Project ID: GFS-1702

Low Income Housing Project: Prados del Sur Urbanization Quito, Ecuador

Submitted to the faculty of the Worcester Polytechnic Institute

In partial Fulfillment of the requirements for the

Degree of Bachelor of Science in Civil Engineering

by:

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Sponsored by: MIDUVI: Ministry of Urban Development and Housing, Quito, Ecuador

MINISTERIO DE DESARROLLO URBANO Y VIVIENDA

MIDUVI

Abstract

Prados del Sur is a 21-apartment low income housing project being developed in Quitumbe located south of Quito, Ecuador and sponsored by the public Ministry of Urban Development and Housing (MIDUVI). This project proposes a Building Information Modeling (BIM) approach to support the design and construction planning of this facility. A 3D model of the architectural design is further developed into a 5D model by incorporating the construction schedule and cost estimate of the building. The design of a beam component of the structural frame is also reviewed.

Capstone Design Statement:

Prados del Sur is a 21-apartment low income housing project being developed in Quitumbe located south of Quito, Ecuador and sponsored by the public Ministry of Urban Development and Housing from Quito, Ecuador (MIDUVI). This project proposes a Building Information Modeling (BIM) approach to support the design and construction planning of this facility. A 3D model of the architectural design is further developed into a 5D model by incorporating the construction schedule and cost estimate of the building. The design of a beam component of the structural frame was also reviewed. The professional design of this facility has been performed by *Constructora Garcia & Sanchez* from Quito Ecuador.

The following constraints have been addressed:

<u>Economic:</u>

One of the deliverables of this project is the cost estimate which was prepared based on architectural design, construction methods, and materials used in Ecuador. Most of the items in the cost estimate were identified, quantified and priced by the *Constructora Garcia & Sanchez* staff using a manual approach and historical cost data bases from previous projects. This MQP complemented and verified this process through a computer-based approach using On Screen Take-Off (OST) and Microsoft Excel software increasing the precision and expediency of the quantification process. The architectural design allowed for a more detailed quantification on some of these items. However, the estimates are much less precise in the case of mechanical, electrical and fire protection systems since detailed information on these systems was not documented in the available drawings.

The economic feasibility of the investment as performed by the design-build firm is also addressed.

Constructability:

A second deliverable of this project includes the construction schedule for this facility. The sequence of execution for the construction progress is based on production methods used in Ecuador. Microsoft Project software was used to create the schedule using the critical path method. The resulting schedule together with the 3D architectural model and the cost estimate were the incorporated into the Navisworks software to create a 5D model that visually displays the sequential construction of the facility indicating date and cumulated costs.

Social:

The development of this project has major impact in the socio-economic aspects of the lives of families in the low-to mid-income range in Ecuador. It involves numerous amount people who work on different stages for this project. It involved the ministry of urban development and housing of Ecuador (MIDUVI) and the construction firm *Constructora Garcia & Sanchez*.

Ethics:

The development of this project was based on professional work ethics, which was encountered on every single stage of the design and construction. The members of the team worked under the company's values; and shared ethical practices such as honesty, transparency, and professionalism. This performance made the development of the project efficient.

Safety:

The current construction of Prados del Sur has not started yet, for this there hasn't been any hazards or injuries. The current conditions of the site are kept the same and in the following two months will start the clearing of the site and excavation, taken to account all the safety factors needed. The professional design meets the local codes.

Professional Licensure Statement:

In order to be part of a Professional Engineering License in the United States, certain requirements are mandatory such as the Fundamentals of Engineering Exam that many fields of engineers need to take. After professional design experience is acquired the next step is to take the Professional Engineering Exam which is also required in order to work as a civil engineer and be part of construction. In construction there are other licensing agencies such as the Occupational and Safety Health Agency which provides training and education or related to safety of different activities in construction.

On the other hand, the license required in Ecuador to be part of the construction industry is approved by the Senesyt (Secretería Nacional de Educación Superior, Ciencia, Tecnología e Innovación) meaning "National Secretary of Higher Education, Science, Technology and Innovation. This license qualifies engineers to work in construction since the country doesn't currently have safety programs such as OSHA.

Acknowledgements:

I would personally like to thank those individuals who made the accomplishment of this project possible. I want to recognize the contributions of every member of *Constructora Garcia & Sanchez*, as well as of architect Andres Garcia, structural engineer Hector Sanchez and their corresponding sons for their help.

Also, I would like to thank and recognize the constant help from professor and advisor Guillermo Salazar and his recommendations on how to lead and manage the results of this project.

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1.0 Introduction:

Prados del Sur is a low income housing project developed by the public Ministry of Urban Development and Housing, a public agency from Quito, Ecuador also known as MIDUVI (Ministerio de Desarrollo Urbano y Vivienda). MIDUVI was established to assist Ecuadorian low-income families with affordable housing in order to improve their current living conditions. MIDUVI is the first public agency to address the housing needs of low-middle income families whose monthly income range from $380.00 to $800.00 USD. MIDUVI's main goal is to offer and deliver affordable housing with the best possible infrastructure and the highest quality of installations.

Prados del Sur is a specific MIDUVI project located in Quitumbe, a neighborhood in the southern cone of Quito. Quitumbe has an estimated population of 10,000 people and has experienced recent urban development and modernization, which has promoted commerce and boosted the local economy. In spite of this recent economic growth, the urban development has been disorganized and has not been regulated, thus, many buildings don't meet the construction codes (Normas Ecuatorianas de Construcción). Prados del Sur is going to be a four story building with 21 apartments and a rooftop level in the fifth floor. It will be surrounded by green areas and will have an underground parking garage. It will be built in a corner lot intersection at Otoya Nan Avenue and Street #4 and it has an estimated area of 650 m^2 or 6996 ft^2. *Constructora Garcia & Sanchez*, a local Ecuadorian construction firm, has been retained by MIDUVI as the design-builder of this project.

This Major Qualifying Project (MQP) proposes a Building Information Modeling (BIM) based construction planning approach to assist *Constructora Garcia & Sanchez* in the future construction of this facility. BIM is an enabling technology based on object orienting, parametric modeling and interoperable computer software such as Autodesk Revit and Navisworks. BIM has the capacity to generate a digitized 3D model incorporating information design of the building. This MQP used information generated by *Constructora Garcia & Sanchez* to create a 3D model of the architectural design and to transform the BIM 3D Model into a 5D Model. To start, a 3D model based on the architectural drawings provided by the designer was developed using Autodesk Revit software. A quantity take-off was conducted using On Screen Take-off software also based on the architectural drawings provided by the designer. The full cost estimate was created by incorporating calculations conducted in this MQP with information generated by *Constructora Garcia & Sanchez*. A construction schedule was created using Microsoft Project software after identifying the major construction tasks and organizing these tasks according to the different Construction Specifications Institute (CSI) divisions. By using Autodesk Navisworks software, a 5D model was created by incorporating the 3D BIM model with the addition of the construction schedule and the cost estimate. Lastly, a simple structural analysis review was performed to verify that the reinforced concrete beams were calculated with the proper moment capacities. This review allows verification that the implementation of ETABS software used by the structural engineer is efficient and correct.

The deliverables of this MQP consist of the 3D architectural model extended to a 5D model that visually displays how the construction will be progressing according to its phases and cumulated cost. Providing a visual 5D representation of the physical and economic progress of the construction allows the company to manage its resources and time efficiently, facilitating the delivery of quality in the project. It is expected that the approach herein developed will benefit *Constructora Garcia & Sanchez* in adopting and adapting the new BIM technology into the Prados del Sur project and other future projects as well.

2.0 Background

2.1 Purpose of MIDUVI

The public Ministry of Urban Development and Housing, is a public agency from Quito, Ecuador also known as MIDUVI (Ministerio de Desarrollo Urbano y Vivienda). MIDUVI was established to assist Ecuadorian low-income families with affordable housing in order to improve their current living conditions. MIDUVI is the first public agency to address the housing needs of low-medium income families whose monthly income range from $380.00 to $800.00. MIDUVI's main goal is to offer and deliver housing with the best possible infrastructure and with the best and highest quality of installations while at the same time making housing affordable. This project approaches people with low-medium income that are currently living under difficulties and cannot afford to live under good living conditions. Usually these people live in the outskirts of the biggest cities of Ecuador such as Quito and Guayaquil that have an average population of 2 million people. Quito's outskirts are formed by a combination of many neighborhoods (in this case Quitumbe) which lack proper installations or access to proper sanitary conditions. This problem exists because the public infrastructure in Ecuador is still developing and only the middle and high classes can afford having decent sanitary conditions in the big cities.

This doesn't only create difficulties for the families who live under poor sanitary conditions but also affects the zones where they live as the buildings that are constructed in them lack architectural aesthetic and structural stability. The residents of 80% of these homes are not safe because these buildings do not meet the safety construction codes.

Figure 1: 24 Provinces in Ecuador

MIDUVI is in charge of working with all the 24 different provinces in Ecuador shown in figure #1 by establishing proper mechanisms that ensure that future urbanization projects follow the construction guidelines. Among the development plans, there is an effort to improve several aspects of the construction process such as creating an optimal plan for the use of the lands. In order to make these planning conditions optimal, the land use needs to be optimized (space wise) and environmentally friendly. On the other hand, other important public companies such as the EPMAPS (public company of water supply and sanitation) and EP (electric company) get involved in the projects due to the demands and needs that these poor neighborhoods have. Each company has its own role in the developing project but they work together in order to maximize its efficiency. Without MIDUVI's intervention and willingness to provide the lands, it would be extremely difficult to start any housing project in these zones because of the lack of economic stability that the country is facing. In the long term, MIDUVI's plan is to not only provide affordable housing opportunities but also improve the quality and amount of education centers in these areas.

2.2 MIDUVI Project Development Approach:

Prados del Sur is one of several projects that MIDUVI has promoted around the country. However, the selection process, the apartment characteristics and the construction guidelines are the same for all the projects. The ministry of urban development and housing (MIDUVI) owns land in many different places around Ecuador. The lots are located in specific zones or neighborhoods that are surrounded by medium class housing development. They try to make the best from each site in terms of use of the lands, aesthetics, improved infrastructure, and basic resources such as water and electricity. In other words, they try to develop areas by providing affordable housing opportunities. MIDUVI goes through the process of identifying land that is feasible for development and that meets their specific needs. Then they proceed to make a public announcement inviting construction companies to submit proposals for the development of the construction project. The ministry posts in their website: http://www.habitatyvivienda.gob.ec/procesos-de-contratacion-bid/ all the specifications of the site and its specific location. Since it is a public entity, the newspapers in Ecuador also contribute in the advertisement of these projects.

For each project, MIDUVI searches for the best strategic partner to design and build it. The interested construction companies respond to the invitation known as request for proposal by preparing their design-build proposals that should meet MIDUVI's requirements and specifications. The final project is presented as a conceptual design for the development of the project in order to give MIDUVI an idea of how the project is going to look. MIDUVI contributes by providing the land/terrain and the design-builders from the private sector contribute with the cost estimate, the design and the construction.

Additionally, the construction company also becomes the realtor of the project and thus gains rights to all the sales from the dwellings. Basically, the company whose proposal is selected by MIDUVI will be in charge of every aspect of the construction from beginning to end while MIDUVI gains political approval.

The public agency of (MIDUVI) analyses the proposals submitted by the private companies and selects the best one based on its price, design and ability to follow their guidelines. One of the most important aspects of the proposals is the affordability of the apartments since the target buyers are people that don't have much income and currently do not own a house. In their guidelines, MIDUVI establishes that the maximum unit price that a buyer should spend for every square meter is $890.00 USD. Additionally, in a partnership with BIESS (Banco del Instituto Ecuatoriano de Seguridad Social), MIDUVI gives potential buyers the opportunity to borrow money for the apartment with an annual loan interest rate of 4.89%. For the design to be a success, the space of each apartment needs to be maximized in order for the project to be feasible for the private company. MIDUVI has guidelines about the size and price that each apartment should have according to the size of the land and the desired number of apartments.

2.3 *Constructora Garcia & Sanchez* Firm

Constructora Garcia & Sanchez is a family owned private company founded in 2015 in Quito, Ecuador with the purpose of designing and building different kinds of construction projects. Both of its managers and current owners Andres Garcia and Hector Sanchez have been involved in the construction industry for more than 30 years, specializing in different fields of civil engineering and working in various projects in the past. Garcia has been working as an architect for all this time, creating beautiful buildings in Quito, Ecuador. He has designed over 15 buildings around the country and designed-built five houses. Now his son, who is also an architect, is taking his lead since 2015 and has assisted in the development of the architectural drawings of Prados del Sur. On the other hand, Hector Sanchez has been working as a structural engineer for almost 25 years. His son also has an important role on the company as he is the structural engineer in charge of doing all the structural design and creating the structural drawings. As of now, the company has been working for almost two years together, focusing the last year and a half on the design and construction of Prados del Sur. MIDUVI has recently awarded *Constructora Garcia & Sanchez* another low income housing project, 10 times bigger in size than Prados del Sur. This private company is willing to continue designing-building more projects that are related with MIDUVI's commitment to provide affordable housing opportunities for Ecuadorians for an extended period of time.

2.4 Prados Del Sur Project

Prados del Sur project is located in Quitumbe, a small neighborhood in the southern cone of Quito, Ecuador. Quitumbe currently houses 10,000 people and has become a popular neighborhood because of its recent urban growth. The main source of urban growth has been residential construction, which has increased by 20% in the last couple of years. In an effort to modernize the area and attract visitors from all around the city, several buildings have been constructed, including the main bus station for the city and a stadium that can host up to 20,000 fans. In addition, a modern and giant mall was recently constructed in the area, largely increasing the popularity and economic activity of Quitumbe. In spite of this recent growth, the urban zone development has not been regulated by the city's government causing the type of architecture and quality of construction to be disorganized and low. Luckily, all the main infrastructure such as potable water, electricity, sewage, telecommunications and roads are provided by the town.

The 650 m^2 site in which the Prados del Sur project is going to be developed, was previously a wasteland area. In figure #2 below the site where Prados del Sur is going to be constructed is highlighted, along the Otoya Nan avenue right on the top corner perpendicular to street #4.

