DYNAMO BASED RISK MANAGEMENT PLUGIN

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National University of Sciences and Technology, Islamabad, Pakistan.

This is to certify that the

Thesis entitled

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Has been accepted towards the partial fulfillment of

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ABSTRACT

Construction project are riddled with risks because of the very nature of this industry. These risks need to be effectively managed so that the project is completed within the triple constraints of time, quality and scope. However, contemporary approach to risk management is reactive. That is to say risks are dealt with after they've occurred. This leads to inflated costs, delayed schedules etc. In the recent years, BIM has emerged as a revolutionary tool for the construction industry; among its many capabilities is operations management. Since the traditional approach clearly is not the answer to risk management, the answer lies in sophisticated software tools that are complemented by BIM. We've aimed at developing such a kind of dynamo based plugin, which facilitates project managers to set aside calculated contingency amounts to be used for risk management.

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ABBRIEVATIONS

PRM- Project Risk Management

ERM- Enterprise Risk Management

PI- Probability and Impact

BIM- Building Information Modelling

5D- Fifth Dimension- Cost Model

SWOT- Strength, Weaknesses, Opportunities, Threats Analysis

MEP- Mechanical, Electrical and Plumbing

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Chapter 1

INTRODUCTION

1.1 BACKGROUND:

Construction projects are unique in their nature, from the start to the end, construction projects involve complex procedures and a varied amount of risk that sets them apart from other projects involving other industries, this risk needs to be effectively managed in order for projects to reach completion within the desired constraints of time, money and scope or in some cases, reach completion at all (Al-Bahar and Crandall, 1990).

Effective risk management is then, a critical factor influencing project success and so has evolved into a discipline of its own.

Project Management Institute defines Project Risk Management (PRM) as encompassing project management with four major processes:

- Risk identification,
- Risk quantification,
- Risk response development and
- Risk control.

It is of relevance that current techniques prevalent in the construction industry, used in each of the above processes tend to lean towards simplicity. Research indicates that the whole process of risk management remains very informal, as seen fit by the professionals depending upon the cost-quality-time tradeoff (Muhammad Jamaluddin Thaheem and Alberto De Marco, 2013).

It is also seen that the use of PRM software tools to tackle risk is not as diffused as some might think, reported reasons being the amount of money that goes into integrating these software tools along with the amount of time taken for the pre and post-processing of data fed into and extracted from these tools respectively.

So, although these tools are being used in the industry, construction managers are still looking for more convenient tools for effective risk management.

1.2 Problem Statement:

The construction industry at the present does not have convenient risk management tools to account for the plethora of risks that could possibly occur in a construction project.

The current techniques being used in this industry for risk management range from the use of spreadsheets, brainstorming, SWOT analysis, risk registers (Patterson and Neailey, 2002; Williams 1994).

These techniques are simplistic and there is also the factor of human error involved. For these reasons the construction industry is plagued with risks unaccounted for.

A void therefore exists in the research and development of better, automated risk management tools.

1.3 Objectives:

The aim is to develop a plugin for Revit that will help project managers to conveniently calculate contingency amounts to be set aside for individual project activities.

This can be achieved through the following objectives:

- To gather Probability and Impact (PI) values of construction project risks.
- To gather 5D project data of already completed projects to be used in plug-in.
- To develop a Dynamo based plugin that will help project managers to conveniently calculate contingency amounts to be set aside for individual project activities.

- Compare contingency cost generated with project cost + overrun cost.

1.4 Areas of Application:

This plugin will be available for use to Project Managers to conveniently set aside calculated contingency values for construction projects to be used in time of need.

Chapter 2

LITERATURE REVIEW

BACKGROUND

Usually in an ideal corporate environment, decisions must be taken with absolute certainty. All the necessary information must be available to the decision maker so that the appropriate decision must be taken that leads to success. But that is not the case, in most scenarios; complete information is not available for the decision maker to make a decision. In fact, most of the decisions in today's corporate environment are taken in the absolute dark. This lack of information gives rise to uncertainty which may lead to multiple risks. Risks are a then part and parcel of today's construction projects. It is very improbable that a construction project will go without a hitch. A Project Manager must then have the necessary oversight to predict possible risks in advance and devise strategies to deal with them if they occur.

2.1 Why should we do Risk Management?

The main purpose of Risk Management is to identify all the likely risks that could occur in a project, classify them on the basis of their harmfulness to the project. Then proceed with what could possibly be done to reduce, mitigate or modify these risks.

This is important because without proper management these risks will run rampant. At the end these risks may lead to inflated cost, delayed schedules and other similar problems that harm the project constraints.

2.2 Risk Management, a Process:

Project risk management is defined as:

"The art and science of identifying, assessing and responding to project risk throughout the life of a project and in the best interests of its objectives"(Wideman, 1992).

Project risk management, in its simplest form, constitutes of four processes.

2.2.1 Phase One – Identification

This phase involves identifying all the likely risks that could occur in a project. Some of these risks may be High Impact/High Probability through High Impact/Low Probability, Low Impact/ High Probability and Low Impact/Low Probability.

To identify all the risks that may occur, it is necessary to undertake a risk identification program. Typically, in the construction industry this is done through a brainstorming process in which all the stake holders are involved.

2.2.2 Phase Two – Assessment

After all the possible risks have been pinpointed, the next step is to evaluate them. This is done by categorizing them on the basis of their impact, probability and type.

The most common way this is done is by the preparation of a risk matrix.

2.2.3 Phase Three – Response

The next step is to develop a response strategy. An insurance maybe taken out against insurable risks while specific actions maybe planned to deal with the ones that remain. This may include keeping a contingency fund, accepting the risks as they are etc.

2.2.4 Phase Four – Documentation

The fourth phase in this process involves developing a database to evaluate the risks of the current project. Not only this, but this database can also be used as a reference for upcoming and future projects.

