Preparing a Construction Cash Flow Analysis Using Building Information Modeling (BIM) Technology

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Abstract: Construction is a competitive industry and successful contractors must be able to win bids to obtain projects. Cash flow analysis not only determines actual profit at the end of the project, but also estimates required cash resources or cash ballances at the end of every month. Cash flow analysis is important in managing a construction project; however, it requires extensive information that is not immediately available to the general contractor. Before contractors can perform cash flow analysis, they must first complete a series of pre-requisites such as the quantity take off, scheduling, and cost estimating, followed by accurate assessments of project costs incurred and billable progress made. Consequently, cash flow analysis is currently a lengthy, uncertain process. This paper suggests improved cash flow analysis can be developed using data extraction in Building Information Modeling (BIM). BIM models contain a wealth of information and tools have been developed to automate a series of process such as quantity takeoff, scheduling, and estimating. This paper describes a prototype tool to support BIM-based, automated cash flow analysis

Keywords: Building Information Modeling, cash flow analysis, ifcXML, planning

I. INTRODUCTION

Managing and forecasting the cash inflows and outflows of a construction project is crucial to ensuring the success of a project. Due to contractual payment delays and retention of cash inflows "many construction projects have negative net cash flows until the very end of construction when the final payment is received" [1]. Mismanagement of cash flow can result in times when cash availability is critically low, which could disrupt the project or even result in bankruptcy for the contractor. The Surety Information Office concluded that the contractor's inability to forecast cash flow is the primary accounting issue that results in financial default [2]. Despite being an essential component of project management, very few tools have been developed to expedite or facilitate the cash flow process.

Although there are spreadsheet-based software tools available to aid in performing cash flow analysis, these applications require an extensive procedure prior to getting to the cash flow analysis. Cash flow forecasting relies on a time-phased expense plan for each activity throughout the life of the entire project. This time-phased expense plan is essentially a project schedule with expected costs assigned to each activity (a cost-loaded schedule). This cost-loaded schedule is dependent on the anticipated planned values of each construction activity, the estimated duration of each activity and the sequencing of all the activities. Subsequently, the cost estimations

and scheduling estimates are dependent on the quantity takeoff. Consequently, cash flow analysis cannot be completed until the entire quantity takeoff, estimation, and schedule are completed. Once the contractor has a time-phased expense plan, further values such as payment lags and retentions must be considered before the contractor is finally prepared for cash flow analysis. This process, which requires collecting a large amount of information, is known to be tedious and can be improved upon with technological advancements.

Cash flow analysis can generally not be performed until after the project is already awarded to the contractor because of the large time requirement to complete the process. Being able to predict when a project will put the most strain on cash resources, however, could be a powerful forecasting tool during the bidding stages of a project. For companies involved in multiple projects, this early forecasting could ensure that it has the necessary financial assets before contractually accepting new liabilities. By automating the cash flow process, contractors will be able to utilize this tool as soon as they receive a BIM model.

II. LITERATURE REVIEW

Research on cash flow analysis has been focused on making cash flow analysis more accurate and more detailed. Many of the early cash flow models in the 1970's did not account for the time lag between cost

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payments [1]. The model suggested by Park et al adjusts the weight percentage of cost categories compared to the remaining budget through the project duration based on actual work performed and actual earned values. Although their research offers a more accurate way to manage cash flow during project construction, it neither expedites the cash flow process nor allows the contractor to perform cash flow analysis earlier in the project life cycle.

Past researchers have recognized that increased data quantity and data quality yields more accurate cash flow forecasts. As with any type of forecasts, however, a certain amount of uncertainty is inevitable. To deal with ambiguous data, Chen et al. [3] applied fuzzy systems theory to cash flow management for construction firms at the project level. Kishore et al. [4] applied fuzzy system theory for managing cash flow at the company level. Their research helps identify the most pessimistic and most optimistic scenarios for cash flow; however their proposed models still require extensive manual processes for the contractor.

Although previous research proposes new algorithms for cash flow analysis, a deficiency remains for automation technologies applied to financial analysis. While neglecting cash flow, the construction industry has developed advancements in the areas of scheduling, cost estimating, and quantity takeoff. Scheduling is aided by software packages such as Primavera and MS Project; estimators often rely on software packages like Timberline, and quantities can be automated with products like Innovaya's Visual Quantity Takeoff. Although the software solutions appear abundant for the aforementioned tasks, the amount of software for automating cash flow or integrating all these tasks into one software solution seems negligible. This indicates a need for automation technologies to be applied through cash flow analysis for construction projects.