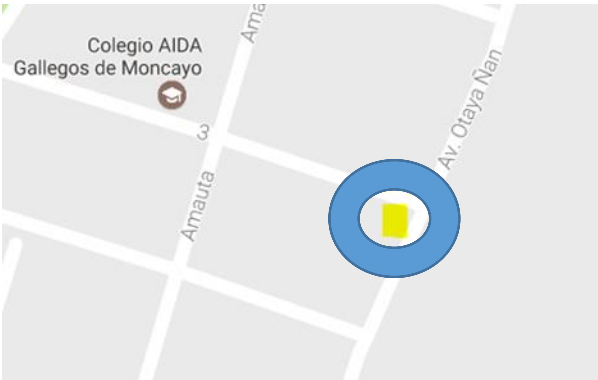


Figure 2: Location of project

Quito used to have many lakes all around the city that were spread out into different zones. Originally, this site of construction was part of a lake and as a consequence the soil had a low bearing capacity that needed to be improved to support the weight of the building. For this reason, an excavation of 2.20 meters deep needed to be done to eliminate the 2100 metric tons' equivalent weight imposed by the pressure of the building over the ground. In this area, many buildings have already collapsed because the land's bearing capacity was not considered properly, creating a feeling of insecurity and distrust among the residents of Quitumbe. Currently, Ecuador has been facing constant earthquakes that so far have happened mainly in the coast region where buildings have been destroyed and hundreds of lives have been lost. The repercussions of these earthquakes in Quito and the rest of the highlands region have been minor. However, they still have created several damages to constructions, specially to the ones that lack proper site work development and structure. For this reason, MIDUVI has established strict regulations for site development in order to ensure the safety of the residents.

Figure 3: Existing conditions of site before development.

The figure #3 shown above, displays the existing conditions of the underdeveloped site before the construction of Prados del Sur project begins. This figure points out the actual aesthetics and physical conditions of the Quitumbe neighborhood. As it is shown, most of the buildings are not even finished and are left without the proper construction regulations mainly because of the lack of planning and economic resources. These houses are usually built without the supervision of experienced architects or engineers who know enough about construction and therefore violate numerous construction regulations.

On the other hand, Prados del Sur will exceed Quitumbe's expectations and standards mainly because it will be built with an outstanding design and aesthetics that follow MIDUVI's specifications.

Constructora Garcia & Sanchez submitted a proposal among nine other private construction companies to take over the Prados del Sur project. Due to its remarkable economic analysis and architectural design, *Constructora Garcia & Sanchez* was selected by MIDUVI to manage the entire project. As already said, the terrain has 650 m^2 and 21 dwellings were projected into four floors with surrounding green areas and corresponding parking lots. The project is going to manage its funds through an escrow to ensure the safety of the buyer and the different companies involved. MIDUVI established that this project has a deadline of 48 months and has to be sold in its totality. The project was subscribed on November 24 of 2016 and the plan is for the construction of the building to last approximately 9 months once it starts.

As part of its proposal, *Constructora Garcia & Sanchez* set the price of the land to be 8% of the final cost of the project, which resulted in a value of $110,000 USD. In order to finance the rest of the project, *Constructora Garcia & Sanchez* asked for a loan of $500,000 USD from Coorporación Financiera Nacional (CFN). CFN is another partner of MIDUVI in these projects and agreed to provide the loan to *Constructora Garcia & Sanchez* with a 6% interest. Once the 6% interest is included, the company owes CFN $530,000 USD in addition to the $110,000 USD that is paid to MIDUVI.

On the other hand, it has been established that each apartment is going to have 65 m^2 and there are going to be one bedroom and two bedroom apartments. Based on the apartment size and the amenities of the building, it has been established that the price of the apartments is $65,000 USD, including a parking garage spot, access to laundry room and storage space. Considering there are 21 dwellings in the project, the expected revenues from Prados del Sur project for *Constructora Garcia & Sanchez* are $1,135,000 USD. In other words, the total net income for the building goes the following:

Total Income from 21 Apartments	$1,365,000.00
CFN loan with 6% interest	-$530,000.00
Cost of land to MIDUVI	-$110,000.00
Net income for Constructora Garcia & Sanchez	$725,000.00

Table 1: Net Income Chart

As shown in table above, the total net income for *Constructora Garcia & Sanchez* is approximately $725,000 USD taking into account that the income from all the apartment sales is subtracted from what they owe CFN for initial loan and MIDUVI for the cost of the terrain.

Constructora Garcia & Sanchez's goal is to cover approximately 80% of the costs with the loan from CFN and to pay the remaining ones with the money received from selling the dwellings. Selling all the apartments is completely feasible because of the conditions set by the partnership between MIDUVI and BIESS. In the case of Prados del Sur, buyers have to provide 5% of the total cost of the apartment to start ($3,250 USD) and will pay the remaining amount throughout a 20-year period with a super low interest rate of 4.89%. This means they have 20 years to pay the remaining $61,750 USD which adds to be $3,087.50 USD annually. Once the interest rate of 4.89% is included, the buyer will have to pay a modest sum of approximately $270 USD per month ($269.87 USD). This sum of money is affordable for the income of the low-medium class, making the target of the project feasible for construction and to continue its development all around the country. If this project finishes as planned it will be a great success and a model for the future as it will satisfy MIDUVI's urban development objectives, bring happiness and a home to families with low-medium income. Additionally, it will give back income to a private construction company that has recently been created and is willing to contribute to planned and safe urban development.

2.5 BIM (Building Information Modeling):

One of the main tools used in this project in order to assist *Constructora Garcia & Sanchez* is BIM (Building Information Modeling) which is defined as: "an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure."[1] This software provides a visual representation of the project before its construction starts and allows the designer to have a better perception of the project. Inside BIM, there exist several software systems that have a specific role on developing different parts of the project. For this specific project, Revit and Navisworks were the two main software applications used in which the design was modeled in 3D and 5D views.

These two software applications assisted this project in the design phase. Revit gives a detailed 3D visual interpretation of how the building is going to look before the construction. In addition, Revit helps the designer to clarify how the spaces are going to be divided and how the building will look in the interiors. On the other hand, Navisworks is the 5D integration of the model that is imported from Revit with the costs obtained from

[1] "What Is BIM | Building Information Modeling | Autodesk." Autodesk 2D and 3D Design and Engineering Software. N.p., n.d. Web. 2 June 2017.

the cost estimate analysis. The model is divided into phases where each phase is assigned a specific schedule and this way the construction of the building is visually divided into phases. As a result, Revit and Navisworks have the capacity to help with the design and development of the project.

3.0 Documentation of Architectural Design

The purpose of this chapter is to explain how the architectural drawings were documented in 2D (AutoCAD) and then used to create a 3D model by using Revit Software. The architectural drawings were created by the architect and provide a 2D view of the construction, which means that the spaces can only be seen in one perspective. For this reason, the 3D model is indispensable since there has to exist a view of how the building is going to look before it is built. Before this MQP, *Constructora Garcia & Sanchez* used to build the 3D models by hand and it was a very time consuming and tedious job. Introducing them to Revit and showing them its fantastic functions was a game changer as it is a tool that will allow them to save time and improve their precision in future projects.

3.1. AutoCAD: 2D Drawings

The 3D model built for Prados del Sur was based first on the site drawing created in AutoCAD with the given dimensions from the surveying made to calculate the elevations and area. The drawings from AutoCAD are created in a 2D model which helps understand the different areas that need to be taken to account in order to use it as a base to create a model in 3D view.

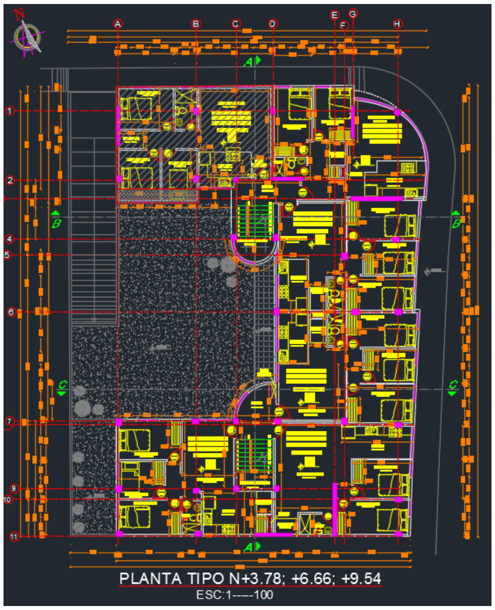


Figure 4: Architectural 2D Drawing 2nd Floor Plan

As shown in Figure #4, the 2D architectural drawings provided by the architect give a plane perspective of the site of construction. All of the architectural drawings used by *Constructora Garcia & Sanchez* were created in AutoCAD.

3.2. Revit: Architectural 3D Model

In order to create a 3D model in Revit for this project, there needs to exist an architectural drawing where the blueprints give the measured dimensions and have to be adjusted to the size of the drawing. In this case the scale used was one of 1:100. The 2D drawings created in AutoCAD had to be saved in DWG format in order for Revit to be able to read the document. Once the design is ready, the DWG drawings are linked via a Cad file and the drawings are opened according to the specified scales. The drawings of every floor are adapted to the corresponding level and this way the building starts to have a 3D perspective. For this to happen, the 3D model uses the imported 2D DWG as a template and then the 3D objects are drawn and extruded. Additionally, for every element that is included in the drawing, one needs to add details such as the heights of the walls and the thickness of the slabs. Revit has families of building objects that are customized to the design specifications for each corresponding material or element. By defining the properties of the different objects that comprise the building, the designer establishes and defines the characteristics of the design.

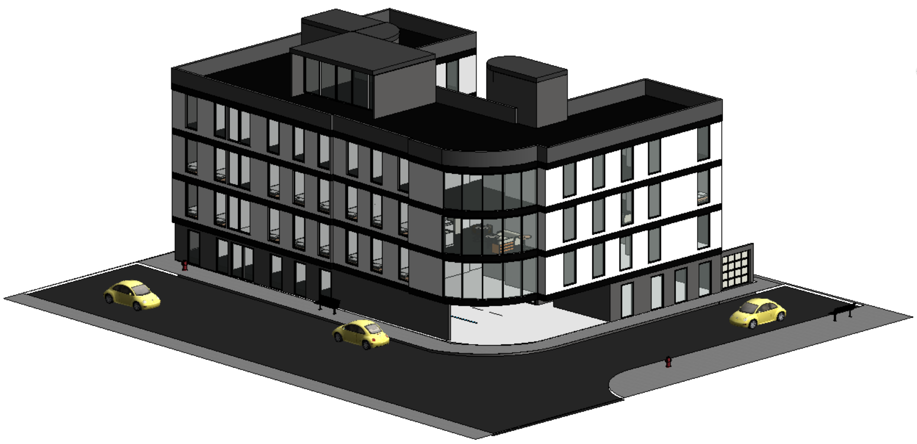


Figure 5: Prados del Sur 3D Model

Architectonically speaking, Prados del Sur consists of four floors that include a total of 21 apartments for sale and a rooftop area for common use as shown in figure #5. The model displays how the building will look as it is going to be constructed in the corner point between Otoya Nan Avenue and Street #4. The first floor is composed by three apartments and an entrance lobby where the concierge will control the entrance of guests. The second, third and fourth floors contain six apartments each. Each apartment is 65 m^2 (700 sqft) and includes all the specialties for the house except for washer and dryer. In order to use these specialties, Prados del Sur's residents will have to go to the fifth floor where there will be a communal laundry room. Unfortunately, the building won't have an elevator and as a replacement, one set of stairs will be constructed in each side of the building.

Prados del Sur will have a basic structure made out of reinforced concrete. Once the structure is built, the exterior walls will be constructed with block. To finish up these walls, plastered concrete will be used in order to complete the masonry and then they'll be covered up with paint. On the other hand, all the interior walls will be made out of gypsum, the doors will be made out of wood and the windows will be framed with aluminum.

Every apartment has its own design but all of them are composed by a kitchen, one bathroom, a living room and either two or three bedrooms. These apartments will have interior finishes in the kitchens and bathrooms. The design of a typical two-bedroom unit is shown in figure #6 and the design of a typical three-bedroom unit is displayed in figure #7.

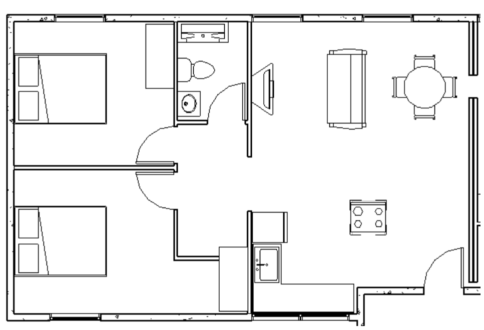


Figure 6: 2 Bedroom Unit Model

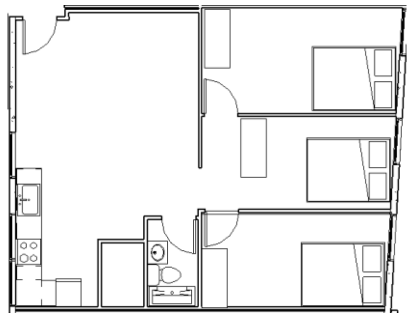


Figure 7: 3 Bedroom Unit Model

Ideally, the design shown in Figure #5 was going to be used because it followed all of the required regulations from MIDUVI in order for the construction to start. However, after they conducted the second study of soil mechanics described in the previous chapter, it was discovered that the design was no longer appropriate because it placed the safety of the residents in danger.

After discovering the poor soil bearing capacity of the land, *Constructora Garcia & Sanchez* came up with a feasible solution that will enable them to maintain the construction schedule on time. The issue was that the actual density of the soil removed was of 1.5 tons per m^3 and has a soil bearing capacity of 4 tons per m^2 which is below the recommendable soil bearing capacity (5 tons per m^2). They decided to remove a volume of existing soil with a total weight equivalent to the total weight of the building that was going to be resting upon the ground. By doing this, the bearing capacity of supporting soil will not be exceeded. The approximate weight of the removed solid is about 2,000 tons and the volume of the excavation is approximately 1300 m^3, with an area of 650 m^2 and depth of two meters.

Once the soil was removed they added structural fill with a concrete slab on top. As depicted in the Figure #8 below, *Constructora Garcia & Sanchez* decided to add an underground parking level with 18 spaces shown in a 2D drawing of the design.

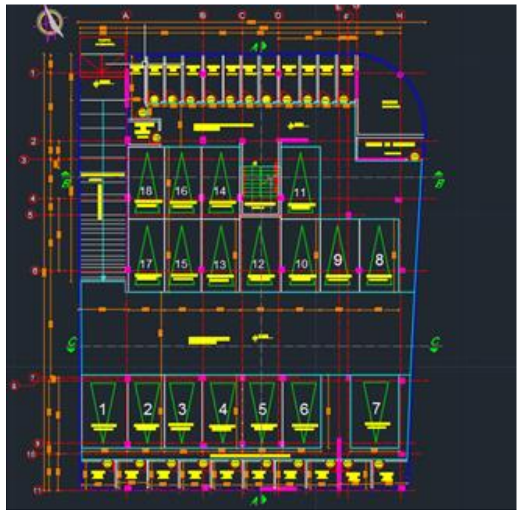


Figure 8: Underground Extension Design

The excavation costs will be funded by the profit obtained from the sale of each parking spot, either to the proprietors or to anyone who is seeking a parking space for their vehicle. The cost of the parking spot has already been included in the $65,000 USD that the buyers are going to be charged for the apartment. Before the parking garage was approved, *Constructora Garcia & Sanchez* had another foundation design. It consisted of installing piles that went from the underground level to the street level. However, it ended up being less feasible because it had higher costs, took longer time to build and generated no additional revenues for the company. In addition to the parking spot, owners of each apartment will have access to individual 8ft by 8ft storage rooms that are located in the same underground level. Residents will have access to the underground parking space from the first floor through a ramp that is 45 feet long and 9 feet wide.