2.3 How should we proceed with Risk Management?

Currently the techniques prevalent in the industry for risk management depend on the expert judgement of the Project Managers. Keeping in mind the cost-quality-time tradeoff, whatever technique suits an organization’s goals is put to practice.

2.4 Risk Management Software Tools:

2.4.1 CURA:

The Enterprise Risk Management software (ERM) of Cura allow firms and organizations to manage risks as well as take advantage of the opportunities that relate to the objectives and goals of the business. A flexible and powerful framework is provided by Cura to manage risks while also enabling organizations and firms to identify, evaluate, analyze, fix risks and treat opportunities for protecting the brand, creating value for owners, customers, employees, shareholders and regulators.

2.4.2 Master-Control Risk Analysis:

The purpose of Master-Control Risk Analysis is to establish risk evaluation as a distinct process. The output, which is based on a consistent process, is a risk score. It allows quality departments to reduce the subjective nature that comes with quality decision making.

2.5 Building Information Modeling:

"Building Information Modeling is the process of using intelligent graphic and data modeling software to create optimized and integrated design solutions." (Gordon V.R Holness, 2008)

In simpler words BIM involves the process of creating information models based on non-graphical as well as graphical information in a shared digital space. The information increases in complexity and richness over time as the project moves forward.

The use of BIM has gained more acceptance over the years owing to its wide range of functionality. The main product BIM provides is a 3D graphical model where each line and each product carries intelligent physical and performance data. It can also extend to 4D (adding the fourth dimension of time, through the use of primavera) modeling and 5D (adding the fifth dimension of cost, through the use of cost estimating soft wares such as Builder trend etc.) modeling.

2.5.1 4D Time Model:

4D BIM links time related information to different fragments of the information model. A particular element could include information on lead time, curing allowances, dependence on other areas.

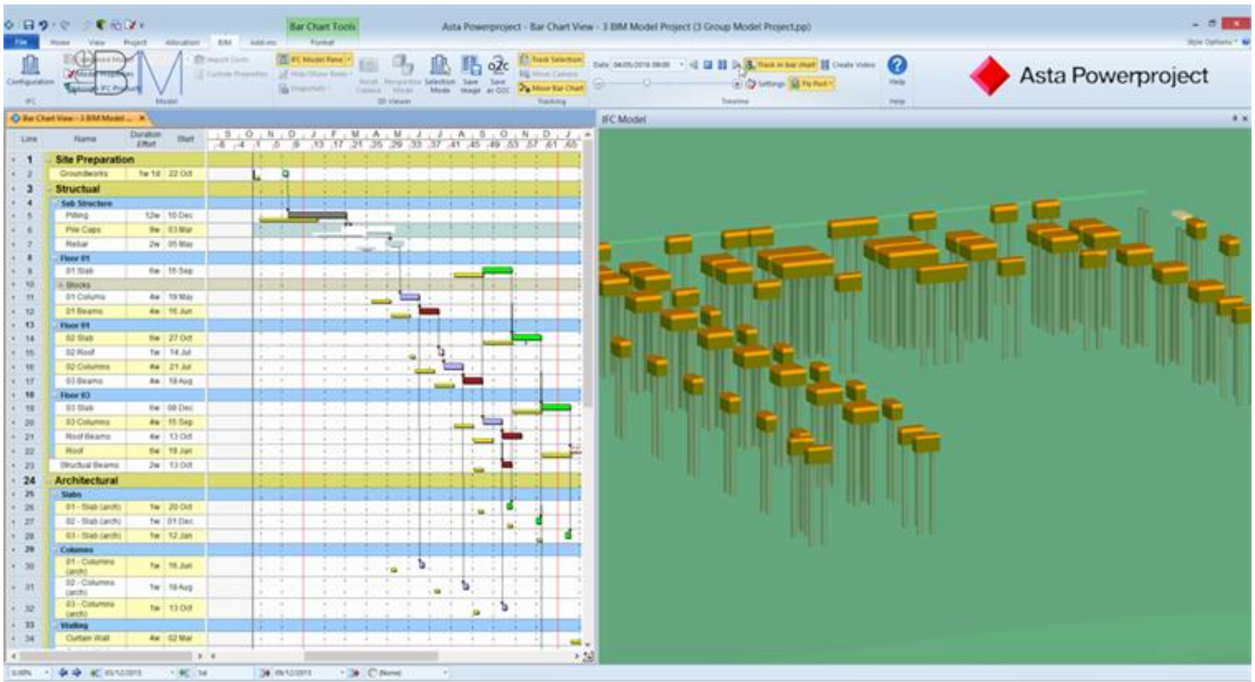


Figure 2-1 Scheduling data linked to foundational components of a 3-D model

With this information planners can quickly develop programs for the project based on a single reliable source of information.

The addition of time based information also results in better visualization of the project, enabling project managers to visualize what the project will look like in each phase of construction.