III. RESEARCH METHODOLOGY

Figure 1 depicts the entire process leading up to the decision to bid on a project starting with the creation of a BIM model. Although not all projects have BIM models, this prototype relies on BIM technology and thus this BIM model is used as the starting point of our process. Cash flow forecasting requires the three processes of quantity takeoff, scheduling, and cost estimating. Therefore, automating and integrating these processes is a prerequisite for automating the cash flow analysis. Prior to delving into the methodologies of each process, it is important to understand what makes this automation possible. The prototype works by gathering information from the BIM model's file by "reading" through it and "grabbing" relevant information. Since the program must "read" the source file, it needs to be in a "language" that it recognizes. This "language" is the ISO-based industry standard of IFC/ifcXML.

Although BIM files contain a wealth of information, this information is generally formatted in a native file format that can only be utilized by the software program that created it. This encumbers interoperability between the various software applications used between the estimator, architect, structural engineer, etc. Consequently, buildingSMART (formerly the International Alliance of Interoperability (IAI)) created Industry Foundation Classes (IFC), which provided "a common data schema that makes it possible to hold and exchange data between different proprietary software applications" [5]. The prototype suggested in this paper relies on a file format called IFCXML, which combines advantages of the Industry Foundation Classes (IFC) and Extensible Markup Language (XML). XML is a schema created by the World Wide Web Consortium (W3C) to structure, store, and transport information in a machine-readable format [6]. Together, these two schemas create a source file for building information models that contains internationally recognized data standards, whilst also organized in a manner that is both machine-readable and a global standard for information publication and information exchange [7]. This prototype cash flow tool utilizes the IFC 2x3 XML file (*.ifcxml) file type.
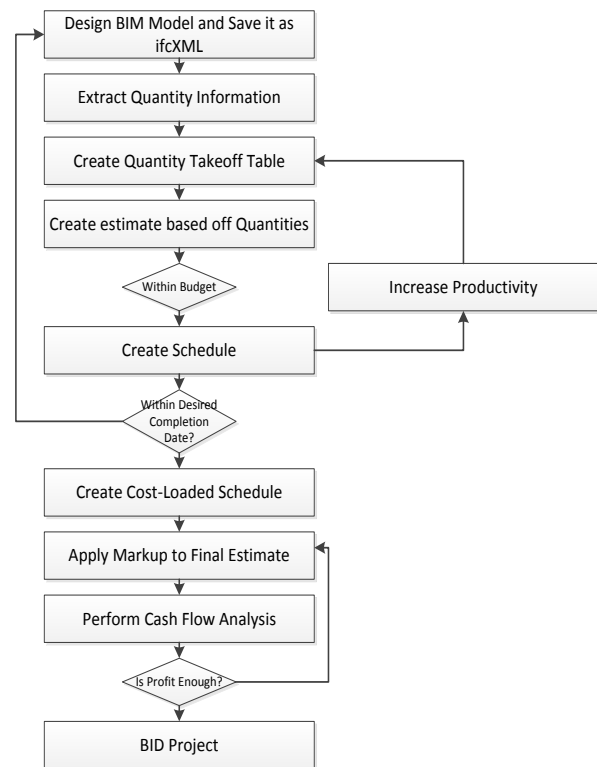

FIGURE I
CASH FLOW PROCESS DIAGRAM

After all the information is gathered from the BIM, it must be processed for takeoff, scheduling, and estimating. In this prototype, the information is combined with certain assumptions that will be discussed in depth to achieve certain output files. For takeoff, scheduling and cash flow, this output file is a text file that can be imported into MS Excel or MS Project as a Delimited file with either semicolons or tabs used as delimiters. Contractors will be able to perform this entire process with only a few clicks of a mouse, and will have generated a cash flow analysis within minutes. This research proposes a prototype tool for automating cash

flow and explores the potential for the integration of cash flow analysis and BIM technology.

IV. FEASIBILITY STUDIES

The model used for the case study is a building envelope of a two-story office building with a building footprint of 5950 square feet. The foundation of the building is orthogonal and the building has two entrance doors with multiple large windows on each floor. Figure 2 shows a screenshot of this model in a BIM program. This type of model would be used for business development strategies or schematic design purposes, which indicates that the contractor would even be able to conduct cash flow analysis very early in the design process. The model must be saved in the '.ifcxml' format for the prototype to be able to read the file. Once saved in this format, the prototype software can extract necessary data; generate quantity takeoff, scheduling, cost estimating, and cash flow analysis.