Figure 9: Cross-sectional View from South to North

The figure #9 above shows a cross-sectional perspective from south to north of the modified and final model of Prados del Sur, in which one can observe how the underground parking space and the car access ramp on the left were added to the previous design.

4.0 Structural Design Review:

Prados del Sur will have a structure based on steel reinforced concrete which will be used for all the beams and columns of the building. The purpose of this section is to conduct a simple review of the structural design in one of the beams of the frame. This was done by conducting a manual calculation of the bending moment capacity of one of the beams of the first floor and compared this value against the one determined by the structural analysis software ETABS[2] used by the professional structural engineer in the analysis and design of the multi-story structural frame of the building. This section covers the structural analysis for beam number 7 as shown in figure #10 point with an orange arrow, which is located in the first floor and it is 16.5 feet long. The metric system is used in Ecuador, meaning that the size for this specific beam is 0.30 cm in height and 0.40 cm in depth. By using the conversion factor to inches, 1 inch is equal to 2.54 cm, converting the given values to: 11.81 inch and 15.748 inch respectively. The beams and columns of the structure are joined together by a moment resistant connection.

[2] "ETABS Training Videos and Manuals • R/StructuralEngineering." *Reddit*. N.p., n.d. Web. 14 July 2017.

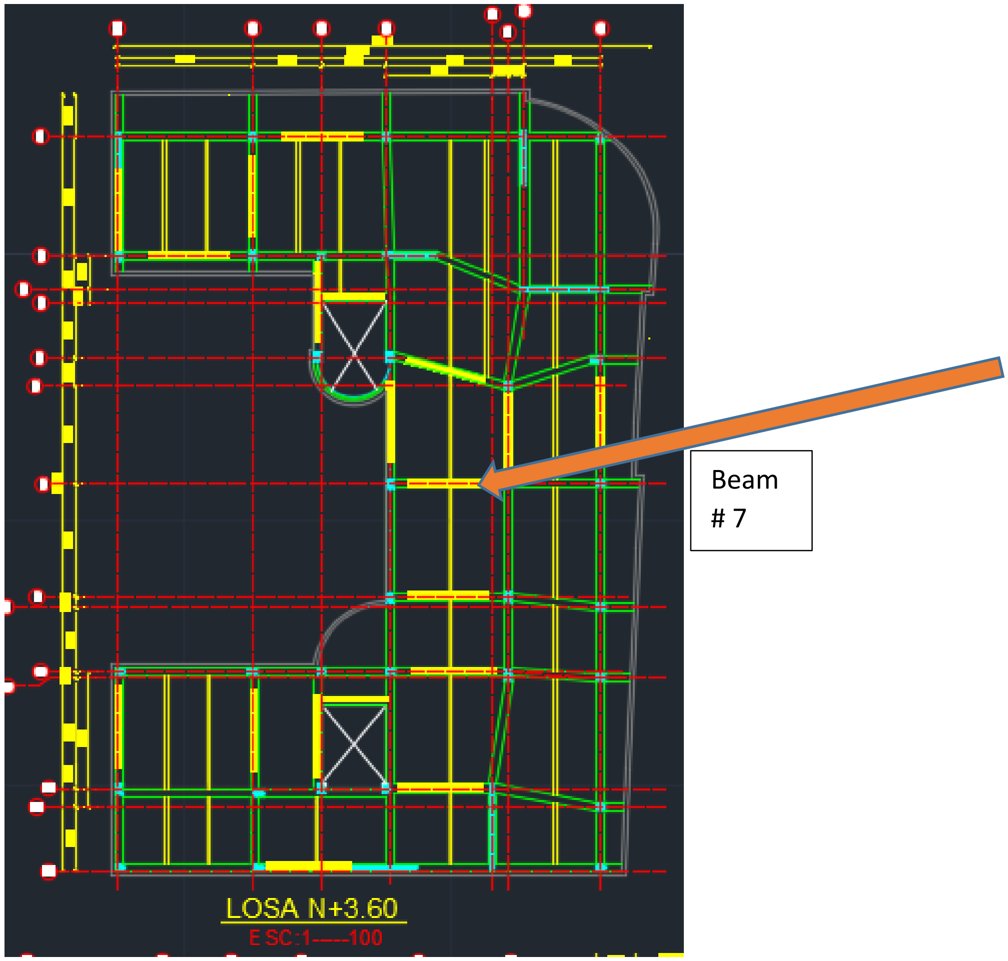


Figure 10: Autocad drawing from structural floor.

The structural engineer used ETABS software in order to design the structure model shown in figure #10 where he draws the beams and columns with specific material properties. After the design was done, he applied the predicted loads to obtain the required moment capacities to design the structure.

All the beams have their particular moment capacity with the given number of rebar's and diameters that are obtained. For the design of the structure, the beams and columns are tested in ETABS where the structural engineer analyzed each beam in term of area of the steel (A_s) and the maximum moment that it can resist or be allowed at the end of the beam. Also, for the load calculations he used the different resistant factors required such as: live load of 1.6, dead load of 1.2 and seismic load of 1.0. In this specific beam shown below in figure #11, the maximum bending moment acting upon the beam that ETABS determined is 489,416 lb-in meaning that the design of the beam needs to surpass that minimum moment for it to resist the acting loads on the structure. Under bending, this beam works in tension and compression. The steel rebars will primarily resist the tension forces while the concrete will primarily resist compression forces.

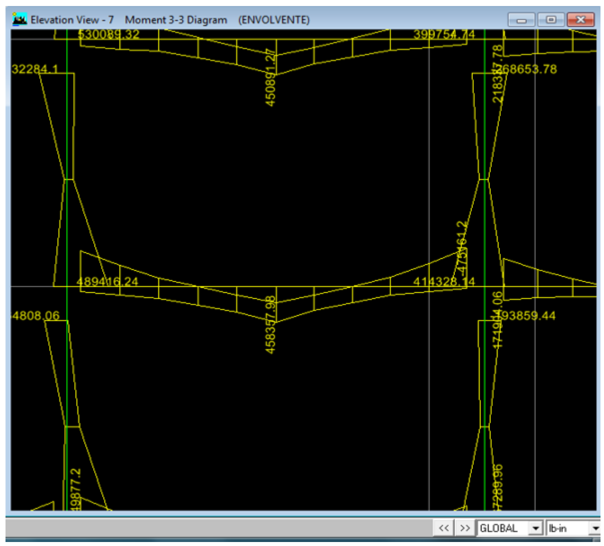


Figure 11: Result of moment diagram from ETABS.

In order to determine the moment capacity of the beam the following equation was used:

Equation 1: Moment capacity equation

$$\phi M_n = \phi f_y A_s jd$$ [3]

Each of these variables are identified as: Phi is the dimensionless factor of tension in the section, Mn is the moment capacity of the beam (lb-in), Fy is the yield strength of

[3] Lin, Andy. "Determine the Capacity of a Reinforced Concrete Beam with Tension Reinforcement." Structural Engineer HQ. N.p., 20 Jan. 2017. Web. 22 June 2017

the steel (lb/in^2), A_s is the area of the reinforcing steel (in^2), J is the ratio between tension and compression, and d is the total beams depth minus the cover and minus the rebar diameter (in). Lastly, F'c is the specified compressive strength of the steel.

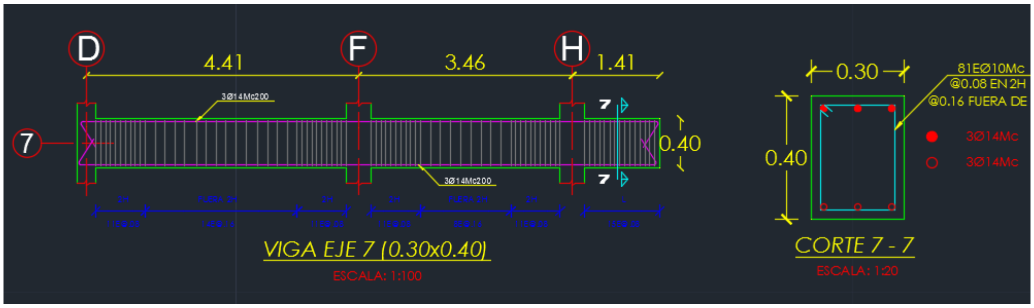


Figure 12: Autocad drawing of Beam #7 design with details.

The beam #7 shown above in figure #12 can't be designed with other width sizes because in Ecuador the structures need to follow certain construction regulations. The diameter of the rebar cannot be more than 20 times bigger in size than the width of the beam. In this particular beam, the width of 30 cm is divided by 20 with a result of 1.5 cm which represent the maximum size in diameter of the rebar allowed. In Ecuador, the 1.5 cm are converted into 15 mm in order to follow with the nominal diameter that will coincide with the number of the bar in metric size. As a result, the maximum diameter of a rebar that can be employed in this beam should have less than 15 mm, or under a #5 imperial bar size or No.14 in metric system as shown in figure 13.

U.S. rebar size chart

Imperial bar size	Metric size	Linear Mass Density		Nominal diameter		Nominal area	
		lb/ft	(kg/m)	(in)	(mm)	(in^2)	(mm^2)
#2	No.6	0.167	0.249	0.250 = ¼	6.35	0.05	32
#3	No.10	0.376	0.561	0.375 = ⅜	9.525	0.11	71
#4	No.13	0.668	0.996	0.500 = ½	12.7	0.20	129
#5	No.16	1.043	1.556	0.625 = ⅝	15.875	0.31	200

Figure 13: U.S. rebar size chart.

According to the calculations done, which are shown in figure #14, the largest moment capacity for this beam is 512,501 lb-in which it supports the best design by using three #14 rebar. The nominal area of these rebars are 0.24 inch^2 each with a total area of 0.72 inch^2. Essentially, the calculated resisting moment given by the dimensions and properties of the materials used, shows that the strength of the reviewed beam is higher than the moment created by the acting forces.

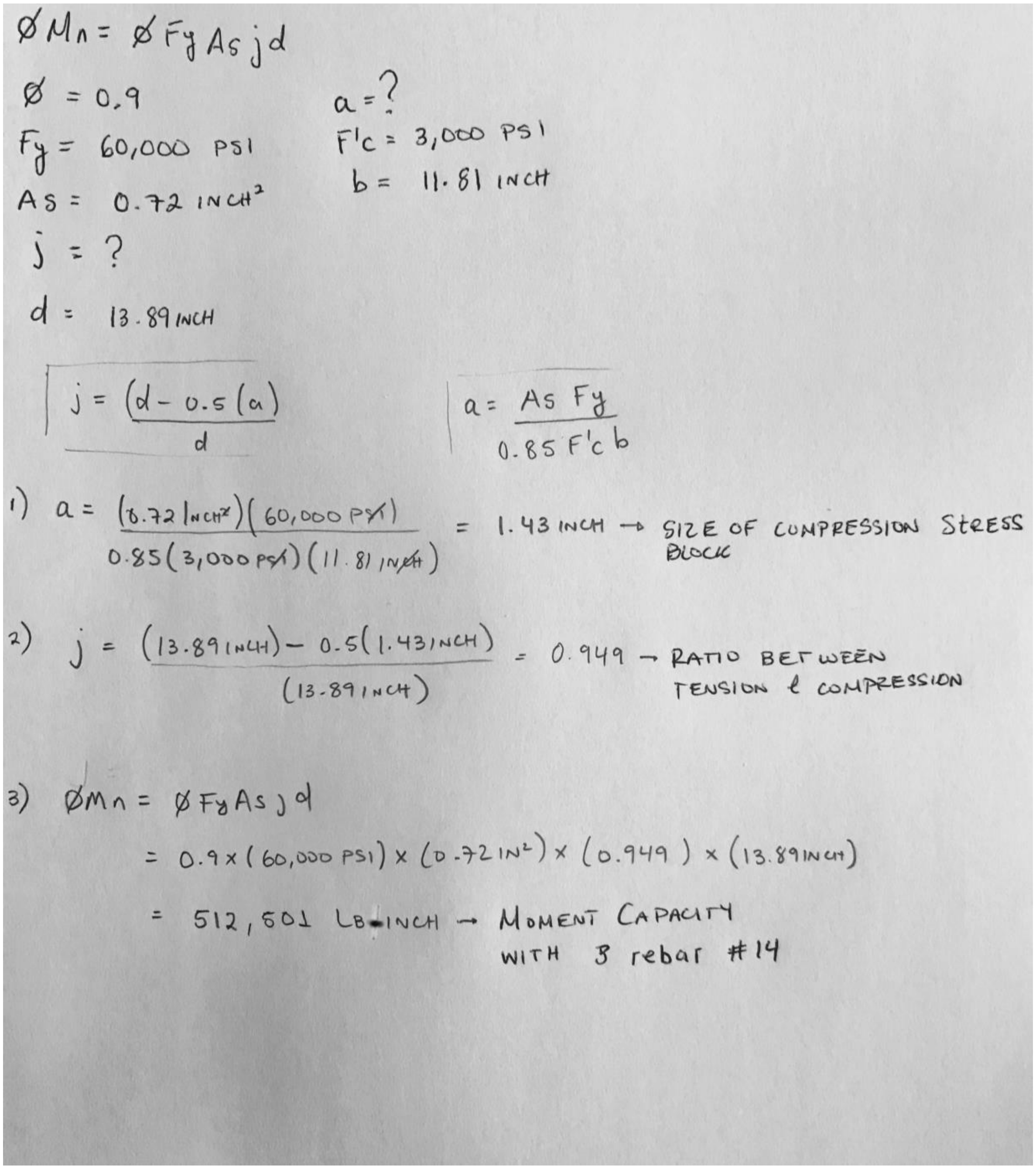


Figure 14: Moment calculations for beam #7

In the calculations shown above, the identified variables are: a is the size of compressive block, b is the width of the beam, and d is the depth minus the cover and minus the rebar diameter (in). The type of steel used is ASTM A992 which has a yield strength (Fy) of 60,000 psi and a specified compressive strength (F’c) of 3,000. Shown below in figure #15 is the cross section with the corresponding dimensions based on the calculations.