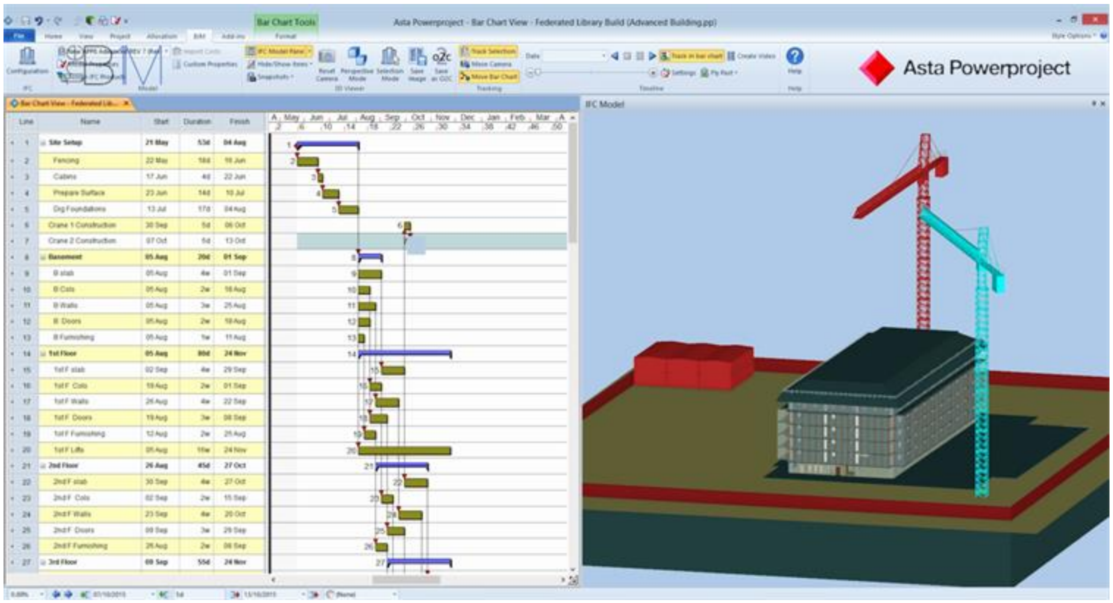


Figure 2-2 Step by Step visualization of a project

It is also a powerful tool for everybody to see how the project will look like during delivery and upon delivery rather than have to envisage that through 2-D models and Gantt charts.

2.5.2 5D model:

When an information model is created, scheduling data can be added to it so that each component of the information model is linked to a time component that can generate precise and accurate program data for the project.

The next step involves producing precise cost estimates from the information model. This process is known as 5-D BIM modeling.

These cost estimates can consider the amount needed to install a particular component, the running cost associated with it once it is installed, and the renovation cost if it is to be renewed in the future. In this way Cost Managers can quickly calculate the overall cost of a package, and the whole project.

Seeing as the traditional methods of quantity estimating are incredibly tedious and time-taking, this has greatly freed up cost managers’ time and enabled them to verify quality and scope.

2.5.3 6D BIM:

6D BIM is taking it a step further to use the attributed data to support Facilities Management (FM). The data could include information on each component about the time it was installed, the manufacturer's details, how to replace it, at what time to replace it and how to use it at its optimum ability, to conserve energy, enhance performance etc.

Once linked in the information model, the data can be used during the design/operational life of the built asset.

2.6 Types of BIM

2.6.1 Hollywood BIM

BIM may only be use for 3D modelling, not utilizing its complete potential.

2.6.2 Lonely BIM:

In this type, BIM is used internally in an organization and all information and data is kept within the organization, not sharing it with other stakeholders

2.6.3 Social BIM:

In this type of BIM, data is shared among different stakeholders. This is a more efficient and inclusive way of doing things in which each party involved in the project has its say.

2.6.4 Intimate BIM:

When the designer, owner and contractor share the risk and reward through integrated project delivery using BIM

2.7 Benefits of BIM:

Following are some of the ways, the construction industry benefits from BIM.

2.7.1 Better collaboration and communication:

Digital BIM models enable the sharing that traditional paper drawings don't. With cloud-based technologies BIM collaboration can occur flawlessly across departments within a construction project.

2.7.2 Model based cost estimation:

BIM allows for model based cost estimation processes which means that cost estimation becomes more efficient as well as automated to some extent.

2.7.3 Better visualization:

3D construction models allow Project managers to better visualize the whole project. Work is being done to integrate virtual reality with BIM models, bettering the visualization process.

2.7.4 Clash detection and removal:

BIM allows for better planning before the project is executed on site enabling reviews and comments across disciplines, lowering the chances for possible clashes, last-minute changes and unexpected issues.

2.7.5 Reduced cost and risk mitigation:

Research indicates that although the integration of BIM poses a financial challenge the ultimate payoff is even higher.

2.7.6 Improved Scheduling/Sequencing:

BIM reduces cost while also saving time by reducing the time of project cycles and by eliminating project scheduling setbacks

2.7.7 Increased productivity and prefabrication:

Production drawings can also be generated at a much faster pace by using BIM rather than by using traditional techniques; it can also be used to generate databases to improve manufacturing processes.

2.7.8 Safer Construction sites:

BIM can be used to visualize and pinpoint hazards before they become problems which results in a much safer construction environment.

2.7.9 Code/Compliance Checking:

BIM can be used to check whether models are compliant of an area code. In this process visual programming is used in conjunction with Revit to check for violations.

2.8 BIM as a risk transformer:

BIM also reduces certain risks associated with the design and construction drawings, helps designers in better visualization, removes clashes and improves prefabrication processes. It also improves communication between the different stake-holders involved in a typical construction project.

The risk mitigation capabilities of BIM can be debated because although it reduces the impact of certain risks and removes others altogether, its use in a construction project introduces a variety of new risks and transforms some of the pre-BIM usage risks too. Ultimately though, the use of BIM in construction projects brings opportunities by eliminating the highest ranked risks (Zubair Ahmed et al, 2018)

2.9 Revit:

Revit is an application developed by Autodesk for the purpose of Building Information Modeling that allows designers, architects, engineers, structural engineers and MEP engineers to design in 3D, building structure and components and allows them to access these designs through the building model's database.

In the past few years Revit has become a staple of the construction industry, owing to its wide range of functionality and customizability through the use of Revit based plugins.

2.10 Revit Plugins:

Revit extensions or plugins expand the capabilities of Revit, Revit Architecture, Revit MEP, and Revit Structure software in desired areas, including interoperability, reinforcement, structural analysis, modeling and construction documentation.

