RM Project 2018: TD_AM_Risks associated with the construction a new Sports Complex in the Foggy Bottom Campus.

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Executive Summary

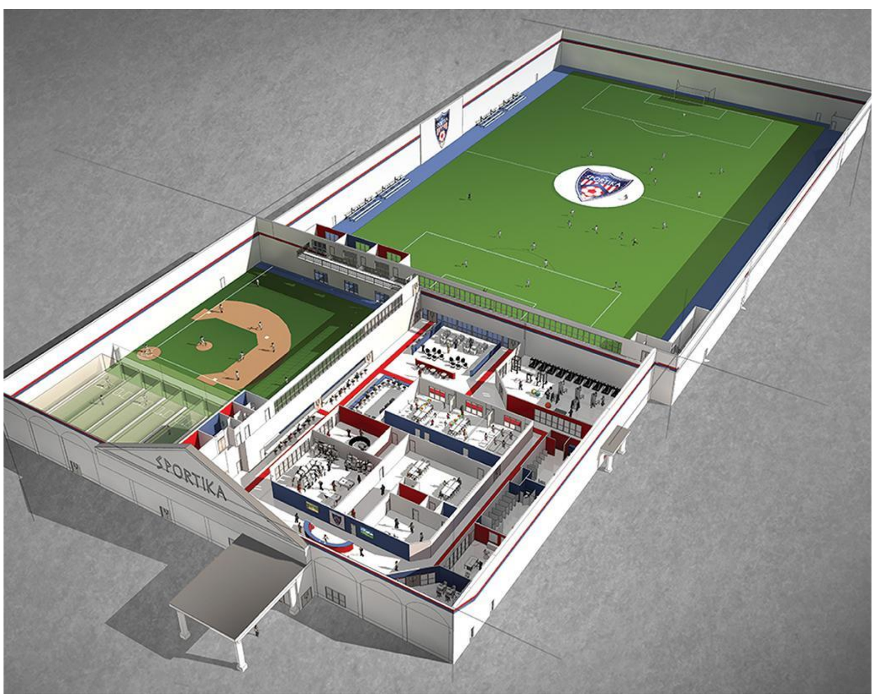
The George Washington University administration would like to construct a Sports Complex on the campus with full access to all students to multiple sports facilities.

In order for the GWU administration to turn this proposed plan into a successful, operational Sports Complex in the vicinity, they have hired a team of experts to plan, prepare, execute and implement a functionally capable, fully equipped Sports Complex. In the various stages of the construction, the team of experts assessed the risks using the Riskion Software and established a risk assessment program that would mitigate all potential risks that one may face during the course of the construction of a commercial property. This report provides a detailed explanation of the risk assessment process and findings.

1. Introduction

The George Washington University is one of the most respected Universities in the Washington DC area. As physically active students who are interested in sports, we decided to look into the current gymnasium at GWU. We found out there were not many sporting fields to allow the varying sports to be played simultaneously. As a result, we decided to explore the idea of building a new Sports Complex in the Foggy Bottom Campus to allow students to engage in any recreational activities of their choice.

The timeline for this project is slated for 3 years. Each construction project is unique and comes with its own set of challenges and opportunities. This construction project to build a new sports complex on Foggy Bottom campus will be very complex and may pose many different types of risks. These risks include financial, contractual, operational, and environmental concerns. When risks come to fruition, they can have a serious impact on costs, schedules and performance of the project, which will lead to delays and disputes down the road. Hence, initially we must analyze these risks and then decide on whether or not the project will still be profitable.



2. Risk Analysis Methodology

Risk is identified as expected loss due to an uncertain event.

2.1 Sources of Risks

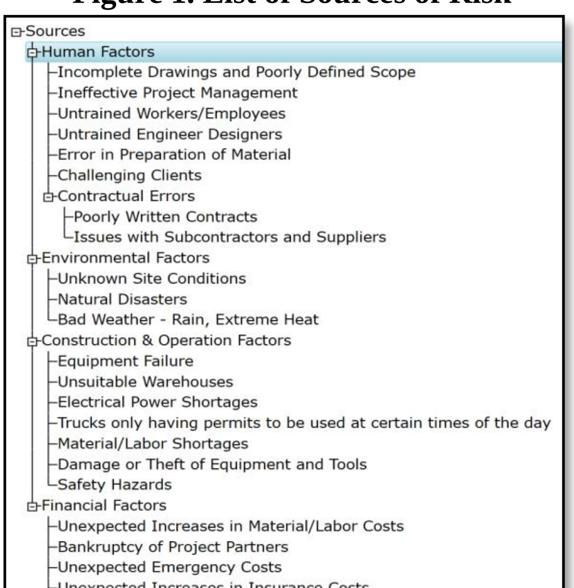
As part of the risk identification process, sources of risk were identified as something/factors that is uncertain that could cause an event. These sources were inputted into Riskion as the starting factors of the risk assessment process, as shown in Table 1 and Figure 1.

Table 1

Source	Source Description
Human Factors	
Incomplete Drawings and Poorly Defined Scope	Drawings and project scope for the construction project that is not fully executable due to its premature state.
Ineffective Project Management	Project Management that has a low maturity - ad-hoc stage. No PM processes or practices are consistently available. The PM is unable to perform his duties effectively and efficiently.
Untrained Workers/Employees	Workers/Employees who are under-trained and are not fully capable of doing their job effectively.
Untrained Engineer Designers	On-site engineers not fully trained on construction design techniques.
Error in Preparation of Material	Using incorrect mixture of raw materials used during the construction process. E.g., concrete.
Challenging Clients	Clients who are not easy to work with. For example, clients who miss scheduled appointments or clients who miss important information in the contracts.
Human Factors - Contractual Errors	
Poorly Written Contracts	Contracts that are not fully detailed and does not provide the reader with clarity
Issues with Subcontractors and Suppliers	Subcontractors and Suppliers not adhering to contractual agreements.
Environmental Factors	
Unknown Site Conditions	Lack of adequate parking spaces for trucks carrying building material. Neighboring buildings and streets being overcrowded. Any other factors that may cause hindrances to the progress of the construction
Natural Disasters	A natural event such as a hurricane, earthquake, tornado, etc.
Bad Weather	Extremely Heavy Rain, Extreme heat that makes the working conditions difficult to be productive in
Construction & Operation Factors	
Equipment Failure	Failure of cement mixers, trolleys used to transfer materials from the truck or any other machinery used during the construction process

Unsuitable Warehouses	Warehouses that are not fit to store material. These warehouses either have inadequate storage space, mishandling of inventory, lack of automated systems to allow ease of access to material.
Electrical Power Shortages	Inadequate power supply to the site due to outages and civil body intervention.
Trucks only having permits to operate at certain times of the day	Based on the permit received from the state, we are only allowed to have the truck in use at certain times of the day, which affects our daily work schedule/layout.
Material/Labor Shortages	Inadequate labor and material due to improper planning and poor inventory management.
Damage or Theft of Equipment and Tools	Based on the safety of the storage of equipment and tools, thieves may have easy access to equipment or the equipment may be damaged if used incorrectly by untrained workers.
Safety Hazards	Lack of sign boards indicating activities on-site like digging, drilling and mixing cement. Lack of knowledge and training on how to use the construction equipment, which leads to an unsafe environment.
Financial Factors	
Unexpected Increases in Material/Labor Costs	Increase in raw material/labor costs that were not planned. During the planning phase, a budget was mapped out for the project. Any upward changes made to this by the suppliers and manufacturers may increase these costs mid-way in the project, jeopardizing the overall budget and plan.
Bankruptcy of Project Partners	Funds being blocked due to one or few of the project sponsors running out of money.
Unexpected Emergency Costs	Medical emergency costs, faulty machinery cost, rehiring engineers due to attrition.
Unexpected Increases in Insurance Costs	Based on the magnitude of the injury of employees/civilians or damage to our equipment on-site, we would have to factor in new insurance costs which may be higher than expected.

Figure 1. List of Sources of Risk



2.2 Risk Events:

The next step in the risk identification process was to identify the risk events that would occur as a result of the sources of risk. Risk events are uncertain incident that matter. It matters because its occurrence adds loss to your objectives. These events were then inputted into Riskion as the factors resulting from the sources of risk, as shown in Table 2 and Figure 2.

Table 2

Risk Event	**Risk Event Description**
Applying Incorrect/Insufficient Project Plan	A plan is the first and the most important step when beginning a project in the construction sector. Applying an incorrect or incomplete project plan would result in further delays in the execution of the project.
Poor Structure Resilience	Post construction, the structural stability of the building not meeting safety standards, which could lead to accidents.
Subcontractors Suing our Company	Due to unpleasant and unsatisfactory business relationships between GWU administration and the subcontractors, there is a possibility of legal involvement and lawsuits.
Delays in the Project	Overall delay in meeting the date of completion as promised to the GWU Foggy Bottom administration, which could lead to dissatisfied client and the student group who are the final users of the facility.
Damaged Material	During the course of the construction process, the material used can be damaged due to natural or human interferences leading to additional cost to be borne by GWU administration and further delay in project completion.
Damaged Infrastructure	Any damage caused to the transportation, communication, water and electrical systems during the course of the construction process.
Employee Lawsuits	Employees working on the construction process may be dissatisfied with financial compensation or any general disagreements that may lead to them filing a lawsuit against GWU administration
Civil Lawsuits	Any non-compliance of the practices as published in the District of Columbia construction codes may lead to civil lawsuits being slapped on GWU administration. This may cost GWU admin a lot of money, time and bad reputation.
Unexpected Overspending	The estimated budget penned down during the initiation and planning phase of the construction may overshoot during the execution and closure phases leading to extra cost and further delay in project completion.
Delays in Unloading Material	There could be a delay in unloading building material on-site. As this is one of the initial steps, it may lead to delays in the following stages of the construction and to the overall delay in completion of the project.
Problems with Contractors	The estimation made by the contractors in terms of money and materials required may be faulty or with a corrupt intent. This may lead to misunderstanding between GWU administration and the contractors.

Figure 2. List of Risk Events

Events
Applying Incorrect/Insufficient Project Plan
Poor Structure Resilience
Subcontractors Suing our Company
Delays in the Project
Damaged Material
Damaged Infrastructure
Employee Lawsuits
Civil Lawsuits
Unexpected Overspending
Delays in Unloading Material
Problems with Contractors

2.3 Vulnerabilities Grid - How Sources Contribute to the Events

Once the sources and risk events were identified, the vulnerabilities grid was used as a tool to map all the sources that may contribute to the occurrence of a risk event, as shown in Figure 3.

For example, the following sources: ‘Unknown Site Conditions’, ‘Natural Disasters’, ‘Bad Weather’, ‘Equipment Failure’, ‘Electrical Power Shortages’, ‘Trucks only having permits to be used at certain times of the day’ and ‘Damage or Theft of Equipment and Tools’ would all contribute to the occurrence of the event, ‘Delays in Unloading Material’. Tornados or heavy rainfall would indeed contribute to this event because the workers would be unable to unload material in these conditions, as a result a delay would occur.

Figure 3. Vulnerabilities Grid

	Sources																					
	Human Factors								Environmental Factors			Construction & Operation Factors							Financial Factors			
							Contractual Error															
Events	Incomplete Drawi	Ineffective Project	Untrained Worker	Untrained Engine	Error in Preparatio	Challenging Clien	Poorly Written	Issues with S	Unknown Site Co	Natural Disasters	Bad Weather - Ra	Equipment Failure	Unsuitable Wareh	Electrical Power S	Trucks only havin	Material/Labor Sh	Damage or Theft	Safety Hazards	Unexpected Incre	Bankruptcy of Pro	Unexpected Emer	Unexpected Incre
Applying Incorrect/Insufficient Project Plan	✓	✓	✓																			
Poor Structure Resilience	✓			✓	✓							✓										
Subcontractors Suing our Company		✓				✓	✓	✓								✓		✓	✓	✓		✓
Delays in the Project	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Damaged Material		✓	✓	✓	✓				✓	✓	✓	✓	✓									
Damaged Infrastructure		✓	✓	✓	✓				✓	✓	✓	✓	✓				✓					
Employee Lawsuits						✓	✓	✓			✓					✓		✓		✓		✓
Civil Lawsuits						✓	✓	✓		✓	✓							✓				
Unexpected Overspending	✓	✓	✓	✓	✓				✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	
Delays in Unloading Material									✓	✓	✓	✓		✓	✓		✓					
Problems with Contractors		✓																✓	✓	✓		✓

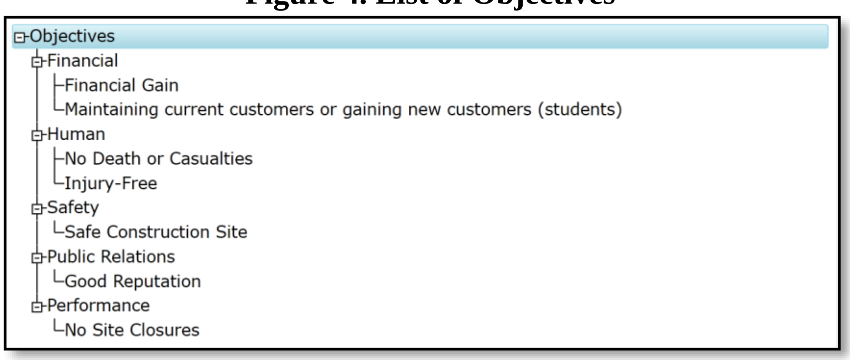
2.4 Objectives:

The next step in the risk identification process was to identify the objectives that would define the overall performance of the project given the consequences from the events. These objectives were then inputted into Riskion to map the consequences of events on the objectives, as shown in Table 3 and Figure 4.