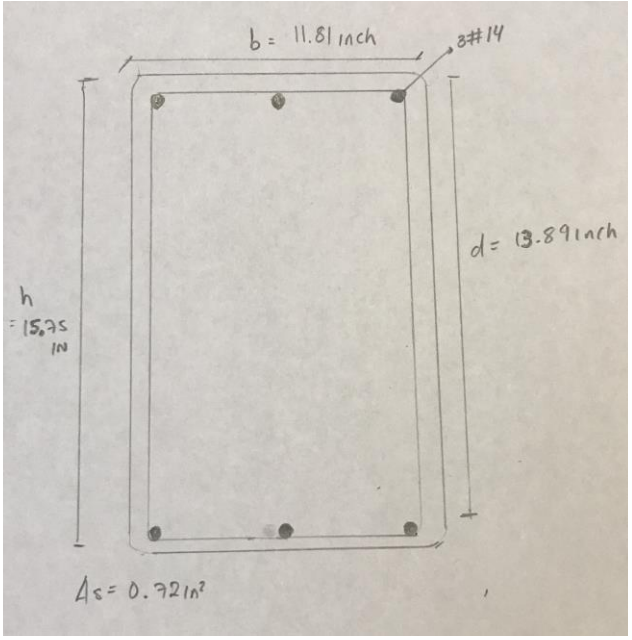


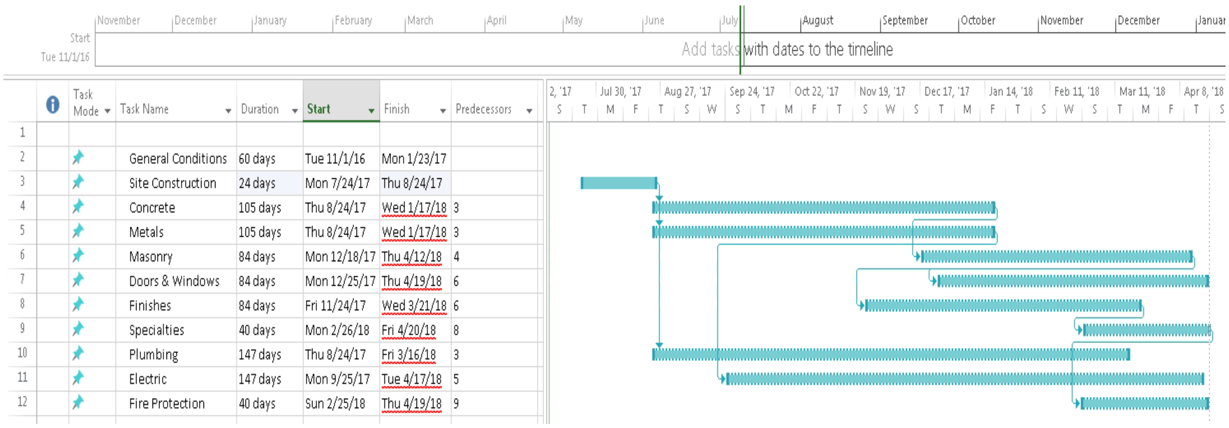
Figure 15: Beam #7 Cross-Section

5.0 Schedule and Project Cost

5.1 Microsoft Project

Prados del Sur is designed to be built in approximately 9 months or 182 days working five days a week (Monday to Friday) based on the intended construction method. The construction method used will start with an excavation that will be done with a small cat excavator. After this is done, the foundations will be poured with concrete by using a pump where the concrete will be delivered on a daily basis by a cement mixer truck. After all the steel and concrete is placed in the building, the masonry for the exterior walls will be block and for the interior gypsum. Since the size of this building is relatively small, a crane won't be necessary to move material, allowing the company to save some costs.

The Critical Path Method was used to identify the critical activities that determine the total duration of the project. A tentative critical path has been developed by taking into account the maximum number of days the project could take. Microsoft Project was used as the tool to assemble the sequence of construction tasks and to determine the timeline of the work flow of the project. This schedule was created in terms of ten major tasks or activities that need to be completed to finish the project. These main tasks were: General Conditions, Site Construction, Structural Metals, Masonry, Door and Windows, Finishes, Specialties, Plumbing, Electrical and Fire Protection. Microsoft Project's main objective is to show the work flow with a tentative schedule of how each division is going to last. The site construction consists of the site development with the landscaping that includes site clearing and excavation. In structural metals division, all the concrete and structural materials are taken into account including the decks, rebar's and metals. Also, the specialties division has all of the major utilities such as toilets, faucets, kitchens and more.



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1						
2		General Conditions	60 days	Tue 11/1/16	Mon 1/23/17	
3		Site Construction	24 days	Mon 7/24/17	Thu 8/24/17	
4		Concrete	105 days	Thu 8/24/17	Wed 1/17/18	3
5		Metals	105 days	Thu 8/24/17	Wed 1/17/18	3
6		Masonry	84 days	Mon 12/18/17	Thu 4/12/18	4
7		Doors & Windows	84 days	Mon 12/25/17	Thu 4/19/18	6
8		Finishes	84 days	Fri 11/24/17	Wed 3/21/18	6
9		Specialties	40 days	Mon 2/26/18	Fri 4/20/18	8
10		Plumbing	147 days	Thu 8/24/17	Fri 3/16/18	3
11		Electric	147 days	Mon 9/25/17	Tue 4/17/18	5
12		Fire Protection	40 days	Sun 2/25/18	Thu 4/19/18	9

Figure 16: Microsoft project timeline with connections

The figure #16 shown above, explicitly describes the flow that the project has and how the activities are connected to each other. The general conditions started November 1st, 2016 where the first draft of design was approved my MIDUVI and conditions were signed by January 13th. The starting date of the site construction is July 24th, 2017 and has an estimated date of completion by April 20th, 2018. The site development will last around 24 working days during which site cleaning will be performed and consequently the excavation will be conducted in order for the structural metals, concrete and plumbing installations to begin. As a result, based on the schedule shown in the figure #16 above there would be a total of 182 working days approximately.

After the schedule is done, the 4D model is created and attached to the sets that are created in the Navisworks file. The original schedule was performed in Microsoft project and adapted to the timeline used in Navisworks to demonstrate the progress of the construction in each phase. The original one could not be attached because the model doesn't include any structural or MEP and only includes the architectural design.

5.2 Cost Estimate using On Screen Take-off (OST) and Excel

For the purposes of preparing the cost estimate of this project, the building was divided into different subcategories using the Construction Specifications Institute (CSI) master format which was also used in the breakdown of the activities identified in the construction schedule of the Prados del Sur project. Most of the items in the cost estimate were identified, quantified and priced by the *Constructora Garcia & Sanchez* staff using a manual approach and historical cost data bases from previous projects. This MQP complemented and verified this process through a computer-based approach using OST and Microsoft Excel software increasing the precision and expediency of the quantification process. The architectural design allowed a more detailed quantification on some of these items. However, the estimates are much less precise in the case of mechanical, electrical and fire protection systems since detailed information on these systems was not documented in the available drawings.

The OST quantification approach uses files of the drawings in PDF format. These PDF drawings are loaded to the program and adjusted to the given scale specified in the drawings. In these drawings the scale is given in the metric system which is 1-100 converting into 1-8'' in the US customary units. Once the drawings are ready to be displayed, analyzed and quantified, the CSI breakdown structure is used to organize the collection of all items included in the cost estimate. Each cost item belongs to a given CSI division and later on is broken down in more detail in order to determine its corresponding cost. The OST program is designed to assist in the quantification of each item by selecting the material and selecting the proper units of measurement. OST allows for the selection of different units of measurement for a given item so the finals cost per item can be determined based on the information available in the cost database.

OST uses color coding to identify different items under given conditions according to a given criterion. Therefore, the color coding scheme needs to be properly set-up before the quantification process starts. Each item quantified is highlighted according to the selected color code, then the scale is defined and the specific units of measurement are assigned. This procedure is repeated into all the items that are being quantified. In this project, all items are divided into four major units being: area in square foot, volume in cubic yards, distance in linear feet and also counting each item.

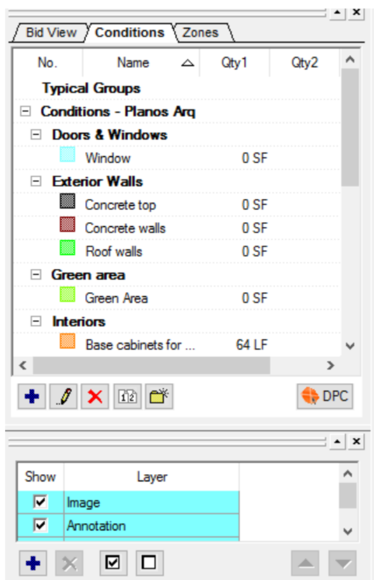


Figure 17: Conditions table on On Screen Take-Off

On the figure above #17, the conditions are set up by color, division and unit. These conditions work by floor and all the quantifications are added to a master worksheet that contains all the items identified in the different drawings.

Figure 18: Sample of quantification in On Screen Take-Off.

Figure #18 shows a sample of how quantification is done in OST and how the process looks like. Every item or material is given different conditions and color in order to display and underline what is being measured. In this specific sample, different quantifications are done such as: floor area and number of specialties (kitchens, bathrooms, sinks and more).

On the existing conditions, all the site clearing and excavation is taken to account as the primarily factor for the construction to start. Initially, the Prados del Sur site was undeveloped. It was a rather flat site with mostly grass and small shrubs and trees. The current soil isn't optimal for construction since it has more water than expected. The excavation of the soil won't be deep enough to touch water since the excavation will have a total depth of 2.20 meters and water is located around 2.80 meters below surface. This way, dewater with a pump won't be necessary and construction costs will be reduced once again. All the concrete needed for the footings is measured in cubic feet. Once all the site clearing is performed, all the concrete is built from the footings and expands to all the foundation. The foundation will have a concrete wall around the perimeter of the building. The quantification needed is obtained from the floor plans that are made in AutoCAD and are adapted as a PDF to On Screen Take-off. The elevations shown in Figure 19, are measured in meters.

Figure 19: Quantifying enclosures from East view

As shown in figure #19, it is shown graphically how the quantification was done for the enclosure and exterior walls. The main materials taken into account are the windows, concrete and plastered concrete. The exterior walls are built with block and then plastered with concrete on the outside. The measuring units for each of the materials mentioned before were quantified in square feet and cubic feet consequently. The units shown in the cost database are in metric system and for the comprehension of this project, the estimate is presented in both units, imperial and metric. This quantification was made all around the building with a total of 5,671 square feet of block including the plastered concrete walls and the roof walls.

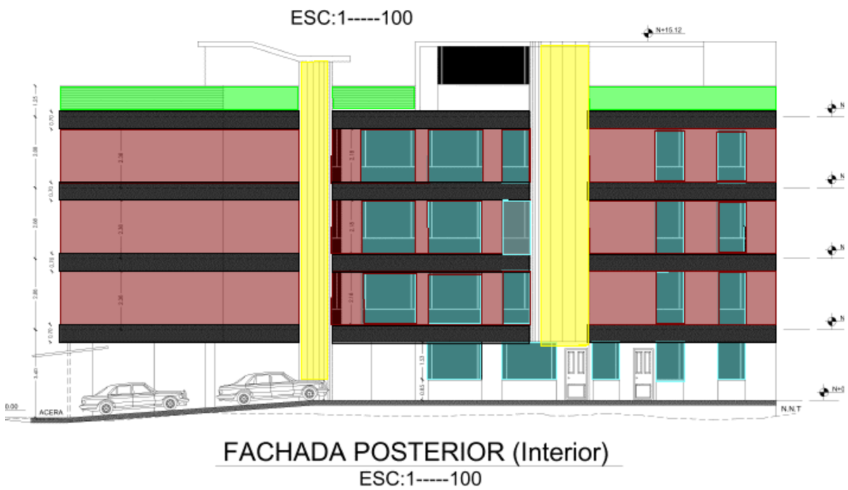


Figure 20: Quantifying enclosures from West view.

In addition, the curtain walls shown in the figure #20 above in yellow, are located vertically in the stairways on both sides of the building. The type of window used in this building are made of aluminum frames. The square footage obtained for the curtain walls is 438 square feet for the five floors. Also this rear façade shows the rest of the windows located in the building in green. Prados del Sur is going to have a total of 2,838 square feet of windows.

On the other hand, all the interiors are divided into many of the divisions in order to obtain the estimate. The slabs are measured mostly by having the square footage of the building and multiplying it by the number of floors there exists, which for Prados del Sur is five. Slabs in the program were calculated in cubic feet and in square foot and in the drawing the slab is represented in aquamarine in figure #18. These slabs are made of deck with 3'' of concrete that is poured on top as a layer. Also, the doors aren't being measured in square or linear foot, they are measured in quantity because the doors are going to be standard and fabricated on industry of wood material and painted.

The cost estimate is a spreadsheet design that with the collaboration of my work with this software and the project managers detail from Ecuador will combine precisely all the materials and work. The herein cost estimate is an integrated one with *Constructora Garcia & Sanchez* and it was divided the following way. I did part of the concrete quantifying and part of demolition, the doors and windows division, the finishes and specialties. In complementation to this, the firm did the remaining part: metals, fire protection and plumbing.

Since Ecuador uses the metric system, all the values obtained will be converted to imperial system including the unit values. The cost estimate will be presented in both units in order to facilitate the comprehension of this project, in both imperial and metric. The final cost will be the same since Ecuador's monetary value is US Dollars. This was done by using the "List of Construction Items from Ecuador" (Listado de Rubros Generales de Construcción) shown in appendix D where one can find all the direct, materials, labor and overhead cost. This book was used as the source for the cost database. For each square meter item, I multiplied the value by 10.7639 obtaining square feet and for the unit price I divided by the same value. Also, for the cubic meter items, I multiplied by 35.3147 to obtain cubic feet and divided the unit price by the same value. As a result, the estimate carries imperial system with the unit cost based on Ecuador's price, which is also the same monetary value US Dollars. Most of the finishes and the interiors have the same quantification as for example the number of toilets, bathrooms, etc. For instance, On Screen Take-off assisted on verifying that these numbers were correct and to provide a better understanding from where each value comes from. Also the final cost estimate was done with the help of Hector Sanchez who agreed on each item and to verify that the estimate was properly done.

After combining the cost estimate with the quantities and prices, the final estimate is calculated to be shown in the following table that contains the main divisions and their cost. Based on the calculations done, we obtained that the highest cost in the construction is the structural metals that contain the whole structure and the concrete with a 42%. The complete cost estimate is found in appendix B and C where it is detailed what belongs to each division with the cost in dollars and with the imperial units.