2.11 Visual programming:

A visual programming language (VPL) is any programming language in computing that enables users to create programs by changing program elements graphically rather than changing them textually. All of these graphical elements represent processes connected through arrows or lines which represent relations.

Visual programming is, although, being implemented in other disciplines, it has only recently become a key supplement to three-dimensional modeling programs in the architectural, engineering and the construction industry. Grasshopper in unison with Rhino currently serves as a leading example of a visual programming environment that is supported by a community of users that has developed additional functionality. But, Grasshopper has not yet worked directly with building information modeling (BIM) software. Dynamo is relatively new, but it shows considerable promise in becoming a constructive tool to complement BIM, 3D modeling, and analyze programs because it includes parametric geometries and also works with Revit, a leading BIM software program (Karen Kansek, 2015).

2.12 Dynamo:

"A visual programming tool that aims to be accessible to both non-programmers and programmers alike. It gives users the ability to visually script behavior, define custom pieces of logic, and script using various textual programming languages".

2.12.1 How Dynamo works

Rather than typing code, dynamo allows you to manipulate graphical elements called nodes. In dynamo, each node performs a specific task. Each node has an input and an output. Each node's output connects to multiple other nodes' input through "wires". The program flows from one node to another through a network of wires, as shown in figure.

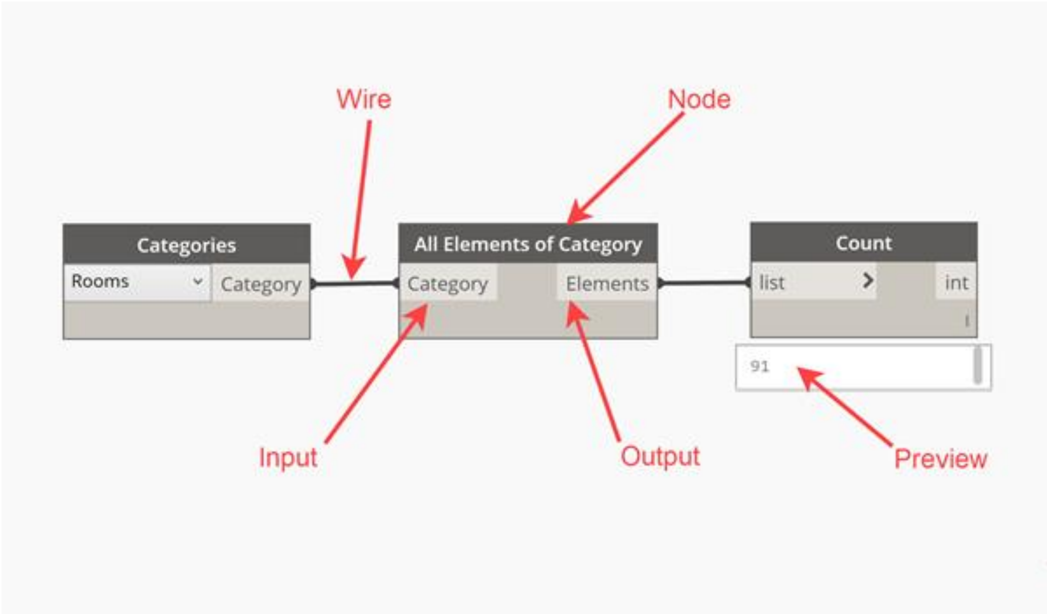


Figure 2-3 Dynamo Working

2.12.2 Ease of use:

One of the many benefits of dynamo is its library of nodes. Instead of remembering the specific code required for achieving a certain task, you could simply search the library and the program gives a corresponding node result/results.

2.12.3 User community:

Another contributing factor to dynamo's success is its community. The online integrated cloud contains a repository updated by users that contains pre-made programs. Users can access the library to use typical programs in their larger program framework.

Dynamo is still new but shows the capability to become one of the leading programs to supplement BIM, 3D modeling and analysis programs because of its ease of use and the fact that it works with Revit, one of the leading BIM soft wares.

2.13 Expected Monetary Value:

Expected Monetary Value is a qualitative risk management technique that compares and quantifies risks and then ranks them on the basis of their priority and urgency. By using Expected Monetary Value you can determine whether your analysis of the project risks is backed by numbers.

Expected Monetary Value method relies on two basic numbers

P - The probability that a particular risk will happen

I - The impact of that particular risk

These numbers are then multiplied with the cost to come up with a contingency cost to account for the particular risk.

Chapter 3

METHODOLOGY

3.1 General

The methodology adopted to develop a contingency calculating plugin.

3.2 Basic Plugin Framework:

The basic plugin framework is detailed as follows

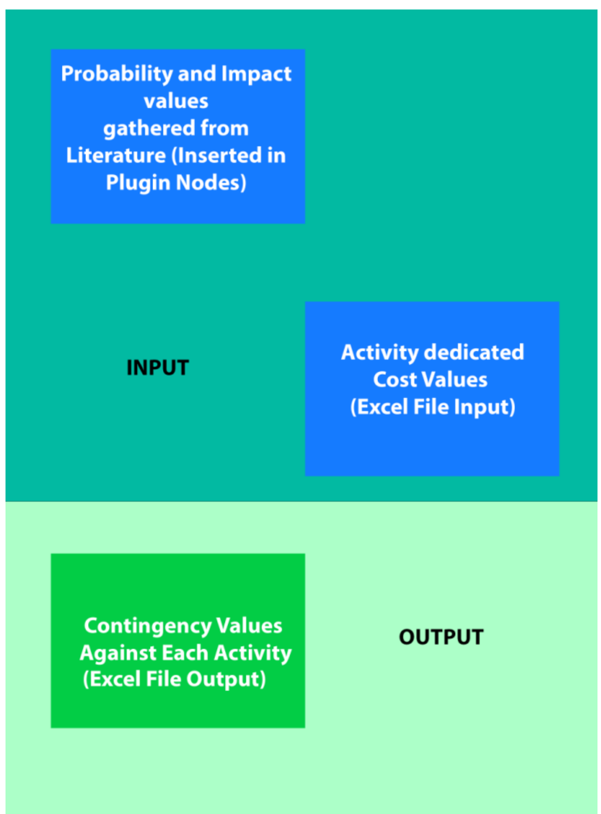


Figure 3-1 Plugin Framework

The plugin operates by taking Input in the form of PI values and detailed activity dedicated cost information. The output is generated in the form of an excel file with detailed contingency amounts for each activity.