Table 3

Objectives	**Objective Definitions**
Financial	
Financial Gain	The aim is to have financial gain, consequences of our risk events may result in loss of money/decrease in financial value of the building being constructed. This needs to be avoided so we this project becomes profitable.
Maintain current customers or gain new customers (students)	With a new gymnasium that would attract new customers or keep our current customers happy. We want to reduce the consequences of any delay in the execution of the project, which may lead to potential loss of our primary customers - GWU administration and the students of GWU.
Human	
No Death or Casualties	During the construction process, there is no room for fatalities resulting from accidents due to lack of safety measures on construction sites.
Injury-Free	Injuries resulting from accidents due to lack of safety measures on construction sites to be avoided as best as possible.
Safety	
Safe Construction Site	Maintain a safe environment under which the construction process can be carried out.
Public Relations	
Good Reputation	GWU already has a very high reputation. The aim is to maintain high standards and a good reputation. GWU will have a bad reputation if we have our students in danger or construct a sports complex that is sub-par in terms of meeting quality guidelines. As long as the consequences of the risk events are controlled, we can maintain a good reputation.
Performance	
No Site Closure	Due to the delay in the project or delays resulting from lawsuits, injuries to employees, lack of funds or any other environmental, financial or human hindrances, the project may come to a standstill. This needs to be avoided so that there are no roadblocks to the overall performance.

Figure 4. List of Objectives



2.5 Consequences Grid - Consequences of the Events on the Objectives

Once the sources, risk events and objectives were identified, the consequences grid was used as a tool to map the consequences of events on the objectives, as shown in Figure 5.

For example, the following events: ‘Poor Structure Resilience’, ‘Damaged Material’, ‘Damaged Infrastructure’ would all contribute to the outcome of the following objective, ‘Injury-Free’. If the resilience of the building is poor or the overall infrastructure is damaged, it may lead to potential accidents at the construction site, which would result in an injury.

Figure 5. Consequences Grid

	Objectives/Consequences						
	Financial		Human		Safety	Public Relations	Performance
Events	Financial Gain	Maintaining curren	No Death or Casu	Injury-Free	Safe Construction	Good Reputation	No Site Closures
Applying Incorrect/Insufficient Project Plan	✓	✓				✓	✓
Poor Structure Resilience	✓	✓	✓	✓	✓	✓	✓
Subcontractors Suing our Company	✓					✓	✓
Delays in the Project	✓	✓				✓	✓
Damaged Material	✓		✓	✓	✓		✓
Damaged Infrastructure	✓		✓	✓	✓		✓
Employee Lawsuits	✓	✓				✓	✓
Civil Lawsuits	✓	✓				✓	✓
Unexpected Overspending	✓					✓	✓
Delays in Unloading Material							✓
Problems with Contractors	✓					✓	✓

3. Risk Measurements and Judgements

3.1 Identification of Measurement Methods

Once all the possible sources, events and objectives were identified and mapped for this construction project, measurement methods were then introduced to evaluate the likelihood of each possibility. We selected measurement methods for the likelihood of events and the impact of events. Within the likelihood of events, measurement methods were appointed to the likelihood of sources and the vulnerability of the events to the sources. Within the impact of events, measurement methods were appointed to the priority objectives and the consequences of events on the objectives.

Likelihood of Events - Measurement Methods for Likelihood of Sources and Vulnerability of Events to the Sources

The rating scale measurement type was selected to measure the likelihood of the human factors, environmental factors, construction and operation factors and financial factors of sources and the vulnerability of events to the sources. The wide likelihood rating scale was selected to allow more variety to determine the likelihood of each source, as seen in Figure 6 and to determine the vulnerability of the occurrence of an event to the source, as seen in Figure 7. If the likelihood of the source was extremely low, extremely high, average or a rating in between these standard scales of measurement, the rating scale considered all intensity levels giving more options to be selected.

Figure 6. Measurement Methods for the Likelihood of Sources

Measure Likelihood	Measurement Type	Measurement Scale or Given Likelihood
Sources		
Human Factors	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Incomplete Drawings and Poorly Defined Scope		
Ineffective Project Management		
Untrained Workers/Employees		
Untrained Engineer Designers		
Error in Preparation of Material		
Challenging Clients		
Contractual Errors	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Poorly Written Contracts		
Issues with Subcontractors and Suppliers		
Environmental Factors	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Unknown Site Conditions		
Natural Disasters		
Bad Weather - Rain, Extreme Heat		
Construction & Operation Factors	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Equipment Failure		
Unsuitable Warehouses		
Electrical Power Shortages		
Trucks only having permits to be used at certain times of the day		
Material/Labor Shortages		
Damage or Theft of Equipment and Tools		
Safety Hazards		
Financial Factors	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Unexpected Increases in Material/Labor Costs		
Bankruptcy of Project Partners		
Unexpected Emergency Costs		
Unexpected Increases in Insurance Costs		

Figure 7. Measurement Methods for the Vulnerability of Events to the Sources

Measure Event Likelihoods	Measurement Type Default: Rating Scale	Measurement Scale or Given Likelihood
Sources		
Human Factors		
Incomplete Drawings and Poorly Defined Scope	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Ineffective Project Management	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Untrained Workers/Employees	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Untrained Engineer Designers	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Error in Preparation of Material	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Challenging Clients	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Contractual Errors		
Poorly Written Contracts	Rating Scale	MID LIKELIHOOD RATING SCALE
Issues with Subcontractors and Suppliers	Rating Scale	MID LIKELIHOOD RATING SCALE
Environmental Factors		
Unknown Site Conditions	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Natural Disasters	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Bad Weather - Rain, Extreme Heat	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Construction & Operation Factors		
Equipment Failure	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Unsuitable Warehouses	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Electrical Power Shortages	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Trucks only having permits to be used at certain times of the day	Rating Scale	HIGH LIKELIHOOD RATING SCALE
Material/Labor Shortages	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Damage or Theft of Equipment and Tools	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Safety Hazards	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Financial Factors		
Unexpected Increases in Material/Labor Costs	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Bankruptcy of Project Partners	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Unexpected Emergency Costs	Rating Scale	WIDE LIKELIHOOD RATING SCALE
Unexpected Increases in Insurance Costs	Rating Scale	WIDE LIKELIHOOD RATING SCALE

Consequences of Events - Measurement Methods for Priority of Objectives and Consequences of Events on the Objectives

Pairwise Comparisons - This method was used to analyze the objectives in pairs to determine whether they were significantly different or similar to each other. The comparison of each pair was also done to see which of each factor was preferred/more consequential or whether or not the two factors were identical. This measurement type was selected to measure priority of the objectives, as seen in Figure 8 and it was selected to measure the intensity of the consequence of each event on the objectives, as seen in Figure 9.

Figure 8. Measurement Methods for the Priority of Objectives

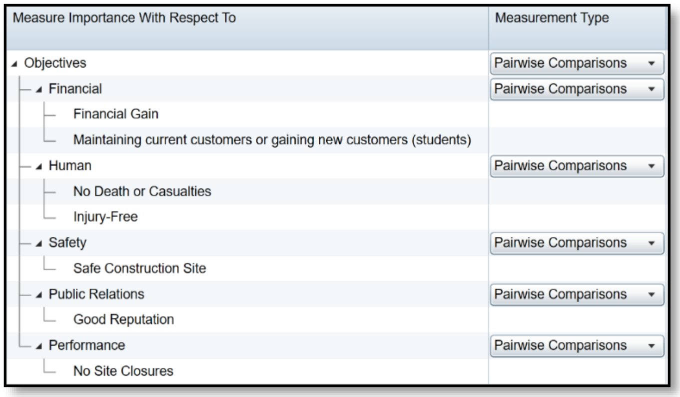
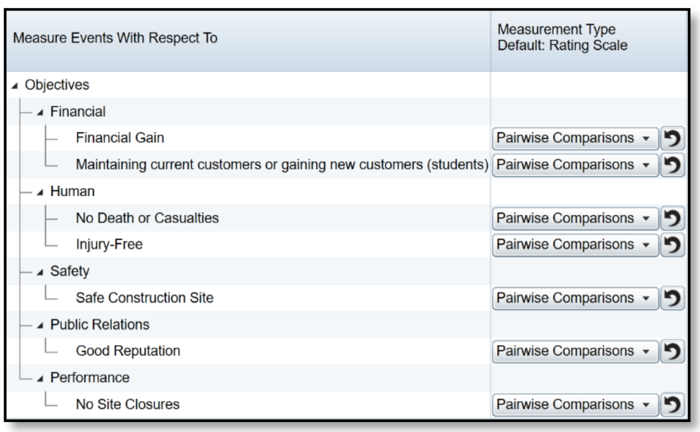


Figure 9. Measurement Methods for the Consequences of Events on the Objectives



3.2 Participants: Their Roles and Judgments

In order to optimize the measurement concept, participants in the construction company were selected to make judgements on sources, risk events and objectives based on their functional expertise, as seen in Table 4.

Table 4

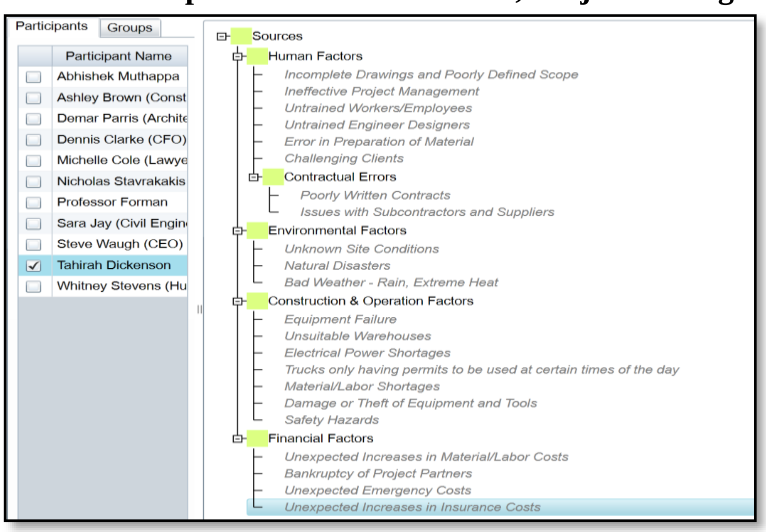
Name	Role	Email Address	Role Description
Steve Waugh	CEO	steve.waugh@gmail.com	Head of the organization, the final decision maker who oversees the entire company
Ashley Brown	Construction Manager	ashley.brown@gmail.com	Manages the construction team and coordinates and oversees all aspects of the building process

Demar Parris	Architect	demar.parris@gmail.com	Produces detailed designs and plans for the new sports complex
Sara Jay	Civil Engineer	sara.jay@gmail.com	Plan, design and oversee the construction of the construction and maintenance of the building
Dennis Clarke	CFO	dennis.clarke@gmail.com	Manages the financial planning, budgeting and forecasting for the project
Michelle Cole	Lawyer	michelle.cole@gmail.com	Drafts the contract, vets the clauses in the contract and represents GWU in legal matter
Whitney Stevens	HR Manager	whitney.stevens@gmail.com	Handles, controls and directs the human resource related policies for GWU
Tahirah Dickenson	Project Manager	tahirah.dickenson@gmail.com	Responsible for overseeing, managing, budgeting and documents all aspects of this project
Abhishek Muthappa	Project Manager	abhishek.muthappa@gmail.com	Responsible for overseeing, managing, budgeting and documents all aspects of this project

Each participant was given specific source categories to evaluate based on the measurement methods selected. On Riskion, there is an option to customize each role to place judgements on specific categories that are more in-line with their skill-set.

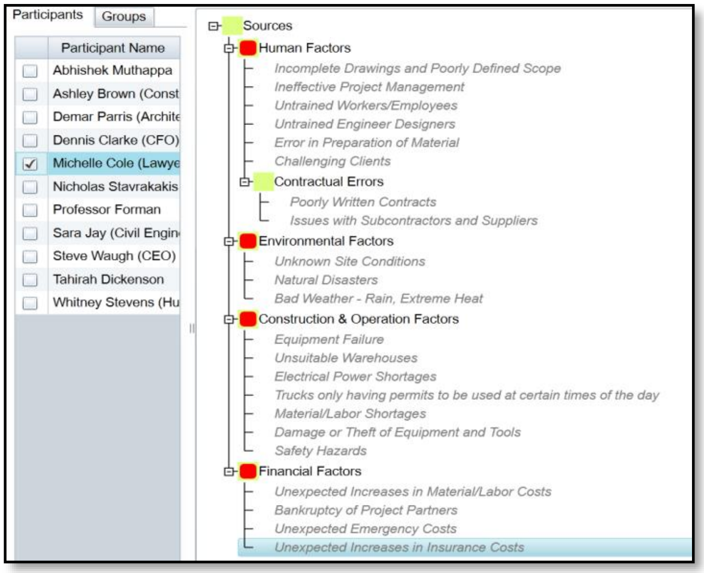
As shown in Figure 10, Tahirah Dickenson, the Project Manager for the construction company was allowed to evaluate all the categories of sources since she will have an overall concept of all the functions of the project.