Division	Total	Cost Percent
Site Prep and Demo	69,056	9%
Structural Metals	313,622	42%
Masonry	79,699	11%
Doors and Windows	86,009	12%
Finishes	79,733	11%
Specialties	31,784	4%
Plumbing	23,297	3%
Electric Installations	40,547	5%
Fire Protection System	20,539	3%
Total	**744,287**	**100%**

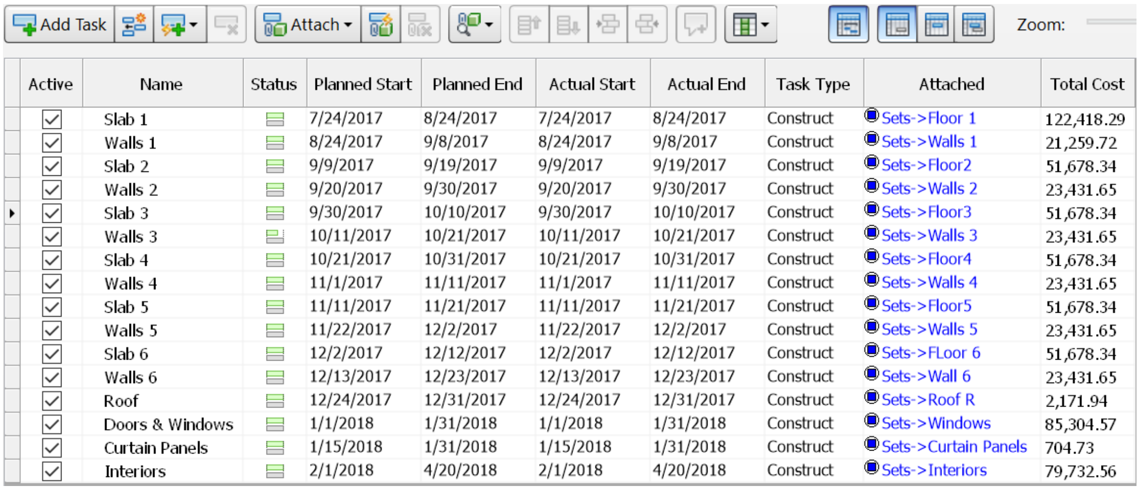
Table 2: Summary of Cost Estimate by Division

6.0 5D Model

The 5D model graphically displays the gradual progress of the construction process with its corresponding cumulative cost. This model is created through Autodesk Navisworks software by integrating the 3D model with the construction schedule and the cost estimate. Chapter 3 discussed the creation of the 3D architectural model using REVIT. This chapter discusses the creation of the 5D model where the model displays the cost estimate as the construction progresses.

The 3D model created with Revit can be converted to a NWC format and exported to Navisworks. Additionally, with the software users may choose different materials and lightings in order to create a realistic model. It also helps with the quantification process since it provides material estimates. The main role of this software is to integrate and allow the view of multiple files. Also, Navisworks can execute a 3D clash detection of potential interferences from object in the 3D model.

The Revit model consisted of 6 total levels which are 5 levels plus the underground level for the parking lots. In total there exists 6 levels which were divided into different sets in order to manage them with different stages of progress. This model was based only from architectural drawings and for this reason I divided the different phases into different sets. Each set represents a floor slab and corresponding walls for each level and the remaining sets are the doors & windows and the interiors. In the following figure # 21, the sets are shown in more details with their respective costs. The tasks created on this software were attached a particular set which were a specific phase of the construction. It is shown in the timeline how each task is assigned a specific date, a task type which is “construct” because it is being constructed and the attached file are the sets shown in the right part of the figure. These sets are simply a collection of a given material that are imported from the Revit model that are found in the selection tree that is also shown in the figure #21.



Active	Name	Status	Planned Start	Planned End	Actual Start	Actual End	Task Type	Attached	Total Cost
☑	Slab 1		7/24/2017	8/24/2017	7/24/2017	8/24/2017	Construct	Sets->Floor 1	122,418.29
☑	Walls 1		8/24/2017	9/8/2017	8/24/2017	9/8/2017	Construct	Sets->Walls 1	21,259.72
☑	Slab 2		9/9/2017	9/19/2017	9/9/2017	9/19/2017	Construct	Sets->Floor2	51,678.34
☑	Walls 2		9/20/2017	9/30/2017	9/20/2017	9/30/2017	Construct	Sets->Walls 2	23,431.65
☑	Slab 3		9/30/2017	10/10/2017	9/30/2017	10/10/2017	Construct	Sets->Floor3	51,678.34
☑	Walls 3		10/11/2017	10/21/2017	10/11/2017	10/21/2017	Construct	Sets->Walls 3	23,431.65
☑	Slab 4		10/21/2017	10/31/2017	10/21/2017	10/31/2017	Construct	Sets->Floor4	51,678.34
☑	Walls 4		11/1/2017	11/11/2017	11/1/2017	11/11/2017	Construct	Sets->Walls 4	23,431.65
☑	Slab 5		11/11/2017	11/21/2017	11/11/2017	11/21/2017	Construct	Sets->Floor5	51,678.34
☑	Walls 5		11/22/2017	12/2/2017	11/22/2017	12/2/2017	Construct	Sets->Walls 5	23,431.65
☑	Slab 6		12/2/2017	12/12/2017	12/2/2017	12/12/2017	Construct	Sets->FLoor 6	51,678.34
☑	Walls 6		12/13/2017	12/23/2017	12/13/2017	12/23/2017	Construct	Sets->Wall 6	23,431.65
☑	Roof		12/24/2017	12/31/2017	12/24/2017	12/31/2017	Construct	Sets->Roof R	2,171.94
☑	Doors & Windows		1/1/2018	1/31/2018	1/1/2018	1/31/2018	Construct	Sets->Windows	85,304.57
☑	Curtain Panels		1/15/2018	1/31/2018	1/15/2018	1/31/2018	Construct	Sets->Curtain Panels	704.73
☑	Interiors		2/1/2018	4/20/2018	2/1/2018	4/20/2018	Construct	Sets->Interiors	79,732.56

Figure 21: Cost associated to Phase

The cost associated with this 5D model was assigned to each set because it is only an architectural model, the costs for structure, masonry, specialties, plumbing and fire protection were taken to account in each set. The main purpose of exporting this model to Navisworks is to virtually show how the building is going to be looking and how much it is going to be costing as the construction progresses. The model only includes an architectural 3D model. The actual timeline is done in Microsoft Project which includes all the divisions including the site development, structure, masonry, doors & windows, plumbing, electrical and fire protection. The specific break down of the schedule matches to the phases of the construction and is directly associated with the graphic representation of the 4D model.

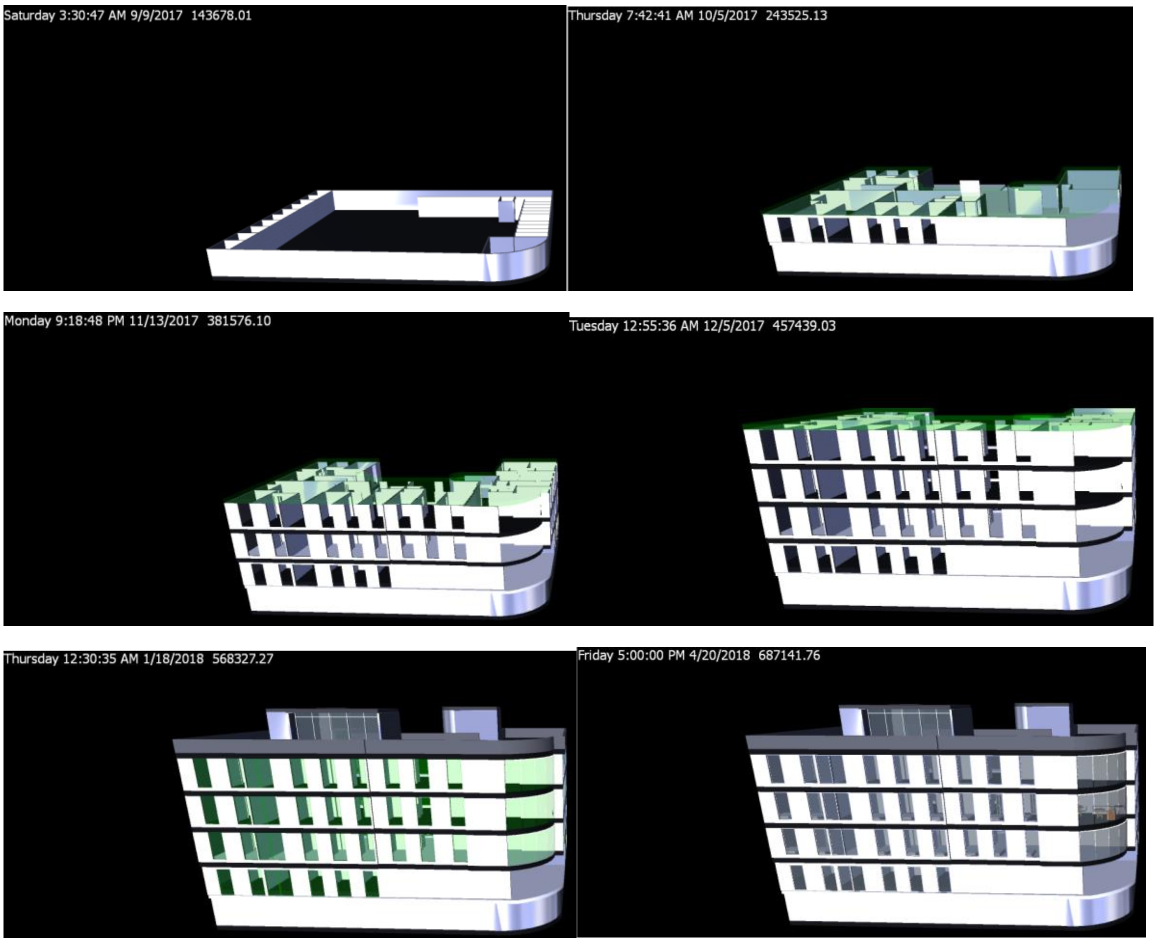


Figure 22: 5D Simulation with Cost

This model 5D shown in figure #22, displays the simulation of the construction progress with a total cost of construction of $687,141.76 USD. To this cost needs to be added the site development which is not shown in model of approximately $57,145.21 USD to have a total construction cost of $744,287.59 USD.

In the final product of this 5D model all the levels are included and the ramp is also shown. The model looks exactly like this as soon it is imported from Revit. The main idea of using Navisworks for this project was to show its development and how each level was going to look with progress.

7.0 Conclusions and Future Work

7.1 Deliverables

The purpose of this project is to assist *Constructora Garcia & Sanchez* with the development of Prados del Sur in the design and project management area. This MQP proposed the use of the BIM software and assisted the firm by creating the 3D model that physically shows how the building is going to look before the construction starts. Additionally, this MQP assisted with the implementation of the software On Screen Take-Off in order to quantify the materials of the project by using the original architectural designs that the company had. Since the project is being constructed in Ecuador the final cost estimate deliverable was done in the metric system with the help of the firm. This MQP also assisted the project manager by quantifying certain materials in order to double check his previous calculations and make sure that the values obtained were correct.

The final deliverable for the planned schedule for this project was created in Microsoft Project and the construction divisions obtained from the cost estimate were integrated. This schedule gives an estimate number of days that each phase or division is going to last and how they are linked together. The final schedule created shows that the estimated time for the completion of this project is going to be approximately 9 months. However, it is important to mention that the starting date and critical path might not be followed precisely since the weather conditions in Quito, Ecuador are not favorable and probably won’t allow the construction to follow the established schedule. In case the start date or any phase is delayed, *Constructora Garcia & Sanchez* will use the time provided in the schedule as a rough guide to know how many days it should be spending in each stage of the project.

The 3D model was used in many ways by the firm because as described before, it provided them with a precise 3D image of how the building is going to look once it's built. This model includes all the architectural properties that the building is going to have, including all the equipment interior details. Once the 3D model was done, it was exported into another Revit file where it was adjusted to the site which includes the streets that are perpendicular (Otoya Nan and street #4) to each other. This model is more realistic as it virtually displays how the building will be located within traffic and pedestrian walking in the sidewalk. By using this model, This MQP created a 3D rendering model of the building and apartments that will turn out to be extremely useful once the apartments are advertised to the public. This Revit model was jointly created with the architect because the 3D model is directly based on the architectural drawings that are imported into the software. In Ecuador the usage of Revit is minimal since it has not been formally introduced to the local architectural market. However, after proposing and using it in this project the architect was completely satisfied with the results obtained and is permanently introducing it into the company's projects.

Furthermore, the 3D model also was used as another physical interpretation of how each phase is going to be constructed and how much they are going to cost. For this, the model was exported to Navisworks where each set of materials was assigned or attached to a task. By doing this, a 5D view of the building was obtained by incorporating a detailed image of the different stages and their costs. Based on this 5D model the firm can establish its total budget and determine how the costs will increase as the construction of the different stages occurs.

Finally, a review of the structural analysis and the design of a reinforced beam was conducted. A manual calculation of the bending moment capacity of one of the beams of the first floor was done and compared this value against the one determined by the structural analysis software ETABS used by the professional structural engineer in the analysis and design of the multi-story structural frame of the building

Essentially, the calculated resisting moment given by the dimensions and properties of the materials used, showed that the strength of the reviewed beam is higher than the moment created by the acting forces.

7.2 Prados del Sur II

Constructora Garcia & Sanchez has already started the design of a new low-medium income housing project with MIDUVI planned to start construction in 2019 called Prados del Sur II. MIDUVI was extremely satisfied with proposal and work with Prados del Sur I, especially how the project has always been up to date in the design and construction process. The new project is going to take place in Quitumbe, two blocks away from the original one and will have an approximate cost of 7 million dollars. Currently the firm *Constructora Garcia & Sanchez* keeps working with the same architects and engineers with the addition of the sons of each owner. Their contribution has optimized the construction process of the project because of their up-to date skills that have been properly developed from their college and prior work experiences. Ricardo Garcia is now part of the team and is designing all the architectural drawings in AutoCAD. Their teamwork has become efficient and the firm has increased its productivity due to the advanced software skills of the junior members and the experience and knowledge of the senior partners. *Constructora Garcia & Sanchez* also counts with a structural engineer with years of experience. The firm has been active for a year and a half and it currently has six employees that contribute equally to the team.