3.3 Input:

3.3.1 Risk Matrix:

For the purpose of input into the plugin a total of ten risks (most reoccurring in literature, highest probability and impact values) were identified, their probability and impact values, averaged, and the results were tabulated. The number was kept to a ten because there are numerous risks listed in literature but it is more probable that the ten most reoccurring ones in literature, with the highest probability and impact values would occur in a project.

The prepared risk matrix is shown in Table 3-1.

Table 3-1 Risk Matrix

Risk and PI Values	Average PI values	Cost	Quality	Time	Environment	Safety
Lack of professional pre-planning studies by project participants (0.71)	0.71	✓		✓	✓	
Schedule delays due to delays in payments (0.62)	0.62	✓		✓	✓	
Delay due to excessive approval procedures (0.72,0.48)	0.60	✓		✓	✓	
Incomplete or inaccurate technical drawings (0.57)	0.57		✓			

Risk and PI Values	**Average PI values**	**Cost**	**Quality**	**Time**	**Environment**	**Safety**
Too tight project schedule due to loose planning activities (0.67,0.57,0.56,0.39,0.45,0.66)	0.55	✓	✓	✓	✓	✓
High expectations or quality standard (0.24,0.57)	0.40			✓		
Variations by the client (0.46,0.47,0.25)	0.39	✓				
Lack of coordination between project participants (0.29,0.26,0.56)	0.37		✓			
General Safety accident occurrence (0.30)	0.30					✓
Unavailability of skilled labor (0.24)	0.24		✓			

The risks identified are listed in column 1 along with their respective PI values, the next column averages the PI values and following columns identify the objectives they affect.

The risks we were concerned with were cost incurring risks.

3.3.2 Activity dedicated cost values:

For the purpose of preparing an excel file with the activity dedicated cost values, we needed detailed BOQ for an already completed project. For this purpose we contacted the Schedule and Cost Control engineers working with the Infrastructure Development Authority of Punjab on the Pakistan Kidney and Liver Institute Research Centre (PKLI & RC) project.

PKLI & RC (Pakistan Kidney & Liver Institute and Research Center), Lahore will be a state-of-the-art center of excellence in medical care that will teach as well as research in particular and specialized areas of kidney, bladder and liver diseases and their treatment including transplantation. It is a public-private partnership where the Government of Punjab has transferred a 60-acre piece of land and has committed funds for the construction of the first phase of the project.

After the completion of PKLI, it will be one of the bigger transplant centers in the world. It will not only provide the poor and the less fortunate free of cost medical services, but will also provide employment to about 5,000 people and train new nurses, paramedics and doctors.

This data was made available to us in the form of a primavera schedule:

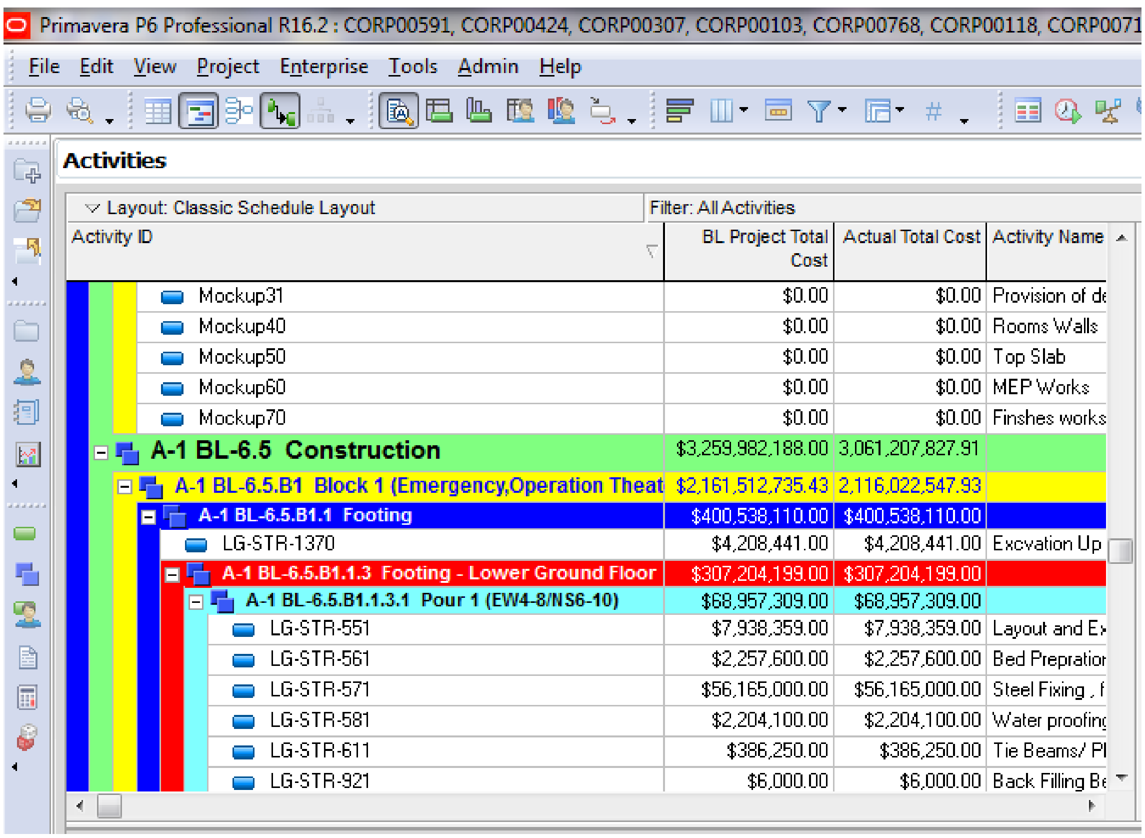
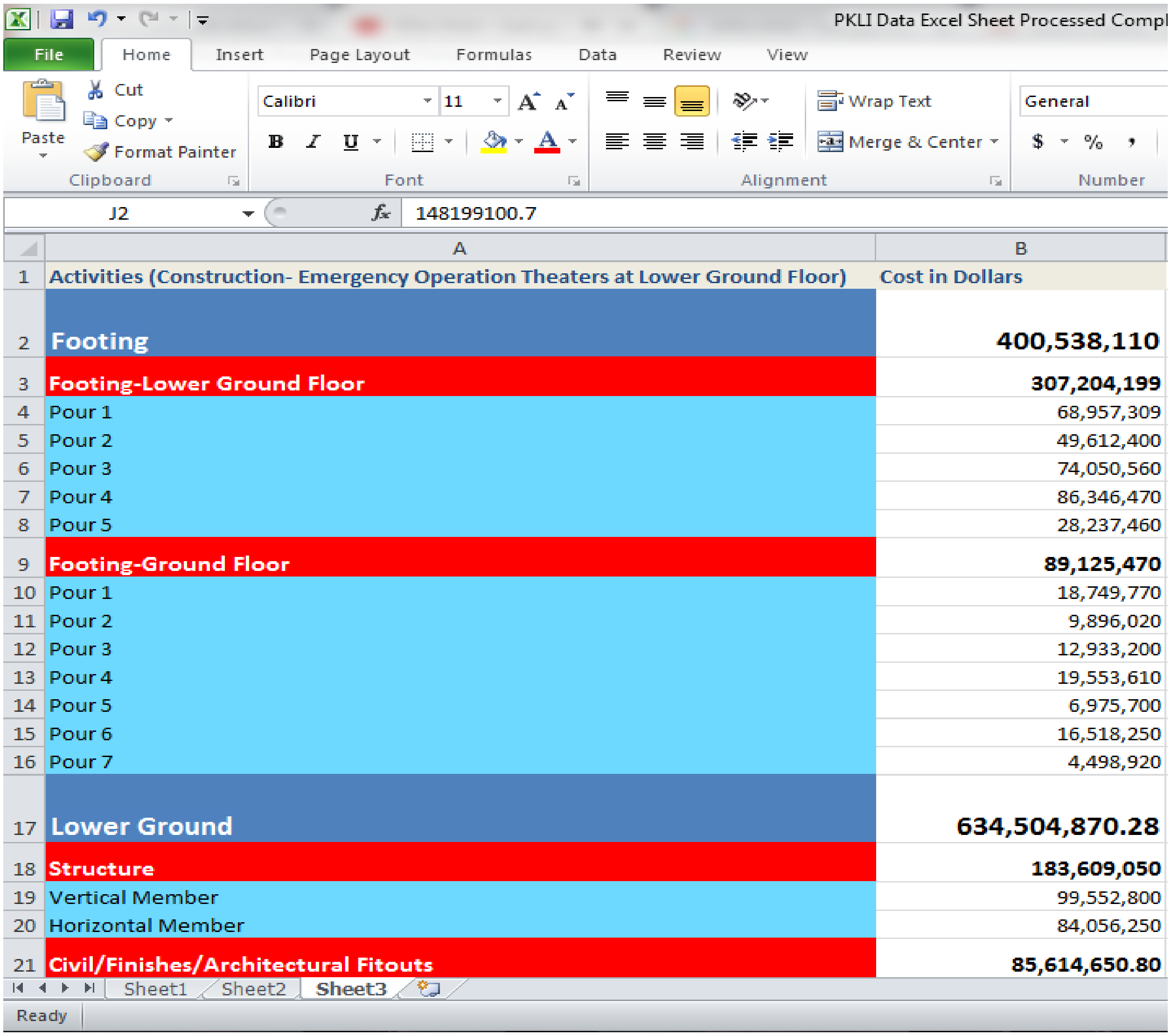


Figure 3-2 Pre-Processed Primavera File

The project itself is divided into a number of packages; the data we choose to use in the plugin was the data of the construction of the Lower Ground Floor.

This data was processed into an excel file. The processed data looked something like this:



Activities (Construction- Emergency Operation Theaters at Lower Ground Floor)	Cost in Dollars
Footing	400,538,110
Footing-Lower Ground Floor	307,204,199
Pour 1	68,957,309
Pour 2	49,612,400
Pour 3	74,050,560
Pour 4	86,346,470
Pour 5	28,237,460
Footing-Ground Floor	89,125,470
Pour 1	18,749,770
Pour 2	9,896,020
Pour 3	12,933,200
Pour 4	19,553,610
Pour 5	6,975,700
Pour 6	16,518,250
Pour 7	4,498,920
Lower Ground	634,504,870.28
Structure	183,609,050
Vertical Member	99,552,800
Horizontal Member	84,056,250
Civil/Finishes/Architectural Fitouts	85,614,650.80

Figure 3-3 Post- Processed Excel File

3.4 Output:

The plugin operation is based on a three node group framework

3.4.1 Import from Excel File Group

This group of nodes imports the cost data of the excel file into the plugin.