Figure 10. Participant Role for Sources
Example - Tahirah Dickenson, Project Manager



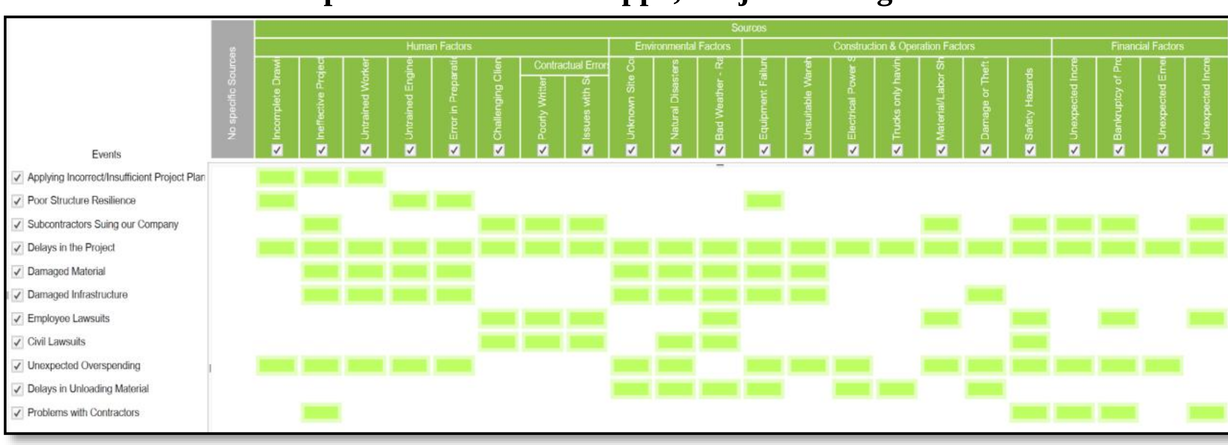
As shown in Figure 11, Michelle Cole, the Lawyer for the construction company was only allowed to evaluate the contractual errors in the Human factor sources as this was more in-line with her law expertise.

Figure 11. Participant Role for Sources Example - Michelle Cole, Lawyer



As shown in Figure 12, Abhishek Muthappa, the Project Manager for the construction company was allowed to evaluate all the categories of events given the sources, since he will have an overall concept of all the functions of the project.

Figure 12. Participant Role for Events Example - Abhishek Muthappa, Project Manager

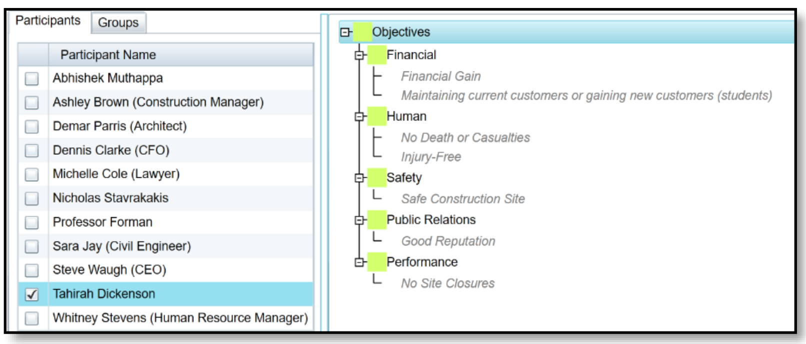


As shown in Figure 13, Michelle Cole, the Lawyer for the construction company was only allowed to evaluate the events that involved lawsuits, given the contractual error sources as this was more in-line with her law expertise.

Figure 13. Participant Role for Events
Example - Michelle Cole, Lawyer

As shown in Figure 14, Tahirah Dickenson, the Project Manager for the construction company was allowed to evaluate all the categories of objectives since she will have an overall concept of all the functions of the project.

Figure 14. Participant Role for Objectives
Example - Tahirah Dickenson, Project Manager



As shown in Figure 15, Abhishek Muthappa, the Project Manager for the construction company was allowed to evaluate all the categories of events that may have had a consequence on the objectives, since he will have an overall concept of all the functions of the project.

Figure 15. Participant Role for Consequences of Events on Objectives
Example - Abhishek Muthappa, Project Manager

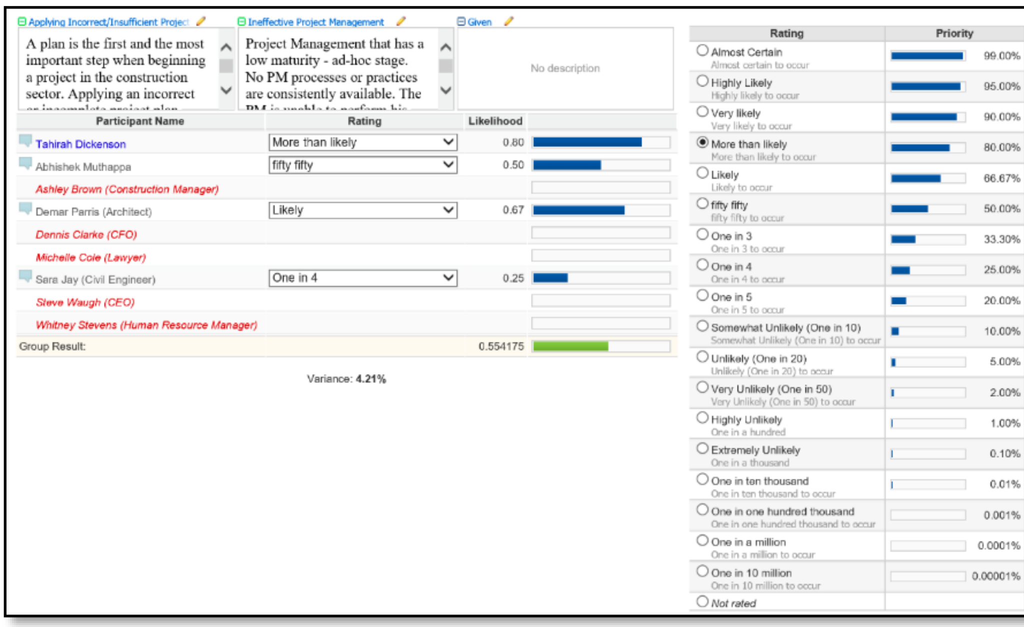
3.3 Risk Judgement/Measurement Examples

Rating Scale - Wide Likelihood Rating Scale

Rating the likelihood of source, ‘Ineffective Project Management’ given Human factors

There were five participants allowed to make judgements on this source. Based on their area of expertise, they rated the likelihood of the occurrence of the source, ‘Ineffective Project Management’. As stated previously, the wide likelihood rating scale allowed a wide variety of measurement rating from 0.00001% to 99%. Once all five participants rated this source, the result showed the likelihood of ‘Ineffective Project Management’ to be 55.4%, as shown in Figure 16.

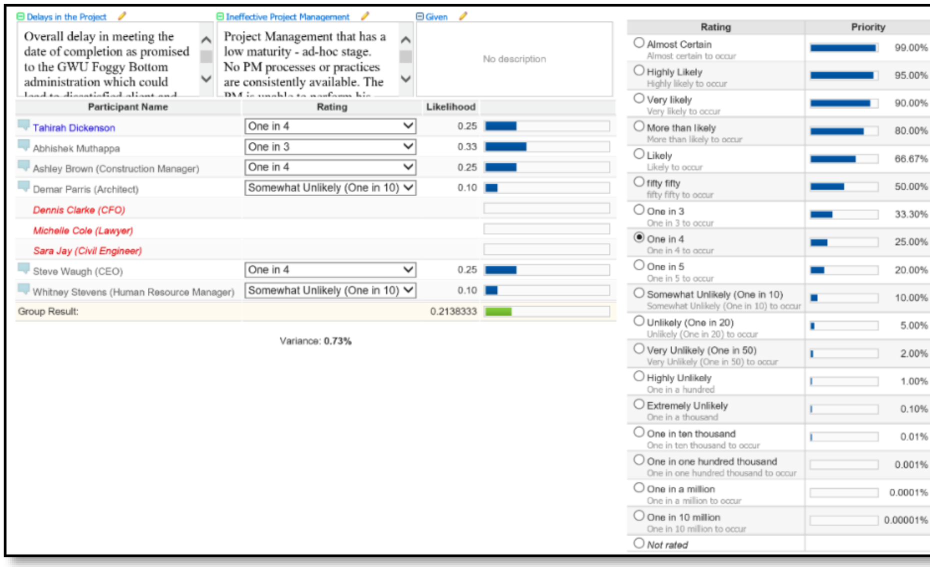
Figure 16. The Likelihood of source, ‘Ineffective Project Management’ given Human Factors



Rating the vulnerability of event, ‘Delays in the Project’ to source, ‘Ineffective Project Management’

There were also five participants allowed to make judgements about the vulnerability of this event, ‘Delays in the Project’ to the source, ‘Ineffective Project Management’. Based on their area of expertise, their result of their ratings was 21%, as shown in Figure 17

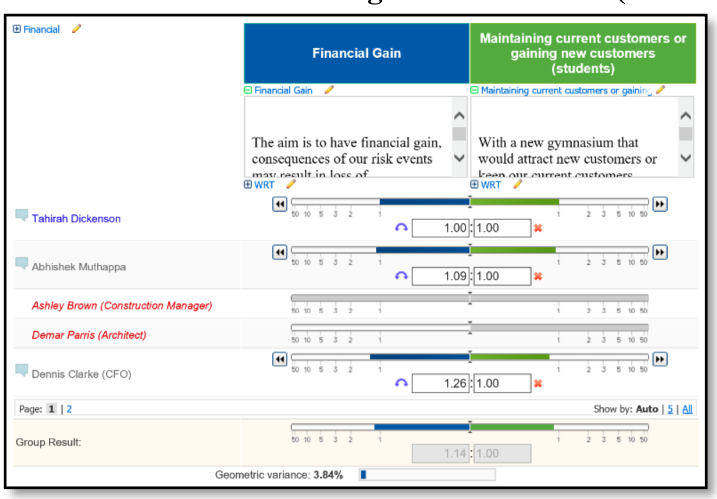
Figure 17. Vulnerability of event, ‘Delays in the Project’ to Source, ‘Ineffective Project Management’



Pairwise Comparison - Comparing the importance of objectives, ‘Financial Gain to ‘Maintaining Current Customers or Gaining New Customers (Students)’

This comparison is performed to gauge the more important objective of the two objectives ‘Financial Gain or ‘Maintaining Current Customers or Gaining New Customers (Students)’. Based on the judgements of the three participants and their corresponding scales of judgements, we can see that ‘Financial Gain’ is the more important objective of the two with a geometric variance of 3.84%, as shown in Figure 18.

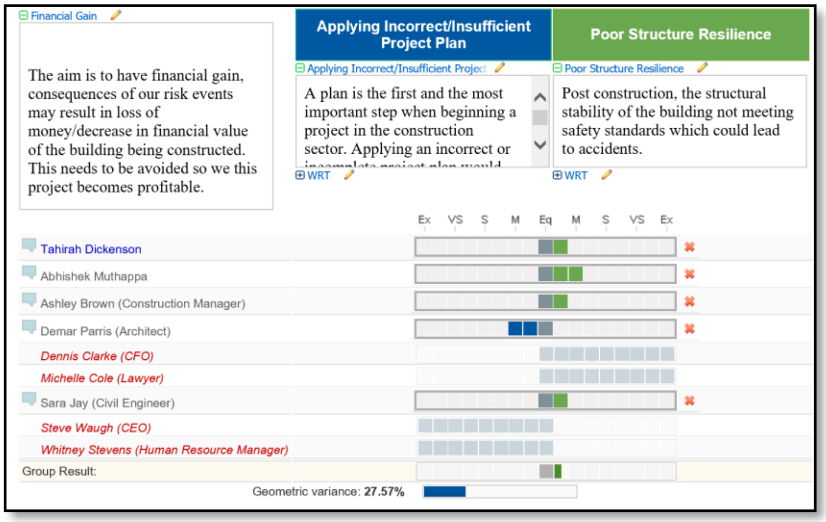
Figure 18. Comparison of the Importance of Objectives, ‘Financial Gain to ‘Maintaining Current Customers or Gaining New Customers (Students)’



Comparing the consequence of two events, 'Applying Incorrect/Insufficient Project Plan' to 'Poor Structure Resilience' with respect to objective, 'Financial Gain'

This comparison is performed to gauge the more important and consequential event of the two events 'Applying Incorrect/Insufficient Project Plan' and 'Poor structure Resilience' and its consequence on the objective 'Financial Gain'. Based on the judgements of the five participants and their corresponding scales of judgements, we can see that 'Poor structure resilience' is more consequential and it has a geometric variance of 27.57%, as shown in Figure 19.

Figure 19. Comparison of the Consequence of Two Events, 'Applying Incorrect/Insufficient Project Plan' to 'Poor Structure Resilience' with respect to Objective, 'Financial Gain'



4. Synthesized Results of Risk Measurements

After the evaluations were completed, we examined the measurement results and synthesized them to make sure any outliers or surprises are eliminated.

