticipated due to the fact that we were able to use recycled materials in building our model. Since it was not possible to obtain containers early enough in the semester, we were not able to build a life-size model on IIT campus as originally planned. This was also a factor in keeping our budget below our approved amount of $1000.00.

Item	Cost
Chip Board	$12
Blue Paper & Plexiglass	$20
MDF	$13
Miscellaneous	$5
TOTAL	$50

Code of Ethics

Overarching Standard:

Improve the low-income housing situation in Chicago by creating safe, affordable housing that blends in with established neighborhoods, through economic and eco-friendly use of existing resources.

1 Law

The team's plans and designs should conform to national, state, and local laws.

Pressure To minimize, bend, or gloss over laws due to time constraints.

Pressure To ignore laws due to lack of knowledge or concern.

Risk Producing a design that is not legal.

Measure Team members should research laws to make sure all plans are compliant. If necessary, consult an expert.

2 Contracts and Agreements

The team must not break any contracts or agreements, and must budget accordingly. Furthermore, the team shall endeavor to not make any promises it cannot fulfill.

Pressure To cut costs in any way possible, in order to stay within budget.

Pressure To make grand promises to help solicit support.

Risk Making an agreement, either written or verbal, that cannot be upheld by this team or future teams.

Measure Team members will not make any promises to or agreements with outside parties without approval of the IPRO Office.

3 Professional Codes of Ethics

The team will ensure the safety and well-being of all potential occupants by following applicable professional building codes.

Pressure Try to fit as many people/amenities into one unit as possible.

Pressure Try to have an ultra-high density site plan and unit configuration.

Risk Compromising building codes and user safety by not providing minimum egress, clearance, or circulation.

Measure Team members should familiarize themselves with the code of ethics for their profession (i.e. architect, civil engineer) to make sure they are complying. If necessary, consult an expert.

4 Industry Standards

The team will design housing that falls within industry standards of safety, comfort, and accessibility for both the Olympic Village and for permanent housing.

Pressure To lower costs by cutting or compromising features.

Pressure To ignore or minimize climate conditions and other risk factors out of ignorance, disregard, or time constraints.

Risk Designing housing inadequately suited to its environment, creating unsafe or harsh living conditions for future occupants.

Measure The team should research industry standards and consider the full range of safety, weather, and other factors.

5 Social, Civic and Geographic Communities

The team will engage with the communities it is attempting to affect, designing housing that will enhance the neighborhood and be welcomed by residents.

Pressure To create a dense and stripped-down housing complex to reduce costs.

Pressure To design a radical or overly artistic piece of architecture.

Risk Creating structures that are eyesores or unwelcome architectural intrusions that are rejected by the community.

Measure Permanent housing units are to be designed with the neighborhood in mind, so as to blend in with existing architectural styles. This can be confirmed by the support of community leaders, such as aldermen.

6 Personal Relationships

Team members should treat each other with mutual respect, be honest in their statements, and take responsibility for contributing to the team effort.

Pressure To make it seem like one has done more work than one actually has.

Pressure To make one's own ideas used over another member's ideas.

Risk Using the ideas of the most forceful team member, rather than the best ideas.

Measure All team members, plus the faculty advisors, will hold each other accountable to respect other people and their ideas. At the end of the project, peer evaluations will be used to help gauge how much work everyone really did.

7 Moral and Spiritual Values

Team members should foster personal moral and spiritual values, contributing to their sense of compassion and community, on which this project is based.

Pressure To see this project as a business proposal, rather than a way to help the community.

Pressure To let one's prejudices about certain demographics bias the team's plans.

Risk Losing sight of individuals who could potentially benefit from the affordable housing – low income families.

Measure Each team member must self-examine his/her motives and prejudices to ensure that he/she is being guided by moral principles, and to stand up for those principles if others loose sight of them.

Results

The local economy has an interest in temporary housing solutions. This includes companies such as restoration, logistics, home improvement, and development. Sometimes they do have funds to provide financial backing for non-profit organizations. Instead of dispensing money ad hoc, they have appropriations channels that must be worked through over time.

J.C. Restoration was willing to provide financial support. Complete shipping was willing to provide free transportation for the materials and supplies. IIT was willing to provide the space for the construction life size model.