Since this is a small and growing firm, there is a huge potential for other MQP projects to assist them in the development of future projects. For example, if more people composed the MQP group, a 3D model that includes all the divisions with their respective materials, the architectural design with the structural design could be created in the desired time. The obtained model could benefit by precisely portraying the interior of the apartments with all their details. This will give the firm and the customers a more vivid and detailed description of the building and the apartments before the construction starts. Also, if the weather conditions were favorable and the country experiences economic stability, a very precise schedule could be created with the starting and ending dates of each division. As a result, a critical path could be created to demonstrate how costs could be crashed in order to reduce construction time.

All these details can be added and developed in future MQP's with more time and collaboration. After working with this company I realized that projects like this one could have a huge impact by implementing BIM software's, especially because firms in other countries aren't familiar with it. Definitely, the perfect fit for these possible future projects in Worcester Polytechnic Institute are civil engineering students who want to focus in the area of project management and design. This way a collaborative effort between the different areas will be enabled as students interested in the design will work with the models and ones interested in project management will provide feedback on what materials exist and will quantify them in order to build the cost estimate. It would be ideal to expand this type of project to other countries because of the impact they can have on foreign engineering industries. However, if that is not feasible, the ideas and techniques used in this MQP are also perfectly relatable to low-medium income construction projects in the US.

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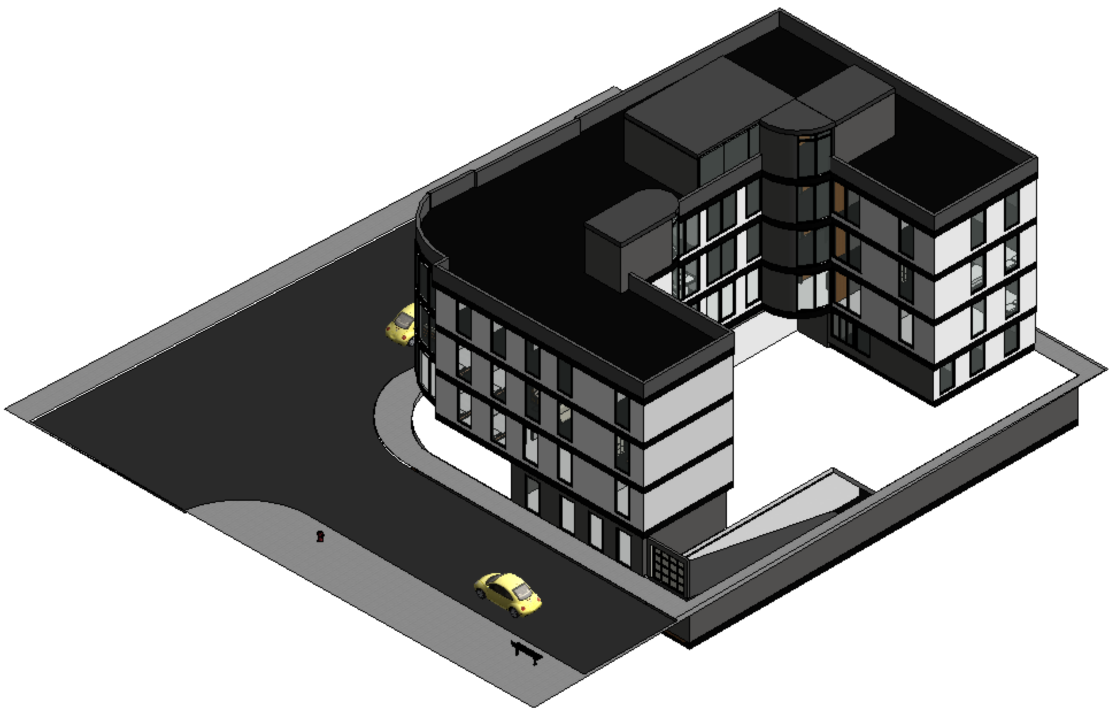
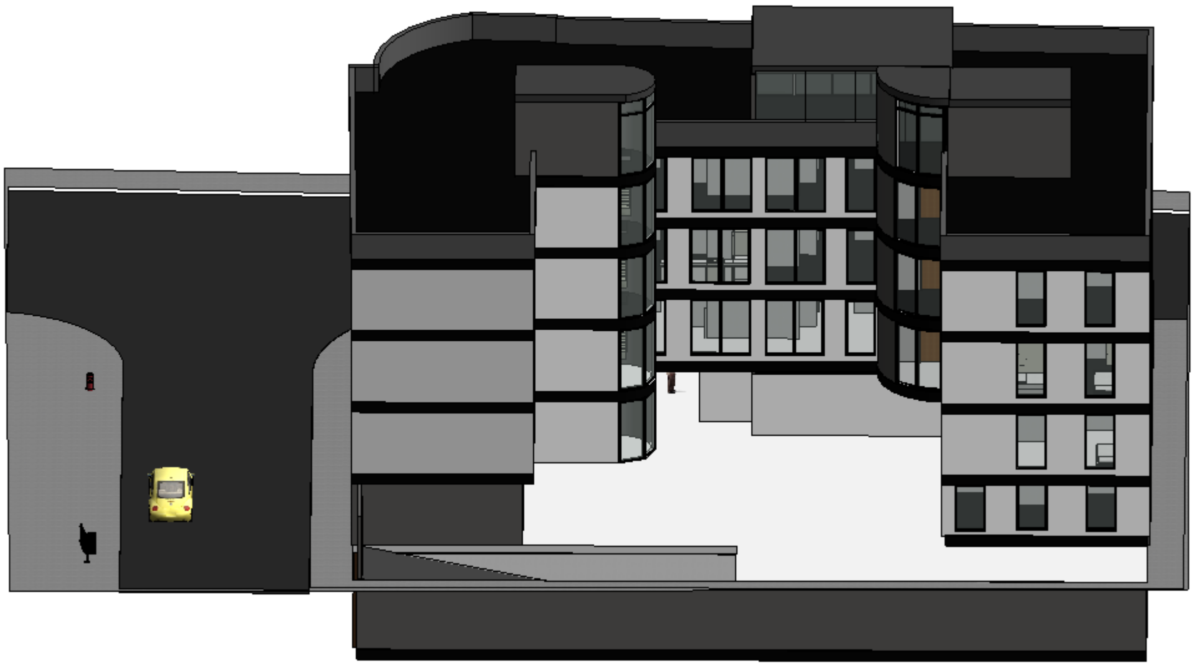
Appendixes

Appendix A: 3D model from Different Angles





Appendix B: Cost Estimate in Metric Units

DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
Site Prep and Demo				
Clear Site:				
Clear site	SM	646.999	$0.22	$142.34
Discard rubbish	CM	129.400	$6.72	$869.57
Excavation	CM	10,596.770	$5.30	$56,133.30
Refill:				
Formwork edge Slabs	SM	5,519.252	$1.21	$6,680.32
System of 60*60*20 cm	Each	811.00	$6.45	$5,230.95
				$69,056.48
Structural Metals				
Replant f´c=180 kg/cm2 e=7cm	CM	7.000	$125.52	$878.64
Formwork 1 side	SM	912.074	$3.75	$3,416.62
Form work Columns	SM	3,595.507	$3.50	$12,592.01
Formworks stairs	SM	487.205	$4.07	$1,980.99
Formworks Beams	SM	3,124.969	$3.15	$9,848.75
Formworks slush	SM	2,099.739	$2.59	$5,440.00
Concrete in chains	CM	18.720	$127.87	$2,393.73
Concrete in foundations	CM	7.560	$100.72	$761.44
Concrete for walls	CM	129.385	$100.72	$13,031.62
Structural Concrete f´c=210 kg/cm2	CM	504.237	$128.86	$64,977.74
Reinforced Steel	LB	137,480.02	$0.66	$90,611.83
Welded mesh	SM	5,363.126	$1.27	$6,800.27
Metallic Structure	LB	22,640.51	$0.73	$16,465.82
Deck 0.64 mm	SM	5,363.126	$3.37	$18,079.56
Concrete Piles L=10 m	ML	660.00	$100.52	$66,343.20
				$313,622.22
Masonry				
Underfloor Concrete f´c=210 kg/cm2	SM	2,099.739	$4.50	$9,446.40
Smoothing floors	SM	4,478.349	$0.84	$3,781.05
Masonry of block 10cm	SM	657.218	$3.94	$2,592.14
Masonry of block 15cm	SM	3,648.952	$4.03	$14,692.16
Vertical Plaster in Interiors	SM	3,937.010	$1.82	$7,152.00
Concrete Plastered outside	SM	3,856.137	$2.45	$9,449.81
Plastered in girdles and edges	M	359.91	$3.44	$1,238.40
Dintel 0.1 x 0.1 x 1.00 F´C=180 kg/cm2	Each	102.0	$13.91	$1,418.82
Gypsum wall Interiors	SM	5,217.391	$5.74	$29,928.69
				$79,699.48
Doors and Windows				
Door with tempered glass e=10mm	SM	36.483	$59.95	$2,187.30
Aluminum window 4mm	SM	263.659	$17.32	$4,566.23
Curtain Wall	SM	40.692	$17.32	$704.73
Principal door 0.9	Each	22.0	$247.23	$5,439.06
Interior Paneled door	Each	58.0	$161.53	$9,368.74
Bathroom paneled door 0.70	Each	22.0	$161.53	$3,553.66
Principal Lock	Each	22.0	$43.38	$954.36
Rooms Lock	Each	58.0	$37.68	$2,185.44
Blinds and curtains	SM	215.070	$21.53	$4,630.00
Bathroom Lock	Each	22.0	$34.26	$753.72
Furniture	M	150.98	$122.01	$18,420.66
Closets	SM	655.315	$35.36	$23,171.84
Bathroom Closet 0.60	Each	21.0	$110.22	$2,314.62
Mesh Enclosure h=2.00	M	74.56	$45.23	$3,372.51
Door with tempered glass 1 1/2"	SM	144.357	$13.81	$1,993.64
Metallic door	SM	121.260	$19.73	$2,392.79

				$86,009.30
Finishes				
Coating of walls	SM	543.307	$6.85	$3,722.69
Coating of floors	SM	835.171	$6.22	$5,198.12
Coating of Mesone	M	61.98	$82.01	$5,083.38
Gypsum Roofing	SM	4,478.349	$3.39	$15,192.45
False ceiling	SM	4,478.349	$0.68	$3,043.95
Vinyl Acrylic Paint Interiors	SM	14,206.044	$0.65	$9,222.90
Cabinets	M	839.90	$78.03	$5,120.00
Vinyl Acrylic Paint Exteriors	SM	3,856.137	$1.39	$5,371.35
Wall Cabinets	M	616.80	$57.30	$2,820.00
Ceramic & Lacquered handrails	M	350.91	$4.67	$1,639.17
Floating Floor AC 3	SM	1,662.206	$5.00	$8,303.83
Carpeting	SM	1,637.927	$2.90	$4,742.78
Extractor	Each	8.0	$201.00	$1,608.00
Aluminum Grids 2"	Each	68.0	$9.31	$633.08
Iron Grids 20 cm	M	3.00	$58.51	$175.50
Floor Grids 4"	Each	1.0	$10.03	$10.03
Ventilation Grids 20x20	Each	44.0	$12.56	$552.64
Plastered Walls	SM	10,925.202	$0.67	$7,292.70
				$79,732.56
Specialties				
Toilet	Each	24.0	$130.00	$3,120.00
Handwash	Each	24.0	$76.00	$1,824.00
Electric showers and accessories	Each	22.0	$50.00	$1,100.00
Stainless steel sink	Each	22.0	$90.00	$1,980.00
Faucet for sink	Each	22.0	$60.00	$1,320.00
Faucet for handwash	Each	24.0	$50.00	$1,200.00
Refrigerators	Each	24.0	$500.00	$12,000.00
Bathroom accessories	Each	24.0	$20.00	$480.00
Stoves	Each	24.0	$300.00	$7,200.00
Mirrors	Each	24.0	$20.00	$480.00
Bathroom Extractor	Each	18.0	$60.00	$1,080.00
				$31,784.00
Plumbing				
PVC	M	891.93	$4.57	$4,080.00
Floor rack	Each	75.0	$8.00	$600.00
Drains		176.0	$22.00	$3,872.00
Downpour manhole D=110 m		4.0	$27.00	$403.92
PVC for ventilation 100 mm	M	110.71	$10.65	$1,179.38
PVC cold water 1/2´´	Point	84.0	$20.92	$1,757.28
PVC hot water 1/2´´	Point	63.0	$25.83	$1,627.29
PVC proof D = 1/2´	M	199.95	$5.27	$1,054.00
Stopcock 1/2´´	Each	21.0	$7.81	$164.01
Valves 125 PSI RW		4.0	$27.00	$108.00
Pressure Reducer PVC	Each	21.0	$4.29	$90.09
Drinking water meter	Each	1.0	$258.50	$258.50
Water Tank c=210 Kg/cm2	CM	40.000	$202.57	$8,102.80
				$23,297.27
Electrical Installations				
Cable outlet	Point	290.00	$21.80	$6,322.00
Illumination 1/2"	Point	350.00	$22.10	$7,735.00
Cable outlet 220v	Each	44.00	$48.02	$2,112.88
Circuit feeder	ML	210.00	$2.81	$590.10
Circuit feeder	ML	656.00	$2.94	$1,928.64
Distribution tables	ML	1,323.00	$3.63	$4,802.49
Hose fitting	M	671.83	$1.33	$893.76
Hose fitting	M	209.95	$1.61	$338.10

Techo magnetic switch	Each	105.00	$10.76	$1,129.80
Bipolar Techo Magnetic Switch	Each	42.00	$13.27	$557.34
Distribution tables	Each	23	$103.20	$2,373.60
Thermostat tank	Each	22.00	$307.54	$6,765.88
Floor mesh	Each	1.00	$943.76	$943.76
Telephone outlet	Point	21.00	$13.94	$292.74
Main dispersion box	Each	1.00	$189.76	$189.76
Hand well	Each	2.00	$99.08	$198.16
Principal distribution and accessories board	Each	1.00	$3,373.02	$3,373.02
				$40,547.03
Fire Protection System				
Pipeline 2 1/2"	M	24.99	$39.06	$976.25
Valves 2 1/2"	M	1.22	$810.30	$987.92
Distribution board 2 - 4 points	Each	1.00	$34.69	$34.69
Pipeline 2"	M	23.99	$28.15	$675.36
Fire protection cabinet	Each	9.00	$406.95	$3,662.55
Fire extinguisher	Each	25.00	$30.00	$750.00
Water motor pump 20 hp	Each	1.00	$9,352.88	$9,352.88
Water pump 3 hp	Each	1.00	$1,828.88	$1,828.88
Preloaded hydro pneumatic tank 80 tls	Each	1.00	$493.21	$493.21
Anti-flame cable 2 x 18 AWG	M	749.81	$2.37	$1,777.50
				$20,539.24
Total Estimate				**$744,287.59**

