

THE COOPER UNION
ALBERT NERKEN SCHOOL OF ENGINEERING

A GUIDE TO ESTIMATING WITH BUILDING INFORMATION MODELING AND TRADITIONAL
MODELING USING AUTODESK QUANTITY TAKEOFF

by

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ABSTRACT

This Master's thesis seeks to develop an understanding of Building Information Modeling in the construction management industry specifically in estimating through the use of Autodesk Quantity Takeoff. The goal is to provide students with a guide into how to accurately and efficiently perform a quantity takeoff and turning that takeoff into an estimate. An overview to what estimators do and the types of projects they work on was analyzed. A comparison between how estimators manually perform quantity takeoffs and using Building Information Modeling to perform quantity takeoffs was performed. A sample from Revit Architecture and Structure was used as the model for the quantity takeoff. An overview of using the building information modeling model to perform a full quantity takeoff was first performed. A subsequent quantity takeoff was then performed using manual takeoff techniques. The structural and architectural trades were taken off with suggestions for a more efficient quantity survey. Pricing of the quantity survey was then performed using RS Means through material and labor unit costs. The estimate was then compiled and a report was created. Conclusions were then formed on the usefulness of the program and building information modeling in not only the estimating portion of construction management, but the industry in general.

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1.0 Introduction

There are three major parts to the design and construction of buildings: the owner, the project team consisting of designers and construction management firms and subcontractors. Besides the project team, the other players that are involved in the life cycle of the building are the owners and subcontractors. The owner is the party who is responsible for paying the project team and whose intentions the project is designed and built for. The designers are the architect and engineers who design the buildings, while the construction management firm is responsible for overseeing the construction aspect of the project. The subcontractors are the companies that are responsible for the actual building of projects.

The construction management industry has begun to improve in the way it takes drawings from the engineers and architects and constructs the project. Construction management (CM) companies have to successfully bid on a project just as an engineering or consulting firm would. Generally there are two types of bids; the design-build (DB) and the design- bid- build (DBB) as well as a negotiated contract. The first step in bidding on a project starts with the Preconstruction group, or more specifically the estimating department of the CM. The estimating department is in charge of performing quantity takeoffs on all aspects on the potential project. If the project is a bid, the estimator will then contact subcontractors to provide a bid on a specific trade which is also called the scope of work. The scope of work will entail everything the subcontractor is responsible for in its specific trade. It would include all material, work and equipment needed for the subcontractor to properly execute and complete its portion of the project. For example, the scope of work for a concrete subcontractor would entail the correct quantity of concrete, delivery of concrete, equipment to pour the concrete, rebars and formwork.

The estimator will then de-scope and level each sub-contractors bid to make sure no scope or quantity is missing within the bid. De-scoping is the process of verifying that the subcontractors bid includes all aspects of its trade throughout the project. To de-scope the subcontractor, the estimator should have a good grasp of the scope of the project for the subcontractor's specific trade. The estimator would then go over scope items with the subcontractor that he might have missed. For example, if an estimator was de-scoping a concrete subcontractor, a scope item the estimator would want to be sure that the subcontractor had was a volume of concrete similar to what the estimator had taken off. If the volume was drastically different, then the estimator would know that either the subcontractor took off more concrete than needed, or was using a wrong thickness. If the subcontractor did miss a scope item, they would be asked for the price of the specific item, otherwise the estimator could take the price for the same item from another sub-contractor and just add that cost onto the sub-contractor missing that piece of scope. This would be the "leveling" part of the bid. Ultimately, the estimator wants to make sure all the sub-contractors have the entire scope of their trade covered. Otherwise, the sub-contractor with an incomplete bid would most likely be the lowest and be selected for the project. This would just cause headaches for the Project Management team, as well as the entire project because the project would be greater than the price the CM initially proposed. If the proposed project is a negotiated contract, then the estimator will use the quantities from his takeoffs and create a detailed estimate out of it to be reviewed by the owner. The difference between an estimator from a construction management firm and one from a designer or subcontractor is that the estimator with the CM is responsible for all phases of the project, whereas the estimators from the designer or subcontractor only focus on their specific trade.

Currently the quantity takeoff process is paper-based. This could lead to many problems such as drawings not being issued on time, incomplete drawings, or even missing drawings that lead to delays and increasing financial costs to projects. Some of the remedies that are currently being used to address these problems include a different organizational format such as the design-build method, project websites that are shared with all members of the project team (architects, engineers and construction managers) and the use of 3D CAD (Computer-Aided Design) software. While these methods do allow information to be exchanged faster and easier, it does not help to eliminate the problems associated with paper documents, as well as saving companies the money that would have been used to print and deliver the documents and drawings.

The usage of building information modeling (BIM) would aid in improving the problems associated with issuing paper documents. BIM technology allows the user to create a virtual model of the building with an integrated design that would help keep project costs and duration lower. It incorporates necessary information throughout different phases of the project life into one single model that would greatly assist not only in the estimating stage of the construction, but the entirety of the construction process. Typically in a larger construction management firm, various types of computer programs are used for various processes such as estimating, scheduling, accounting and procurement. Through the implementation of BIM tools, contractors can use the models created by the architects and engineer for estimating, scheduling and planning without resorting to a multitude of different programs. The information the contractor would need would be right in the model.

Autodesk (makers of AutoCAD) have a number of BIM software that can be used throughout the design and construction process ranging from its Revit programs used in

design, to Navisworks, Constructware and Quantity Takeoff which are used in construction. If the model is created correctly, Autodesk Quantity Takeoff (QTO) can create a takeoff in a few minutes based on the building model. It also has the capability to perform manual takeoffs. This thesis will show how to import a Revit file into Autodesk QTO and performing automatic and manual takeoffs in the architectural and structural trades as well as turning the takeoffs into cost estimates. Autodesk Quantity Takeoff 2011 was used in this thesis.

Before the estimator starts his or her quantity takeoff, they must first know what type of delivery method the owner wants; whether it is one of two types of bids or a negotiated contract.

1.1 Difference Between a General Contractor and a Construction Manager

The difference between a construction management company and a general contractor is sometimes hard to differentiate. Generally a general contractor is a family owned business that specializes in a specific area of work (such as carpentry, excavators, brick layers etc) and employs a small workforce of up to 10-15 employees with up to seven of the employees being employed as office staff and the rest of the employees being tradespeople who also function as field personnel such as on-site superintendents. The in-house work or work that is not subcontracted out would often require the GC to hire additional people to complete. Generally the general contractor would focus on bidding for smaller jobs such as those around \$1 million or less.

On the other hand, a construction management company generally has no full-time tradespeople in its workforce as employees. Instead, the employees of a CM are all office staff or part of project management teams. All the tradespeople that the CM needs to complete its job are subcontracted out. Because the CM is usually a larger business versus

the GC, the CM focuses on larger projects that could range from millions to hundreds of millions of dollars.

In essence, a GC and a CM are very similar and are often times used interchangeably. They both bid on projects and oversee the construction aspect of jobs. The only real discerning difference between the two is that the GC specializes in a trade, has less employees and usually bid on smaller projects.

1.2 Design-Bid-Build (DBB) Method

The design-bid-build method used to be the contract type of choice for public buildings with around 55 percent of public buildings opting to go this method in 2000. In the design phase of this type of bid, the owner would hire an architect to develop a program, or list of requirements for the building as well as the design objectives. After the architect and accompanying consultants such as structural, HVAC, plumbing and electrical have designed and drawn their specific components to the project, all the drawings are then compiled into the construction documents.

These documents would then be used for bidding by construction management (CM) companies or general contractors (GC) depending on the size of project. In larger construction management companies the task of bidding falls to the Preconstruction Services division of the company. The estimators in this division are tasked with going out to subcontractors for bids, de-scoping bids and coming up with a final bid for the building based on subcontractor coverage. However, despite the fact that the drawings would be used for bidding, there is oftentimes missing or minimal details on purpose to protect the architects from any potential liabilities. The owner and/or architect could either shortlist a certain

number of companies to bid on the project, or have an open bid, where anyone could have a chance of winning the bid.

Throughout the bidding process for the CMs or GCs, there will be a period of time for Request for Information (RFIs) where the bidders could ask questions about inconsistencies or missing information based on the documents. These questions are directed towards the Architecture and Engineering firms for clarification on what is shown on the drawings and can be asked by the CMs or GCs or by subcontractors. Examples of questions asked during the RFI could be as simple as “Please clarify the finish in this room” or “Please clarify the thickness of the concrete slab”. The Architect or Engineer will then respond to all of the RFIs answering the questions, thus allowing the CMs or GCs to provide a more competitive and accurate bid based on subcontractor pricing. After the bid has been won, the estimating portion will end, and then it is up to the project management team to construct the project.

1.3 Design-Build (DB) Method

Unlike the DBB method, in the design-build method all the responsibility of designing and construction for a project falls onto one single company generally a construction management company. This one entity could be a joint venture between a few other companies, or it could be one company. This method allows owners a single point of contact (the design-build team) regarding decisions on the program for the building. Unlike the DBB method, the design-build method allows contractor input throughout the design process thus possibly saving the owner in cost and time. Besides the cost and time savings to a project, this method also provides owners with reduced risk. Owners have a reduced risk on their projects because the design-build team would assume most of the risks associated to the

building. Furthermore, in the design-build method, the contractor and the designers work together as one team. According to the Design-Build Institute of America (DBIA), in 2000, around 35 percent of projects in the USA used this method. However, in 2010 both the DB and DBB methods were used in roughly 45 percent of non-residential projects in the United States. The remaining 10 percent followed the construction management (at risk) method which will be talked about in the following section.

The owner selects the design-build firm in one of two methods. In the first method, the design-build firm is chosen based on its past experience, managerial skill and quality. This is called the “direct selection”. In the second method, the owner creates a short list of design-build firms. These firms are then asked to submit a proposal based on the owner’s program, which would be judged based on past performance, design solutions, price, and managerial skills. During the preconstruction or estimating portion in this delivery method, the estimator will once again reach out to subcontractors for bids. However, this time the bids will be based on not only the drawings that the owner provides, but also any supplemental information given by the estimators. When a construction management company has been selected to be the design build contractor, they end up taking the lead throughout the whole life of the building from the design to construction phase. Unlike the design-bid-build method, the estimating portion of the project does not end after being awarded the bid. Estimating of the project will most likely continue throughout the duration of the project to track changes in pricing.

1.4 Negotiated Contract

There is another project delivery method that does not involve the bidding process and instead involves a direct relationship between the owner and the construction

management company. That method is called the negotiated contract. There are many types of negotiated contracts ranging from cost-plus-fee to a lump sum. The difference between the different types of contract is how the CM is paid. In a cost plus fee contract the payment to the CM is determined by the cost of the work and the CM's fees. The owner will be able to see the changes in cost per phase of the project based on the estimates provided by the estimating group. Any savings that might occur throughout the duration of the project is generally shared by the owner and the CM. In a lump sum contract, the owner just sees the final value of the project and any savings that might be gained throughout the project goes to the CM. This type of contract is beneficial to both parties because if the project is estimated correctly, then the CM could see a large profit margin while the owner will have a level of certainty as to the cost of the project.

Similarly to the estimating of the design build after a firm has been awarded the bid, estimates would have to be done in each phase of the design process to track the cost ranging from the conceptual documents to the construction documents. Whichever one of the delivery methods the owner chooses, the estimating process is vital for the success of not only the construction management company but also for the project. An estimate where the cost is lower than the final cost of the project would mean there most likely were some scope items missing from the estimate. Furthermore, a lower estimate than the final project cost would mean the project would cause the company to lose money as well as tarnishing its reputation for providing bad or incomplete estimates. On the other hand, if the estimate ends up being more expensive than the final cost of the project, then that would mean that the project saved or earned the CM money. There is a saying in the estimating world and that is "it is always better to estimate higher than lower." However, the estimate cannot be that

much larger than the project as in 10 percent greater; otherwise the owner might begin to think that the CM is trying to take advantage of him.

1.5 Traditional (Paper) Usage in Preconstruction (Quantity Takeoff and Estimating)

The use of BIM technology in the preconstruction stage has a wide range of uses. One of the biggest differences in using BIM technology over using traditional CAD based designs is the ability to easily extract quantities straight from the model as opposed to doing manual quantity takeoffs. Throughout the design phase of a building, many cost estimates would be created by the preconstruction team of the construction management company. This is an integral part of the design process because it allows the architects and engineers to figure out the cost of the building and whether or not it is within the owner's budget. In the preconstruction group of a CM, estimators would develop estimates based on quantity takeoffs off of the drawings provided by the architect and engineers. From the structural drawings, estimators could estimate the total cubic yards of concrete on the job, the amount of rebar in the concrete, or the tonnage of steel. From the architectural set, estimators could estimate all of the interior finishes and partitions and other architectural aspects from the project.

However, this is usually a tedious and time consuming process. Depending on the contract that the CM has with the owner and/or architects as well as the level of detail in the drawings, the turnaround time for an estimate could range from one week to a month. If the drawings are in the conceptual phase with very minimal detail, the estimator would have to use his or her experience and knowledge to try to fill in gaps in information that the architect has not designed, and probably will not design until the later parts of the project such as the finishes of a room, accessories in the toilet rooms, or doors. For example, based on the floor

plan and building program, a bathroom might be shown as just a typical room with a note that says that the room is a bathroom. However, in the conceptual drawing, there would be no mention of finishes, door type, partition type or accessories in the bathroom. This is where estimators would have to use their knowledge from previous projects or experience to fill in missing information, such as adding moisture resistant gypsum board for partitioning, or ceramic tiles on the floor and walls. Generally these estimates based on conceptual drawings are more conservative due to the lack of information and amount of guess work that needs to be done to complete the project. To take into account all of the missing information in the drawings, the estimator would most likely include a large percentage for design and construction contingencies.