A. Data Extraction

The prototype utilizes computer code that performs syntactic analysis to extract information needed to generate a quantity takeoff (QTO) from the ifcXML file. All information within an ifcXML file is organized within a tree of nodes that are labeled with industry standard tag names. Because the information is stored in ifcxml format, it is possible for a computer program to navigate any ifcxml file and extract the requested information. Ifcxml documents store spatial measurements (as well as other information) of each building element under specific tags (or nodes). Each of these nodes can contain attributes, values, and text that store additional information about the specific building element.
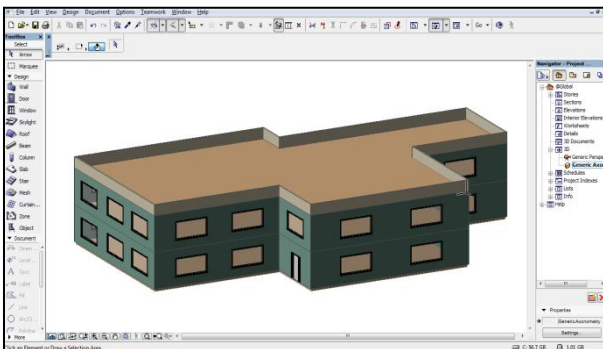

FIGURE II
THREE-DIMENSIONAL MODEL USED FOR CASE STUDY

The buildingSMART International (bSI) has developed open data standards for information found in building information models. These standards make the process of locating information within the source files much easier and reliable. This standard schema is the ifcxml format and the particular version used in this prototype is version 2x3. Gross volumes, for example, are located under the tag name "GrossVolume". Gross Volume is defined by bSI as "Total gross volume of the [building element], not taking into account possible openings and recesses. The

exact definition and calculation rules depend on the method of measurement used." [bSI 2011] Volumes (and all other information) correlate with various building elements through a series of nodes that are identified and related to each other by 'id' and 'ref' attributes. Every node that has a 'ref' number will have a corresponding node that contains the same number but as an 'id' attribute. These 'id' numbers make each value unique to its relating building element. Thus, one must follow the trail of 'id' and 'ref' attributes to discover which building element a certain "GrossVolume" is describing. For example, all gross volumes are labeled under the node "<GrossVolume>", however, this has a parent node that has an 'id' number that matches a 'ref' number that can be traced back to its relating building element such as 'IfcSlab' or 'IfcWall'. Below is a visual representation of the nodes that must be used to trace information back to its related building element –a wall in this particular case. Figure 4 is a simplified tree of these relationships to show how the desired quantitative and material information is related to a building element. The complete ifcxml tree contains many more nodes with information that although is used to generate the BIM model, is not necessary for creating the quantity list, thus the complete complex tree is not shown. This process is repeated for each building element to obtain the necessary lengths, areas, and volumes for slabs, walls, roof, etc. A similar process is also required to obtain the number and size of the doors and windows. As seen in Figure 3, material and layer information is stored in a similar manner but with different node tags. To get to the final material names and thicknesses, you must first navigate through a series of nodes. At the top of the tree is the 'IfcRelAssociatesMaterial' node. Under this node you will find which building element the material layers relate to. Once all the information is extracted from the source file, it is stored into arrays until called upon for output.

B. Quantity Takeoff

The data arrays contain all the necessary quantity and material information that is later used for the scheduling and estimating processes. The program stores these data arrays internally. In other words, the user cannot readily view these arrays. The user can, however, create an output file to manually check the quantity takeoff. The prototype creates a simple text file as an output. This file, however, can be imported into excel with semicolons as the delimiting character to signify a new cell. The spreadsheet created by the prototype includes material information such as layer names, material names, layer thickness, area, and volume. For doors and windows it also includes operation type. Table 1 shows a portion of the quantity takeoff spreadsheet generated from the text output file. Within the BIM model, building elements such as slabs, windows, doors and windows are assigned unique names. Generally these names are generic and numbered (i.e. Wall 1, Wall 2, Etc). The names for these elements were included in the spreadsheet, which allows you to find that particular building element in the 3D software and visualize its location within the structure.
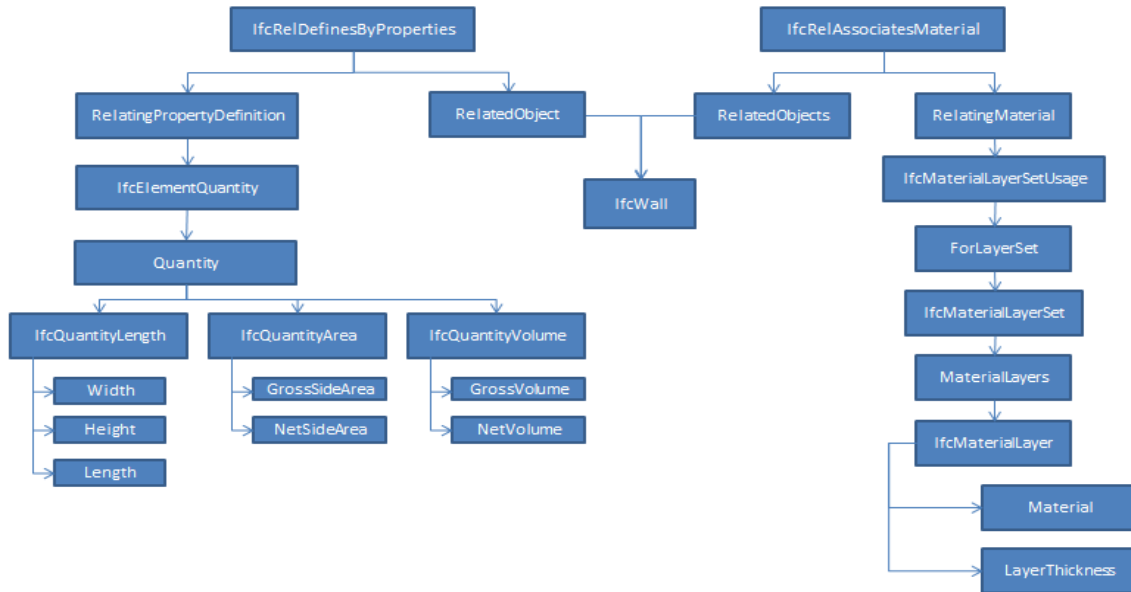
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FIGURE III
IFCXML TREE