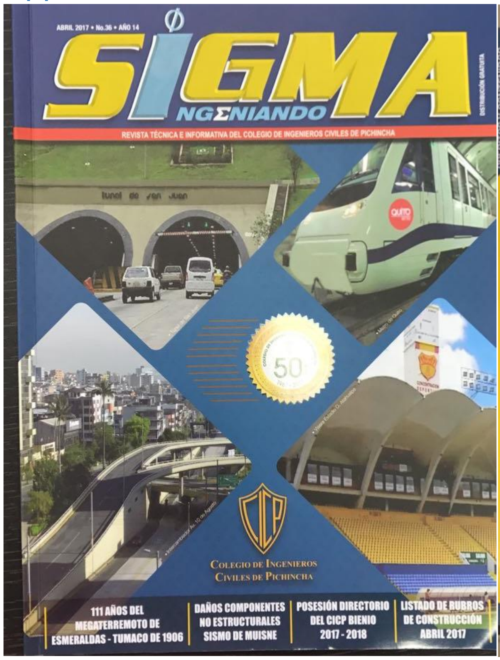
Appendix C: Cost Estimate in Imperial Units:

DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
Site Prep and Demo				
Clear Site:				
Clear site	SF	6,964.24	$0.02	$142.34
Discard rubbish	CF	4,569.72	$0.19	$869.57
Excavation	CF	374,222.00	$0.15	$56,133.30
Refill:				
Formwork edge Slabs	SF	59,408.76	$0.11	$6,680.32
System of 60*60*20 cm	Each	811.00	$6.45	$5,230.95
				$69,056.48
Structural Metals				
Replant f´c=180 kg/cm2 e=7cm	CF	247.20	$3.55	$878.64
Formwork 1 side	SF	9,817.49	$0.35	$3,416.62
Form work Columns	SF	38,701.73	$0.33	$12,592.01
Formworks stairs	SF	5,244.23	$0.38	$1,980.99
Formworks Beams	SF	33,636.90	$0.29	$9,848.75
Formworks slush	SF	22,601.41	$0.24	$5,440.00
Concrete in chains	CF	661.09	$3.62	$2,393.73
Concrete in foundations	CF	266.98	$2.85	$761.44
Concrete for walls	CF	4,569.18	$2.85	$13,031.62
Structural Concrete f´c=210 kg/cm2	CF	17,807.00	$3.65	$64,977.74
Reinforced Steel	LB	137,480.02	$0.66	$90,611.83
Welded mesh	SF	57,728.23	$0.12	$6,800.27
Metallic Structure	LB	22,640.51	$0.73	$16,465.82
Deck 0.64 mm	SF	57,728.23	$0.31	$18,079.56
Concrete Piles L=10 m	ML	660.00	$100.52	$66,343.20
				$313,622.22
Masonry				
Underfloor Concrete f´c=210 kg/cm2	SF	22,601.4	$0.42	$9,446.40
Smoothing floors	SF	48,204.6	$0.08	$3,781.05
Masonry of block 10cm	SF	7,074.2	$0.37	$2,592.14
Masonry of block 15cm	SF	39,277.0	$0.37	$14,692.16
Vertical Plaster in Interiors	SF	42,377.6	$0.17	$7,152.00
Concrete Plastered outside	SF	41,507.1	$0.23	$9,449.81
Plastered in girdles and edges	FT	1,180.8	$1.05	$1,238.40
Dintel 0.1 x 0.1 x 1.00 F´C=180 kg/cm2	Each	102.0	$13.91	$1,418.82
Gypsum wall Interiors	SF	56,159.6	$0.53	$29,928.69
				$79,699.48
Doors and Windows				
Door with tempered glass e=10mm	SF	392.7	$5.57	$2,187.30
Aluminum window 4mm	SF	2,838.0	$1.61	$4,566.23
Curtain Wall	SF	438.0	$1.61	$704.73
Principal door 0.9	Each	22.0	$247.23	$5,439.06
Interior Paneled door	Each	58.0	$161.53	$9,368.74
Bathroom paneled door 0.70	Each	22.0	$161.53	$3,553.66
Principal Lock	Each	22.0	$43.38	$954.36
Rooms Lock	Each	58.0	$37.68	$2,185.44
Blinds and curtains	SF	2,315.0	$2.00	$4,630.00
Bathroom Lock	Each	22.0	$34.26	$753.72
Furniture	FT	495.3	$37.19	$18,420.66
Closets	SF	7,053.8	$3.29	$23,171.84
Bathroom Closet 0.60	Each	21.0	$110.22	$2,314.62
Mesh Enclosure h=2.00	FT	244.6	$13.79	$3,372.51
Door with tempered glass 1 1/2"	SF	1,553.8	$1.28	$1,993.64
Metallic door	SF	1,305.2	$1.83	$2,392.79

				$86,009.30
Finishes				
Coating of walls	SF	5,848.1	$0.64	$3,722.69
Coating of floors	SF	8,989.7	$0.58	$5,198.12
Coating of Mesone	FT	203.4	$25.00	$5,083.38
Gypsum Roofing	SF	48,204.6	$0.32	$15,192.45
False ceiling	SF	48,204.6	$0.06	$3,043.95
Vinyl Acrylic Paint Interiors	SF	152,912.7	$0.06	$9,222.90
Cabinets	LF	256.0	$20.00	$5,120.00
Vinyl Acrylic Paint Exteriors	SF	41,507.1	$0.13	$5,371.35
Wall Cabinets	LF	188.0	$15.00	$2,820.00
Ceramic & Lacquered handrails	FT	1,151.3	$1.42	$1,639.17
Floating Floor AC 3	SF	17,891.8	$0.46	$8,303.83
Carpeting	SF	17,630.5	$0.27	$4,742.78
Extractor	Each	8.0	$201.00	$1,608.00
Aluminum Grids 2"	Each	68.0	$9.31	$633.08
Iron Grids 20 cm	FT	9.8	$17.84	$175.50
Floor Grids 4"	Each	1.0	$10.03	$10.03
Ventilation Grids 20x20	Each	44.0	$12.56	$552.64
Plastered Walls	SF	117,598.0	$0.06	$7,292.70
				$79,732.56
Specialties				
Toilet	Each	24.0	$130.00	$3,120.00
Handwash	Each	24.0	$76.00	$1,824.00
Electric showers and accessories	Each	22.0	$50.00	$1,100.00
Stainless steel sink	Each	22.0	$90.00	$1,980.00
Faucet for sink	Each	22.0	$60.00	$1,320.00
Faucet for handwash	Each	24.0	$50.00	$1,200.00
Refrigerators	Each	24.0	$500.00	$12,000.00
Bathroom accessories	Each	24.0	$20.00	$480.00
Stoves	Each	24.0	$300.00	$7,200.00
Mirrors	Each	24.0	$20.00	$480.00
Bathroom Extractor	Each	18.0	$60.00	$1,080.00
				$31,784.00
Plumbing				
PVC	FT	2,926.3	$1.39	$4,080.00
Floor rack	Each	75.0	$8.00	$600.00
Drains		176.0	$22.00	$3,872.00
Downpour manhole D=110 m	FT	118.1	$3.42	$403.92
PVC for ventilation 100 mm	FT	363.2	$3.25	$1,179.38
PVC cold water 1/2´´	Point	84.0	$20.92	$1,757.28
PVC hot water 1/2´´	Point	63.0	$25.83	$1,627.29
PVC proof D = 1/2´	FT	656.0	$1.61	$1,054.00
Stopcock 1/2´´	Each	21.0	$7.81	$164.01
Valves 125 PSI RW		4.0	$27.00	$108.00
Pressure Reducer PVC	Each	21.0	$4.29	$90.09
Drinking water meter	Each	1.0	$258.50	$258.50
Water Tank c=210 Kg/cm2	CF	1,412.6	$5.74	$8,102.80
				$23,297.27
Electrical Installations				
Cable outlet	Point	290.00	$21.80	$6,322.00
Illumination 1/2"	Point	350.00	$22.10	$7,735.00
Cable outlet 220v	Each	44.00	$48.02	$2,112.88
Circuit feeder	ML	210.00	$2.81	$590.10
Circuit feeder	ML	656.00	$2.94	$1,928.64
Distribution tables	ML	1,323.00	$3.63	$4,802.49
Hose fitting	FT	2,204.16	$0.41	$893.76
Hose fitting	FT	688.80	$0.49	$338.10

Techo magnetic switch	Each	105.00	$10.76	$1,129.80
Bipolar Techo Magnetic Switch	Each	42.00	$13.27	$557.34
Distribution tables	Each	23	$103.20	$2,373.60
Thermostat tank	Each	22.00	$307.54	$6,765.88
Floor mesh	Each	1.00	$943.76	$943.76
Telephone outlet	Point	21.00	$13.94	$292.74
Main dispersion box	Each	1.00	$189.76	$189.76
Hand well	Each	2.00	$99.08	$198.16
Principal distribution and accessories board	Each	1.00	$3,373.02	$3,373.02
				$40,547.03
Fire Protection System				
Pipeline 2 1/2"	FT	82.00	$11.91	$976.25
Valves 2 1/2"	FT	4.00	$246.98	$987.92
Distribution board 2 - 4 points	Each	1.00	$34.69	$34.69
Pipeline 2"	FT	78.72	$8.58	$675.36
Fire protection cabinet	Each	9.00	$406.95	$3,662.55
Fire extinguisher	Each	25.00	$30.00	$750.00
Water motor pump 20 hp	Each	1.00	$9,352.88	$9,352.88
Water pump 3 hp	Each	1.00	$1,828.88	$1,828.88
Preloaded hydro pneumatic tank 80 tls	Each	1.00	$493.21	$493.21
Anti-flame cable 2 x 18 AWG	FT	2,460.00	$0.72	$1,777.50
				$20,539.24
Total Estimate				**$744,287.59**

Appendix D: Cost Database Book with detailed Item List



DESCRIPCIÓN	UNIDAD	CUAD. TIPO	REND. UNI. JORNADA	C.DIRECTO	C.MATERIAL	COSTO MANO	C.EQUIP.
DOMO ACRILICO 4MM CON ESTRUCTURA METALICA (PROVISION Y MONTAJE)	m2	0.9 Alb+1 Peon	7,93	112,32	105,10	6,44	0,78
TRANSLUCIDO T. ETERNIT ESTR. MADERA	m2	1 Alb+1 Peon	20,00	88,63	85,77	2,70	0,16
TRANSLUCIDO T. ETERNIT ESTR. METALICA	m2	1 Alb+1 Peon	20,00	88,79	85,93	2,70	0,16
INSTALACIONES AGUA POTABLE							
H.G.							
INSTALACION AGUA CALIENTE	m	1 Alb+2 Peon+1 Plom	0,00	17,58	4,02	13,16	0,40
PUNTO DE AGUA POTABLE 1/2"	pto	1 Alb+1 Peon	3,20	19,25	1,86	16,89	0,50
SALIDA MEDIDORES HG. LLAVE DE PASO Y ACCESORIOS H.G	pto	1 Alb+1 Peon	3,25	21,32	5,12	16,00	0,20
TUBERIA H.G. 1"	m	1 Peon+1 Plom	12,31	8,22	3,57	4,39	0,26
TUBERIA H.G. 1/2"	m	1 Peon+1 Plom	16,00	6,75	3,17	3,38	0,20
TUBERIA H.G. 3/4"	m	1 Peon+1 Plom	13,33	7,73	3,44	4,05	0,24
PVC							
CODO HIDRO3 3/4"-1/2" (PROVISION E INSTALACION) O SIMILAR	u	1 Alb+1 Peon	26,67	4,59	2,50	2,03	0,06
INSTALACION AGUA FRIA	m	1 Alb+2 Peon+1 Plom	0,00	17,58	4,02	13,16	0,40
TUBERIA HIDRO3 1 1/4" (PROVISION E INSTALACION) O SIMILAR	m	1 Alb+2 Peon	32,07	6,78	4,34	2,39	0,05
TUBERIA HIDRO3 1" (PROVISION E INSTALACION) O SIMILAR	m	2 Peon+1 Plom	0,00	6,56	4,03	2,48	0,05
TUBERIA HIDRO3 1/2" (PROVISION E INSTALACION) O SIMILAR	m	1 Peon+1 Plom	0,00	1,41	0,71	0,68	0,02
ABRAZADERAS							
ABRAZADERA DE PLETINA 38X5MM SIMPLE	u	1 Peon	80,00	4,90	4,52	0,36	0,02
ABRAZADERA DE PLETINA 50X5MM DOBLE	u	1 Peon	75,65	11,18	10,80	0,36	0,02
ABRAZADERA DE PLETINA 50X5MM SIMPLE	u	1 Peon	80,00	6,82	6,12	0,68	0,02
ABRAZADERA DE PLETINA 50X6MM SIMPLE	u	1 Peon	80,00	9,01	8,63	0,36	0,02
ABRAZADERA DE PLETINA PARA BASTIDOR	u	1 Peon	80,00	5,26	4,88	0,36	0,02
ABRAZADERA PLATINA 2"	u	1 Alb	133,33	2,77	2,55	0,21	0,01
INSTALACIONES AGUAS SERVIDAS							
DESAGUE PVC							
CODO PVC 110MM DESAGUE	u	1 Peon+1 Plom	0,00	5,74	3,73	1,95	0,06
CODO PVC 110MM DESAGUE 45°	u	1 Peon+1 Plom	0,00	6,80	4,79	1,95	0,06
CODO PVC 160MM DESAGUE	u	1 Peon+1 Plom	0,00	13,50	11,34	2,10	0,06
CODO PVC 200MM DESAGUE	u	1 Peon+1 Plom	0,00	49,41	47,11	2,23	0,07
CODO PVC 250MM DESAGUE	u	1 Peon+1 Plom	0,00	90,87	88,57	2,23	0,07
CODO PVC 315MM DESAGUE	u	1 Peon+1 Plom	0,00	135,31	132,88	2,36	0,07
CODO PVC 400MM DESAGUE	u	1 Peon+1 Plom	0,00	187,03	184,46	2,50	0,07
CODO PVC 50MM DESAGUE	u	1 Peon+1 Plom	0,00	2,98	1,24	1,69	0,05
CODO PVC 50MM DESAGUE 45°	u	1 Peon+1 Plom	0,00	3,30	1,29	1,95	0,06
CODO PVC 75MM DESAGUE	u	1 Peon+1 Plom	0,00	3,73	1,85	1,83	0,05
CODO PVC 90MM DESAGUE 45°	u	1 Peon+1 Plom	0,00	4,16	2,15	1,95	0,06
CRUZ PVC 200MM DESAGUE	u	1 Alb+1 Peon	24,24	36,14	33,84	2,23	0,07
DESAGUE PVC 110MM	pt	1 Peon+1 Plom	4,00	24,25	9,94	13,51	0,80
DESAGUE PVC 50MM	pt	1 Peon+1 Plom	4,00	24,61	9,23	14,58	0,80
DESAGUE PVC 75MM	pt	1 Peon+1 Plom	4,08	24,24	9,93	13,51	0,80
REDUCCION DESAGUE PVC 110 A 50MM	u	1 Peon+1 Plom	0,00	3,46	2,76	0,68	0,02
REDUCCION DESAGUE PVC 200 A 160MM	u	1 Alb+1 Peon	80,00	12,90	11,88	1,00	0,02
SIFON PVC 110MM DESAGUE	u	1 Peon+1 Plom	0,00	5,04	3,65	1,35	0,04
SIFON PVC 50MM DESAGUE	u	1 Peon+1 Plom	0,00	3,97	2,58	1,35	0,04
TAPON PVC 110MM DESAGUE	u	1 Peon+1 Plom	0,00	2,97	0,96	1,95	0,06
TAPON PVC 160MM DESAGUE	u	1 Peon+1 Plom	0,00	6,06	3,90	2,10	0,06
TAPON PVC 200MM DESAGUE	u	1 Peon+1 Plom	0,00	10,06	7,76	2,23	0,07
TAPON PVC 250MM-DESAGUE	u	1 Peon+1 Plom	0,00	10,06	7,76	2,23	0,07
TAPON PVC 315MM DESAGUE	u	1 Peon+1 Plom	0,00	30,45	28,02	2,36	0,07
TAPON PVC 400MM DESAGUE	u	1 Peon+1 Plom	0,00	54,93	52,36	2,50	0,07
TAPON PVC 50MM DESAGUE	u	1 Peon+1 Plom	0,00	2,36	0,62	1,69	0,05
TAPON PVC 75MM DESAGUE	u	1 Peon+1 Plom	0,00	2,63	0,75	1,83	0,05
TEE PVC 110MM DESAGUE	u	1 Peon+1 Plom	0,00	5,86	3,85	1,95	0,06
TEE PVC 160MM DESAGUE	u	1 Peon+1 Plom	0,00	14,69	12,53	2,10	0,06
TEE PVC 200MM DESAGUE	u	1 Peon+1 Plom	0,00	46,60	44,30	2,23	0,07
TEE PVC 250MM DESAGUE	u	1 Peon+1 Plom	0,00	90,87	88,57	2,23	0,07
TEE PVC 315MM DESAGUE	u	1 Peon+1 Plom	0,00	114,25	111,82	2,36	0,07
TUBERIA PVC 110MM	m	1 Peon+1 Plom	8,00	13,69	6,73	6,76	0,20
TUBERIA PVC 160MM DESAGUE	m	1 Peon+0.5 Plom	0,00	14,15	12,02	2,05	0,08
TUBERIA PVC 200MM DESAGUE	m	2 Peon+1 Plom	0,00	18,59	16,57	1,98	0,04
TUBERIA PVC 250MM DESAGUE	m	1 Peon+0.5 Plom	0,00	18,70	16,57	2,05	0,08
TUBERIA PVC 315MM DESAGUE	m	1 Peon+0.4 Plom	0,00	29,32	26,56	2,41	0,35
TUBERIA PVC 400MM DESAGUE	m	1 Peon+0.4 Plom	0,00	61,08	58,21	2,51	0,36
TUBERIA PVC 50MM	m	1 Peon+1 Plom	8,00	10,75	3,79	6,76	0,20
TUBERIA PVC 75MM	m	1 Peon+1 Plom	8,00	13,44	6,48	6,76	0,20
TUBERIA PVC D=200MM SERIE 5 HPROM = 1.77 M AL INVERT	m	1 Alb+1 Peon	26,67	2,54	0,55	1,91	0,08
TUBERIA PVC D=250 MM SERIE 5 HPROM =1.91 M AL INVERT	m	1 Alb+1 Peon	26,67	2,54	0,55	1,91	0,08
YEE DOBLE PVC 200MM DESAGUE	u	1 Peon+1 Plom	0,00	36,20	33,84	2,23	0,13