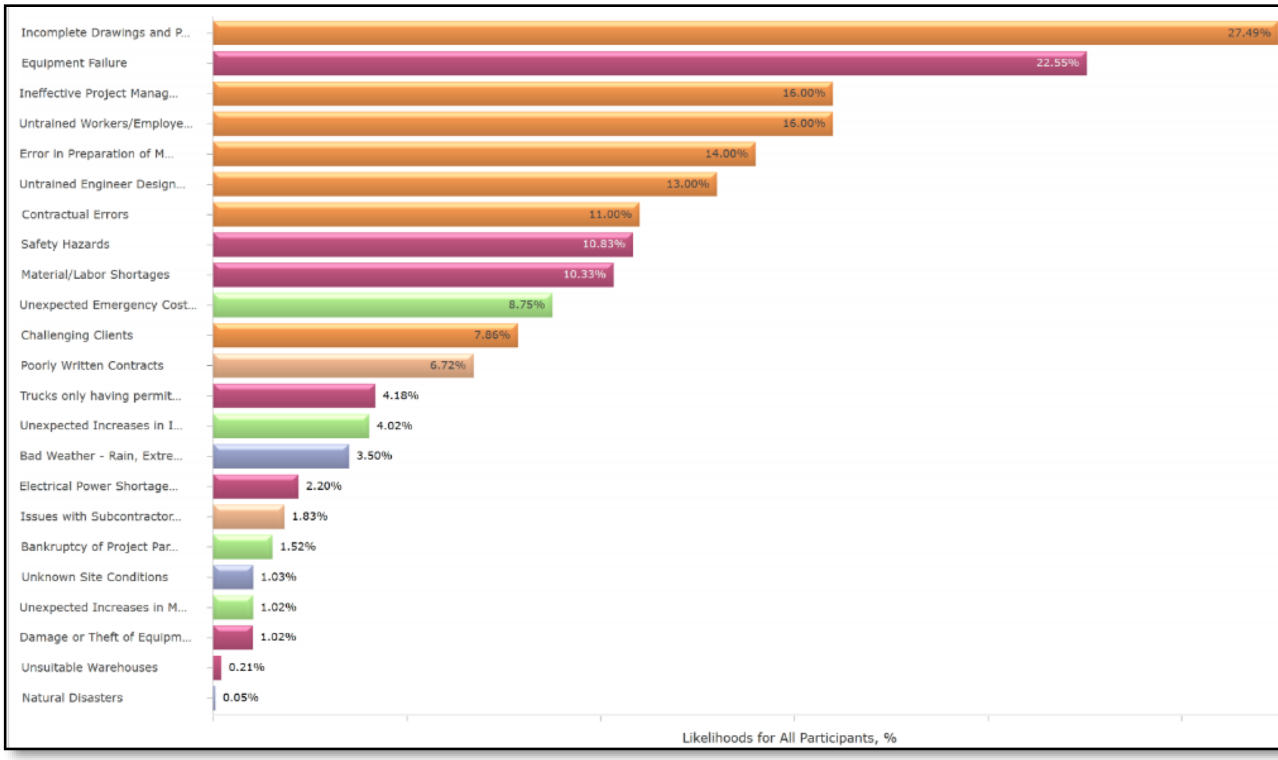
4.1 Likelihood of Sources

As shown in Figure 20, the normalized synthesized results after the evaluations showed that 'Incomplete Drawings and Poorly Defined Scopes' and 'Equipment Failure' had the highest likelihood of occurrence with 27.49% and 22.55% respectively. They are significantly higher than the other sources and this depicts that these two sources are most likely to occur. In addition, 'Natural Disasters' had the lowest likelihood of occurrence with 0.05%.

Based on Figure 20, the majority of the sources with higher likelihoods are represented by the orange bars on the bar chart. The orange bars are represented by the Human factor sources, which means the most likely source category is the Human factor source. As previously mentioned, the most likely source occurrence is 'Incomplete Drawings and Poorly Defined Scopes', which is represented by an orange bar which is a part of the Human factor source group. A few other sources from this group can be seen at the top of the chart, ranging from 'Ineffective Project Management' at 16% to 'Contractual Errors' at 11%.

The second most likely source category is the Construction and Operation sources, which is represented by the dark red bars. Also, as previously mentioned, the second most likely source is 'Equipment Failure', which is represented by a dark red bar which is a part of the Construction and Operation source group. A few other sources from this group can be found ranked beneath the Human factor sources such as 'Safety Hazards' at 10.83% and 'Material/Labor Shortages' at 10.33%.

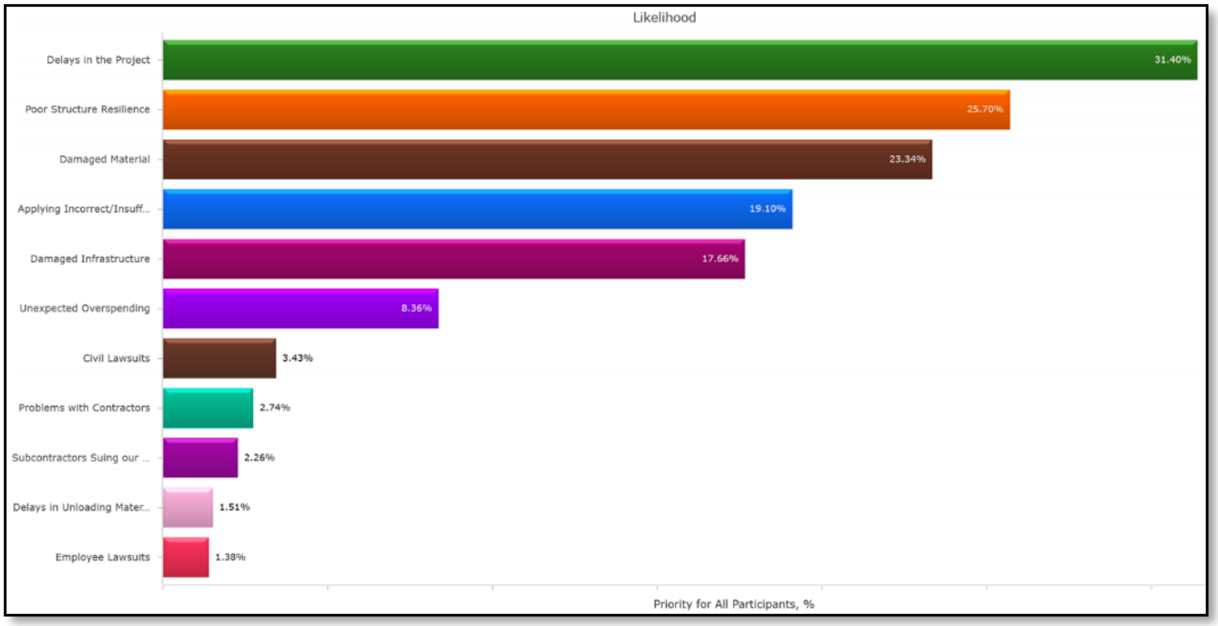
Figure 20. Likelihood of Sources with respect to all Sources



4.2 Vulnerability of Events to Sources

As shown in Figure 21, the normalized synthesized results after the evaluations showed that 'Delays in the Project' and 'Poor Structure Resilience' were the most vulnerable events with 31.40% and 25.70% respectively. They are significantly more vulnerable than the other events and this depicts that these two events are most likely to occur based on the evaluated sources. Also, 'Employee Lawsuits' was the least vulnerable event with 1.38%.

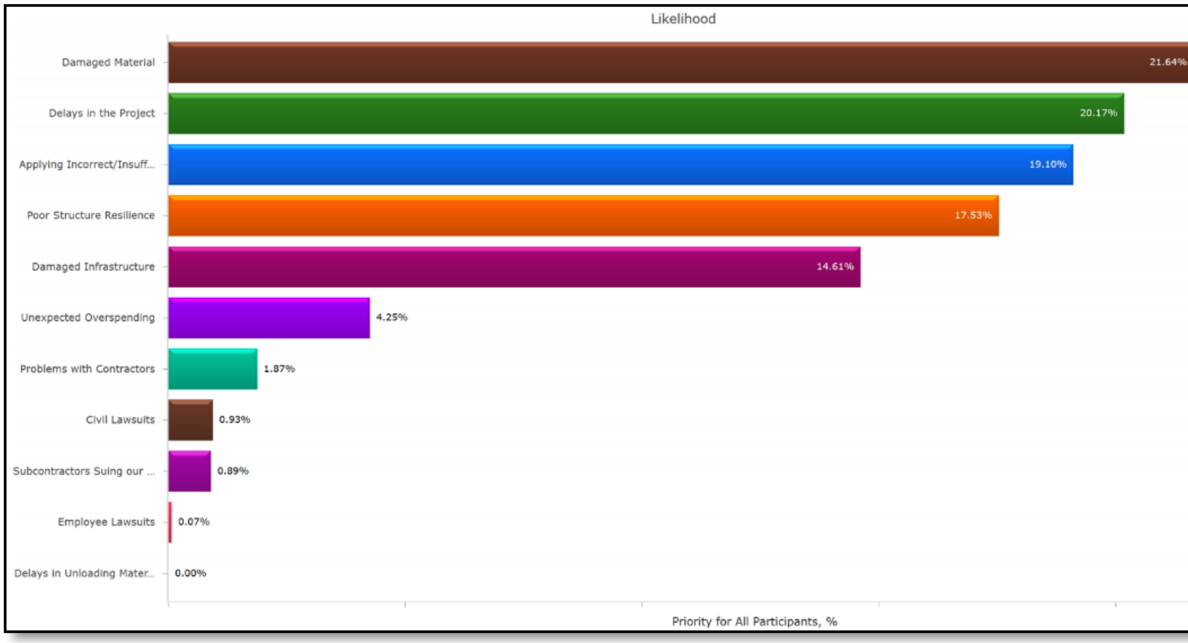
Figure 21. Bar Chart of Vulnerability of the Events to all Sources



As shown in Figure 22, amongst the sources relating to Human factors, the normalized synthesized results after the evaluations showed that ‘Damaged Material’ and ‘Delays in the project’ with 21.64% and 20.17% respectively were the events that were the most vulnerable due to the likelihood of sources under Human factors. These two events were also among the top three most vulnerable events to all sources. The event that was relatively least vulnerable to the Human factor sources was ‘Delays in unloading material’ with 0.00%. This event showed no vulnerability because it was not mapped to these Human factor sources on the vulnerabilities grid as these Human factor sources had no contribution to the occurrence of this event.

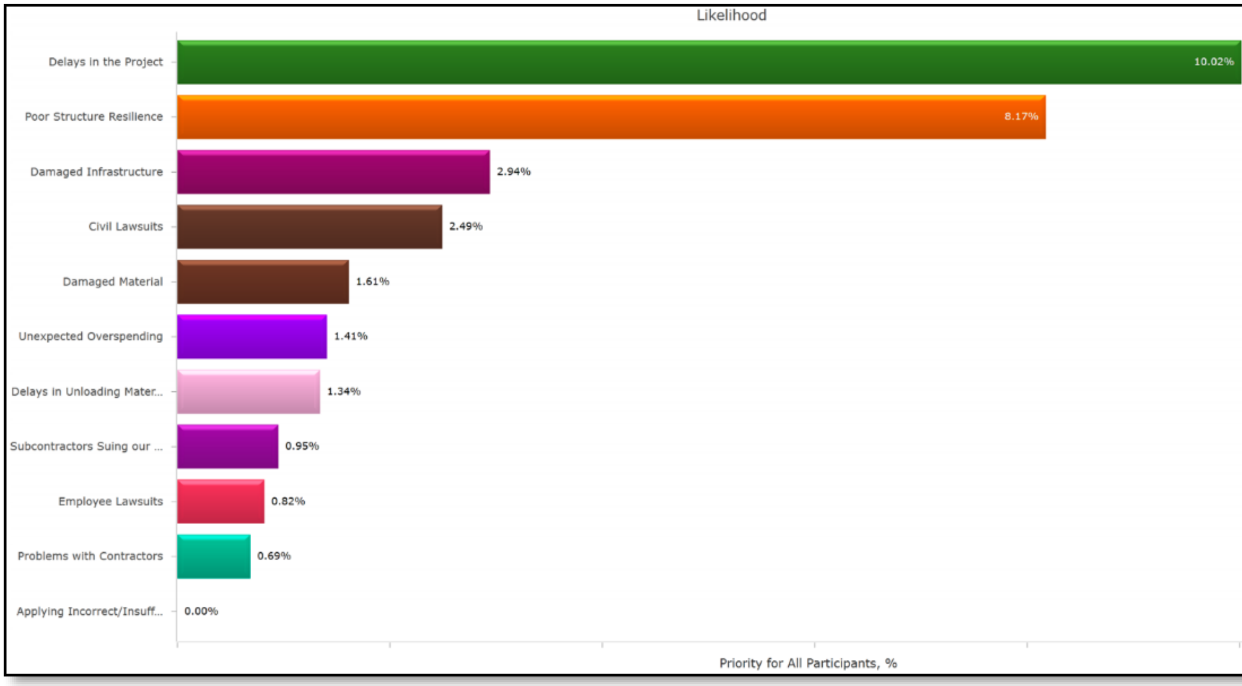
The Human factor sources accounted for the majority of the occurrence of the next set of most vulnerable events. The most vulnerable events to Human factor sources were ‘Damaged Materials’ at 21.64%, ‘Delays in the Project’ at 20.17%, ‘Applying Incorrect/Insufficient Project Plan’ at 19.10% and ‘Poor Structure Resilience’ at 17.53%.

Figure 22. Bar Chart of Vulnerability of the Events to Human Factor Sources



As shown in Figure 23, amongst the sources relating to Construction and Operation factors, the normalized synthesized results after the evaluations showed that 'Delays in the Project' and 'Poor Structure Resilience' with 10.02% and 8.17% respectively were the events that were the most vulnerable due to the likelihood of sources under Construction and Operation factors. The event that was relatively least vulnerable was 'Applying Incorrect/insufficient project plan' with 0.00%. This event showed no vulnerability because it was not mapped to these Construction and Operation factor sources on the vulnerabilities grid as these Construction and Operation factor sources had no contribution to the occurrence of this event.

Figure 23. Bar Chart of Vulnerability of the Events to Construction and Operation Factor Sources



As seen in Figure 22 and Figure 23, the three events most vulnerable events with respect to all the sources, 'Delays in the Project', 'Poor Structure Resilience' and 'Damaged Material' were most vulnerable to Human factor sources and Construction and Operation factor sources.