TABLE I
QUANTITY TAKEOFF

Name	Layer Set Name	Material Name	Layer Thickness	Perimeter (inches)	Width(in)	Area (sqFt)	Volme(CF)
SLABS							
Slab-02	Slab-04" on gravel_1	03 ┃ Concrete Random	3.999999952	4560	7.999999952	5950	3966.666643
Slab-01	2 x 12 + 3/4" Plywood_1	06 ┃ Plywood-1/8" ply	0.75	4560	12	5950	5950
Slab-02	2 x 12 + 3/4" Plywood_1	06 ┃ Plywood-1/8" ply	0.75	4560	12	5950	5950
WALLS							
Wall-01	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	250	
Wall-02	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	300	
Wall-03	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	350	
Wall-04	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	500	
Wall-05	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	200	
Wall-06	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	400	
Wall-07	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	500	
Wall-08	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	600	
Wall-09	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	100	
Wall-10	Wall 2 x 4+1/2" Gyp.Board	09 ┃ Gypsum- Board	0.49999	4.49999	120	600	

DOORS				
Name	Height(in)	Width(in)	Panel Depth(in)	Operation Type
2	80	36	1.251968504	single_swing_right
3	84	72		double_door_single_swing

WINDOWS				
Name	Height(in)	Width(in)	Panel Depth(in)	Operation Type
21	60	118.5	1.75	single_ panel
5	60	118.5	1.75	single_ panel
9	60	118.5	1.75	single_ panel
8	60	118.5	1.75	single_ panel
11	60	118.5	1.75	single_ panel
10	60	118.5	1.75	single_ panel
14	60	118.5	1.75	single_ panel
13	60	118.5	1.75	single_ panel
17	60	118.5	1.75	single_ panel
16	60	118.5	1.75	single_ panel
15	60	118.5	1.75	single_ panel
20	60	118.5	1.75	single_ panel
19	60	118.5	1.75	single_ panel
18	60	118.5	1.75	single_ panel
7	60	118.5	1.75	single_ panel

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TABLE II
RS MEANS LINE ITEMS

ID	Description	Crew	Daily Output	Labor Hours	Unit	Material	Labor	Equipment	Total	Total inc.O&P
03 11 1365 3050	Edge forms, wood, 4 use, on grade, up to 6" high	C-1	600	0.053	LF	0.27	21	0	2.37	3.54
03 30 5340 4650	CIP SOG 3500 psi, not incl finish, 4" thick	C-14E	60.75	1.449	CY	117	59.5	0.51	177	222
03 24 10 0600	SOG #3-#7	4 Rodm	2.3	13.91	Ton	760	650		1410	1875
06 11 1040 6140	Studs, 8' high wall, 2"x4"	2 Carp	0.92	17.39	Mbf	375	725		1100	1525
06 11 1018 2740	Joist Framing 2x12	2 Carp	1.75	9.143	Mbf	530	380		910	1175
06 16 23 0200	Subflooring 3/4	2 Carp	1250	0.013	SF	0.58	0.53		1.11	1.46
07 22 16 0030	Roof Deck Insulation Fiberboard low density 1"thick	1 Rofd	800	0.1	SF	0.64	0.35		0.77	1.05
08 11 16 0020	Entrance Doors and Frames Aluminum, narrow stile	2Sswk	2	8	ea	745	375		1120	1475
08 11 16 0300	6"x7" opening	2Sswk	1.3	12.31	ea	1075	575		1650	2200

Although importing into excel gives the user an opportunity to visualize the quantities, changes made to the excel file will not be recognized by the prototype program. The excel file simply shows the output information of the arrays stored within the prototype. The user would have to change the data within the arrays for the prototype to recognize them. To alter the original data in the arrays one must make changes to the original 3D model or the source code of the prototype.