Acquisition of two shipping containers was a goal that was accomplished. However, we were unable to meet the construction goal of building a life size model on IIT. However, we did succeed in developing contacts with local resources to begin the acquisition process to build models in the future. We also need to make sure that the funds raised were used ethically and properly by the IPRO to build the model.

From a structural perspective, the integrity of the structure has been confirmed. These containers are quite strong and durable. They can fairly easily resist any wind loading in the Chicagoland area, provided that too much steel is not cut away from the container. The connections were determined to be able to resist a typical wind shearing force and an uplift force.

The heating and cooling systems were tailored to suit the Olympic Units and the permanent housing units respectively. In terms of the Olympic units, the heating system was completely omitted as it was deemed that it was not necessary due to the fact that the Olympics will occur in the summer. The cooling system consists of a standard window A/C unit. When the housing units are converted to permanent housing, the heating system chosen was radiant in-floor heating. There are two main reasons for this choice. One of the biggest challenges that needed to be resolved was the issue of space utilization. It was imperative that space was utilized to its full potential. As a result, in-floor radiant heating was the best choice since it did not require much space. The second reason for this choice was that this particular system was one of the most efficient heating systems currently on the market. The cooling system specified for the permanent housing units was also chosen on the basis of space constraints and efficiency and affordability. It consists of a through wall unit manufactured by Magik-Pac with ducts delivering the cooled air to various rooms in the building. The ducts would run along the ceiling near a wall and would be concealed within a soffit.

The foundation was determined to be adequate in a temporary setting with a 14" by 14" square column, 2' deep. For the permanent housing, it was determined that a twelve inch concrete slab on grade will be used.

From a design perspective, we designed a master plan of the Olympic village, housing the athletes in low-rise building, with access to the lake front. We have enhanced the transitioning process between the Olympic housing to the single family housing. The ability to blend the units into a standard Chicago lot was also improved. In addition, some plumbing issues were resolved.

The following images showcase various aspects of our designs as digital renderings and CAD drawings.