The makeup of the top three most vulnerable events:

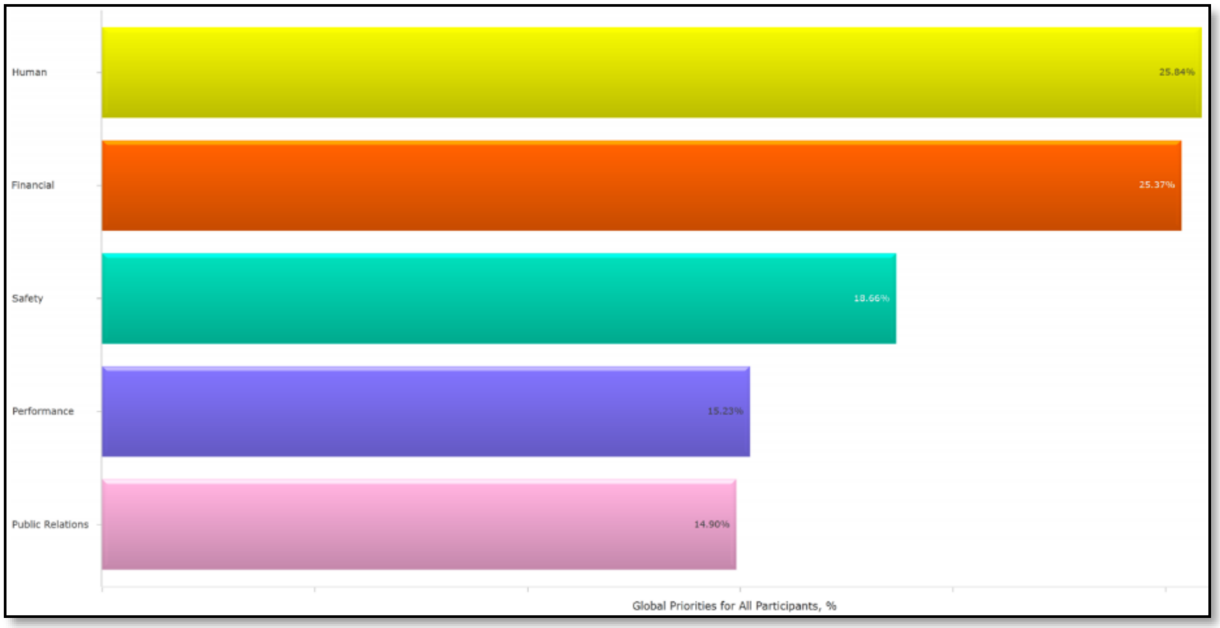
- Delays in the project: Human factor sources (20.17%), Construction and Operation factor sources (10.02%), Financial factors (1.16%) and Environmental factors (0.04%)
- Poor Structure Resilience: Human factor sources (17.53%), Construction and Operation factor sources (8.17%).
- Damaged Material: Human factor sources (21.64%), Construction and Operation factor sources (1.61%) and Environmental factors (0.09%)

4.3 Priority of Objectives

As shown in Figure 24, the normalized synthesized results after the evaluations showed that Human factor and Financial factor objectives were the highest priority of objectives with 25.84% and 25.37% respectively. They are significantly higher than the other objectives, this reflects their importance to the company, and they would prefer if the consequences of risk events on these categories of objective would stay the lowest. If the consequences of the events on the Human factor objectives - 'No Death or Casualties', 'Injury-Free' and Financial objectives - 'Financial

Gain', 'Maintaining Current Customers or Gaining New Customers' are high, the company would incur the biggest loss. Safety, Performance and Public Relations were also ranked at 18.66%, 15.23% and 14.90% respectively. These objectives are also important to the company. If the consequences of events on these objectives are high, the company would also incur a loss, however the loss would be relatively low in relation to the Human factor and Financial factor objectives.

Figure 24. Priorities of Objectives

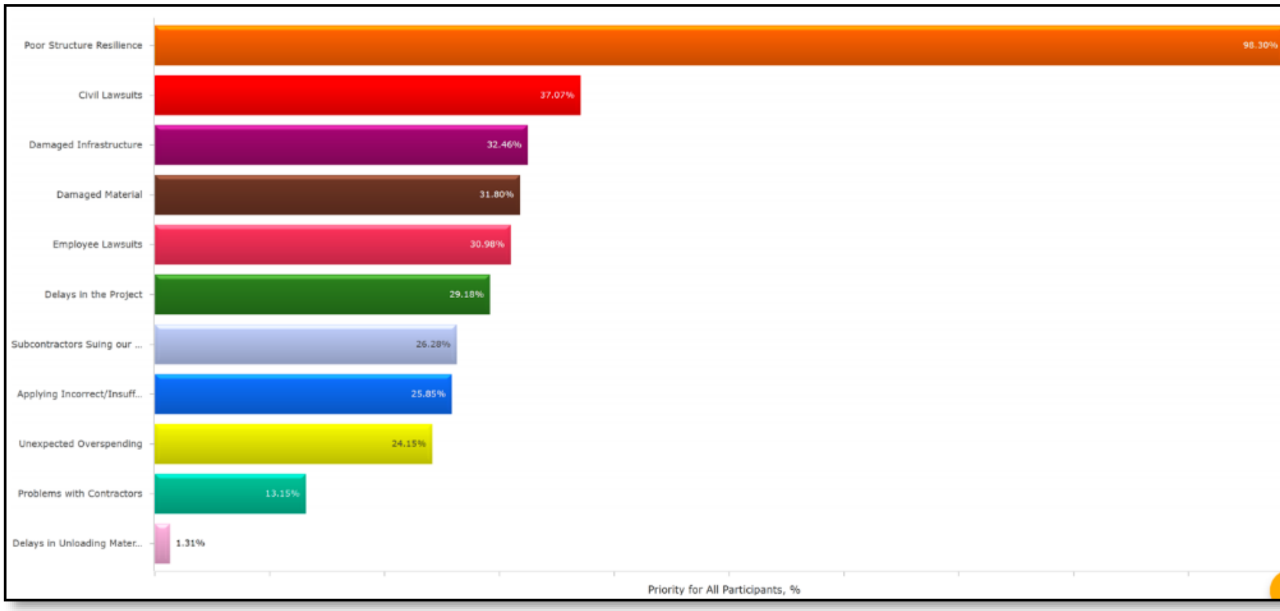


4.4 Consequences of Events on Objectives

Figure 25 shows the event 'Poor Structure Resilience' being the most consequential event to the objectives at 98.30%. This means that if the building's structure resilience is poor, it will result in the most negative consequence on objectives under all categories that is Human, Financial, Safety, Performance and Public Relations. This is in line with the overall objective of the management of the University, which is the financial and physical stability of the property.

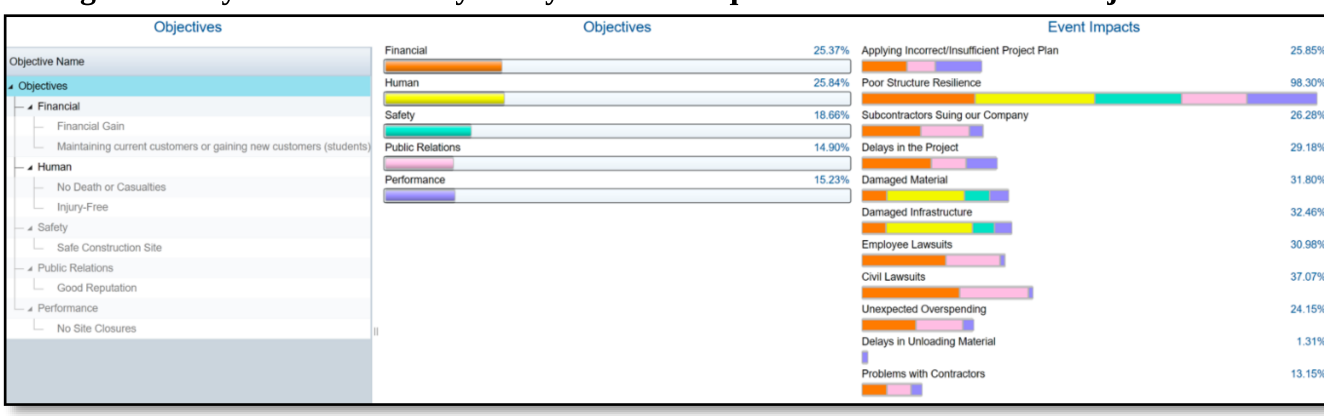
A poorly constructed building may threaten the safety of the students or may cause a huge financial loss, which is why Human and Financial objectives are the most important objectives. It contributes in a relatively lower scale of consequence to the other objectives as well. 'Delay in Unloading Material' had 1.31% consequence, which was the lowest on all the objectives.

Figure 25. Bar Chart of Consequences of Events on Objectives



The Dynamic Sensitivity Chart of the consequences of events on objectives can be seen in Figure 26. This visual representation shows the percentage combination of all the events and the consequences this specific combination has on each objective category. This chart allows you to make changes to the percentages of the objectives and allows you to see what would happen to the events if the percentage of the objectives would increase or decrease. The total percentage of the objectives has to remain at 100%, therefore as you increase or decrease one category, the other categories will change accordingly. It gives you an idea of what events to focus on decreasing so the consequence on the objectives would decrease as well.

Figure 26. Dynamic Sensitivity Analysis of Consequences of Events on the Objectives



5. Risk without Controls

Risk is uncertain loss. Although the assessment of risk is mostly subjective, a corresponding financial value can be ascertained. Since we already know, the measurement and ratio of the likelihood of the sources, the vulnerability of events, the priority of objectives and the consequences of risk events on the objectives, we can associate them with a financial value. A monetary value for the objective, 'Financial Gain' was given at $4,000,000.00. From this, monetary values of all other objectives were computed in proportion to their priorities. The value of the overall project was also computed based on the value of the 'Financial Gain' objective. Computed results account for potential results applicable which makes the results exaggerated due to double counting, while simulated values are calculated using the Monte Carlo simulation method. It is a technique used to understand the impact of risk and uncertainty, especially when we are using judgements to arrive at results. You cannot know with certainty what the actual value will be, but based on historical data, or judgements of expertise in the field, you can make an estimate. This method is used to correct the flaw of averages since we have to consider multiple sources, events and their probability of occurrence and their impact, multiple trials can be made through the Monte Carlo simulation method, which calculates the values hundreds or thousands of times, with using a different value each time, which provides results that are more accurate.

The value of our project is $29,636,075.00 and the computed and simulated financial values of the impact of risk events without controls are shown in Figure 27 and Figure 28 respectively. The total computed value of the evaluated risks is $16,955,918 and the total simulated value of the evaluated risks is $11,275,673.

Figure 27. Computed Overall Likelihood, Impacts, and Risks without Controls

No. ▲	Event	All Participants Likelihood Computed	All Participants Impact, $ Computed	All Participants Risk, $ Computed
[01]	Applying Incorrect/Insufficient Project Plan	19.10%	7,660,914	1,463,284
[02]	Poor Structure Resilience	25.70%	29,132,809	7,488,097
[03]	Subcontractors Suing our Company	2.26%	7,787,739	176,381
[04]	Delays in the Project	31.40%	8,648,191	2,715,320
[05]	Damaged Material	23.34%	9,425,556	2,200,335
[06]	Damaged Infrastructure	17.66%	9,619,039	1,698,627
[07]	Employee Lawsuits	1.38%	9,181,870	126,956
[08]	Civil Lawsuits	3.43%	10,985,635	376,339
[09]	Unexpected Overspending	8.36%	7,158,130	598,144
[12]	Delays in Unloading Material	1.51%	388,490	5,859
[15]	Problems with Contractors	2.74%	3,896,131	106,571
			Total Risk	Computed $16,955,918

Figure 28. Simulated Overall Likelihood, Impacts, and Risks without Controls

No. ▲	Event	Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
		All Participants		
[01]	Applying Incorrect/Insufficient Project Plan	18.16%	5,936,648	1,078,095
[02]	Poor Structure Resilience	23.10%	21,214,138	4,900,466
[03]	Subcontractors Suing our Company	2.36%	5,431,651	128,186
[04]	Delays in the Project	27.55%	6,395,162	1,761,867
[05]	Damaged Material	21.62%	6,615,133	1,430,191
[06]	Damaged Infrastructure	16.77%	6,707,936	1,124,920
[07]	Employee Lawsuits	1.28%	5,851,773	74,902
[08]	Civil Lawsuits	3.29%	7,849,119	258,236
[09]	Unexpected Overspending	8.49%	5,108,957	433,750
[12]	Delays in Unloading Material	1.49%	325,535	4,850
[15]	Problems with Contractors	2.85%	2,814,233	80,205
			Total Risk	Simulated $11,275,673

As seen in Figure 29, the loss exceedance curve represents the probabilities that the loss will exceed the corresponding financial value. For example, there is 61.57% probability that the loss will exceed $7.11 million. There is a 39.46% probability that the loss will exceed $11.26 million. The average loss without controls is valued at $11.28 million, however the closest point that could be mapped on the graph was $11.26 million, therefore the approximated probability of $11.28 million will be a little over 39.46%, as seen in Figure 30.