In the design development set of drawings, there is a considerable more amount of information shown than was shown on the conceptual drawings. Some of the lesser items of importance such as doors or accessories are still not shown in the drawings, but most of the pertinent info will be depicted. Information such as partition types, finishes, structural steel or concrete drawings will be detailed. Nonetheless, in this set of documents estimators will have sufficient information to modify their estimates from the conceptual drawings and thus provide a more accurate number to the owners regarding the cost of the project. In this phase, the design and construction contingencies will be decreased due to more information.

The construction documents are the final set of drawings issued by the architects and engineers. As the name might suggest, the construction documents should be detailed enough that the CM should be able to go out and build the project. Granted, there might be occasional information that might not be fully detailed, drawn or scheduled, but those aspects such as an accurate door or millwork schedule are usually the last items for an architect to

draw or perfect. Furthermore, those items are also installed or brought to the job site towards the end of the project so they do not affect most of the construction going on.

Furthermore, when estimators are performing their quantity takeoffs or surveys on paper drawings, they would oftentimes have to keep flipping between drawings or even different sets of drawings. If multiple estimators are working on one project then they would have to share the documents which might lead to downtime if one estimator is using a drawing that the other estimator also needs. Also, depending on one's preference, some estimators write the quantities they have found right onto the drawings thus leading to double the work when they have to then compile all their quantities into an estimate format. Even with the use some of the specialized computer software for estimating, the quantity takeoff portion can be a long arduous task. Generally pdfs of drawings are issued to the construction management company for liability reasons. The estimator can then take these pdfs and upload them into the estimating software and then start marking up the drawings digitally like they would on a paper copy. However, the same problem arises that only one drawing can be viewed at a time. Furthermore, these pdf files are generally large and to flip between drawings on the computer can often take a few seconds to a few minutes depending on how large the file is. Also, once the quantity survey has been completed, the quantities are then going to have to be input into the estimate which is also time consuming.

2.0 Autodesk Quantity Takeoff – Overview

Autodesk Quantity Takeoff (QTO) can assist in combining various sources of two dimensional and three dimensional designs to create a quantity takeoff that can then be used to create a cost estimate. QTO can use various file types as its source files such as Design Web Format™ (DWF) or non DWF files such as PDF files, DWG files, JPG or TIF image files. The DWF file is a type of file created by Autodesk that is capable of combining 2d and 3d designs created from Revit into one file. Depending on the level of the DWF file that is imported into QTO, the user may be able to use the **Automatic Takeoff** function. When importing non DWF files into QTO, the user would have to manually perform the quantity takeoff.

Currently there is a number of software that is used for quantity takeoffs. However, these programs generally only allow manual takeoffs to be performed, thus making life for the estimator easier than performing takeoffs on drawings. QTO allows the estimator to automatically extract quantities based on the model, but to also have the ability to fill in any missing gaps in the model. Another benefit to using QTO is that estimators could adjust the taken off quantities based on waste factors.

2.1 Summary on Performing a Takeoff

There are very few rules when it comes to quantity takeoffs. Everyone performs takeoffs differently. Some choose to dive right into the drawings and start taking off everything and organize their takeoffs after they are done while others choose to organize their takeoffs so it is easier to create an estimate after the takeoffs have been completed. To organize the takeoff to make creating an estimate easier there are a few simple guidelines to follow.

The first comes with setting up the takeoff project which includes creating the project name, the units to be used (metric versus imperial), the drawings, and in the case of Autocad Quantity Takeoff the catalog or how the takeoffs will be formatted. Choosing the correct unit is very important because in most takeoff programs, once the units are chosen, it cannot be changed. Choosing the catalog and how the estimate would be formatted would help in organization too, especially if the company has their own format for estimates.

After the project has been created the bulk of organizing the takeoffs has been completed. Groups and subgroups can then be added into the catalogs or “WBS” for similar items to further organize the quantity takeoffs. For example, if there are a number of concrete slab thicknesses, a group can be created under the Concrete WBS for Concrete Slabs and the items under this group would have the various slab thicknesses.

As you continue with your takeoffs keep in mind to make sure you are using the right units for each item. A simple mistake such as having square inches or square yards instead of square feet for walls could greatly affect the cost of the project.

Generally there is no set rule on where to begin the takeoffs once you have your project organized. Some choose to follow the organization of their company’s estimate

format, starting from superstructure and concrete and then moving onto the architectural trade, while others choose to do the opposite and start from architectural than move to the superstructure. It is all a matter of preference.

2.2 Setting up a Takeoff Project

To start a new takeoff after Autodesk Quantity Takeoff is opened, click on the **New Project** button. This will open the **Project Setup Wizard** which will help create the takeoff project. There are four steps to creating a new takeoff project: Name Project, Specify Settings, Select Catalog, and Import Files. This first example will show how to use the Model Takeoff function as well as using a pre-created catalog to perform a quantity takeoff.

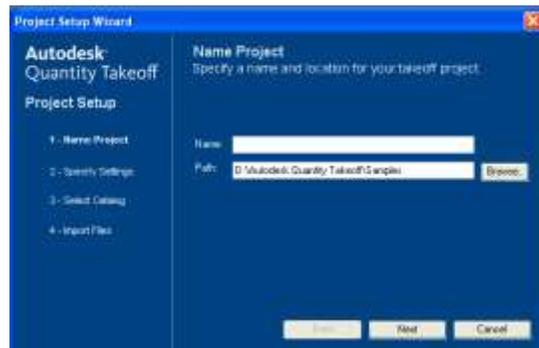


Figure 1: Project Setup Wizard Screen

In this screen you specify the name and path for the project. The **Name** is what you want your takeoff to be named. The **Path** is where the takeoff will be saved. Once the name of the file and the path has been selected, click **Next** to go to the next screen.

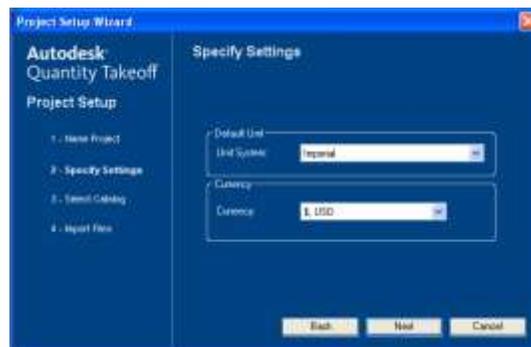


Figure 2: Specify Settings Screen

In this screen you specify what unit you want to work with; imperial or metric. You can also specify what currency the estimate will be in. There are four currencies to choose from, the US dollar (\$), the European Euro (€), the Britain Pound (£) or the Swiss Franc (SFr). It is important to note that the units cannot be changed once the project is set up. Once the unit and currency have been selected, click **Next** to go to the next screen.

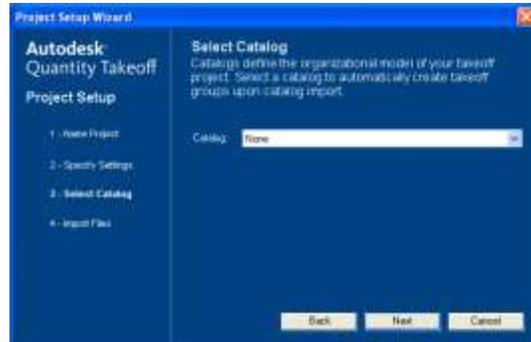


Figure 3: Select Catalog Screen

In this screen, you can select a pre-created catalog such as the Construction Specifications Institute (CSI) 16 format, CSI 48 format or Unifomat or create your own. A catalog creates groups to help organize the takeoff. The difference between the two CSI formats is the number of divisions the estimate will be split into. Divisions are used to organize information about a building or project's construction requirements and associated work. The appendix has a listing of the 16 divisions. You can also create your own catalog based on company standards. For this example, the Unifomat catalog will be used.

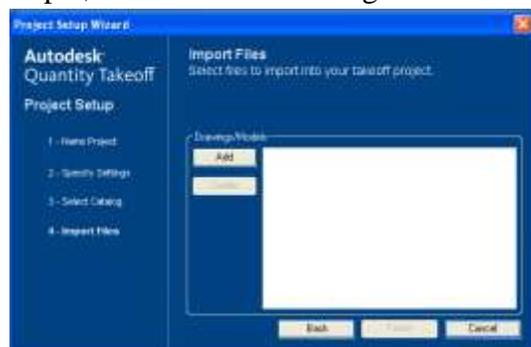


Figure 4: Import Files

In the Import Files screen you select the drawings and/or model that will be used in your takeoff. After the drawings and/or model have been imported, the model or drawings will be ready to be taken off.

2.3 Autodesk Quantity Takeoff Interface

Once the project has been created, you will see the QTO interface as well as a number of docketed palettes. The four palettes (Documents, Takeoff, Model and Workbook) shown are the ones that are important for use in performing a quantity takeoff. The palettes can be shown or viewed in a number of different ways. They can be viewed as tabs as seen along the left side of the window (Documents, Takeoff and Model) or they can be shown as windows such as the Workbook Palette. If you are working with a dual monitor setup, than the palettes can be floating in space on the other monitor to avoid clutter.

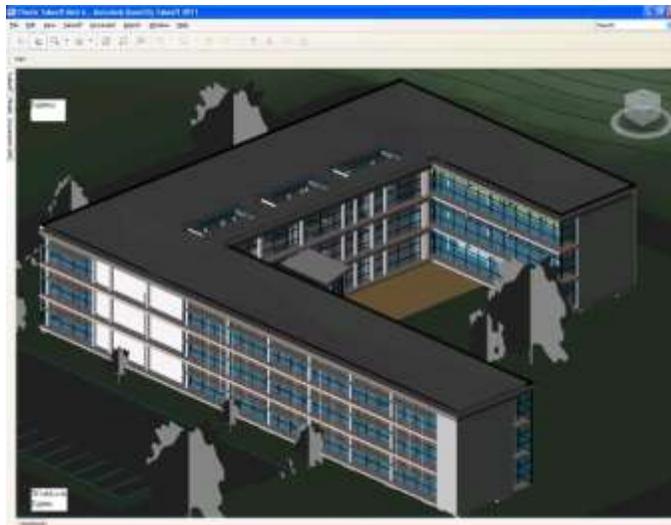


Figure 5: QTO Interface

The **Documents** palette is used to show all the different views and floor plans associated with the building. When different drawings are imported into QTO, a new folder

would appear with the new drawings, thus making it easier to keep track of changes in the model.

The **Model** palette which is only used in a 3D DWF file allows the user to see what applications have been created in the design. This palette also allows you to show or hide various aspects of the project to ease the takeoff process. Takeoffs can also be performed using the Model palette thus allowing you to perform specific takeoffs.

The **Takeoff** palette is the backbone or structure of your estimate as it organizes the estimate. When creating a project and a catalog is selected, it will be shown in this palette. This palette is organized into Work Breakdown Structure (WBS) groups which can be used in CSI divisions, takeoff items that need to be taken off and have assembly or cost info such as interior walls or floor finishes, and objects which are the parts of the takeoff items to be quantified such as gypsum wall boards or tiles. As the name suggests, the WBS is essentially how the takeoffs will be divided and provides the organizational structure to the takeoff and estimate. It is terminology that is used only in Autodesk Quantity Takeoff so other takeoff software would not use it. The WBS can be further divided into multiple groups or sub-groups as shown on figure 6.

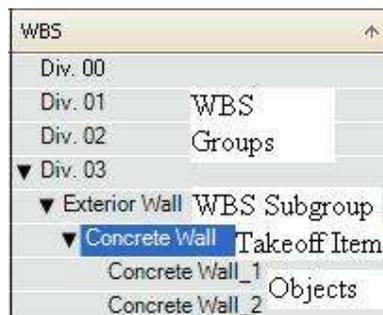


Figure 6: WBS Structure

Within each WBS, takeoff items that need to be quantified can be created. Then within the takeoff items will be the individual objects that are actually being taken off per drawing or

sheet. The type of takeoff you want to perform on an item: count, linear, area or volume, can be modified in this palette. Generally when an object is created, the type will be “Undefined”.

The **Workbook** palette is where all the takeoff quantities will appear. It also allows you to modify an object’s assembly as well as the actual quantity. For example, if the interior partition of a project is taken off, the partition assembly can be edited so the takeoff will include stud counts and insulation.

2.4 Automatic Takeoff Tools

As already mentioned, one of the benefits of using Autodesk QTO instead of other takeoff software is its ability to perform a quantity takeoff of the model based on a 3D DWF file. The level of quantity takeoff depends on how detailed the model is. There are a number of methods for QTO to aid in the quantity takeoff process such as its four different methods of automatic takeoffs. The first of these methods is the **Model Takeoff**. In this method, the entire model will be taken off with just one click. However, the level of takeoff is dependent on the detail in the model. Therefore, even after using the **Model Takeoff**, the entire model should still be checked for objects not taken off or missing objects from the model. The second method is using the **Model** palette to perform the takeoffs. This will help in visually seeing specific trades within the model. The third method is the **Single-Click Auto Takeoff**. This method can be used in a 3D DWF model or on 2D DWF drawings and allows you to create a takeoff measurement with the click of an object. The last method is the **Search Takeoff**. In this method, takeoffs can be performed by using design data as the search criteria such as family the family name or type name.