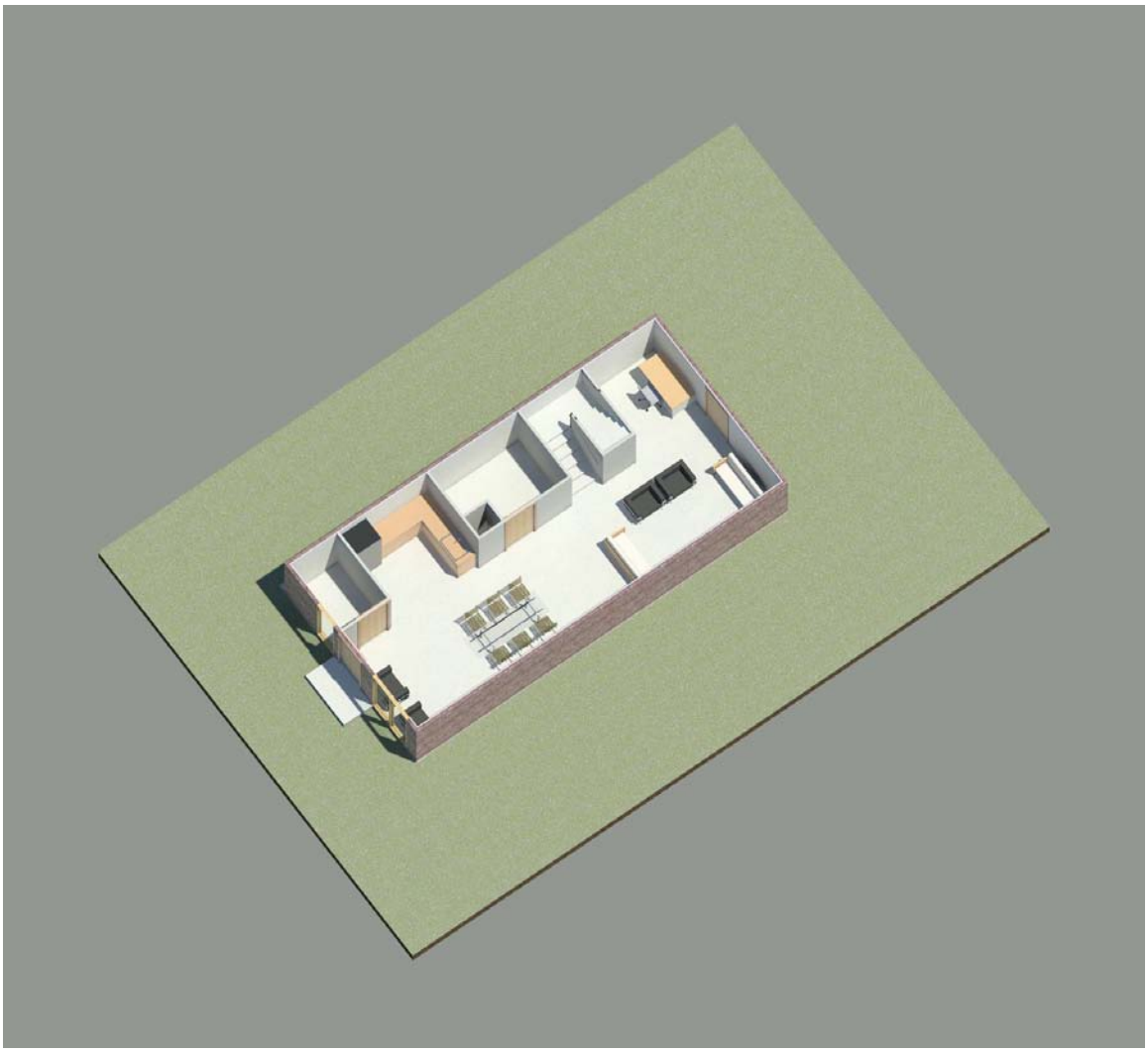

Figure 1: Axonometric plan for the first floor of the affordable housing unit.