Figure 29. Loss Exceedance Curve for Risks without Controls

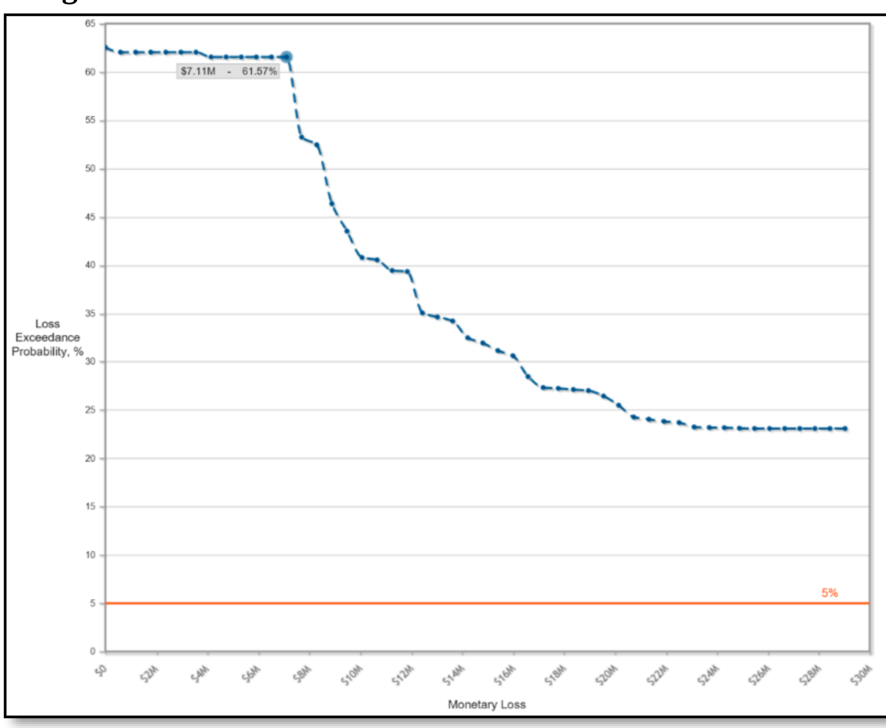
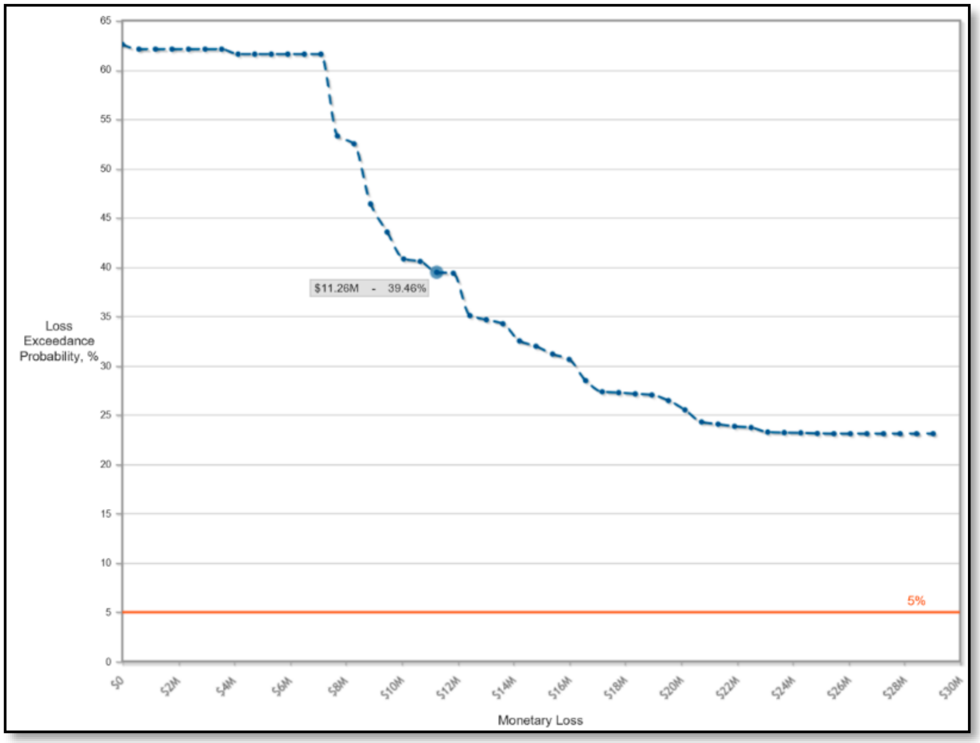


Figure 30. Loss Exceedance Curve for Risks without Controls at Average Loss Value $11.26 - $11.28M



As seen in Figure 31, the bow-tie diagram represents the risk value based on the likelihood of sources, vulnerability of the events to the sources, priority of the objectives and consequences of the risk events on the objectives. All factors that define the value of a particular risk event are considered to arrive at the financial value of a risk. In this case, we can see that the risk event 'Poor Structure Resilience' has a risk value of $ 4.9 million. This is a serious risk given that the total value of the project is $29,636,075.00.

Figure 31. Bow-Tie Diagram for Risks without Controls

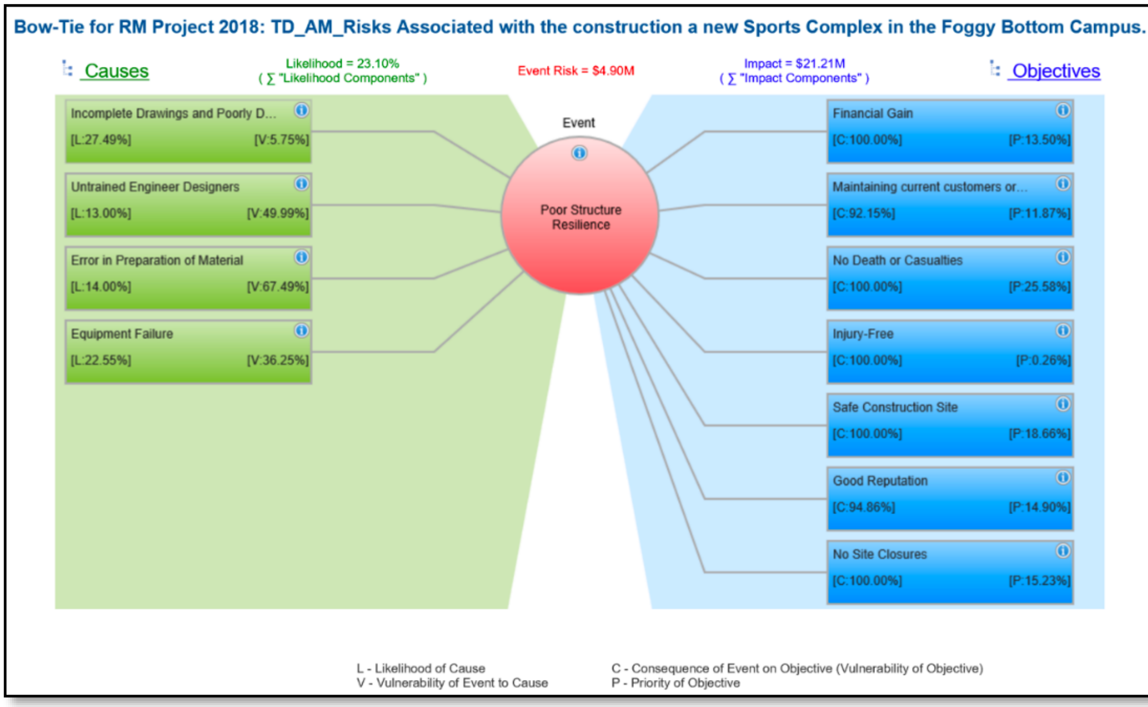


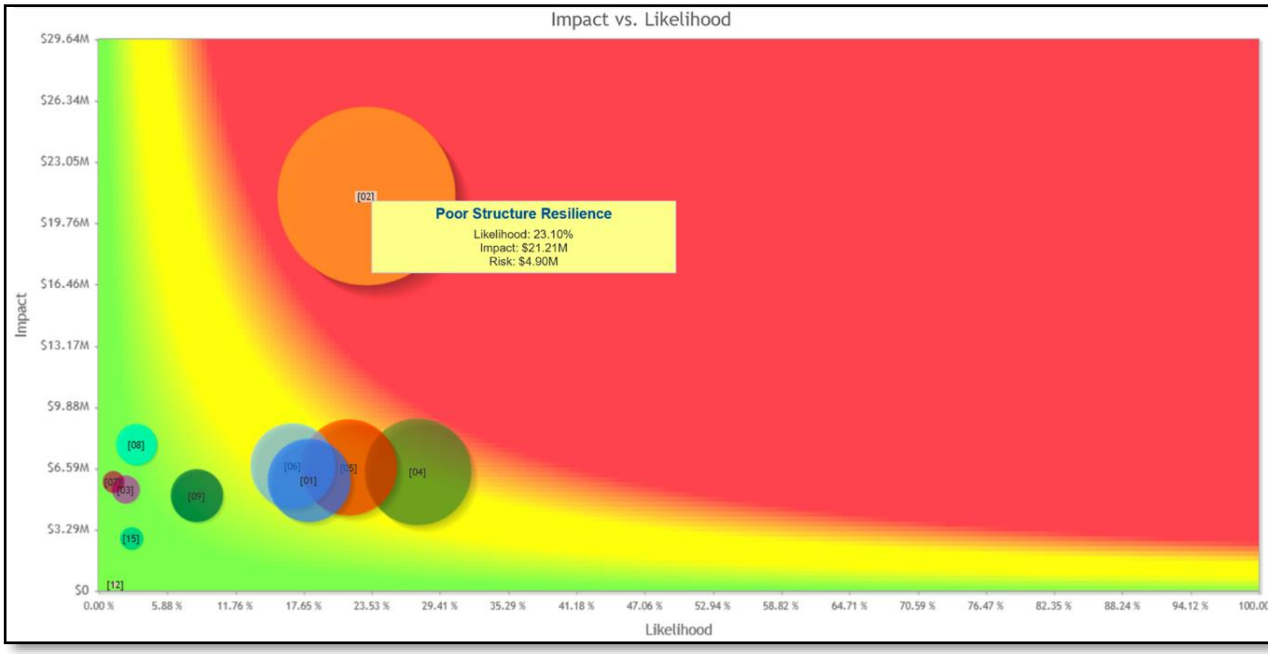
Table 5. Explanation of Bow-Tie Diagram Symbols

Symbol	Explanation
L	Likelihood of the causes/source
V	Vulnerability of the event to the source. How likely is this event to occur given that this source occurs?
Sum Product	Sum of all the (L * V)
C	Consequences of Events on objectives
P	Priority of objective. How important is it compared to the others?
Sum Product	Sum of all the (C * P)
Risk	Likelihood * Impact (We were able to convert to $)

As seen in Figure 32, the risk map is a data visualization tool used to represent the likelihood (%) vs. impact of risk events ($) as per the monetary value attached to the corresponding risk. It assists our company in identifying and prioritizing the risk based on bubble size and their location on the heat map. The larger the bubble, the higher the likelihood and greater the impact on the construction project.

There are three different regions: green - under 2%, yellow - 2% to 7%, and red - over 7%. As seen in Figure 32, the most impactful risk event is 'Poor Structure Resilience'. This is clear as it has the largest bubble and it is the only risk event in the red region. It has a 23.10% likelihood of occurrence and a $21.21 million impact; as a result, this event poses the greatest risk to the project of $4.90 million. As seen previously throughout the project, 'Poor Structure Resilience' was the most consequential risk event as it has the greatest consequence on the highest priority objectives, human objects - No Death or Casualties and Injury-Free, which if this risk occurred, it would result in the greatest loss.

Figure 32. Risk Heat Map without Controls



5.1 Risk Tolerance for Risk without Controls

Based on the total value of our project, we have to assess what level of risk the company is willing to tolerate. Based on a simulated value of $11,275,673 for the risks and the total value of the project is $29,636,075.00, we can say that the current value of risk is worth 38% of the total project. Risk tolerance is the level of risk our construction company is willing to take. Based on the discussion with the stakeholders and management team, the threshold for the tolerance level was set at 10% of the total cost of the project, which amounts to $2,963,607.50.

6. Implementation of Risk Controls

As previously discussed, there are various sources, events and objectives in this project. We are now at the stage where we can identify the magnitude of our risks and before deciding whether this project should proceed with these risks, we have to identify whether or not these risks can be mitigated with the use of controls. Controls were applied to the likelihood of sources, vulnerability of events and consequences of the events on the objectives.

6.1 Controls for Sources

As part of the risk mitigation process, controls for sources of risk were identified as factors that could lessen the likelihood of the occurrence of sources, which in return, would lessen the impact they have on the vulnerable risk events. These controls listed below were inputted into Riskion as the starting factors of the risk mitigation process, and mapped to any source it could potentially mitigate, as seen in Figure 33.

- Project Management Advancement Training
- Automated Material Inventory Forecasting Systems
- Robust Weather Tracking
- Employee Training and Development Sessions
- Emergency Spending Funds
- Regular Inspections
- Employee Maintaining Mandatory Checklist of Processes
- Backup Power Generator

Figure 33. Controls for Likelihood of Sources

Control Name	Human Factors							
	Incomplete Drawings and Poorly Defined Scope	Ineffective Project Management	Untrained Workers/Employees	Untrained Engineer Designers	Error in Preparation of Material	Challenging Clients	Contractual Errors	
							Poorly Written Contracts	Issues with Subcontractors and Suppliers
1. Project Management Advancement Training	☑	☑	☐	☐	☐	☐	☐	☐
2. Automated Material Inventory Forecasting Systems	☐	☐	☐	☐	☐	☐	☐	☐
3. Robust Weather Tracking	☐	☐	☐	☐	☐	☐	☐	☐
4. Employee Training and Development Sessions	☑	☑	☑	☑	☑	☐	☑	☑
5. Emergency Spending Funds	☐	☐	☐	☐	☐	☐	☐	☐
6. Regular Inspections	☑	☑	☑	☑	☑	☐	☐	☐
7. Employee Maintaining Mandatory Checklist of Processes	☑	☑	☑	☑	☑	☐	☐	☐
8. Backup Power Generator	☐	☐	☐	☐	☐	☐	☐	☐

6.2 Controls for Vulnerability of Events

The next step in the risk mitigation process was to identify controls for risk events. These were identified as factors that could lessen the vulnerability of risk events to sources, which in return, would lessen the consequences of events on the objectives. These controls listed below were inputted into Riskion as the next factors of the risk mitigation process, and mapped to any event it could potentially mitigate, as seen in Figure 34.