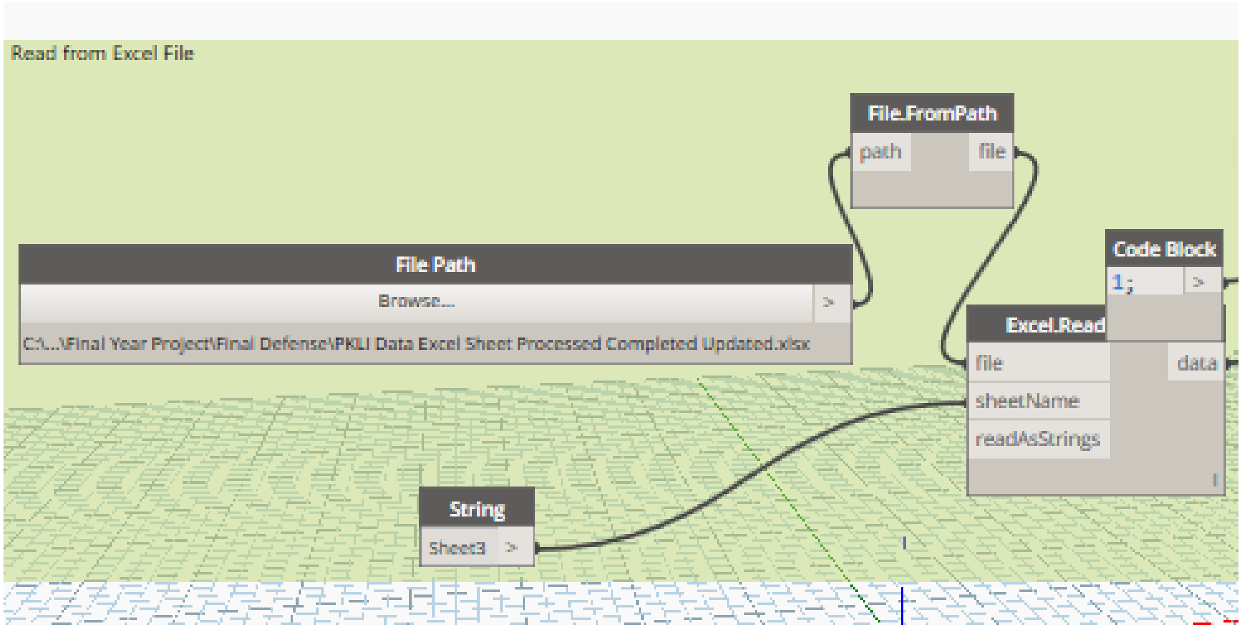


Figure 3-4 Node Group 1

3.4.2 Multiplication with PI values Group

This group of nodes multiplies each of the activity costs with the PI values of each cost incurring risk.

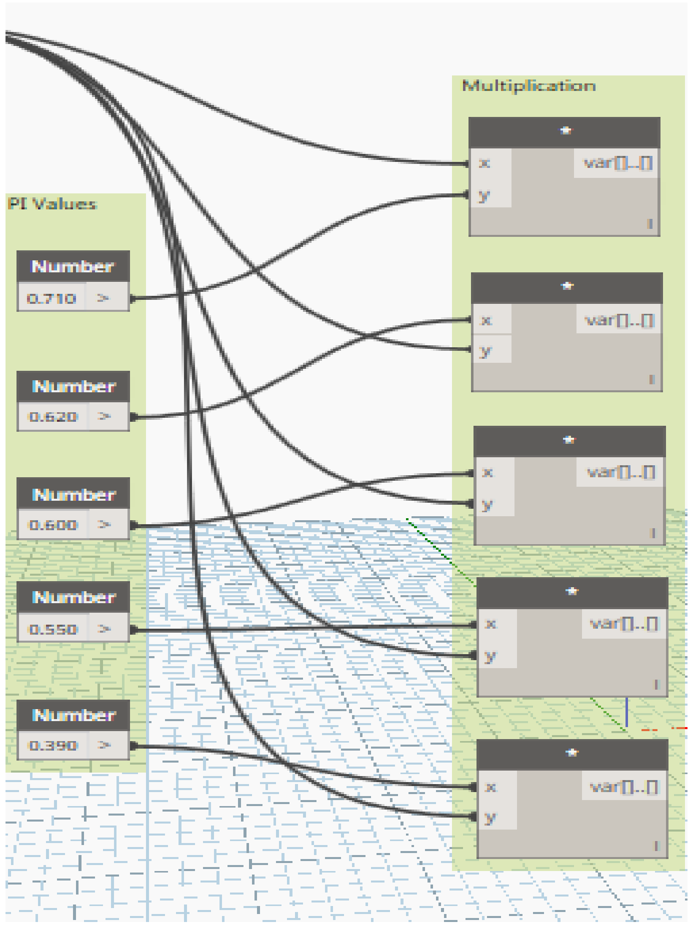


Figure 3-5 Node Group 2

3.4.3 Export to Excel File Group

This group of nodes writes the contingency amounts for each activity onto an excel file.