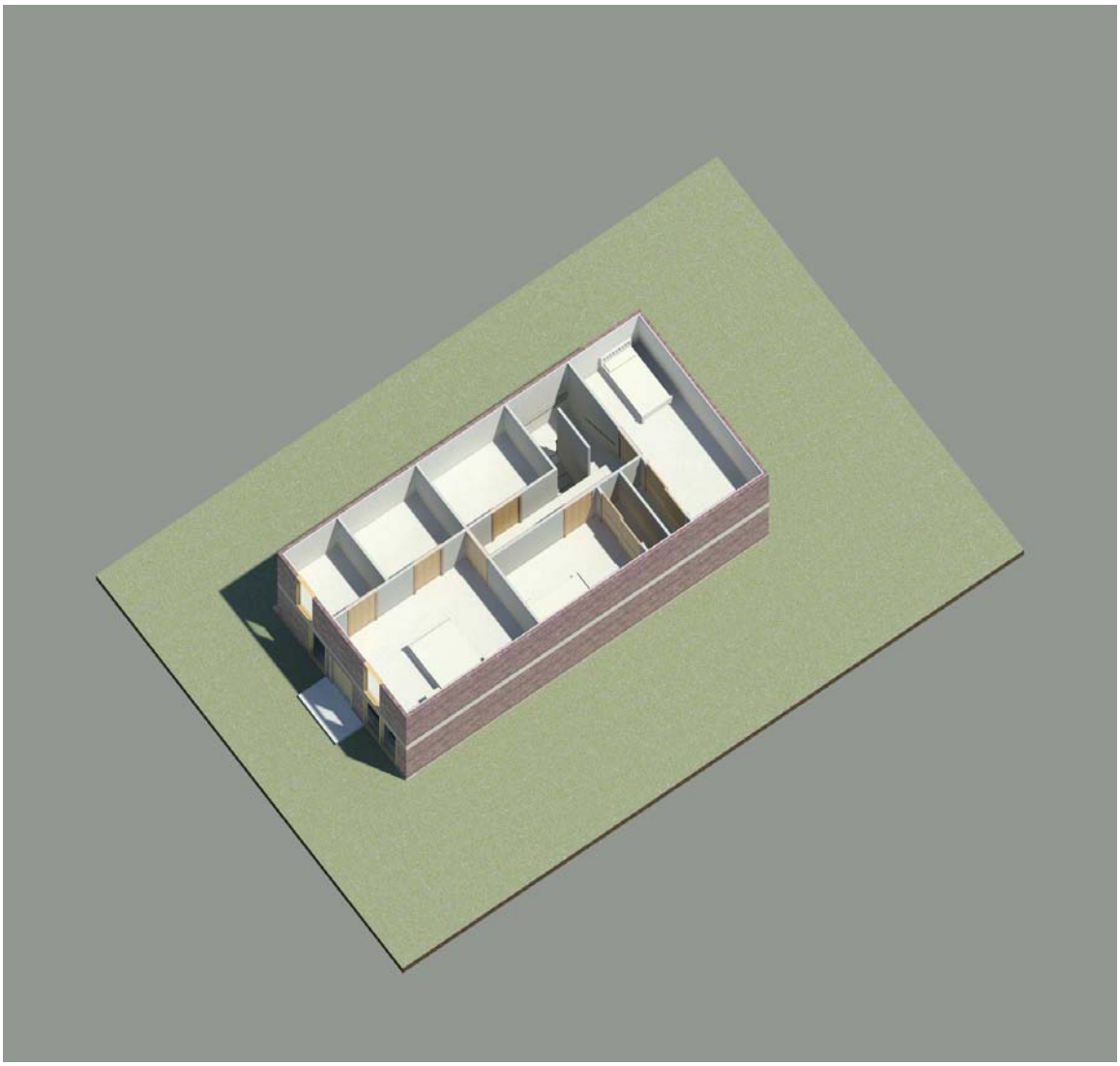

Figure 2: Axonometric plan for the second floor of the affordable housing unit.

Figure 3: Rendering of a container on IIT's campus.

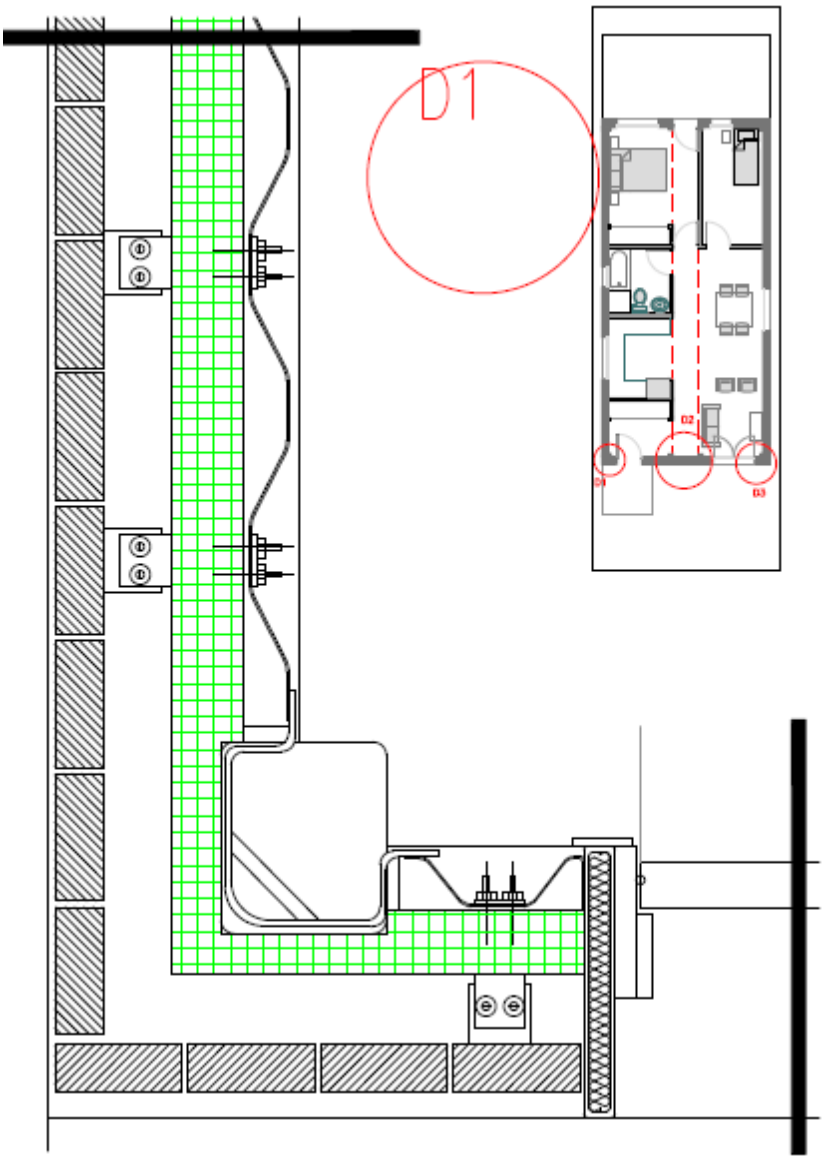

Figure 4: Aerial layout highlighting the fastened brick and insulation on the shipping container.