2.3.1 Model Takeoff

For the **Model** Takeoff to work, the 3D model has to be selected. To turn the view or drawing to the 3D view, click on the **Documents** palette and select the “3D View: {3D}”. The view should be similar to that shown in Figure 5. Then click on the **Model Takeoff** button as shown on Figure 7 or press “M” for the shortcut and click anywhere on the model. The three buttons shown on Figure 7 are the takeoffs that can be performed on a 3D model. The 2D takeoff buttons will be shown later.



Figure 7: Model Takeoff Button

Depending on the size of the project, after a few seconds or minutes, the 3D model will be shaded in assorted colors. This signifies that those objects have been taken off. Furthermore, a window will appear telling you how many objects have been taken off, as seen on Figure 8.

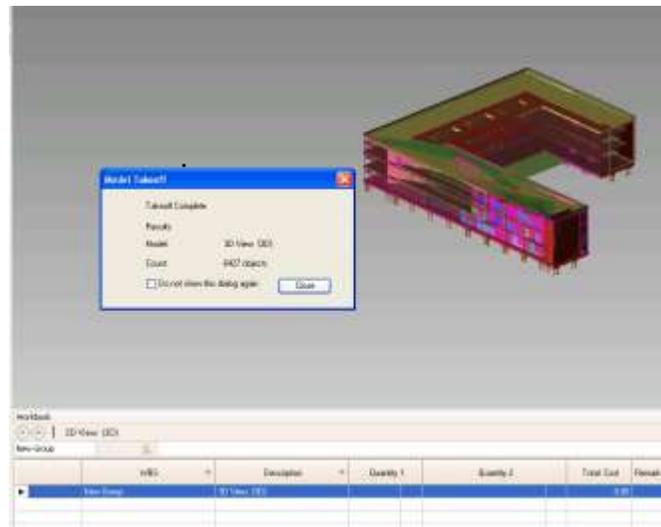


Figure 8: Building after Model Takeoff

After the model takeoff has been completed, you will notice that a new group has been added to the **Workbook** and **Takeoff** palettes. If nothing appears in the **Workbook** palette that

means the type of takeoff in the **Takeoff** palette is for a specific item is set as “Undefined”. To change the type, click on the “Undefined” and a drop down menu of the four choices (Linear, Area, Volume and Count) will appear. Select the type of takeoff for each item. Expand “New Group_3” with the description “Floors (5)” in the **Takeoff** palette. Four line items of different types of floors will appear. Floors are taken off as an area, so under each item, click on the “Undefined” and select “Area” from the dropdown menu. If there are multiple items under a certain subgroup, the type of takeoff can be changed at one time by holding the Shift key and selecting both items.

The floors group can be moved from the “New Group” that was created from the **Model Takeoff** to Div. 09 Finishes. To move a group, item, or object to a different group in the **Takeoff** palette, simply drag and drop what you want to move to the desired location. The group and item names can be renamed to avoid the confusion of having a number of “New Groups.”

After the floor takeoff type has been changed from “Undefined” to “Area” and moved to Div. 09 Finishes, open the **Workbook** palette. You will notice that the quantity of each type of floor is shown, as seen on Figure 9. The type of flooring is shown in the description. On the bottom of the palette, there are a number of tabs. With each item taken off and put into their respective divisions, a new tab will appear for that division. This aids estimators into seeing what was taken off in each division, such as exterior or interior closures. The Div.09 tab shows only takeoffs that were moved into those respective groups in the **Takeoff** palette. The “Summary” tab shows every piece of quantity takeoff that has been taken off thus far in the project.

	WBS	Description	Quantity 1	
▼	Div. 09	Finishes		
▼	Div. 09.New Group_3	Floors		
▼	Div. 09.New Group_3.New Group	Floor		
	Div. 09.New Group_3.New Group...	Generic Concrete 300mm	3,101.613	sq. m
	Div. 09.New Group_3.New Group...	160mm Concrete With 50mm Me...	71.061	sq. m
	Div. 09.New Group_3.New Group...	Concrete Deck - Tapered Insulat...	1,620.617	sq. m
	Div. 09.New Group_3.New Group...	Generic 300mm	1,740.540	sq. m

Figure 9: Workbook Palette with Quantities

2.4.1 Model Palette for Takeoffs

As mentioned earlier, the **Model** palette can be used to perform takeoffs of a 3D DWF file. This method of performing a takeoff is different than the **Model Takeoff**. Using the **Model** palette, you can takeoff certain parts of the project without seeing the whole model. This method would help if you are performing a takeoff only on a certain aspect of the project such as floors. To use this method for takeoffs, open up the **Model** palette. This will show all the groups that are within the project. Right-clicking on any of the groups, items or objects will give you seven different options as shown on Figure 10: Hide, Hide Others, Show All, Transparent, Invert Selection, Takeoff and Takeoff to Item.

The first three of the options allow you to hide the group or object in the **Canvas** thus showing the rest of the project, or hide the rest of the project and only show the selected group or object, or to show everything once something has been hidden. The Transparent option allows you to view the selected object as either an opaque, solid object, or a transparent object. The Invert Selection option allows you to select everything but the selected group or object. The Takeoff option allows you to create a takeoff that will appear at

the bottom of the **Takeoff** palette in its own group. This takeoff option can be used for the selected group, item or object and would need to be moved into the correct location within the **Takeoff** palette. The Takeoff to Item option lets you perform a takeoff for a specific item or object and QTO will put the takeoff in the selected item location.

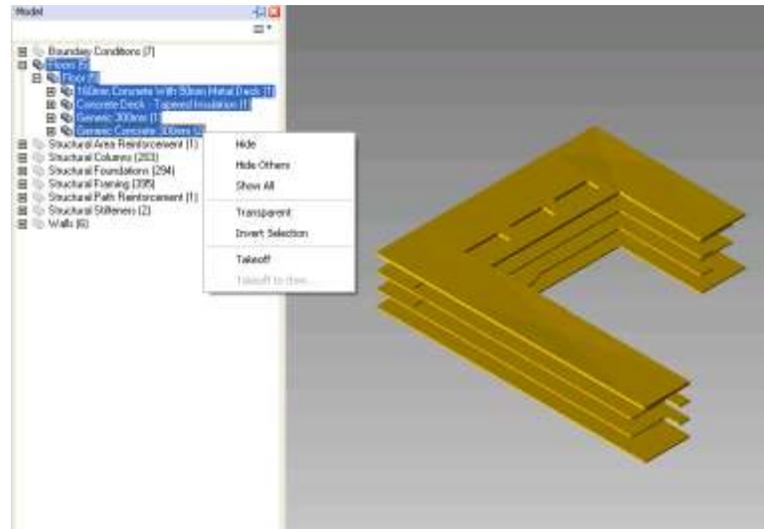


Figure 10: Model Palette Takeoff

If we wanted to view and takeoff only the concrete slabs we would right click on the “Floors” item and select Hide Others so only the concrete slabs would appear on the Canvas. Assuming all five objects under the “Floors” item is to be taken off and there is not a specific item for the wood deck in the **Takeoff** palette, we would right click on the “Floors” item again and select Takeoff. This would create a “Floors” item at the bottom of the **Takeoff** palette with all seven wood deck objects being taken off. If the Type value for these objects is set as “Undefined” change it to “Area”. If there was an item created for the wood deck in the Catalog selected when creating the project, than the Takeoff to Item option would have been used.

2.4.2 Single Click Auto Takeoff

Another method of taking off a project is using the **Single-Click Auto Takeoff** button as shown on Figure 11, or press “G” for the shortcut. When the **Single-Click Auto Takeoff** button is clicked, the option of grouping the takeoffs by family or selection is given. As the name suggests, this is where you can perform takeoffs of elements of the project individually as opposed to the entire model at one time. This can be done in either the 3D or 2D model.



Figure 11: Single-Click Auto Takeoff Button

The default setting is grouped by family meaning that the takeoffs would be grouped as defined by the object’s properties. In another word, if floor finishes were the items being taken off using the **Single-Click Auto Takeoff** grouped by family, then each click on the model would either create a new item and object based on the different floor types, such as wood deck, slate or vinyl carpet tile that would appear on the bottom of the **Takeoff** palette.

Grouping by selection means the takeoff will be added to the group or item selected on the **Takeoff** palette. After the first takeoff, each subsequent takeoff will have the same object name as the first object taken off. Thus, care has to be taken when performing takeoffs using this grouping method.

To use this method, simply select the **Single-Click Auto Takeoff** button, then select the objects you want to takeoff on the canvas. The first time you use this method to group objects by family, all items in that group will have an Undefined item type. Once the group’s item type has been selected, QTO will remember the item type for that item for use in future

takeoffs. This method is very similar to using the **Model** palette to perform takeoffs because of its ability to takeoff specific items.

2.4.3 Search Takeoff

The last method of performing a takeoff on a 3D or 2D DWF file is the **Search Takeoff** method. To select this method, click the **Search Takeoff** button as shown on Figure 12 or press “R” for the shortcut. This method allows you to create a takeoff using the model’s design data as search criteria.



Figure 12: Search Takeoff Button

To use this method click on the **Search Takeoff** button, and then select the object on the canvas you want to search for in the project. If you want the takeoff to be added to a group or item click on the item or group in the **Takeoff** palette first. In this example, slate flooring will be chosen. When one slate object is selected using this takeoff method the **Search Takeoff** window will appear as shown on Figure 13. In the **Search Takeoff** window there are a large number of possible search criteria that you could use in your takeoff ranging from object dimensions, family names and the object’s type. Generally the two criteria used would be to search by the family name and type name as shown on Figure 13. When the criteria for your takeoff has been selected, click “Search” to complete the takeoff. Any objects that fit in the parameters will be taken off and will appear on the **Workbook** palette.

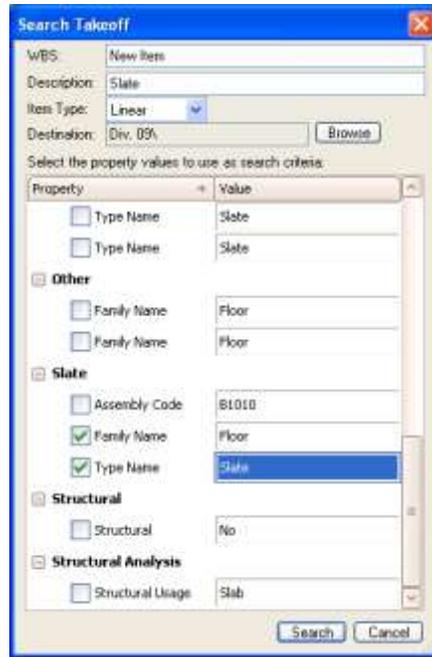


Figure 13: Search Takeoff Window

3.0 Using Autodesk Quantity Takeoff as Traditional Takeoff Software

Autodesk QTO can also be used for quantity takeoffs if the drawings were created from an AutoCAD file instead of a Revit file. When performing a quantity takeoff on traditional or non BIM models, the takeoff options will differ from the BIM/3D DWF model options. The biggest difference from a BIM or 3D DWF model and traditional sheet drawings is that the takeoffs can only be performed on the drawing sheets as opposed to a 3D model of the building. Performing takeoffs only on sheet drawings is decidedly more time consuming than performing a takeoff on a BIM model. To fully demonstrate how to use QTO for takeoffs on sheet drawings, we will perform a full quantity takeoff of the structural and architectural trades using a model of a building utilizing the manual takeoff buttons shown in Figure 14. The four buttons used for manual takeoffs are: Single-Click Linear Takeoff, Polyline Area Takeoff, Count Takeoff, and Polyline Backout. Each of these options will be further explained as we go through a takeoff. The model we will be using is the sample model from Autodesk Revit Architecture and Structure.



Figure 14: Manual Takeoff Buttons

The first step of creating a takeoff is to create a new project and follow the steps outlined in section 2.1 of this thesis. Be careful to change the “Units” to metric. We will be using the CSI-16 catalog for this takeoff.

3.1 Concrete Takeoff

Since the building is a concrete framed building as seen on Figure 15, we will start by performing manual quantity takeoffs on the foundation, starting with the footings then

moving onto the slab on grade and then finally the concrete beams and columns. Generally anything concrete related will be taken off by volume because that is how concrete subcontractors tend to price and figure out the quantity of concrete needed for their work.

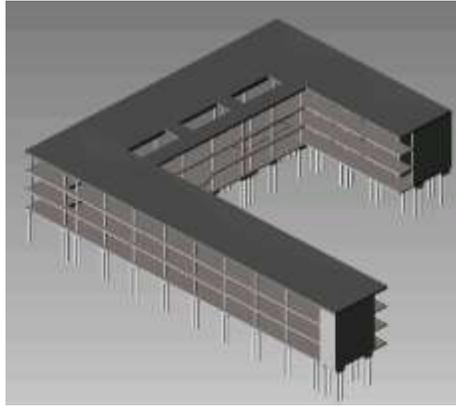


Figure 15: Concrete Structure of Model Building

3.1.1 Performing Takeoffs on Foundation (Piles and Pile Caps) using Count

The foundation of the building is shown in Figure 16.