C. Estimating

Once the all the quantities are gathered, the next step is to estimate their costs. In order to assign a cost factor to the quantities, the program must be able to recognize what the quantities belong to. This is achieved by storing additional information such as relating building elements and material type with the quantities. Once the program knows which quantity to use, it is also important to make sure that it is in the right units. The preferred units for each item is determined by the unit values given from the RS Means book. The prototype is written so that is automatically converts to the desired units. For example, the dimensions for concrete slabs are initially in inches or cubic feet, which are converted into cubic yards (the

preferred unit value in RS Means). To produce an estimate, line items from the RS Means handbook were chosen and matched with the gathered quantities.

Table 3 demonstrates the type of information used in the RS Means handbook. The "CIP SOG 3500 psi" line item, for example was applied only to the bottommost slab quantities. Being only a prototype, it does not account for different types of slabs yet. At this time it only has the cost factors for a limited number of items used for the example model. For the program to expand and cover more scenarios for different projects, it would need to have a more extensive internal library. The unit cost used in the prototype is from the "Total inc. O&P" column, which includes cost for materials, labor, equipment, as well as overhead and profit. The daily cost for each activity is found assuming a linear cost curve for each activity. This is simply calculated by dividing the total cost of the activity by its total duration. This assumes that the cost of an activity is evenly distributed throughout its duration. Because cash flow analysis is generally performed on a monthly basis the schedule is then broken up into monthly segments. Site work and MEP systems are not modeled, and therefore not accounted for.
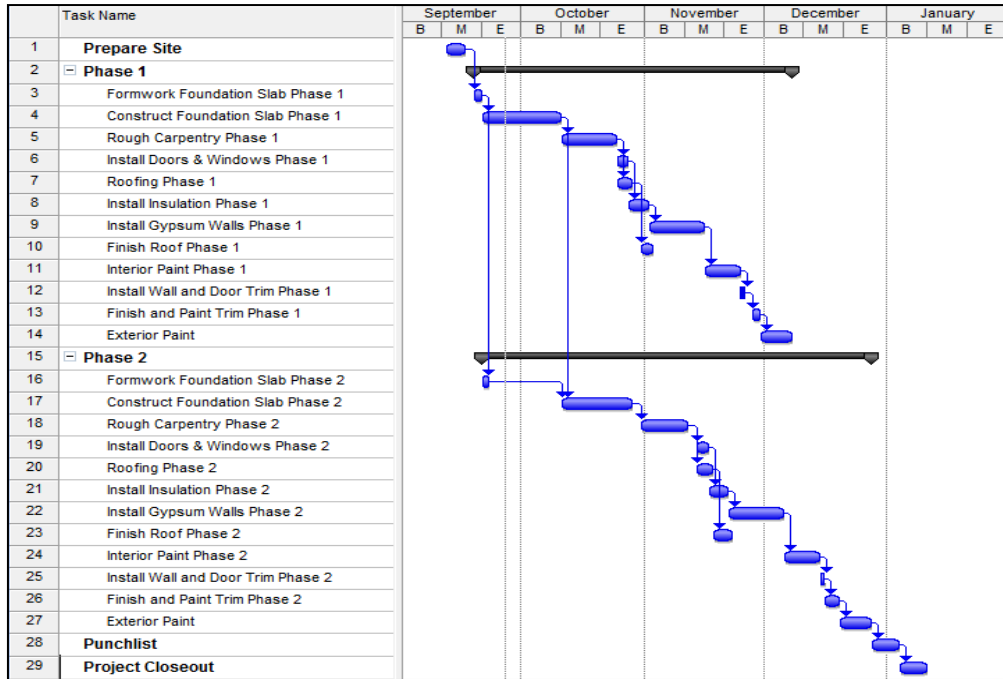
FIGURE IV
GANTT CHART