Figure 5: Interior rendering of the dining area.

Figure 6: Exterior perspective of multiple adjacent units.

Figure 7: Overall Perspective of the unit.

Figure 8: Design rendering of the bedroom.

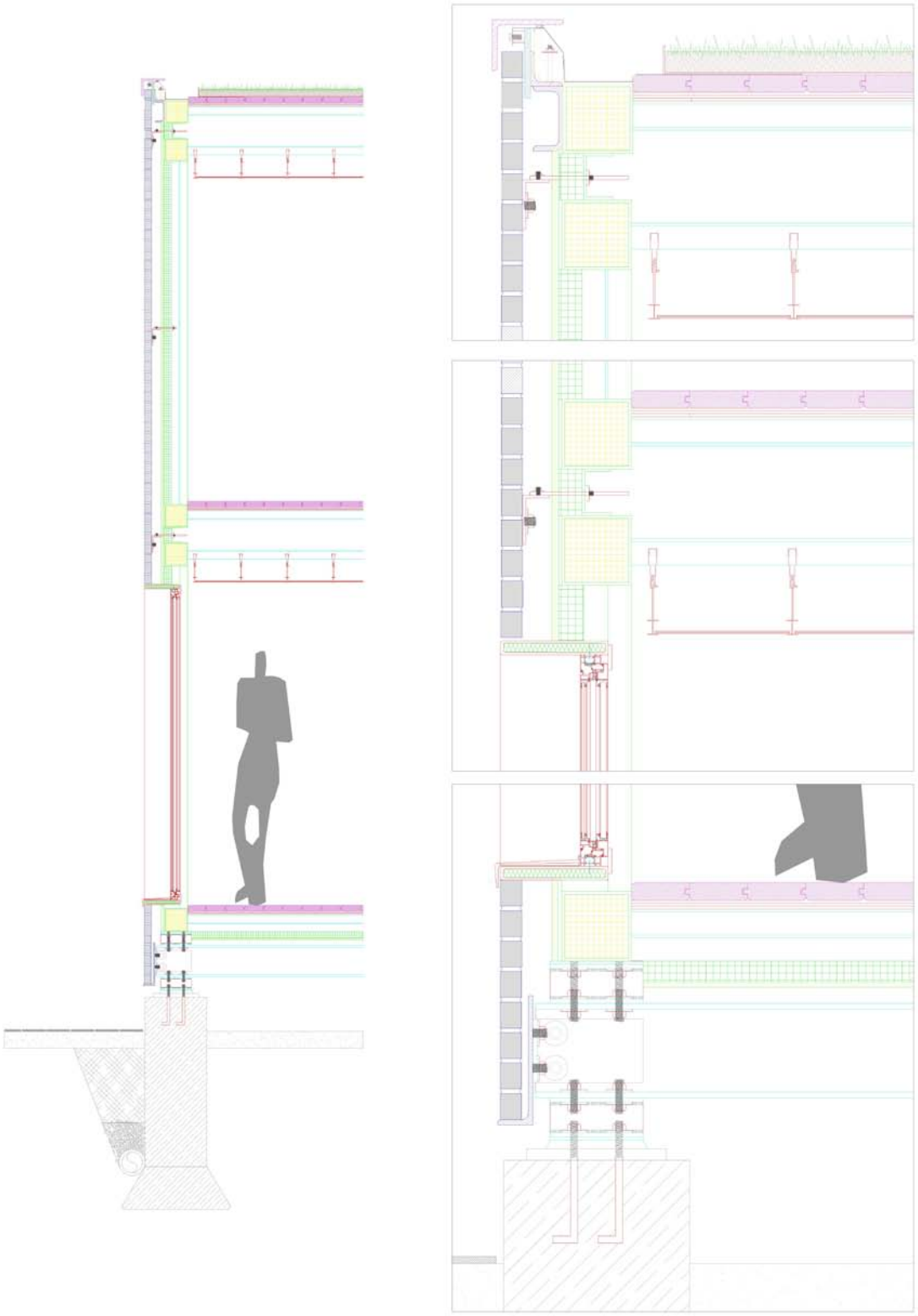

Figure 9: Design of the vertical facade.