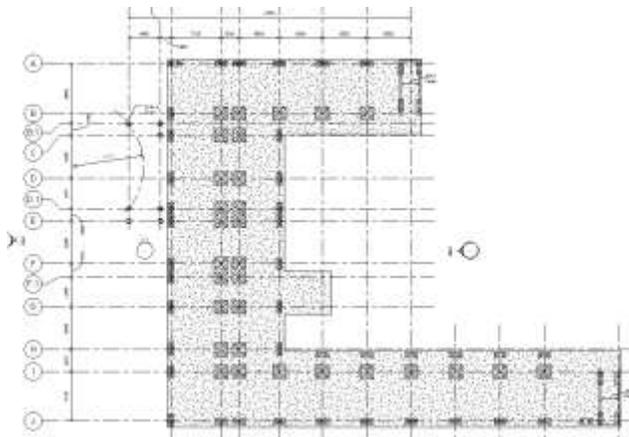


Figure 16: Foundation of Model Building

As can be seen, the foundation of the building consists of groups of two and four piles with a pile cap on top of them. Instead of counting how many individual piles are in the foundation, we will count how many pile caps are in the foundation keeping note of which pile caps are

on groups of four piles and which are on groups of two piles. Before we start any takeoffs we have to first organize our **Takeoff Palette** with the correct items. Under the Div. 03 Concrete make a group called Foundations and two sub groups, one for pile caps and one for piles. In the Pile Caps subgroup, make two items, one for groups of four piles and one for groups of two piles. In the Piles subgroup, make an item for 400 mm steel pipe and one for 500 mm steel pipe. Change all the item types to Count. Now that we have created all the items for foundations we are ready to count how many pile caps are in the foundation.

Click on the Count Takeoff button as seen on Figure 17 or press the “C” shortcut. Then go to the **Takeoff Palette** and click on the item created for pile caps with two piles. Now start clicking on all the pile caps with two piles. Repeat the same process with the pile caps with four piles. There should be 48 pile caps with two piles and 30 pile caps with four piles.



Figure 17: Count Takeoff Button

To takeoff the number of piles we can create assemblies based on the pile caps. Based on the drawings, we know that the groups of two piles are 400 mm steel pipes and the groups of four piles are 500 mm steel pipes. To create an assembly, we will first create a new subgroup called “Pile Cap and Piles Assembly” that will be under the Foundations group. We will create two line items called “2 Piles and Pile Cap Assembly” and “4 Piles and Pile Cap Assembly” under the Assembly group we just created. Double click on the “2 Piles and Pile Cap Assembly” item that we just created in the **Takeoff Palette** for groups of two piles and click on Properties and then the Assembly tab. You should see a screen similar to Figure 18.

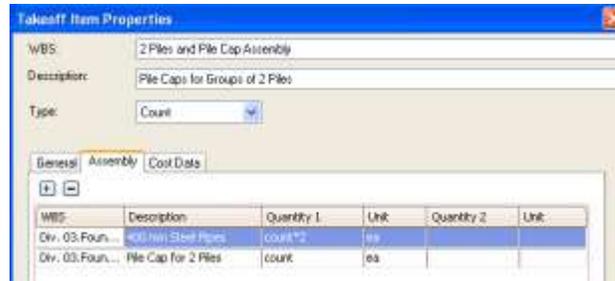


Figure 18: Creating an Assembly

Click on the “+” or “Add Unit” to add an assembly item to this item. Navigate your way through the browser and click on the items you created for the pile cap for two piles and 400 mm steel pipe. A formula can be written for the number of steel pipes in the quantity tab to take into account the fact that there are two steel pipes within each pile cap of this type. To write the formula, we want the Count of pile caps for groups of 2 piles multiplied by two (because there are two piles in each pile cap). The formula is shown on Figure 17 under the “Quantity 1” column. Similarly, the same method is applied to create an assembly for the 500 mm steel pipes on the pile caps with groups of 4 piles. However, because steel pipe piles are priced in vertical linear foot (VLF), we will assume the length of each steel pipe pile is 10 meters. We also have to add a length quantity to the “Pile Caps for Groups of 2 Piles” and “Pile Caps for Groups of 4 Piles”, so change quantity 2 to “Length” in the Cost Data tab, and change Length in the General Tab to 10 meters.

The foundation of the building has now been taken off as seen on Figure 19. Next we will move onto structural concrete such as slabs and columns.

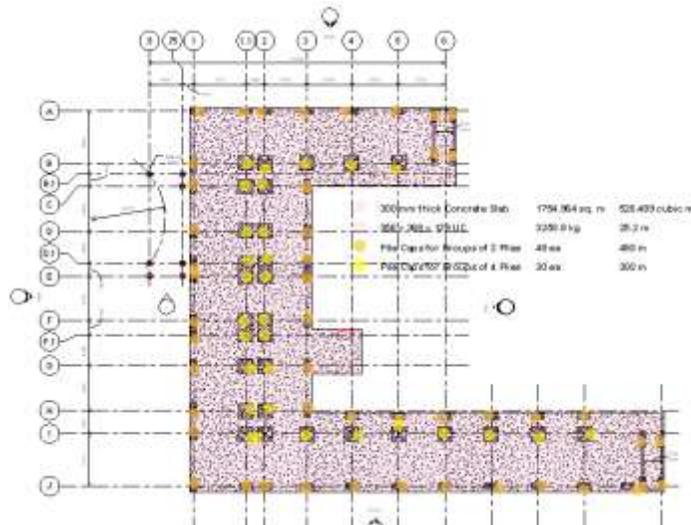


Figure 19: Pile and Pile Cap Takeoff

3.1.2 Performing Takeoffs on Structural Concrete (Slabs) using Polyline Area Takeoff

The thickness of the concrete slabs on each level will be 300 mm. As mentioned before, concrete is usually taken off in terms of volume. First go back to the **Takeoff Palette** and add a new group in the Div. 03 Concrete section called “Structural Concrete”. Then under that group make a subgroup called “Slabs”. Under this Slabs subgroup create an item for “300 mm thick Concrete Slab”. Because we will be performing an area takeoff, be sure to change the Item Type to Area. In this takeoff we will use the Polyline Area Takeoff feature as shown on Figure 20.



Figure 20: Polyline Area Takeoff Button

This button allows you to perform an Area takeoff of any shape. The other two buttons under this option are the Rectangle Area Takeoff and Ellipse Area Takeoff for use when you have more normal shapes. Once the Polyline Area Takeoff button has been selected, click on each

point along the slab, and the cursor should snap to each point. The overall square footage of the 300 mm concrete slab should be roughly 1,700 m².

However, as mentioned earlier we want a volume for the concrete slab. To add a volume quantity or to change the area to a volume, right click on the item for the slab and click on Properties. Under the “General” tab you can add a thickness to the area in one of three imperial units. Change the Thickness to one foot to account for the 300 mm thickness of the slab. After that click on the “Cost Data” tab and depending on your preference you can either add a new second quantity for the Volume or change quantity 1 to Volume. Figure 21 shows what happens in the **Workbook Palette** when two quantities are added. Figures 22 and 23 show the concrete slab takeoff as well as the concrete beams and steel beams (to be discussed later).

Workbook					
Structural Plan: 02 - Floor					
Div. 03.Structural Con		Structural Concrete			
	WBS	Description	Quantity 1	Quantity 2	
▼	Div. 03	Concrete			
▼	Div. 03.Structural Concrete	Structural Concrete			
	Div. 03.Structural Concrete.Slabs	300 mm thick Concrete Slab	1,707.2...	sq. m	512.166 cubic m

Figure 21: Area and Volume of Concrete Slab

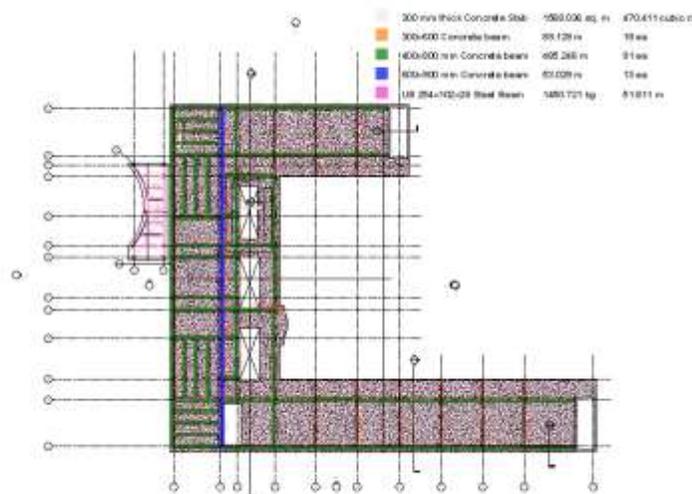


Figure 22: Structural 2nd Floor Plan – Slab, Concrete Beam and Steel Beam Takeoff

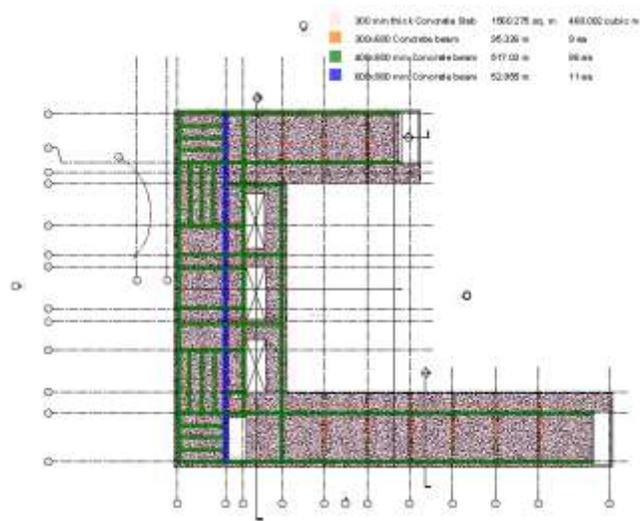


Figure 23: Structural 3rd Floor Plan – Slab, Concrete Beam and Steel Beam Takeoff

3.1.3 Performing Takeoffs on Structural Concrete (Slabs) using Polyline Backout

After taking off the slab on the first floor, we will now perform a takeoff of the concrete slabs on the 2nd and 3rd floors of the building. Once again we will assume that these floors will be 300 mm thick slabs. As can be seen in the structural floors plans for these two floors, there are holes in the concrete slab for the stair shafts. Because we do not want to over-estimate the concrete needed on this project we will use the Polyline Backout button to subtract the areas we do not want in our estimate.

First we can use the Polyline Area tool to find the gross area of the two floors. They should be similar to the area of the first floor. There might be discrepancies between each floors square footage quantity but that would be because there might be some areas that were clicked that were not exactly at a corner. This will not be a problem because in the end, there will be a waste factor added onto the concrete takeoff. Thus any discrepancies will be accounted for based on the waste factor.

Now we will use the Polyline Backout tool shown on Figure 24, to erase the areas we do not want in our concrete slab takeoff.



Figure 24: Polyline Backout Tool

Click on the button or press the “B” shortcut. Now click around the areas we do not want in our takeoff similar to creating an area takeoff. Once you complete the backout, the area should no longer be colored in, and the overall square footage and cubic footage will be decreased.

Repeat this step for the 3rd floor. We have now finished taking off the concrete slabs on this project.

3.1.4 Performing Takeoffs on Structural Concrete (Columns)

Most sets of developed drawings will come with a column schedule. Using this schedule is often a good way to perform a takeoff of columns. Based on the column schedule, all the concrete columns in this building have a 430mm diameter. To takeoff the columns we will once again use the Count tool. First, go back to the **Takeoff Palette** and create an item for the “Columns”. Be sure to change the item type to Count then click on each column show in the schedule. The concrete column as well as the steel column (to be discussed later) count takeoff is seen on Figure 25.

From the column schedule we see that the column goes up 3500 mm between floors 1 and 3 and then 3400 mm from the 3rd floor to the roof for a total height of 10,400 mm. Go to the Properties window on the Column item and change the height to 10,400 mm. We have to create another assembly to calculate the total volume of concrete needed for these columns.

First create another item called “Volume of Concrete Columns”. We will be using the counts and height of the columns to create the assembly for the volume of columns. Open the Assembly tab in the Properties of the Columns item. Click the “Add Unit” button and link it to the “Volume of Concrete Columns” item that was just created. The formula to create the volume is a little trickier than the pile caps. As we know, the volume of a cylinder (essentially what a column is) is $\frac{4}{3} * \pi * \text{radius}^3$. Thus, taking the 420 mm diameter into account, the formula that would need to be input into the Formula Editor would be:

$$\text{Count} * \text{Height} * \frac{4}{3} * 3.14 * \text{pow}(0.21,3)$$

The power function takes a number and raises it to the degree of the second number. Thus the 0.21 ft (half of the 0.42 meter diameter) would be raised to the third power.

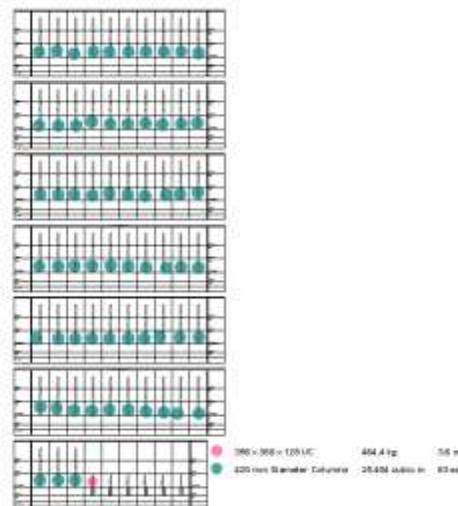


Figure 25: Concrete and Steel Column Takeoff

3.1.5 Performing Takeoffs on Structural Concrete (Beams)

Next, we will perform a takeoff on the concrete beams within the building. There are three types of concrete rectangular beams: 300 x 600 mm, 400 x 800mm, 600 x 900 mm. For this takeoff we will see the difference between the Single-Click Linear Takeoff and the

Polyline Linear Takeoff. As their name suggests, both of these options can be used to perform linear takeoffs. However, the difference is that the Single-Click Linear Takeoff option follows a line on the drawing, while the Polyline Linear Takeoff allows the user to create the line used in the takeoff.