DESCRIPCIÓN	UNIDAD	CUAD. TIPO	REND. UNI. JORNADA	C.DIRECTO	C.MATERIAL	COSTO MANO	C.EQUIP.
PUERTA CORREDIZA ALUMINIO-VIDRIO BRONCE 4MM (INCLUYE INSTALACION)	m2	1 Alb+1 Peon	4,00	133,91	120,00	13,51	0,40
PUERTA CORREDIZA ALUMINIO-VIDRIO CLARO 4MM (INCLUYE INSTALACION)	m2	1 Alb+1 Peon	4,00	133,91	120,00	13,51	0,40
PUERTA DE ALUMINIO Y VIDRIO CON PIVOTE	u	1 Alb+1 Peon		250,50	237,30	12,80	0,40
PUERTA DE ALUMINIO Y VIDRIO CON SISTEMA JACKSON	u	1 Alb+1 Peon		250,50	237,30	12,80	0,40
PUERTA DE ALUMINIO Y VIDRIO CORREDIZA	u	1 Alb+1 Peon	4,00	229,20	216,00	12,80	0,40
PUERTA DE HIERRO Y TOOL 1 HOJA	u	1 Alb+1 Peon		90,40	90,40	0,00	0,00
PUERTA DE HIERRO Y TOOL 2 HOJAS	u	1 Alb+1 Peon		135,60	135,60	0,00	0,00
PUERTA DE MALLA GALVANIZADA	u	2 Peon	6,16	120,81	89,38	13,43	18,00
PUERTA DE REJA DE HIERRO-INCLUYE INSTALACION Y PINTURA	m2	1 Alb+1 Peon	3,92	42,71	20,80	13,51	8,40
PUERTA ENRROLLABLE	m2	1 Fier+1 Peon	10,00	115,57	110,00	5,41	0,16
PUERTA ENRROLLABLE LAMINA NEGRA .7 (INCLUYE INSTALACION Y PINTURA)	m2	1 Alb+1 Peon	8,00	118,29	111,13	6,76	0,40
PUERTA MALLA 50/10 TUBO 1 1/2" (INCLUYE INSTALACION Y PINTURA)	m2	3 Alb+4 Peon	0,00	41,37	18,03	22,74	0,60
PUERTA MALLA 50/10 TUBO 2" (INCLUYE INSTALACION Y PINTURA)	m2	3 Alb+4 Peon	0,00	45,64	22,30	22,74	0,60
PUERTA METALICA - REJAS (AULA 90 X 210)	m2	1 Alb+1 Peon	8,00	82,84	76,24	6,40	0,20
PUERTA METALICA CORREDIZA (PROVISION, MONTAJE Y PINTURA)	m2	3 Alb+1 Peon	7,75	114,22	98,22	14,63	1,37
PUERTA METALICA PLEGABLE (INCLUYE INSTALACION)	m2	1 Fier+1 Peon	9,83	69,42	63,85	5,41	0,16
PUERTA METALICA TOL - CORRUGADO	m2	1 Fier+1 Peon	8,00	140,46	140,46	0,00	0,00
PUERTA METALICA TUBO RECTANGULAR (PROVISION Y MONTAJE)	m2	6.6 Alb+0.5 Peon	7,62	38,23	12,85	23,20	2,18
PUERTA TOOL)	m2	1 Alb+1 Peon	8,00	82,84	76,24	6,40	0,20
PUERTA TOOL DOBLADO CON MARCO (INCLUYE INSTALACION Y PINTURA)	m2	1 Alb+1 Peon	7,91	83,20	76,24	6,76	0,20
PUERTA TUBO RECTO	m2	1 Alb+1 Peon	2,67	149,20	98,22	41,04	9,94
PUERTA VEHICULAR TIPO MIXTA, COMPLEJO DEPOR.BELLAVISTA(INCL.INSTAL,PARANTES)	glb	2 Alb+2 Peon	0,13	2.780,79	1.370,37	1.003,62	406,80
VENTANAS							
VENTANA BATIENTE ALUMINIO/VIDRIO FLOTADO E=6MM	m2	1 Alb+1 Peon	3,96	90,52	76,61	13,51	0,40
VENTANA CORREDIZA ALUMINIO BRONCE (NO INCLUYE VIDRIO)	m2	2 Peon	5,17	45,40	34,48	10,08	0,84
VENTANA CORREDIZA ALUMINIO-VIDRIO CLARO (INCLUYE INSTALACIÓN)	m2	1 Alb+1 Peon	4,94	65,11	53,98	10,81	0,32
VENTANA DE ALUMINIO	m2	1 Fier+2 Peon	3,13	66,20	40,86	24,84	0,50
VENTANA DE HIERRO CON PROTECCIÓN (INCLUYE INSTALACIÓN Y PINTURA)	m2	1 Alb+1 Peon	15,85	31,78	28,30	3,38	0,10
VENTANA DE HIERRO CON REJILLA	m2	1 Fier+1 Peon	7,04	97,20	89,38	7,60	0,22
VENTANA DE HIERRO CON VIDRIO 4MM (PROVISION Y MONTAJE)	m2	1 Alb+1 Peon	15,85	26,07	22,59	3,38	0,10
VENTANA DE HIERRO SIN PROTECCIÓN (INCLUYE INSTALACION Y PINTURA)	m2	1 Alb+1 Peon	15,85	16,46	12,98	3,38	0,10
VENTANA DE HIERRO SIN REJILLA	m2	1 Fier+1 Peon	6,86	39,74	31,92	7,60	0,22
VENTANA FIJA ALUMINIO BRONCE (NO INCLUYE VIDRIO)	m2	2 Peon	5,17	35,32	24,40	10,08	0,84
VENTANA FIJA ALUMINIO-VIDRIO CLARO 4MM (INCLUYE INSTALACION)	m2	1 Alb+1 Peon	4,94	87,74	76,61	10,81	0,32
VENTANA HIERRO Y MALLA 50/10 PLASTIFICADA	m2	3 Alb+1 Peon	0,00	28,05	14,25	13,20	0,60
VENTANA TIPO CELOSIA ALUMINIO BRONCE (NO INCLUYE VIDRIO)	m2	2 Peon	5,17	36,87	25,95	10,08	0,84
PROTECCIONES							
FRONTÓN DE TOOL CORRUGADO	ml	1 Fier+1 Peon	4,00	15,18	1,98	12,80	0,40
PROTECCION DE HIERRO VENTANA/PUERTA	m2	1 Alb+1 Peon	4,00	49,14	20,80	19,94	8,40
PROTECCION HIERRO CUADRADO 1/2" (INCLUYE INSTALACION Y PINTURA)	m2	1 Alb+1 Peon	3,92	48,74	26,83	13,51	8,40
PASAMANOS							
PASAMANOS DE METAL (TUBOS DE ACERO INOXIDABLE)	m	1 Fier+1 Peon	16,00	32,44	28,96	3,38	0,10
PASAMANOS PARA SANITARIOS DE DISCAPACITADOS	u	1 Fier+1 Peon		248,60	248,60	0,00	0,00
PASAMANOS TUBO CUADRADO Y MANGON DE MADERA (INCLUYE INSTALACION Y PINTURA)	m	0.5 Alb+2 Peon	5,00	29,83	12,05	13,33	4,45
PASAMANOS TUBO HG 1 1/2" (INCLUYE INSTALACION Y PINTURA)	m	0.5 Alb+1 Peon	4,99	22,37	10,64	8,24	3,49
PASAMANOS TUBO HG 2" (INCLUYE INSTALACION Y PINTURA)	m	0.5 Alb+1 Peon	5,00	28,29	16,56	8,24	3,49
PASAMANOS TUBO HG 3" (INCLUYE INSTALACION Y PINTURA)	m	0.5 Alb+1 Peon	5,00	32,79	21,06	8,24	3,49
PANELADOS							
DIVISION DE TOL DOS LADOS EN BAÐO (INSCLUYE PINTURA,INSTALADO,TUBO RECTANG)	m2	2 Alb+2 Peon	8,00	34,86	19,78	13,16	1,92
DIVISION PANEL MODULAR TELA-VIDRIO ESTRUCTURA METAL 50MM	m2	1 Fier+1 Peon	24,00	95,53	93,21	2,25	0,07
DIVISION PANEL MODULAR FORRADO TELA ESTRUCTURA METAL 50MM	m2	1 Fier+1 Peon	23,55	73,83	71,51	2,25	0,07
DIVISION PANEL MODULAR VIDRIO ESTRUCTURA METAL 50MM	m2	1 Fier+1 Peon	23,55	81,49	79,17	2,25	0,07
DIVISION/ PUERTA/ MAMPARA DE ALUMINIO (PANEL DE ALUMINIO) INCLUYE INSTALACION	m2	1 Alb+1 Peon	4,00	133,91	120,00	13,51	0,40
MAMPARAS DE ALUMINIO Y VIDRIO	m2	1 Alb+1 Peon		95,77	95,77	0,00	0,00
CERRAJERIA							
CERRADURAS							
CERRADURA DE BAÐO (INCLUYE INSTALACION)	u	1 Alb+1 Peon	16,00	17,99	14,69	3,20	0,10
CERRADURA DE MUEBLE / CLOSET/ LOCKER (INCLUYE INSTALACION)	u	1 Alb+1 Peon	16,00	5,74	2,26	3,38	0,10
CERRADURA DE POMO (INCLUYE INSTALACION)	u	1 Alb	15,72	23,01	21,12	1,79	0,10
CERRADURA DORMITORIO LLAVE - SEGURO	u	1 Carp+1 Peon	9,69	27,04	21,47	5,41	0,16
CERRADURA LLAVE-LLAVE (INCLUYE INSTALACION)	u	1 Alb+1 Peon	15,98	20,82	17,52	3,20	0,10
CERRADURA LLAVE-SEGURO (INCLUYE INSTALACION)	u	1 Alb	16,00	23,18	21,47	1,61	0,10
CERRADURA PLANA PARA PUERTA METALICA (INCLUYE INSTALACION)	u	1 Alb+1 Peon	15,58	20,17	15,83	3,38	0,96
CERRADURA PRINCIPAL LLAVE - LLAVE	u	1 Carp+1 Peon	9,69	23,09	17,52	5,41	0,16
CERRAJERIA DE BAÑO	u	1 Carp+1 Peon	10,00	20,26	14,69	5,41	0,16
PICAPORTES							
CERRADURA DE PICAPORTE	u	1 Peon	8,00	5,33	1,59	3,54	0,20
PICAPORTE	u	1 Alb+1 Peon	15,46	9,86	6,38	3,38	0,10