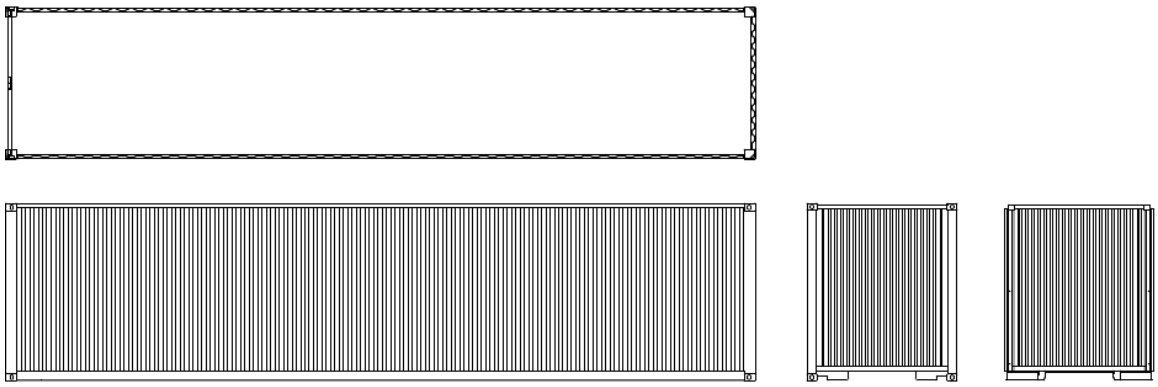

Figure 10: Shipping Container.

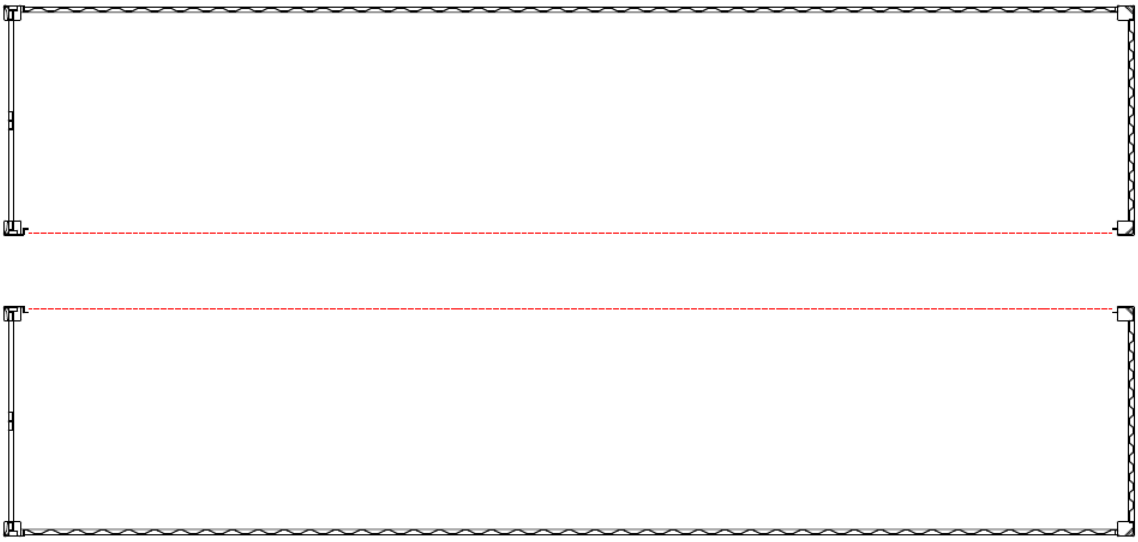

Figure 11: Two containers with one wall cut out.