For this takeoff we will use the Single-Click Linear Takeoff option as seen on Figure 26. Go back to the **Takeoff Palette** and create a subgroup for Concrete Beams under the Structural Concrete Group and make three items, one for each of the beam sizes. Change the item types to Linear, as we will be performing a linear takeoff and then converting those quantities to volume.



Figure 26: Single-Click Linear Takeoff

Select the Single-Click Linear Takeoff button or press the “L” shortcut and we are now ready to perform takeoffs on the concrete beams. We will start by taking off the 300x600 mm concrete beams. With the item and type of takeoff selected, click on each line with the “C300” tag on it. There should be 18 instances of the C300 tag on it for 89 meters. Repeat the steps for the other two sizes of concrete beams. There should be 485 meters of 400x800 mm concrete beams and 53 meters of 600x900 mm concrete beams. To convert these quantities into volume, we will have to go into each item’s properties and add the volume into the Quantity 2 selection as well as adding the height and thickness of each beam. We will assume that the third floor will have the same concrete beam design despite no concrete beam sizes being shown in the drawings. To show the takeoffs on the other floors, simply copy and paste the takeoffs on one floor and paste them onto the other two floors.

3.2 Steel Takeoff

Unlike concrete takeoff, steel is usually taken off per weight. To do this, the linear foot is measured and then multiplied by the unit weight of the steel member. There is not a lot of steel on this project, but the process is similar for all steel takeoffs such as beams and columns.

3.2.1 Steel Takeoff (Beams)

The steel on this project are not the typical I-beams (W-shaped), but are instead the British Universal Beams. Nonetheless, steel takeoff is performed the same way. The 254 x 102 x 28 UB means that the beam has a typical depth of 254 mm with a width of 102 mm and a unit weight of 28 kg/m.

To takeoff the steel on this project, create an Item in the Div. 05 Metals section for the steel beams. Make sure to change the Item Type to Linear. For this takeoff we will use the Polyline Linear Takeoff as shown on Figure 27.



Figure 27: Polyline Linear Takeoff button

The steel is shown on the second floor structural plans. As mentioned before, the Polyline Linear Takeoff allows you to perform linear takeoffs by clicking on the points you want to takeoff. You are also given the option of creating a line or an arc and segmented or one continuous line. First perform the takeoffs on the straight beams on the canopy at all the beams with the 254 x 102 x 28 UB tags.

To perform the steel takeoff on the bent steel select the “Arc Mode”. First click on one end of the curve then the other end. This will give QTO a starting point and another point

to base its curve on. Now click on another point of the curve, and you should notice that the line will snap to the curve.

Once we have the linear quantity of steel taken off we can convert this quantity into weight in kilograms. Go to the line item in the **Workbook Palette**. In the quantity box will be the linear quantity of steel. However, we can put in an equation to convert this quantity to weight. Click on the quantity box, and change the equation to “=Length * 28”. This will take the length that was taken off and multiply it by the unit weight of the steel beams which is 28 kg/m. The units can be changed by clicking on the “m” unit then clicking one more time. A drop down box will appear and the unit can then be changed to kg.

The takeoffs for the steel beams were shown in Figures 19, 22 and 23

3.2.2 Steel Takeoff (Columns)

There are seven steel columns in this building. From the column schedule we can see that these columns are 356 x 368 x 129 UC (Universal Columns) and that they rise up 3.6 meters. To perform this takeoff we will go to the first floor plan and perform our count of the columns on the floor plan. We will once again use the “Count Takeoff” to perform this takeoff. Create an item for the columns under Div.05 in the **Takeoff Palette** and change the item type to “Count” then takeoff the seven columns shown in the floor plan.

Once again, we want a linear quantity of the amount of steel columns to be able to convert the quantity into weight. Go to the “Properties” of the steel columns and change the length to 3.6 meters and add “Length” as quantity 2. We are changing length instead of the height of the columns because QTO uses only length as a means of calculating the linear dimension of an object. The height would have been used to calculate the area of the column (a quantity we do not need for estimating purposes.) The total linear measurement of the

columns should be 25.2 meters. Change the length of steel columns to weight in the same way we changed the steel beams from linear to weight. The steel columns takeoff was shown on Figure 25.

We have finished taking off the structural (both concrete and steel) elements of the building. The next step is to perform a takeoff of the roof.

3.3 Roof Takeoff

Roof takeoffs are generally one of the harder elements to takeoff on a project. This is due to the various layers of the roof. The roofing takeoff will be simplified to concrete roofs. There are two types of roof on this project; the main roof over the building, and the roof for the entranceway canopy.

Because the roof will be a concrete roof, we will make another group in the Div. 03 Concrete section called “Roofing”. The main roof over the bulk of the building will be a 160 mm thick concrete roof. Create a new item for this roof and use the Polyline Linear Takeoff. Click at each edge of the roof similar to the slab takeoffs from before. Follow the same steps to take off the canopy roof which would be a 75 mm thick concrete roof.

We will also take off the perimeter flashing of the roofing by using an assembly. First, create a new line item called “Perimeter Flashing” under the “Roofing” group. Change the line item to “Linear”. Now go to the 160 mm Concrete Roof line item and click on the “Assembly” tab then add the Perimeter Flashing to the assembly, and change the quantity to “Perimeter”. Do the same for the 75 mm Concrete Roof. Under the **Workbook Palette**, you will now see the perimeter flashing for both of the roofs. Now that we have finished taking off the roof, we will move onto the exterior wall. The roof takeoff is shown on Figure 28.

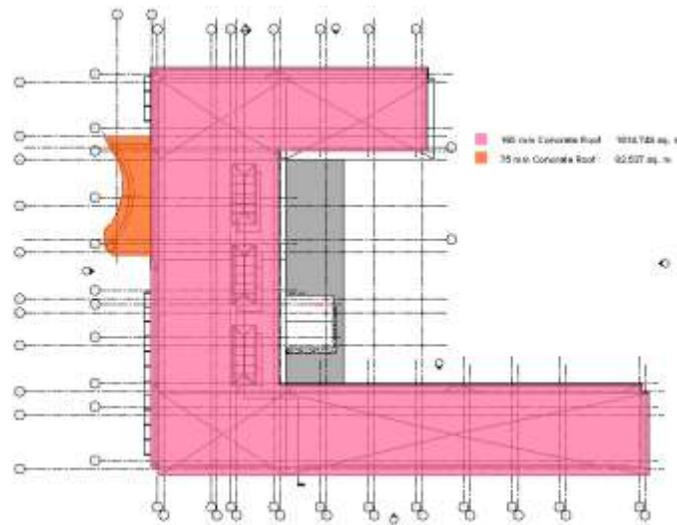


Figure 28: Roof Takeoff

3.4 Exterior Wall Takeoff

We will now perform takeoff of the exterior wall of the building. Similar to the roof, the exterior wall could be a complicated takeoff because of the different faces of the building and different types of wall within a building, ranging from a glass storefront and curtain wall to masonry, stone or concrete walls. There are two possible methods of performing a takeoff of the exterior wall. The first one is to perform the takeoff on the exterior elevation plans. This method is effective if the building is rectangular shaped and has many different types of exterior finishes on it. However, if the building is not rectangular shaped and has many different faces, then the exterior wall takeoff should be performed on the floor plans while using the exterior elevation drawings as a guide to the changes within the exterior wall. The floor plans are used with multiple faces because the exterior plans would not show the ins and outs of extruded walls, thus the estimate would miss out on a large amount of area. A combination of the two types of drawings can also be used to create the takeoff. For this project we will use the floor plans for the glazing, and the elevation plans for the rest of the

exterior wall to perform the exterior wall takeoff. Looking at the exterior elevation plans, we are going to assume that there is a curtain wall system, 203.6 mm (8 inch) concrete masonry units (CMU) and a 300 mm thick concrete wall. The 203.6 mm CMU wall is the hatched area, while the curtain wall system is the non shaded or hatched areas. The large white space on the East elevation drawing is the two concrete walls. Looking at the floor plan, the CMU walls would have a triangular hatching, while the curtain wall would have a bolder, darker line as seen on Figure 29.

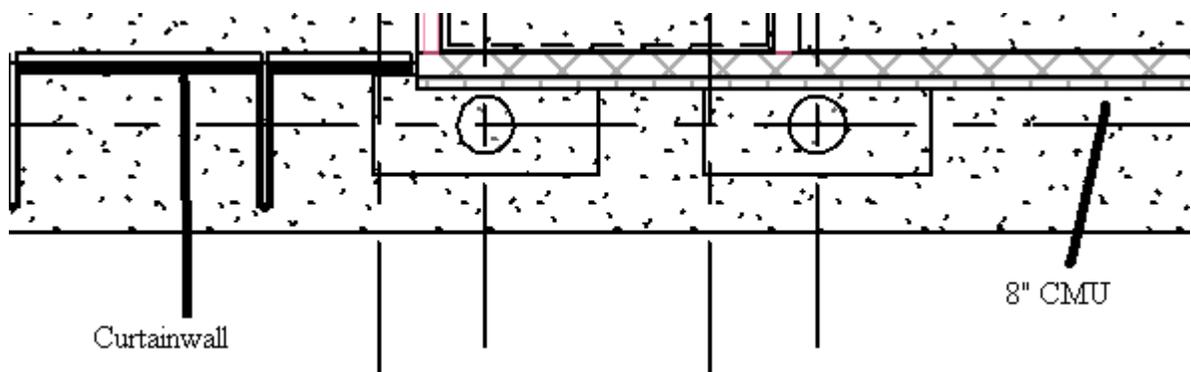


Figure 29: Difference Between CMU and Curtain Wall on Floor Plan

We will start with the masonry takeoff first. Create a group called “Exterior Wall” under Div. 04 Masonry and then create a line item for “203.6 mm CMU” and change the item type to “Area”. Start the takeoff from the North elevation and keep in mind that the windows in the wall need to be backed out. Takeoff the rest of the CMU walls in the other three elevation drawings.

Next we will take off the two concrete walls. Create a new group under Div. 03 Concrete called “Exterior Wall” and create an item for the 300 mm thick concrete wall. Change the item type to “Area”. Takeoff the two walls on the East elevation.

Now we will perform a takeoff on the curtain wall. Create a group under Div. 08 Door and Windows called “Exterior Wall” and an item called “Curtain Wall”. Change the

item type to “Linear”. The item type is linear instead of area because we will be doing a linear takeoff based on the floor plans, then calculating the area of curtain wall using the height of the walls. After taking off the curtain wall, go to “Properties” and change the height to 11.4 which is the height from the group to the roof. Then go to the “Cost Data” tab and change Quantity 2 to Area. We now have the curtain wall taken off.

The last part of the exterior wall that needs to be taken off are the fixed windows. The windows are all 915 mm x 1220 mm. In the “Exterior Wall” subgroup under Div. 08 Door and Windows, create a new item for the “915 mm x 1220 mm Fixed Windows” and change the item type to “Count”. Go to the North elevation drawing and takeoff the 24 fixed windows. We have now finished taking off the exterior wall, and will be taking off the interior partitions next.

The takeoffs for the exterior wall components are shown on Figures 30, 31, 32 and 33.