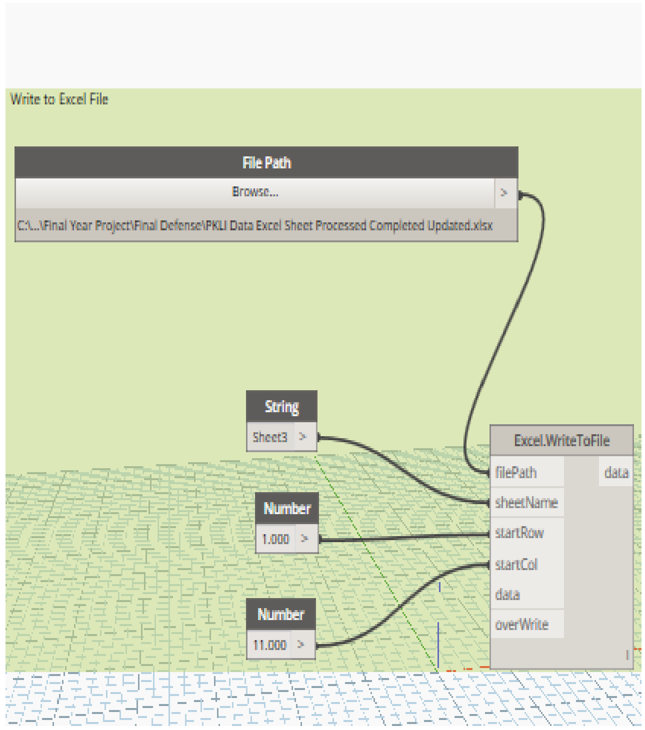
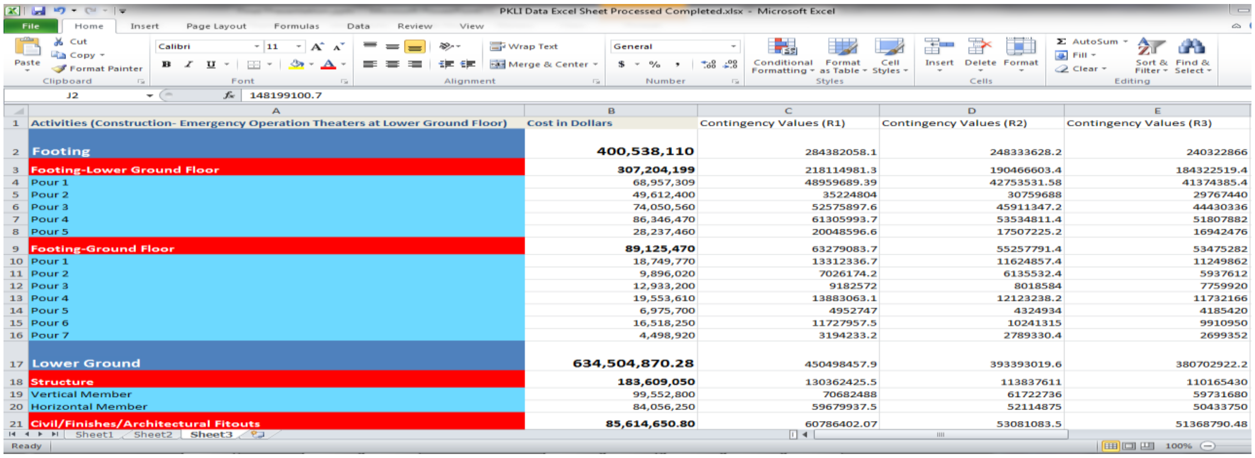


Figure 3-6 Node Group 3

RESULTS AND ANALYSIS

4.1 Results

The excel file result is as shown:



	A	B	C	D	E
1	Activities (Construction- Emergency Operation Theaters at Lower Ground Floor)	Cost in Dollars	Contingency Values (R1)	Contingency Values (R2)	Contingency Values (R3)
2	Footing	400,538,110	284382058.1	248333628.2	240322866
3	Footing-Lower Ground Floor	307,204,199	218114981.3	190466603.4	184322519.4
4	Pour 1	68,957,309	48959689.39	42753531.58	41374385.4
5	Pour 2	49,612,400	35224804	30759688	29767440
6	Pour 3	74,050,560	52575897.6	45911347.2	44430336
7	Pour 4	86,346,470	61305993.7	53534811.4	51807882
8	Pour 5	28,237,460	20048596.6	17507225.2	16942476
9	Footing-Ground Floor	89,125,470	63279083.7	55257791.4	53475282
10	Pour 1	18,749,770	13312336.7	11624857.4	11249862
11	Pour 2	9,896,020	7026174.2	6135532.4	5937612
12	Pour 3	12,933,200	9182572	8018584	7759920
13	Pour 4	19,553,610	13883063.1	12123238.2	11732166
14	Pour 5	6,975,700	4952747	4324934	4185420
15	Pour 6	16,518,250	11727957.5	10241315	9910950
16	Pour 7	4,498,920	3194233.2	2789330.4	2699352
17	Lower Ground	634,504,870.28	450498457.9	393393019.6	380702922.2
18	Structure	183,609,050	130362425.5	113837611	110165430
19	Vertical Member	99,552,800	70682488	61722736	59731680
20	Horizontal Member	84,056,250	59679937.5	52114875	50433750
21	Civil/Finishes/Architectural Fitouts	85,614,650.80	60786402.07	53081083.5	51368790.48

Figure 4-1 Detailed Contingency Amounts

In the figure above contingency amounts for each of the cost-incurring risk is calculated against each activity.

To calculate a contingency amount for the project, risks were identified, after consultation with the engineers over at IDAP, which occurred in the project. A number of activities were assumed to be affected by these cost incurring risks and their contingency amounts were totaled.

The project contingency total came out to be approximately 2 percent of the project cost.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

Effective Risk Management:

Effective Risk Management as seen through the scope of our research is a function of the following three processes:

- Reducing the amount of risks that could occur in a project.
- Reducing the probability of these risks occurring and the impact they have on the project.
- Reducing the amount of activities affected by the risks.

Through the adoption of the above suggested measure can the contingency amounts be lowered, which means that the risks have been effectively managed.

Recommendations:

The plugin functionality can be improved furthermore if the PI values were region tailored. Through literature review, it was found that different risks could have vastly different PI scores depending on the region. For example in a region such as Jordan, the risk : shortage of labor had a very PI score, higher than what is considered average.

For this reason research needs to be carried out to detail region tailored risks and their respective significance (PI) scores.

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