TABLE III
SEQUENCE TABLE

	Duration	ES	EF	LS	LF	TF	FF	DF	Critical Path
Prepare Site	5	0	5	0	5	0	0	0	yes
Formwork Foundation Slab Phase 1	2	5	7	5	7	0	0	0	yes
Construct Foundation Slab Phase 1	14	7	21	7	21	0	0	0	yes
Rough Carpentry Phase 1	10	21	31	21	31	0	0	0	yes
Install Doors & Windows Phase 1	3	31	34	34	37	0	0	0	no
Roofing Phase 1	4	31	35	31	35	0	0	0	yes
Install Insulation Phase 1	3	34	37	34	37	0	0	0	yes
Install Gypsum Walls Phase 1	10	37	47	37	47	0	0	0	yes
Finish Roof Phase 1	3	35	38	46	49	11	11	0	no
Interior Paint Phase 1	7	47	54	47	54	0	0	0	yes
Install Wall and Door Trim Phase 1	1	54	55	54	55	0	0	0	yes
Finish and Paint Trim Phase 1	2	55	57	55	57	0	0	0	yes
Exterior Paint Phase 1	6	57	63	65	71	8	8	0	no
Formwork Foundation Slab Phase 2	2	7	9	19	21	12	12	0	no
Construct Foundation Slab Phase 3	14	21	35	21	35	0	0	0	yes
Rough Carpentry Phase 2	10	35	45	35	45	0	0	0	yes
Install Doors & Windows Phase 2	3	45	48	48	51	3	0	3	no
Roofing Phase 2	4	45	49	45	49	3	0	3	yes
Install Insulation Phase 2	3	48	51	48	51	0	0	0	yes
Install Gypsum Walls Phase 2	10	51	61	51	61	0	0	0	yes
Finish Roof Phase 2	3	49	52	74	77	25	25	0	no
Interior Paint Phase 2	7	61	68	61	68	0	0	0	yes
Install Wall and Door Trim Phase 2	1	68	69	68	69	0	0	0	yes
Finish and Paint Trim Phase 2	2	69	71	69	71	0	0	0	yes
Exterior Paint Phase 2	6	71	77	71	77	0	0	0	yes
Punchlist	5	77	82	77	82	0	0	0	yes
Project Closeout	5	82	87	82	87	0	0	0	yes

D. Scheduling

A schedule was created for the building based off the quantities and building elements extracted from the model. The durations for each activity were determined using historic values from the RS Means Construction handbook 2010. The quantities were converted to the indicated units in RS Means and multiplied by the "labor hours" factor to obtain durations in hours. The activities were then sequenced in a sensible manner in the order demonstrated in Figure 4 with a few assumptions described below. To help sequencing, the project was

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divided into 2 phases to allow different trades to work simultaneously on different phases of the project. Windows and doors are assumed to be able to be installed at the same time and thus started at the same time after the rough carpentry is completed. Roofing will also be started after rough carpentry and will be worked on simultaneously with the installation of windows and doors. The schedule assumes 8-hour workdays, and 40-hour workweeks. Walls are designated as 2"x4" construction from the model; however, stud spacing is not called out. This model accounts for a stud spacing of 16-inches. Gypsum installation is assumed to be at a level 4 finish. Interior painting is assumed to be 2 coats and includes a smooth finish with brushwork and exterior painting is also 2 coats applied to stucco with rollers. Table 3 is a summary table of the activities. The activities are assigned predecessor relationships and can be imported into Microsoft Project. The original output file is a simple text file with the columns separated by tabs. MS Project is able to import this text file and recognize the tab delimiters. Once in MS Project, the schedule can be viewed in the traditional Gantt chart view (Figure 4).

TABLE IV
CASH FLOW SPREADSHEET

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Summations
Direct Cost	23088	24934	5939	10920	10186			120069
Indirect Cost(11.47%)	2648	2860	5843	1253	1168			13772
Tatal Cost	25737	27794	56782	12173	11354			133840
Markup 0.05	1287	1390	2839	609	568			6692
Total Worth	27024	29184	59621	12782	11922			140532
Client Retainage	2702	2918	5962	1278	1192			14053
Payment Due	24321	26265	53659	11503	10730			126479
Payment with Delay	0	0	24321	26265	53659	11503	24783	140532
Cumulative Payments	0	0	24321	50587	104246	115749	140532	
Cash Outflow	-25737	-27794	-56782	-12173	-11354	0	0	-133840
Cumulative Worth	27024	56207	115829	128610	140532	140532	140532	
Cumulative Outflow	-25737	-53531	-110313	-122486	-133840	-133840	-133840	
Cumulative Income	0	0	24321	50587	104246	115749	140532	
Cumulative Interest	0	-257	-795	-1663	-2399	-2719	-2927	
Overdraft	-25737	-53788	-86787	-73562	-31993	-20810	**3765**	
Interest 1%	-257	538	-868	-736	-320	-208	0	