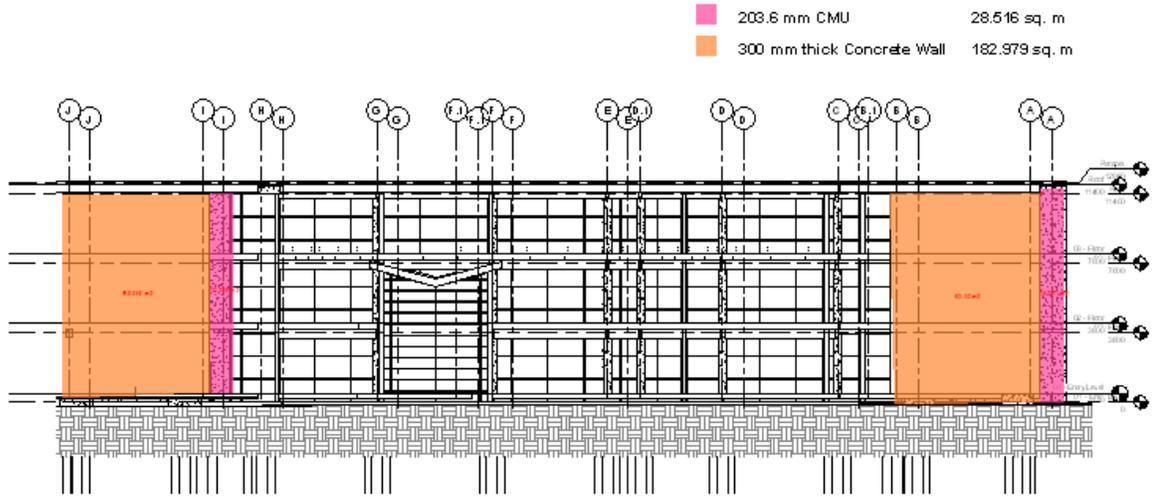


Figure 30: East Elevation – Exterior CMU and Concrete Wall Takeoff

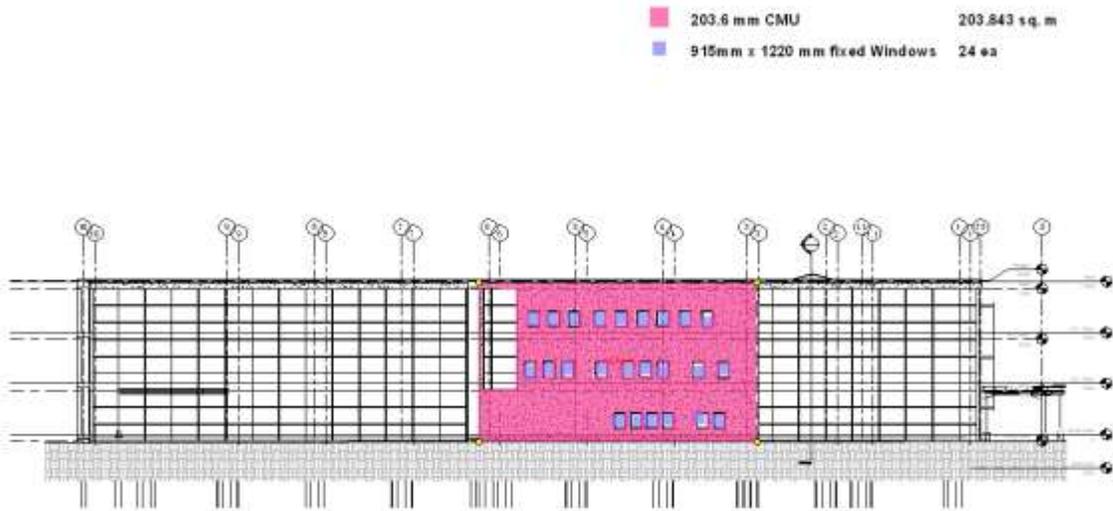


Figure 31: North Elevation – Exterior CMU Wall and Windows Takeoff

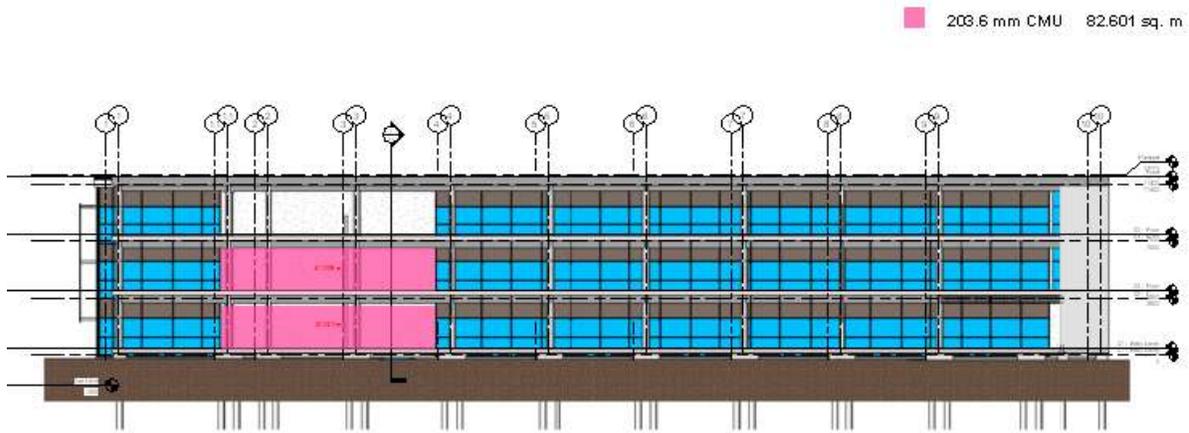


Figure 32: South Elevation – Exterior CMU Wall Takeoff

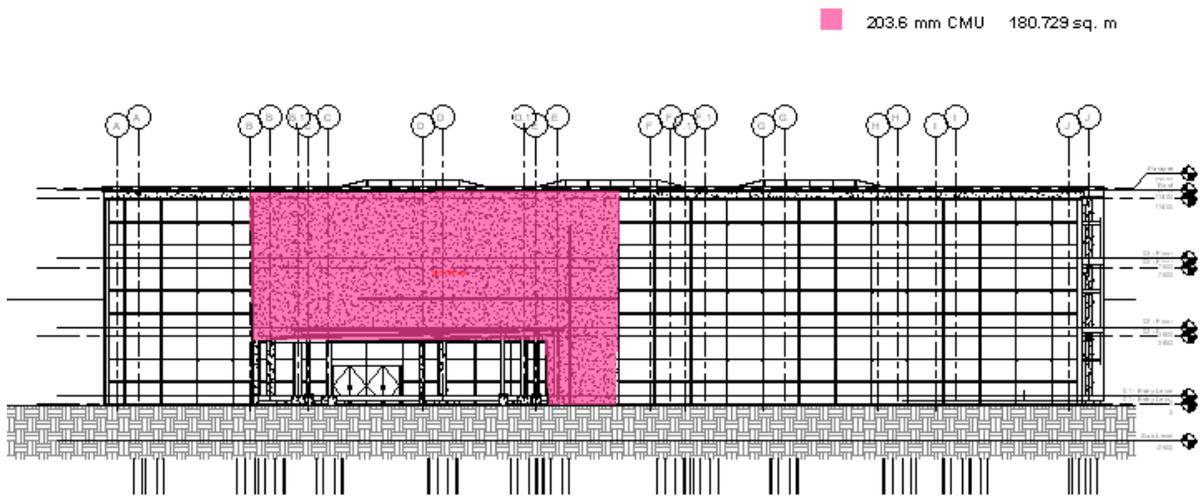


Figure 33: South Elevation – Exterior CMU Wall Takeoff

3.5 Interior Partitions

There are generally two types of partitions within a building: the gypsum wallboard (GWB) or concrete masonry unit (CMU). Generally the gypsum wallboard assembly is a 92mm (3-5/8 inch) thick steel stud with a layer of 15.9mm (5/8 inch) gypsum wallboard on both sides of the stud. The actual assembly is a 138mm assembly which accounts for spacing between the stud and the gypsum wallboard for sound attenuation for firestopping within the partition. This assembly is rated for 1-hour meaning that it will prevent the spread of fire for at least one hour.

Before any takeoff is performed we need to first create a group and item for this partition. Gypsum wallboards fall under the Div.09 – Finishes, so create a group called “Interior Partitions” then create a line item for the 138 mm Interior Gypsum Wallboard Partition and change the item type to Linear. We will once again use the Polyline Linear Takeoff to perform the takeoff then use the height of the partitions to calculate the area of gypsum wallboard partition throughout the building. Follow the partitioning similarly to how we took off steel beams on the first floor structural plan.

Once the takeoff is completed go to the Properties of the partition and change the height of the partition to 3.8 meters which is the distance from the top of the each floor to the bottom of the floor above it. Also, change the thickness to 1.38 meters for the 138 mm assembly. In actuality, the thickness of the partition does not matter when finding the area of the partitions, but it is good practice to include the thickness if it is needed in the future. Now go to the Cost Data tab and change Quantity 2 to Area, and leave the units in square meters.

Repeat the steps for the second and third floors. Depending on how detailed the estimate is, you could either create a new line item for the partitioning of the second floor or

keep with the same line item. The square foot of partitions on the first floor is around 1,060 m², the second floor is 1,315 m² and the third floor has 1,190 m².

Generally estimates created by CMs do not separate the assembly for a partition wall, namely between shear studs and gypsum wall board. Rather, they are grouped together under one line item and the pricing is adjusted accordingly. If the studs are to be taken off then an assembly would have to be used. For the one hour rated partition, metal studs are placed at 0.61m (24 inches) on center. To create a count of how many metal studs would be needed, a new line item for “92 mm Metal Stud” needs to be created under the same division (Div. 09) as the Gypsum Wall Board and change the item type to “Count” Now go to the “Properties” of the Gypsum Wall board line item and click on the “Assembly” tab. Click on the “Add Units” button and link to the “92 mm Metal Stud” line. Because there’s only one metal stud every 0.61 meters, the quantity would be: linear / 0.61. As you go between floor plans, the **Workbook Palette** will show the number of metal studs on each floor under the area of the partitions. The interior partitions takeoffs are shown in Figures 34, 35 and 36.

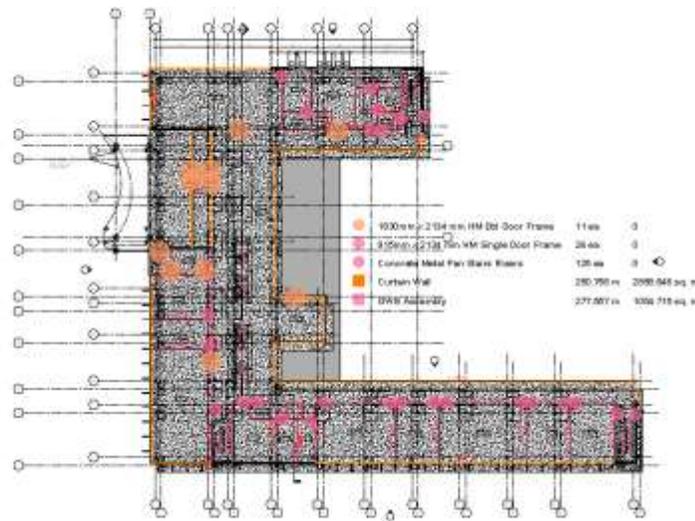


Figure 34: Floor 1 – Interior Partition, Curtain Wall, Stairs and Door Takeoff

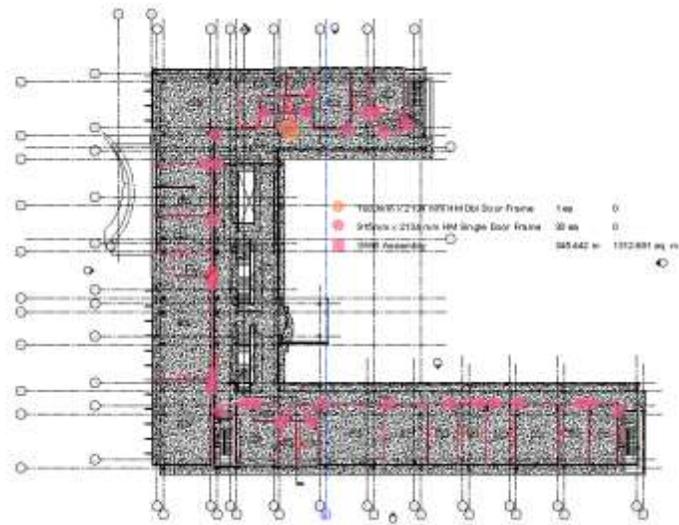


Figure 35: Floor 2 – Interior Partition and Door Takeoff

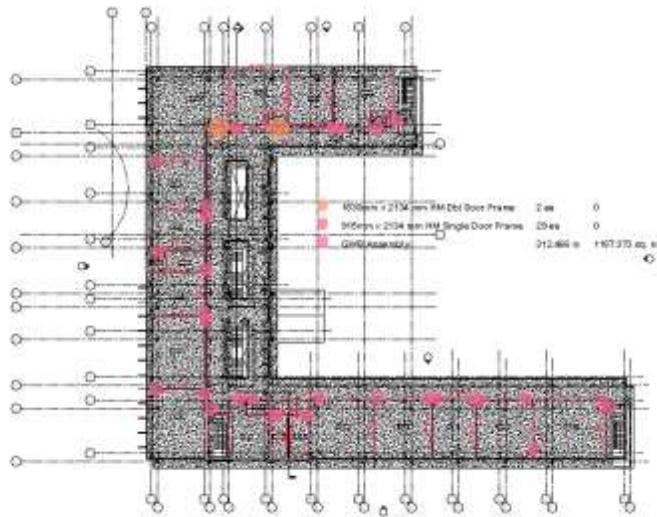


Figure 36: Floor 3 – Interior Partition and Door Takeoff

3.6 Interior Finishes

Depending on the type of building, there could be a large number of interior finishes. Generally this section is broken down into four parts: the flooring, base, walls and ceilings. Some possible options for flooring are tile, stone, epoxy, wood, carpet or vinyl carpet tile (VCT). For the base around a room the options generally are tile, rubber or wood. The walls of buildings generally are paint, tile or wall covering. Ceilings are a bit simpler with acoustic ceiling tiles (ACT), gypsum board ceilings or exposed with no finish. Each of these options comes in a variety of different sizes and styles, thus drawings generally come with a finish schedule that describes what finishes go into what rooms.

We will start off with the flooring and base takeoff. Because there is no finish schedule in this set of drawings, we will be making an assumption on the finishes of the rooms. We will assume that all the rooms except for bathrooms and back of house rooms (electrical closets, storage) will have a vinyl carpet tile flooring with a 101.6 mm (4 inch) rubber base. The back of house rooms will have sealed concrete floors and no base.

For this takeoff we will once again use the Polyline Area Takeoff again. Instead of using the floor plans we will use the Area Plan (Gross Building) floor plans to perform our takeoff. These plans break down the building into four categories: Instruction, Service, Circulation and Administration. The Instruction category takes into account computer labs and class rooms. The Service category includes the back of house rooms and bathrooms. The Circulation category is the corridors throughout the building, and the Administration includes the offices and other rooms that fill the administrative needs.

To begin the takeoff, we will first create an “Interior Finishes” group and a “Flooring” subgroup under Div.09 – Finishes. Then we will create a line item for the vinyl

carpet tile and change the item type to “Area”. Now perform the VCT takeoff using the Polyline Area Takeoff on the Instruction, Administration and Circulation areas. For the Service areas and main lobby on the first floor, create a new item for “Sealed Concrete” under the “Flooring” subgroup and change the item type to “Area”. When performing this takeoff you could either have one large area encompassing all three types of areas or you could do a room by room takeoff. There should be a minimal area difference between whichever method you choose to perform your takeoff. However, if you choose to perform the flooring takeoff with one over-encompassing area then you would have to go back and perform a linear takeoff for the base and also walls of the rooms. For this guide we will be doing the finish takeoffs per room.