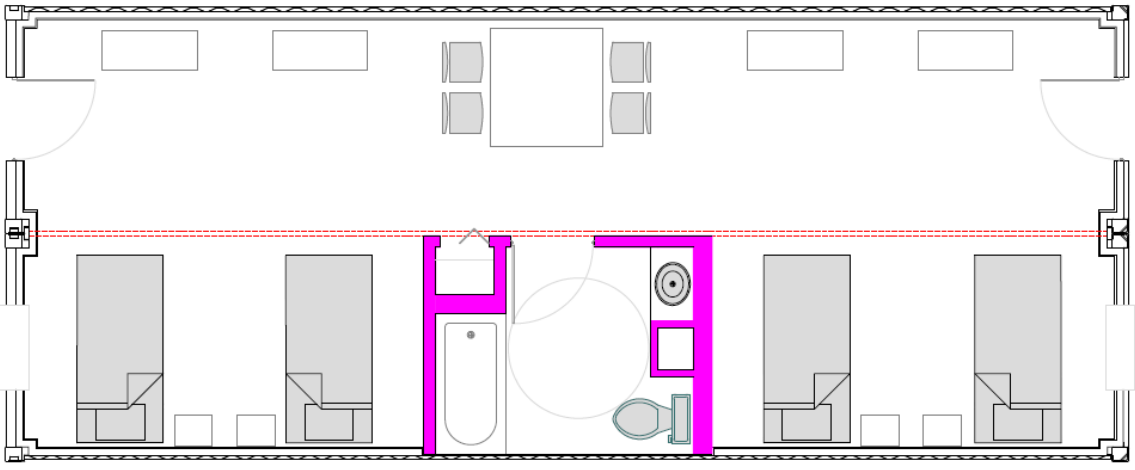

Figure 12: Olympic unit – houses four athletes.

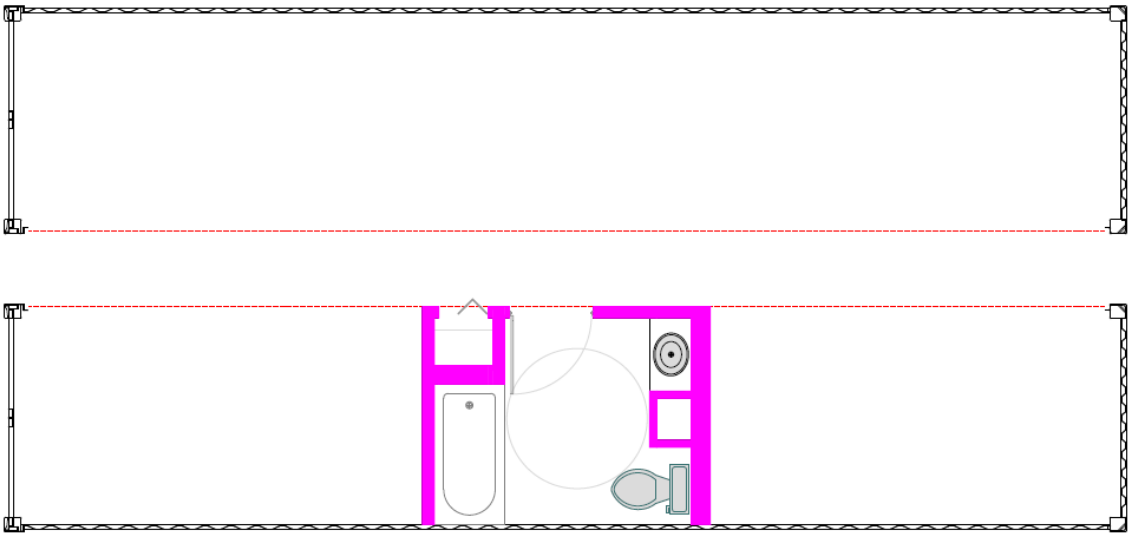

Figure 13: Disassembled for transport, bathroom remains.

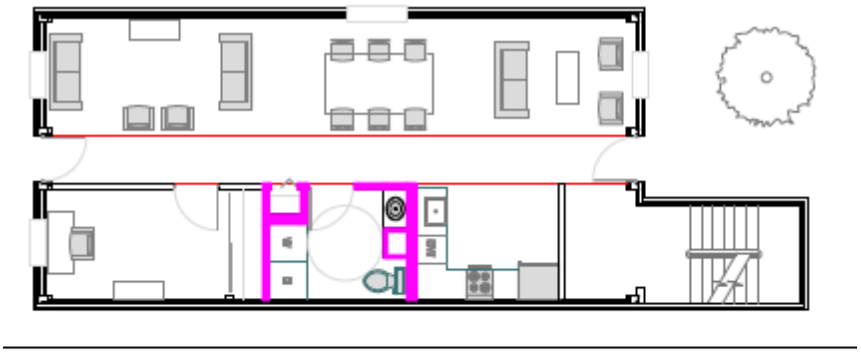

Figure 14: Two-story single family home; 3 bed 2.5 bath.