TABLE IV
SUMMARY OF CASH FLOW EQUATIONS

Indirect Cost	= Direct Cost * 12%
Tatal Cost	= Indirect Cost + Direct Cost
Markup	= Direct Cost * 5%
Total Worth	= Direct Cost + Markup
Client Retainage	= Total Worth *10%
Payment Due	= Total Worth - Client Retainage
Payment with Delay	= Payment Due delayed by pay periods
Cumulative Payments	= Sum of Payment with Delay
Cash Outflow	= -(Tatal Cost)
Cumulative Worth	= Sum of Total Worth
Cumulative Outflow	= Sum of Outflow
Cumulative Income	= Sum of Payment with Delay
Cumulative Interest	= (Cumulative Outflow $_{n-1}$ + Cumulative Income $_{n-1}$ + Cumulative Interest $_{n-1)*1\%}$ + Cumulative Interest
Overdraft	= Cumulative Outflow + Cumulative Income + Cumulative Interest
Interest 1%	= Overdraft *1%(only applied to negative Overdrafts)

E. Cash Flow

The cash flow spreadsheet that is generated has built in formulas that are based on certain inputs and assumptions. The only input is the first row, which is the Direct Costs. Direct costs for each month are the cost estimates from the schedule in monthly segments and are automatically entered into the spreadsheet. The prototype assumes all work is self-performed. Indirect Costs are set to a default value of 12 percent of the direct costs, but can be adjusted if the company has a more accurate value based on their previous projects. The sum of the direct cost and indirect costs gives the total cost. Total worth is the total cost with a percent markup applied. Markup is defaulted at 5 percent in this model; however the user can change this to any value. It is common for owners to hold a certain percentage of payments until the end of the project called client retainage. The model accounts for a 10 percent client retainage of the total worth at the end of each month. The payment due values is the total worth less the client retainage for the work completed at the end of that month. This payment however, isn't realized by the contractor usually until 2 months after the actual month. The 2-month lag time is common practice and comes from roughly 3-4 weeks of contractual agreement that the

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owner has to review the Schedule of Values compared to actual work performed.

The remaining time of the 2-month lag accounts for the time it takes the bank to process the payment and release funds once the owner approves the work. This lag is represented by the row "Payment with Delay" in the spreadsheet. Similar to client retainage, contractors normally apply a retainage to their subcontracts. Although no subcontracts are assumed in this model, the spreadsheet is formulated to account for a 10 percent retainage to be paid at the finish of the project. Payments to subcontractors are also subject to a 2 month delay, and are represented as "Sub Pay with delay". All expenditures for that month are included to calculate Cash Outflow and are calculated by adding Total Cost and the Sub Pay with Delay for the given month. It is also necessary to calculate the cumulative values of worth, outflow, income, which are the cumulative values for

Total Worth, Cash Outflow, and Payment with Delay, respectively. Most contractors must borrow money for the large cash outflows and thus pay interest. The cumulative interest item is calculated as the previous month's interest plus 1 percent of the sum of the previous months Cumulative Outflow, Cumulative Income and Cumulative Interest. Overdraft is the ultimate target value for calculating cash flow because it indicates a surplus or debt. Overdraft is essentially the sum of all cash inflows and outflows at any given time of the project. A positive number means a net gain; a negative number means a net loss. The final Overdraft value will indicate whether the project was profitable or not. Overdraft is calculated by the sum of Cumulative Outflow, Cumulative Income, as well as Cumulative Interest. The spreadsheet also calculates for 1% interest on all months where the overdraft has a negative value. Table 5 is a summary of all the equations used within the spreadsheet.
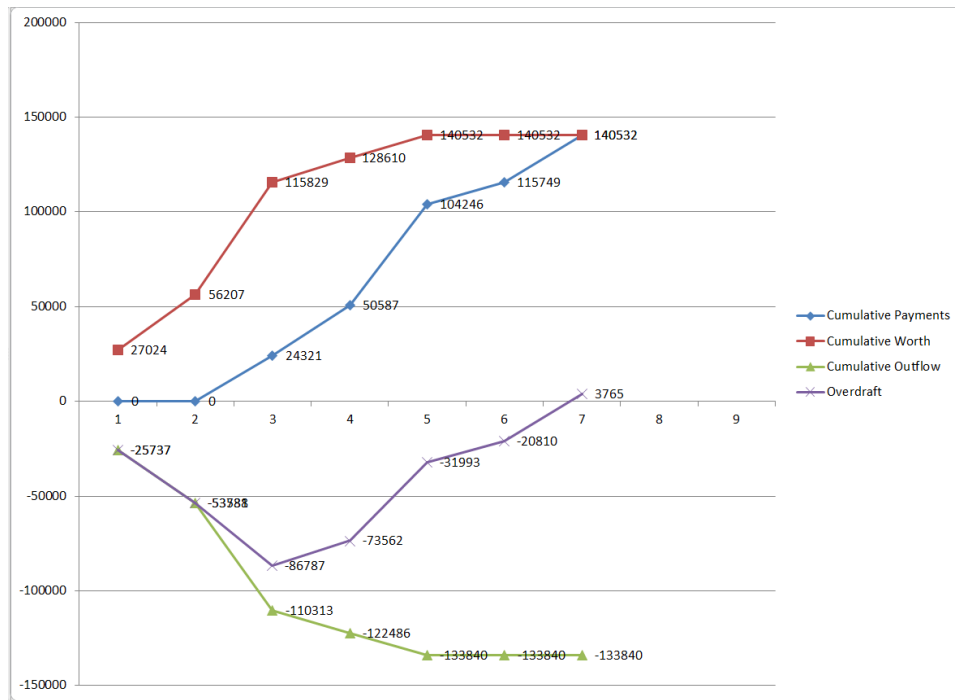