After completing the takeoffs per room, we will now perform the base takeoff. First, create another subgroup under the “Interior Finishes” group called “Base”. Then create the item for the “101.6 mm Rubber Base” and change the item type to “Linear”. We will now create an assembly for the length of rubber base throughout the project. Go to the properties of the “Vinyl Carpet Tile” item and into the “Assembly” tab. Add the 101.6 mm Rubber Base into the Vinyl Carpet Tile assembly. The quantity would just be “Perimeter” as seen on figure 24. Now in the **Workbook Palette** you will see the area of VCT and the length of rubber base needed.

Just like with the various options for flooring, the finish on walls could be a plethora of options. They could also be combinations of various options. For example the walls could have a wainscot then paint above the wainscot. We will assume that the walls in all the areas will be paint. Because we have the perimeter of all the rooms we can use that information along with the heights of the wall to figure out how many square meters of paint are in the

building. To do this, we will continue using the assembly we created with the Vinyl Carpet Tile and Rubber base.

Create a new subgroup under the “Interior Finishes” group called “Walls”. Create a Paint line item and change the item type to “Area” then add this line item to the VCT assembly and Sealed Concrete assembly. The walls are all 3.05 meters (~10 feet) high. Thus the equation for the amount of paint needed would be “Perimeter x 3.05” as seen on figure 37. If you look at the **Workbook Palette** you will see the square meters of paint needed for the walls of this project.

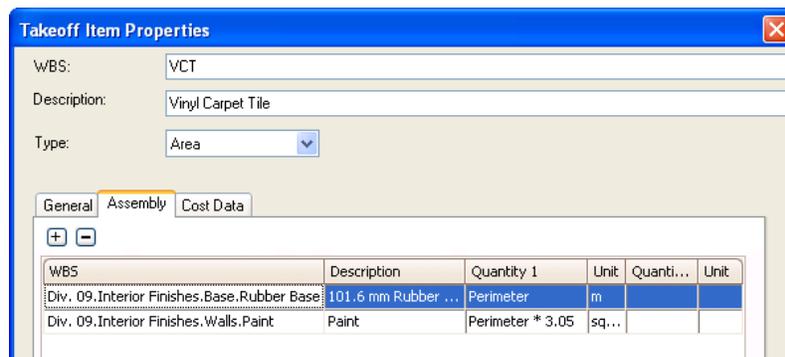


Figure 37: Vinyl Carpet Tile Assembly with Base and Wall Finish

The final part of the interior finishes is the ceiling finish. The finish schedule generally would call out the type of finish goes into a ceiling, however the reflected ceiling plan would show more details such as soffits or changes in ceiling finish within a single room. The reflected ceiling plan is also used to show the lighting within the building. However, that is not within the scope of this thesis. Generally the reflected ceiling plan would have a key or legend to determine what each symbol represents. We will assume that the rooms with grids are the 600 mm x 600 mm Acoustic Ceiling Tiles, the rooms with hatching will be exposed concrete, and the rooms with no hatching or grids will be gypsum ceiling.

Once again we will be using the Polyline Area Takeoff to perform the ceiling finish takeoff. As with all new takeoffs, first create a new subgroup called “Ceilings” under the “Interior Finishes” group, and create line items for a 600 mm x 600 mm Acoustic Ceiling Tile, Concrete Finish, and Gypsum Ceiling Finish. For the takeoff of ceiling finishes, you can perform the takeoff room by room or just cover large areas that span over multiple rooms. The little amount of extra area taken off covering multiple areas in one area is generally negligible when compared to the overall area of the finish. The interior floor, base and wall takeoffs are shown in Figures 38, 39 and 40. The ceiling finish takeoffs are shown in Figures 41, 42 and 43.

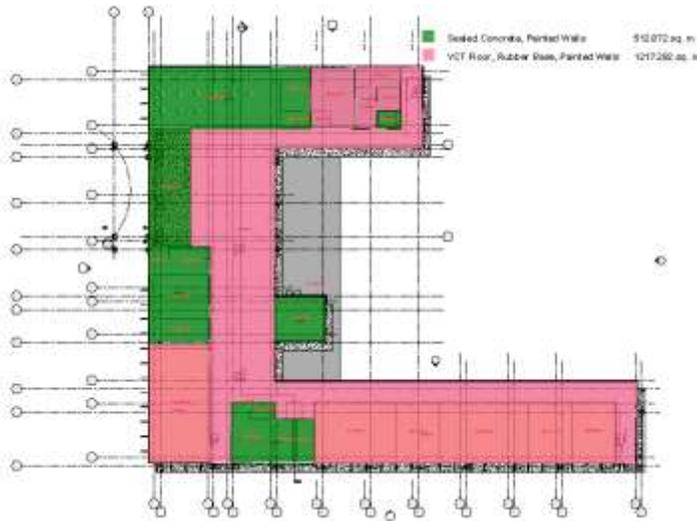


Figure 38: Area Plan Floor 1 – Interior Finish Takeoff

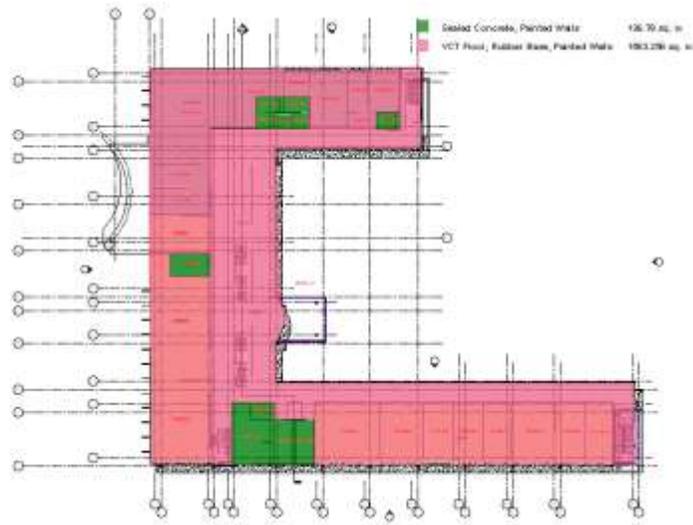


Figure 39: Area Plan Floor 2 – Interior Finish Takeoff

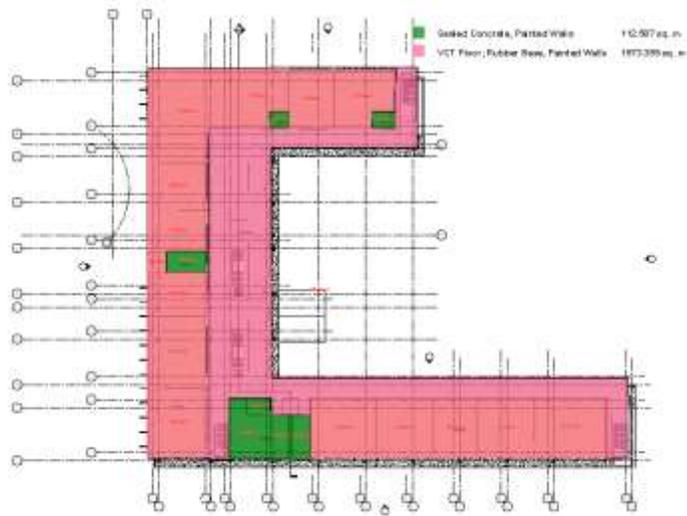


Figure 40: Area Plan Floor 3 – Interior Finish Takeoff

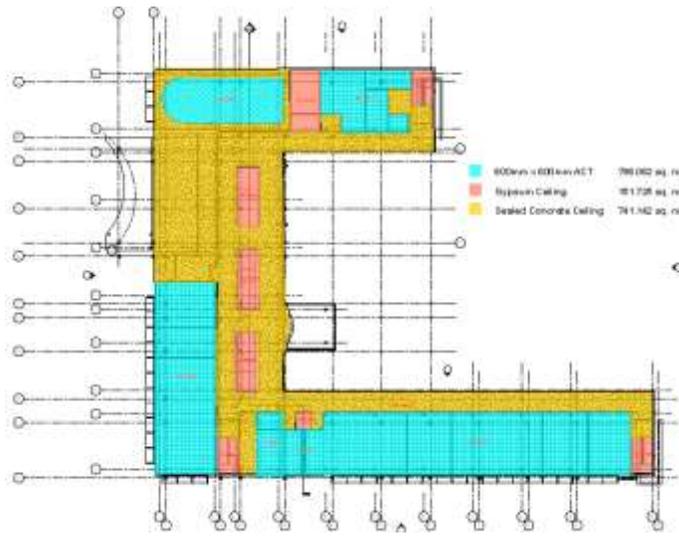


Figure 41: Reflected Ceiling Plan Floor 1 – Ceiling Finish Takeoff

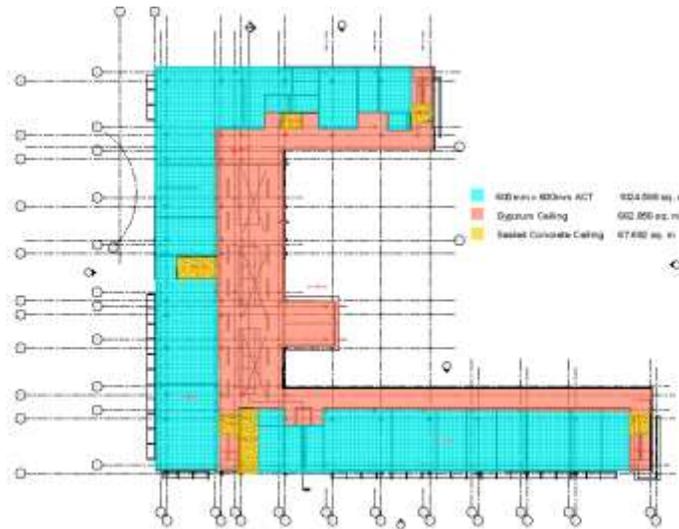


Figure 42: Reflected Ceiling Plan Floor 2 – Ceiling Finish Takeoff

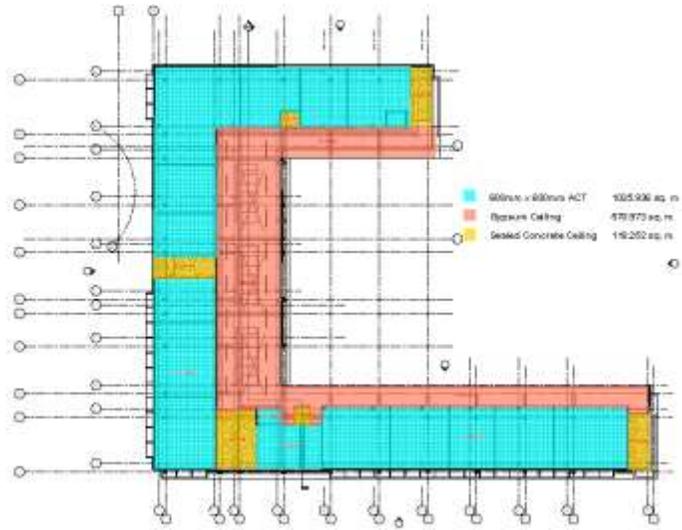


Figure 43: Reflected Ceiling Plan Floor 3 – Ceiling Finish Takeoff

3.7 Doors

Taking off the doors seems like a simple task, but could quickly turn into a daunting task. Generally drawings come with a door schedule that should have all the doors, frames and hardware clearly listed on the project. However, these door schedules are the last things architects worry about when creating the drawings, thus more often than not the door schedule would not watch what is on the drawings. For example, door schedules could have a particular door listed as a double door; however the plans would show a single door. When this happens, the door shown on the floor plan usually takes precedence because they are usually the more current of the drawings.

For door takeoffs we count the number of door frames needed, and how many door leaves there are. This is due to the fact that a double door is just two single leaf doors. There is no door schedule in this set of drawings we will assume our own door and frame types. We will assume two types of frames, one for a hollow metal 915mm x 2134mm (3 ft x 7 ft) single door and one frame for an 1830 mm x 2134 mm (6 ft x 7 ft) hollow metal double door. Create a line item for each type of frame under the Div. 08 Doors and Windows and change the item type to “Count”. Go through the three floor plans taking off the frames using the Count button.

3.8 Stairs

The last piece of item we are going to takeoff would be the stairs. There are three types of stairs: concrete stairs, concrete filled metal pan stairs and steel stairs. The difference between concrete stairs and concrete filled metal pan stairs would be that concrete stairs are, as its name suggests, just all concrete with rebars, similar to concrete slabs. The concrete

filled metal pan stairs have a metal pan to form the outline of the treads and riser. Concrete is then poured into the pan to form the treads or steps of the stair.

Similar to the rest of estimating, there are multiple ways to perform a takeoff of stairs such as taking it off by the total rise (vertical height), number of treads or risers. For this takeoff we will be counting the number of risers for our estimate. In most sets of drawings there are elevation plans that show exactly how many treads and risers there are for each set of stairs. However, those drawings are not in this project, so we will go by what is shown on the floor plans. We will assume that the stairs are of the metal pan concrete filled type which falls into Div. 05 Metals. Create a line item under Div.05 Metals for the Concrete Filled Metal Pan Stairs and change the item type to "Count". We will now go to the First Floor Plan and count the number of risers in each stairs. There are 125 total risers, 25 risers in each of the 5 stairs. Instead of spending the time to count the risers in the stairs going from the 2nd to the 3rd floor we will assume the same number of risers, for a total of 250 risers throughout the project.