- Project Management Advancement Training
- Building & Equipment Quality Assessments
- Periodic Employee Surveys
- Emphasis on Building Customer and Supplier Relationships

Figure 34. Controls for Vulnerabilities of Event 'Poor Structure Resilience' to Sources

Control Name	No specific Cause	Human Factors				
		Incomplete Drawings and Poorly Defined Scope	Ineffective Project Management	Untrained Workers/Employees	Untrained Engineer Designers	Error in Preparation of Material
9. Project Management Advancement Training		☑			☐	☐
10. Building & Equipment Quality Assessments		☐			☑	☑
11. Periodic Employee Surveys		☐			☑	☐
12. Emphasis on Building Customer and Supplier Relationships		☐			☐	☐

6.3 Controls for Consequences of Events on Objectives

The next step was to identify controls for the consequences of events on the objectives. These were identified as factors that could lessen the impact of the consequences of risk events on the project's objectives. These controls listed below were inputted into Riskion as the next factors of the risk mitigation process, and mapped to any consequence it could potentially mitigate, as seen in Figure 35.

- Experienced Public Relations Team
- Full Insurance Coverage
- Personal Protective Equipment and Clothing (PPE)
- Isolation - Safety/Caution Signs on the Work Site

Figure 35. Controls to mitigate consequences of event 'Poor Structure Resilience' to Objectives

Control Name	Objectives						
	Financial		Human		Safety	Public Relations	Performance
	Financial Gain	Maintaining current customers or gaining new customers (students)	No Death or Casualties	Injury-Free	Safe Construction Site	Good Reputation	No Site Closures
13. Experienced Public Relations Team	☐	☐	☐	☐	☐	☑	☐
14. Full Insurance Coverage	☑	☐	☐	☐	☐	☐	☐
15. Personal Protective Equipment and Clothing (PPE)	☐	☐	☑	☑	☑	☐	☐
16. Isolation- Saftey/Caution Signs on the Work Site	☐	☐	☑	☑	☑	☐	☐

6.4 Risk Control Measurements

Once all the risk controls were labeled and mapped, an approximated cost was also identified for each control, as seen in Figure 36.

Figure 36. Controls for Construction of a new Sports Complex Project

Select Controls

Total Risk*: $11,275,673
Risk With Selected Controls*: $11,275,673 (Δ: $0)
Risk With All Controls: $326,793 (Δ: $10,948,880)

Selected controls: 0
Cost Of Selected Controls: $0 (unfunded: $4,757,000)
Total Cost Of All Controls: $4,757,000

Simulations Settings
Number of trials: 10000 Seed: 792 ☑ Keep Seed

☑ Show Monetary Values (Value of Enterprise: $29,636,075,Value of "Financial Gain": $4,000,000)

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	☐	Project Management Advancement Training	Cause		250000	2		☐	☐
02	☐	Automated Material Inventory Forecasting Systems	Cause		270000	1		☐	☐
03	☐	Robust Weather Tracking	Cause		5000	3		☐	☐
04	☐	Employee Training and Development Sessions	Cause		200000	11		☐	☐
05	☐	Emergency Spending Funds	Cause		3000000	4		☐	☐
06	☐	Regular Inspections	Cause		150000	7		☐	☐
07	☐	Employee Maintaining Mandatory Checklist of Processes	Cause		20000	7		☐	☐
08	☐	Backup Power Generator	Cause		12000	1		☐	☐
09	☐	Project Management Advancement Training	Vulnerability		80000	11		☐	☐
10	☐	Building & Equipment Quality Assessments	Vulnerability		30000	12		☐	☐
11	☐	Periodic Employee Surveys	Vulnerability		30000	8		☐	☐
12	☐	Emphasis on Building Customer and Supplier Relationships	Vulnerability		100000	8		☐	☐
13	☐	Experienced Public Relations Team	Consequence		250000	8		☐	☐
14	☐	Full Insurance Coverage	Consequence		300000	1		☐	☐
15	☐	Personal Protective Equipment and Clothing (PPE)	Consequence		50000	9		☐	☐
16	☐	Isolation- Saftey/Caution Signs on the Work Site	Consequence		10000	10		☐	☐

The measurement method selected was the direct measurement, which is a method that measures the effectiveness of the control on a scale of 0 to 1, the closer the result is to 1, is the more effective the control as seen in Figures 37 – 39.

Figure 37. Measurement Methods for Controls for Sources

Control Name	Sources												
	Human Factors								Environmental Factors				
							Contractual Errors						
	Incomplete Drawings and Poorly Defined Scope	Ineffective Project Management	Untrained Workers/Employees	Untrained Engineer Designers	Error in Preparation of Material	Challenging Clients	Poorly Written Contracts	Issues with Subcontractors and Suppliers	Unknown Site Conditions	Natural Disasters	Bad Weather - Rain, Extreme Heat	Equipment Failure	Unsuitable Warehouses
1. Project Management Advancement Training	Direct	Direct											
2. Automated Material Inventory Forecasting Systems													
3. Robust Weather Tracking									Direct	Direct	Direct		
4. Employee Training and Development Sessions	Direct	Direct	Direct	Direct	Direct		Direct	Direct				Direct	
5. Emergency Spending Funds													
6. Regular Inspections	Direct	Direct	Direct	Direct	Direct								Direct
7. Employee Maintaining Mandatory Checklist of Processes	Direct	Direct	Direct	Direct	Direct								
8. Backup Power Generator													

Figure 38. Measurement Methods for Controls for Vulnerability of Events

Control Name	No specific Cause	Human Factors				
		Incomplete Drawings and Poorly Defined Scope	Ineffective Project Management	Untrained Workers/Employees	Untrained Engineer Designers	Error in Preparation of Material
9. Project Management Advancement Training		Direct				
10. Building & Equipment Quality Assessments					Direct	Direct
11. Periodic Employee Surveys					Direct	
12. Emphasis on Building Customer and Supplier Relationships						

Figure 39. Measurement Methods for Controls for Consequences of Events on Objectives

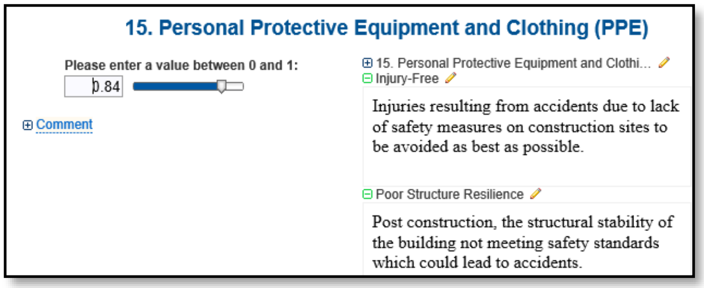
Control Name	Objectives						
	Financial		Human		Safety	Public Relations	Performance
	Financial Gain	Maintaining current customers or gaining new customers (students)	No Death or Casualties	Injury-Free	Safe Construction Site	Good Reputation	No Site Closures
13. Experienced Public Relations Team						Direct	
14. Full Insurance Coverage	Direct						
15. Personal Protective Equipment and Clothing (PPE)			Direct	Direct	Direct		
16. Isolation- Saftey/Caution Signs on the Work Site			Direct	Direct	Direct		

In order to optimize the measurement concept, various participants in the construction company would have been selected to make judgements on the controls based on their functional expertise, however since this is a hypothetical project, we have chosen one participant to make judgements on the controls, as seen in Figure 40. Using the direct measurement method, a value between 0 and 1 was to be chosen, to indicate the effectiveness of the control, Personal Protective Equipment and Clothing (PPE), as seen in Figure 41. The effectiveness of this control was given an 84% chance of reducing the impact of the event, 'Poor Structure Resilience' on Objective, 'Injury-Free'.

Figure 40. Participant Role for the Controls

Control Name	☐ Abhishek Muthappa (abhishekm25@g	☐ Ashley Brown (Construction Manager) (ashley.brown@g	☐ Demar Parris (Architect) (demar.parris@gr	☐ Dennis Clarke (CFO) (dennis.clarke@g	☐ Professor Forman (forman@gwu.ed	☐ Michelle Cole (Lawyer) (michelle.cole@y	☐ Nicholas Stavrakakis (nstavrakakis@gv	☐ Sara Jay (Civil Engineer) (sara.jay@gmail.c	☐ Steve Waugh (CEO) (steve.waugh@gr	☑ Tahirah Dickenson (tdickenson@gwu
Controls for Causes										
☐ Project Management Advancement Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Automated Material Inventory Forecasting Systems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Robust Weather Tracking	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Employee Training and Development Sessions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Emergency Spending Funds	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Regular Inspections	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Employee Maintaining Mandatory Checklist of Processes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Backup Power Generator	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Controls for Events										
☐ Project Management Advancement Training	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Building & Equipment Quality Assessments	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Periodic Employee Surveys	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Emphasis on Building Customer and Supplier Relationships	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
Controls for Consequences										
☐ Experienced Public Relations Team	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Full Insurance Coverage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Personal Protective Equipment and Clothing (PPE)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑
☐ Isolation- Saftey/Caution Signs on the Work Site	☐	☐	☐	☐	☐	☐	☐	☐	☐	☑

Figure 41. Example of Judgement/Measurement of a Control



7. Risk with Controls

After the controls judgements were made and analyzed, assuming we had the budget to apply all the controls, we can see the value of the different risks have substantially reduced, as seen in Figure 42 (computed) and Figure 43 (simulated). The risk reduction is valued at $16,613,604.00, which results in residual risk of $342,314.00 (computed) and $10,948,880.00, which results in residual risk of $326,793.00 (simulated), however we incurred $4,757,000.00 to implement all the controls.

Figure 42 Computed Overall Likelihood, Impacts, and Risks with Controls

No. ▲	Event	All Participants Likelihood Computed	Impact, $ Computed	Risk, $ Computed
[01]	Applying Incorrect/Insufficient Project Plan	0.02%	6,119,260	1,342
[02]	Poor Structure Resilience	0.77%	10,620,367	81,321
[03]	Subcontractors Suing our Company	0.31%	5,021,126	15,534
[04]	Delays in the Project	1.56%	6,868,546	107,267
[05]	Damaged Material	0.98%	3,537,853	34,745
[06]	Damaged Infrastructure	1.02%	3,177,791	32,492
[07]	Employee Lawsuits	0.15%	6,179,968	9,018
[08]	Civil Lawsuits	0.43%	7,363,752	31,993
[09]	Unexpected Overspending	0.52%	4,820,577	24,968
[12]	Delays in Unloading Material	0.99%	128,202	1,273
[15]	Problems with Contractors	0.07%	3,186,963	2,354

# Controls	Cost of Controls	How Selected		Computed
16	$4,757,000	Manually selected	Total Risk	$16,955,918
			Risk Reduction	$16,613,604
			Residual Risk	$342,314

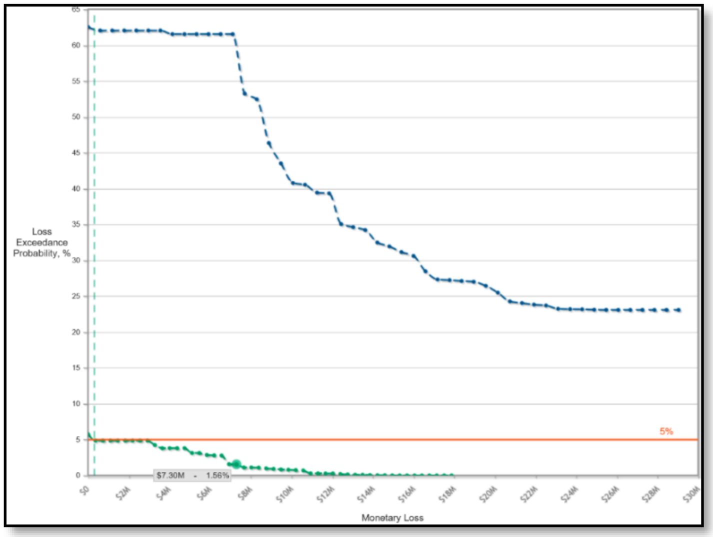
Figure 43. Simulated Overall Likelihood, Impacts, and Risks with Controls

No. ▲	Event	All Participants Likelihood Simulated	Impact, $ Simulated	Risk, $ Simulated
[01]	Applying Incorrect/Insufficient Project Plan	0.02%	5,781,125	1,156
[02]	Poor Structure Resilience	0.69%	9,815,100	67,724
[03]	Subcontractors Suing our Company	0.29%	4,479,425	12,990
[04]	Delays in the Project	1.63%	6,512,023	106,145
[05]	Damaged Material	0.97%	3,160,346	30,655
[06]	Damaged Infrastructure	1.21%	2,848,440	34,466
[07]	Employee Lawsuits	0.12%	5,393,317	6,471
[08]	Civil Lawsuits	0.52%	7,075,616	36,793
[09]	Unexpected Overspending	0.60%	4,560,917	27,365
[12]	Delays in Unloading Material	1.02%	127,209	1,297
[15]	Problems with Contractors	0.06%	2,878,736	1,727

# Controls	Cost of Controls	How Selected		Simulated
16	$4,757,000	Manually selected	Total Risk	$11,275,673
			Risk Reduction	$10,948,880
			Residual Risk	$326,793

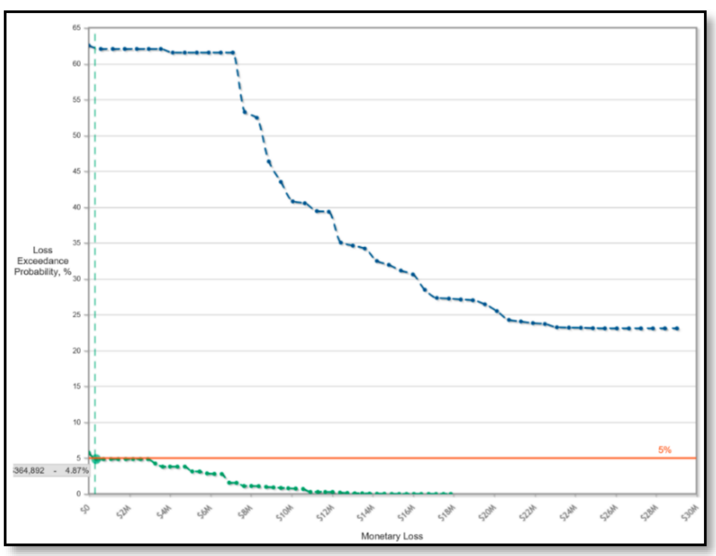
As previously mentioned, the loss exceedance curve reflected that there is 61.57% probability that the loss will exceed $7.11 million without controls. With implementing the controls, there is a 1.56% probability that the loss will exceed $7.30 million with controls, as seen in Figure 44. The probability decreased by 57% with the implementation of controls.