Figure V
CASH FLOW CHART

A cash flow line chart is a visual representation of cash flow trends and is helpful to visualize peaks and troughs of cash availability as shown in Figure 5. The graph shows trends for cumulative payments, cumulative cash outflow, cumulative worth, and overdraft. The two lines in the positive values represent cumulative worth and cumulative payments. Cumulative worth represents how much the project is worth inclusive of markup. Contractors expect to receive payments equal to the worth at the conclusion of the project, and expect payments equal to worth less owner retention throughout the project. This is reflected in the trend lines as you can notice the cumulative payments trend line lags behind the cumulative worth line by two months and also has a

slightly lesser value. The cumulative payment line coincides with the cumulative worth line at the last month because of the owner retention money that is released with the last payment. The cumulative outflow line represents the summation of all expenses made by the contractor, and thus is always negative. The overdraft line, however, is the sum value of all contractor expenses and payments received. The overdraft is the most telling of the trend lines. It always starts off in the negative direction because the first payment is always delayed. When this line crosses the horizontal axis, the contractor has broken even. It is important to note times when this line becomes very negative. If the contractor is borrowing money, a very negative overdraft value also means higher

interest. It is also important to note that this line should terminate in the positive field at the end of the project. This would indicate a net profit. Being able to generate this graph within minutes or receiving a 3D model would tell a company if a project is expected to be profitable, and during which months when they can expect the project to place a large strain on its financial assets. The company would also be able to adjust the markup percentage, and perform the analysis again to determine optimal markup based on profit and bidding strategy.

VI. CONCLUSION

The proposed methodology demonstrates that an automated cash flow analysis is possible based on the information from a building information model. Furthermore, the framework of this prototype utilizes ifcXML, an international industry standard; which creates interoperability between users and recognized on in international level. The purpose of this prototype is to demonstrate that cash flow analysis, which is historically a difficult and tedious task, can be automated with the help of BIM technology and ifcXML standards. Further development can add details to the cash flow automation program such as applying fuzzy systems theories or adding the option to apply 'S-curves' rather than linear curves. The cash flow analysis can also become more accurate with a more detailed model. This type of model would have much more information but because of the standard ifcXML schema, this data would be similarly machine-readable. The prototype would have to be expanded to accommodate for this increase in information, although the methods for retrieving the additional data would be similar.

This research intends to make aware that current technology is available and capable of automating the cash flow process. Further development and research is warranted for the program to be used on more complex projects. This includes adding built-in libraries for scheduling and estimating to account for different types of construction project, materials, and activities.

As Park et al. [1] pointed out, the accuracy of cash flow models is dependent on how they manage unpredictable factors such as time delays, cost overrun, change orders, etc. This accuracy can be increased during the construction phase as more information and conditions are revealed. Because this prototype is generated from a BIM model, it can only be as accurate and detailed as the model. Consequently, updated cash flow analysis reports could be performed at any stage of the project as long as the BIM model reflects the most current changes.

A unique value of this prototype is dramatically automating the time required to generate cash flow analysis. Traditionally, contractors could spend weeks performing the quantity takeoff, scheduling, cost estimating, and cash flow analysis. This prototype offers a method that can produce a cash flow in minutes. Architects will often propose multiple designs, each represented by its own 3D model. With this technology, contractors would be able to quickly compare cash flow

scenarios for each model, which would be potentially useful for value engineering decisions and bidding strategies. Contractors who are considering bidding on multiple projects would be able to quickly perform cash flow analysis for each project and determine which one has the best possibility to earn the highest profit margins. The contractor could then focus its resources on preparing bids for only the most profitable projects.

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