We have now finished with our quantity takeoff and will focus on pricing up all the line items to complete our estimate.

4.0 Unit Pricing

After the quantity takeoff we have to price up each line item for the estimate. RS Means is a good start for pricing of each line item and will get the estimate to a bottom line that would be close to the actual. But, RS Means gives a general pricing for the line items and does not take into account where the project is situated. The material and labor cost in New York City will greater differ than other locales such as Los Angeles or Chicago. Thus, estimators usually use their own knowledge and pricing from previous jobs to come up with unit pricing or they ask sub-contractors or vendors for unit pricing. For this estimate we will be using RS Means for unit pricing.

To input a unit cost right-click on a line item in the **Workbook Palette** to bring up the Properties of that line item. Go to the Cost Data tab and under the Cost Computations section there will be four different costs that can be input: Material Cost, Labor Cost, Subcontractor Cost, and Equipment Cost. There are three ways the cost can be input into these cost types, per unit (based on quantity 1 or 2), a lump sum or hourly. To input cost per unit measure, select either quantity 1 or 2 depending on which quantity unit is to be used. For a lump sum, or the total cost of that line item select “1”. If the cost has to be hourly then the amount of time per unit measure has to be input into the Time section of this tab. We will be using RS Means for pricing on labor, material and equipment (if needed) costs. Using the 101.6 mm Rubber Base as an example, we will open the Cost Data tab and input the Material and Labor unit costs as shown on Figure 44.



Figure 44: Inputting Unit Cost for 101.6 mm Rubber base

5.0 Creating the Estimate

Now that we have our takeoffs and pricing completed, it is time to create the estimate that can be shown to owners. Every company has different ways in which estimates are created. Some use Microsoft Excel, while others use Sage Timberline which is a program that can create detailed estimates using various pricing catalogs (such as RS Means) once the quantities are input. Many takeoff software also prints out reports of the takeoffs and cost to create an estimate, however companies usually are set in the ways they present their estimates so they prefer not to rely on the takeoff software's version of an estimate. Luckily these software allow the quantity and costs to be exported to a number of different file types such as Microsoft Excel, Microsoft Word or PDFs. This allows the estimator to extract whatever data they need and input it into their own estimate format.

We will go over how to create a report with the quantity and pricing using Autodesk QTO and then how to export that to an excel file for use in other programs. To create a report, go to the "Report" menu and you will have the option to view "Recent Reports" or create a "Custom Report". Because we have not created any reports yet, we will click on the "Custom Report" to create our first report. A window similar to Figure 45 will pop up.

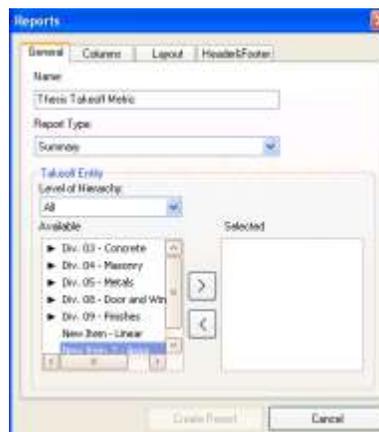


Figure 45: Custom Reports Window

The default name of the report will be the same as the file's name. There are five options in the pull down menu for Report Type: Summary, Group (Items Only), Group (Items and Objects), Material (Items Only) and Material (Items and Objects). The Summary report type creates a report that shows quantity and cost information for each takeoff group with takeoffs in it. The Group (Items Only) report type creates a report that could include cost, quantity and description for the items in the project. The Group (Items and Objects) report type creates a report that could include everything in the Group (Items Only) report but also with dimensions and sheet locations of each specific object. The two Material options are used for creating a bill of material that could be given to vendors for unit pricing (if pricing is unknown). These two options create the bill of materials that have the same options as the Group options.

To create an estimate we will select the Group (Items Only) because the Group (Items and Objects) report type would create an estimate that is too long and detailed. Under the Takeoff Entity portion there is a pull down menu for "Level of Hierarchy". This allows you to control how much detail will be shown in the report by displaying the levels of groups defined in the **Takeoff Palette**. For example, in our Div.03 group, we have a subgroup called "Exterior Wall" and a sub-subgroup called "Concrete Wall". If the "Level of Hierarchy" was set to 0, then only the items would appear, with no grouping. If the "Level of Hierarchy" was set to 1, then only the main group name would appear, if the level was set to 2, then the main group and sub group would appear along with the items. We will leave the "Level of Hierarchy" as all to show all the groups.

Under the "Level of Hierarchy" is the "Available" list. This is where you can choose what groups you want displayed in the report. To select a group, click on the desired group

and click the right arrow to bring that group over to the “Selected” list. To select more than one group, you could hold down the “Shift” key on the keyboard and select a group of groups. Or to select specific groups you can hold down the “Ctrl” key on the keyboard and click on the desired groups. Select all the groups and bring them to the “Selected” list.

In the Columns tab you are given a number of column choices to choose from, ranging from Description and Quantity to Labor and Material Costs as shown on Figure 26. We will choose the Description, Equipment Cost, Material Cost, and Quantity 1 and 2 for this report.



Figure 46: Column Choices for Report

In the Layout tab, you are given options on how you want the report to be presented, such as with grid lines, or paper orientation as shown on Figure 27.



Figure 47: Layout Tab for Creating a Report

On the Header/Footer tab, you are given the option of including a header or footer into the report as shown on Figure 28. There are a number of preset header and footer templates to use. Or you can create your own.

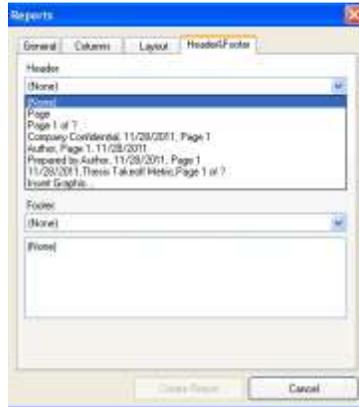


Figure 48: Header and Footer Tab for Creating Reports

Click on “Create Report” to create the report.

As can be seen by the cost estimate in the appendix, the total cost of the structural and architectural aspects of the building comes out to be \$7.97 million. In normal high rise or office buildings, the cost of the structural and architectural aspects of a building is a lot less than the mechanical and electrical systems within the building. Generally, the structural and architectural scope accounts for 1/3 to 1/4 of the total cost of the building.

6.0 Conclusion

Building Information Modeling is a powerful tool in both the design and construction fields. In terms of estimating, the sheer advantage of having all the quantity takeoffs done in one click would save companies a large amount of money in terms of labor costs. Instead of spending one or two weeks to perform a full takeoff, a takeoff can be performed quickly. BIM models also allow the Estimator to more accurately visualize certain scope of the project. However, the quality and detailed of the design and drawings determines the level of quantity that can be taken off using BIM. If the BIM design is lacking in detail, then the quantities that are taken off by QTO would be minimal.

While the time saved is a distinct advantage to using BIM for estimating, there are also a number of issues such as checking the models. Just like with estimating using paper drawings, or CAD models, the BIM models would still have to be checked by the Estimator to make sure there is nothing missing in the model.

Another problem with using BIM for estimating is that it is still a relatively new technology so not every design firm or construction management firm uses it. If a design firm does not use or have the ability to create models using BIM than quantity takeoffs would have to be taken off using “Manual” takeoff methods such as by hand, or using non-BIM or traditional approach. Furthermore, it would take a number of years before every design firm and construction management company switch to using BIM programs.

Autodesk QTO is just one of a number of quantity takeoff software on the market that allows for manual takeoff. However, it is one of the few that can also perform a takeoff on a building information model. While changing from another takeoff software to QTO would require a learning curve, the learning curve would not be a steep one. All takeoff software

would allow the user to perform a takeoff using a Count, Linear measurement or Area measurement. One part that users will have to get used to is the effective use of different palettes and being able to switch between them while performing the takeoff. Nonetheless, Autodesk QTO is a very effective tool when it comes to estimating with its ability to not only perform manual takeoffs with ease, but to also takeoff BIM models. The ability to also create catalogs to follow a CM's estimate format is valuable in that it allows the takeoffs to be presented in a concise format that can either be used as an estimate or to be exported into the CM's estimate program.

Appendix

CSI 16 Divisions:

Division 1 – General Requirements

Division 2 – Site Construction

Division 3 – Concrete

Division 4 – Masonry

Division 5 – Metals

Division 6 – Wood and Plastics

Division 7 – Thermal and Moisture Protection

Division 8 – Doors and Windows

Division 9 – Finishes

Division 10 – Specialties

Division 11 – Equipment

Division 12 – Furnishings

Division 13 – Special Construction

Division 14 – Conveying Systems

Division 15 – Mechanical

Division 16 - Electrical

Thesis Cost Estimate

WBS	Quantity 1		Quantity 2		Material Cost		Labor Cost		Total Cost
					Unit Cost	Total Cost	Unit Cost	Total Cost	
Materials									\$7,972,436.00
Div. 03.Exterior Wall.Concrete Wall	182.979	sq. m			247.57	45,300.06	33.26	6,085.87	51,385.93
Div. 03.Foundation.Pile Caps.Pile Cap for 2 Piles	96.000	ea			239.00	22,944.00	350.00	33,600.00	56,544.00
Div. 03.Foundation.Pile Caps.Pile Cap for 4 Piles	30.000	ea			345.00	10,350.00	455.00	13,650.00	24,000.00
Div. 03.Foundation.Piles 400 mm	48.000	ea	480.000	m	1,275.00	612,000.00	150.00	72,000.00	684,000.00
Div. 03.Foundation.Piles 500 mm	120.000	ea	300.000	m	2,250.00	675,000.00	163.00	48,900.00	723,900.00
Div. 03.Roofing.160 mm Concrete roof	1,814.749	sq. m			48.44	87,906.42	21.53	39,071.54	126,977.95
Div. 03.Roofing.75 mm Concrete Roof	82.537	sq. m			51.67	4,264.67	12.38	1,021.81	5,286.48
Div. 03.Structural Concrete.Beams.300x600mm	287.602	m	37.000	ea	865.00	32,005.00	158.00	5,846.00	37,851.00
Div. 03.Structural Concrete.Beams.400x800mm	1,519.305	m	263.000	ea	980.00	257,740.00	210.00	55,230.00	312,970.00
Div. 03.Structural Concrete.Beams.600x900mm	158.939	m	35.000	ea	1,225.00	42,875.00	240.00	8,400.00	51,275.00
Div. 03.Structural Concrete.Columns	25.404	cubic m	63.000	ea	15,894.00	403,769.37	17,130.00	435,168.57	838,937.94
Div. 03.Structural Concrete.Slabs	6,443.549	sq. m	1,933.065	cubic m	25.83	166,436.88	7.53	48,519.93	214,956.81
Div. 04.Exterior Wall.CMU	495.688	sq. m			149.08	73,897.20	67.28	33,349.90	107,247.10
Div. 05.Metal Pan Stairs	125.000	ea			390.00	48,750.00	45.00	5,625.00	54,375.00
Div. 05.Steel Beams	1,450.721	kg	51.811	m	265.68	13,765.27	19.52	1,011.36	14,776.63
Div. 05.Steel Columns	3,715.200	kg	28.800	m	649.44	2,412,799.49	16.40	60,929.28	2,473,728.77
Div. 08.Doors.HM Double Door Frame	14.000	ea			143.00	2,002.00	42.00	588.00	2,590.00
Div. 08.Doors.HM Single Door Frame	85.000	ea			132.00	11,220.00	36.50	3,102.50	14,322.50
Div. 08.Exterior Wall.Curtain Wall	252.720	m	2,881.005	sq. m	468.26	1,348,972.76	74.27	213,972.21	1,562,944.96
Div. 08.Exterior Wall.Fixed Windows	24.000	ea			43.00	1,032.00	66.00	1,584.00	2,616.00

WBS	Quantity 1		Quantity 2		Material Cost		Labor Cost		Total Cost
					Unit Cost	Total Cost	Unit Cost	Total Cost	
Div. 09.Interior Finishes.Base.Rubber Base	2,201.698	m			0.21	462.36	0.27	594.46	1,056.82
Div. 09.Interior Finishes.Ceiling.ACT	2,846.586	sq. m			13.35	38,001.92	17.44	49,644.46	87,646.38
Div. 09.Interior Finishes.Ceiling.Exposed	927.086	sq. m			0.54	500.63	2.45	2,271.36	2,771.99
Div. 09.Interior Finishes.Ceiling.Gypsum Ceiling	1,385.554	sq. m			8.61	11,929.62	26.91	37,285.25	49,214.87
Div. 09.Interior Finishes.Flooring.Sealed Concrete	762.239	sq. m			0.54	411.61	2.90	2,210.49	2,622.10
Div. 09.Interior Finishes.Flooring.VCT	4,353.937	sq. m			53.82	234,328.89	6.14	26,733.17	261,062.07
Div. 09.Interior Finishes.Walls.Paint	8,520.410	sq. m			9.35	79,665.84	2.37	20,193.37	99,859.21
Div. 09.Interior Partitions.138 mm GWB	3,554.769	sq. m			11.95	42,479.49	18.08	64,270.23	106,749.72
Div. 09.Interior Partitions.Metal Studs	1,533.550	ea			0.25	383.39	0.25	383.39	766.78
Total Cost									\$7,972,436.00

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