Obstacles

The main obstacle encountered was that of communication amongst the subgroups. It was a rather large IPRO group of 21. This was identified and resolved early on by designating a primary contact person in each subgroup who was able to effectively ensure that the necessary information flowed in a timely manner. In the future, group contacts should be chosen in the very beginning of the semester.

Organizationally, it was difficult to obtain certain materials from other members due to the fact that the team meetings were only once per week. While this was necessary and helpful to accommodate as many schedules as possible, the lack of face-to-face interaction at times bogged down progress. Emails are distant and impersonal and it was found that phone calls were most effective in accomplishing tasks.

There was also an issue of conflicting design ideas. This was most prominent amongst the Engineering and Architecture subgroups. The former group gave preference to feasibility and the latter gave preference to aesthetics. This obstacle was viewed positively as it highlighted that individuals were giving serious thought to finding the best solutions. Furthermore, such obstacles are healthy as long as they do not derail the IPRO from efficiently accomplishing its goals.

The presentation group ran into a lack of funding for transportation. Many of the group members have summer jobs. They needed to take time off of work and spend substantial time commuting. Without transportation expense coverage, it was not feasible for the team to make as many business calls as necessary.

Given the current economic climate, there was a lack of interest by corporations to support the project. Many of the companies we contacted believed that the Chicago would not get the Olympics. Consequently, the funding issue was not resolved. However, the Olympic idea was reconciled by the fact that our presentation was geared towards the low income housing options.

The biggest obstacle the engineers had to face was designing a system that would facilitate ease of assembly and dismantlement of the units that minimizes cost and maximizes efficiency. The concepts presented by the Architecture sub-group had to be modified, debated and eventually designed to suit the purpose of this project. A major engineering obstacle was the reuse of the steel container. These containers can obviously take a huge vertical gravity load, but how well would they handle the wind forces if they are used in a light, temporary setting like our Olympic Village housing?

There were also many issues from an energy perspective. The goal was to use the most economical and efficient systems, while applying them individually to each unit where these units can be later taken apart with ease and reused as low-income housing.

The major obstacles faced by the design team included creatively allocating space so that the dual purposes of Olympic housing and permanent housing could be served with minimal transition costs . The transition costs were a major obstacle and focus of substantial attention. Ensuring that accessibility options were compatible with ADA guidelines was also another challenge, especially with keeping costs minimal. There was also the issue of housing 17,000 athletes in a limited space for the Olympic Village. The transition process required some careful attention in regards to areas such as plumbing, room layout, accessibility, and facade. It was also necessary to avoid the past problems of social housing.

Recommendations

It would be recommended that the ideas and solutions that were produced be evaluated by actual architects, engineers, and respective firms. Feedback from professionals would be invaluable and an outside perspective will be able to help shape the next steps to bring these efforts to fruition. The feedback will also help in the identification of potential drawbacks and can guide the course of any necessary revisions.

In terms of fundraising, it would be best to continue working with the corporations where there are current links. It may be beneficial to explore potential sponsorships with hotels companies as they may be willing to assist in development and amenities.

Resources

Team Member	Total Time Spent (Hr)
Ahsan, M. Saad	40.2
Anderson, Aaron	31
Bais, Rajiv	51.7
Chan, Ronald	4.5
Dunn, Michael	48
Gibbons, Jennifer	21
Gregory, Nicole	26.8
Jacobson, Joel	9
Kucher, Rostislav	38
LaBuda, Timothy	7
Lima, Nancy	32
Park, Ji Ae	34
Park, Lucas	84
Pederson, Erin	31
Pyciak, Mark	35.8
Rahman, Raihan	12
Ribot Garcia, Anna	35.5
Roseen, Michae	13.5
Silvestre, Ivan	37
Specht, Cassandra	67

Total: 638.0 Hr

References

- Reed Construction
- RS Means 2009
- Professors M. Glyn and B.
-Thermal Fluid Sciences, Cengel, 3rd Edition.

Acknowledgements

We would like to thank Prof. Michael Glynn and Prof. Blake Davis for their expert opinions, ideas and assistance throughout the project. We would also like to thank the sponsors.