Figure 44. Loss Exceedance Curve with and without Controls



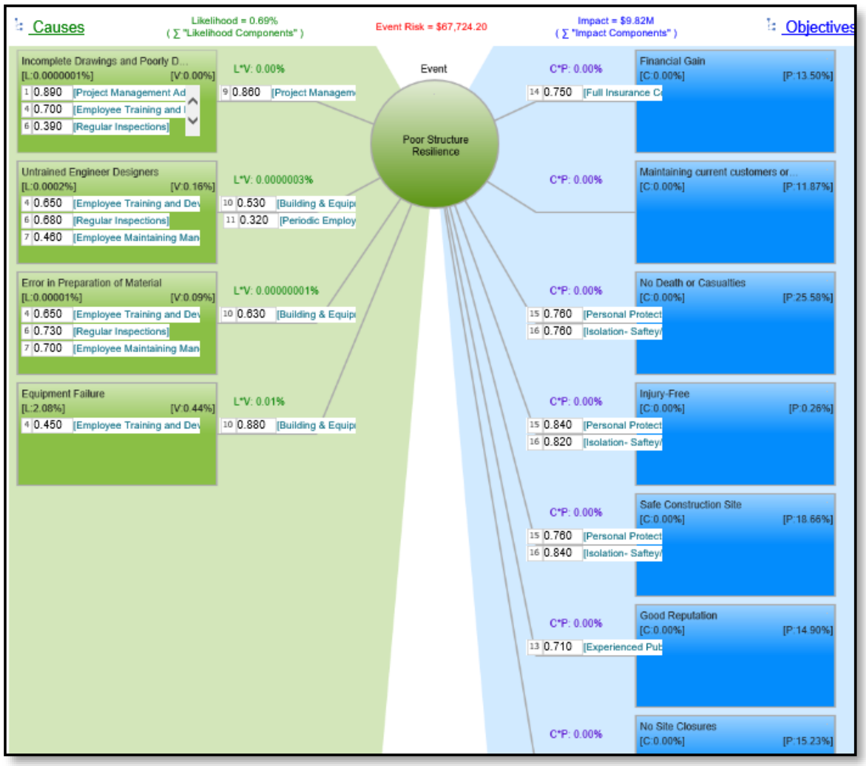
The loss exceedance curve also reflects that there is 5% probability that the loss will exceed $311,593.00 with implementing all the controls; however, the closest point that could be mapped on the graph was $364,892.00 at 4.87%, as seen in Figure 45. This value is well below our risk tolerance level of 10% of the total cost of the project ($2,963,607.50.).

Figure 45. Loss Exceedance Curve with and without Controls – 5% Value at Risk



As previously mentioned, the bow-tie diagram reflects the risk value based on the likelihood of sources, vulnerability of the events to the sources, the priority of the objectives and the consequences of risk events on the objectives. In the Event, ‘Poor Structure Resilience’, it previously had a risk value of $4.9 M without controls. As seen in Figure 46, with implementing the controls, the event ‘Poor Structure Resilience’ now has a risk value of $67,724.20. It is evident that by implementing all sixteen controls, the risk value of this event has decreased significantly by $4,832,275.80

Figure 46. Bow-Tie Diagram for Risks with Controls



As seen in Figure 32, the most impactful risk event was ‘Poor Structure Resilience’. It had a 23.10% likelihood of occurrence and a $21.21 million impact; as a result, this event poses the greatest risk threat to the project of $4.90 million. With the implementation of the controls, all the likelihood of all the events decreased tremendously, specifically, ‘Poor Structure Resilience’ decreased to a 0.69% likelihood and a $9.82 million impact, as a result this event now poses a risk threat to the project of $67,724.20, as seen in Figure 47.

What is also noticeable is that, without the controls, ‘Poor Structure Resilience’ had the largest bubble representing the greatest likelihood and risk. With the controls being applied, Event ‘Delays in the Project’ now has the largest bubble representing the greatest risk of $106,145.99

with a likelihood of 1.63% and an impact of $6.51 million as seen in Figure 48. This shows that the impact is lesser than the impact from the 'Poor Structure Resilience' event; however, the monetary value of this risk is larger. Both events are controlled and will not put the project in danger, this just shows you that with the implementation of controls, some risks are more mitigated than others.

Figure 47. Risk Heat Map with all Controls – Event 'Poor Structure Resilience'

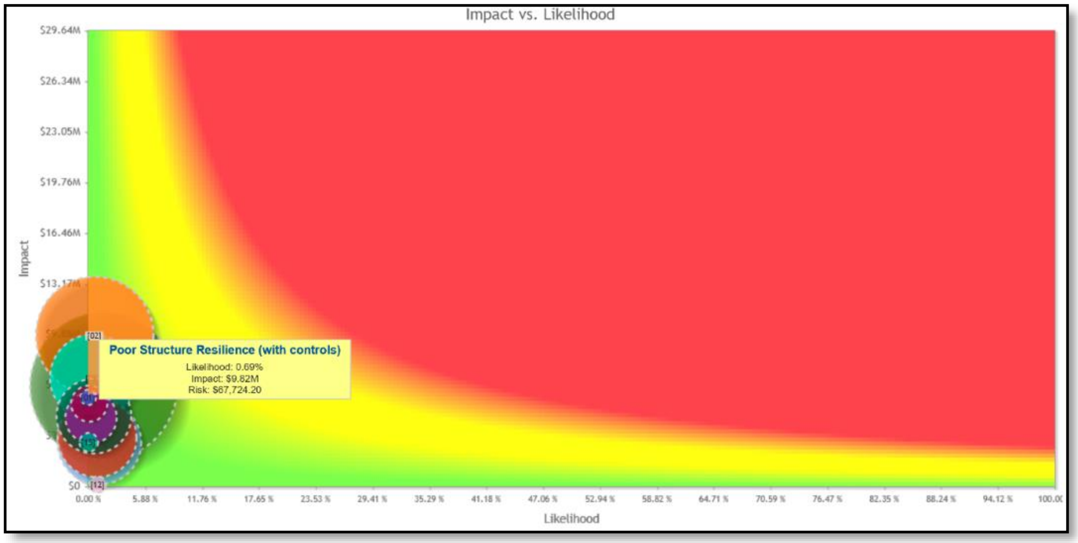
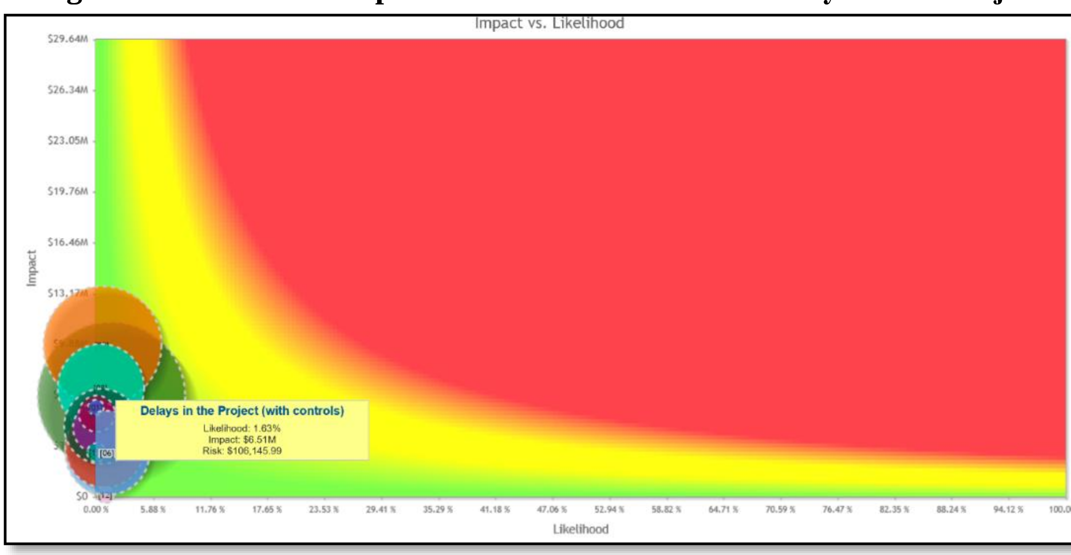


Figure 48. Risk Heat Map with all Controls – Event 'Delays in the Project'



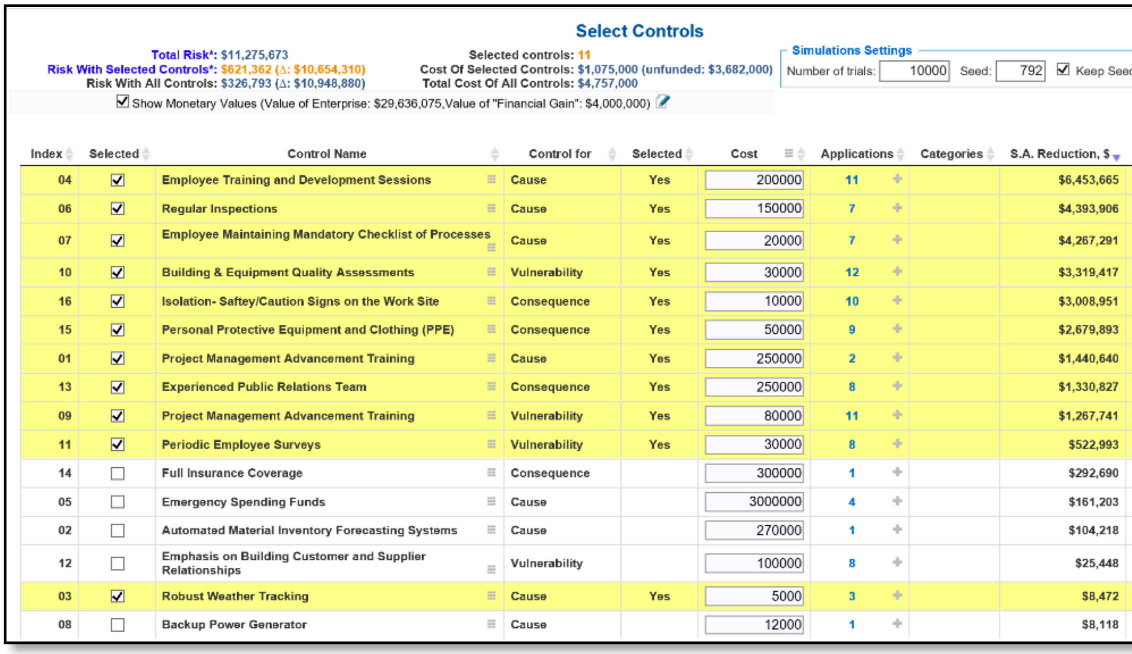
7.1 Manual Selection of Risk Controls

The cost of the project is $29,636,075.00 with the implementation all 16 controls valued at $4,757,000.00, which saves $10,948,880 worth of risk. However, an analysis had to be done to decide which controls were financially feasible. A stand-alone reduction analysis was done to see how much risk would be reduced for a particular control, as seen in Figure 49, in the column to the extreme right. Once the stand-alone reduction analysis was completed, further analysis was done to see whether the cost of the control valued more than the monetary value of risk being mitigated, as seen in Figure 50. In the event that the cost was more than the amount being saved, this would be a loss for our company. From this analysis, controls were manually selected. As seen in Figure 49, ‘Emergency Spending Funds’ costs $3,000,000.00 however its stand-alone reduction value is only $161,203 which means the cost of the control would exceed the actual risk reduction value by $2,838,797.00 which would not be feasible for the project.

In relation to the eleven controls that were selected, they each reduced more than what their cost. Also, as a group, the cost of these controls is $1,075,000.00, while saving $10,654,310.00 while using all 16 controls valued at approximately $3,682,000.00 more, would only save an additional $294,570.00.

The risk reduction is valued at $10,654,310.00, which results in residual risk of $621,362.00, which is well below the risk tolerance of the company.

Figure 49. Manually Selected Controls for Construction of a new Sports Complex Project



Select Controls

Total Risk*: $11,275,673
Risk With Selected Controls*: $621,362 (Δ: $10,654,310)
Risk With All Controls: $326,793 (Δ: $10,948,880)

Selected controls: 11
Cost Of Selected Controls: $1,075,000 (unfunded: $3,682,000)
Total Cost Of All Controls: $4,757,000

Simulations Settings
Number of trials: 10000 Seed: 792 ☑ Keep Seed

☑ Show Monetary Values (Value of Enterprise: $29,636,075,Value of "Financial Gain": $4,000,000)

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	S.A. Reduction, $
04	☑	Employee Training and Development Sessions	Cause	Yes	200000	11		$6,453,665
06	☑	Regular Inspections	Cause	Yes	150000	7		$4,393,906
07	☑	Employee Maintaining Mandatory Checklist of Processes	Cause	Yes	20000	7		$4,267,291
10	☑	Building & Equipment Quality Assessments	Vulnerability	Yes	30000	12		$3,319,417
16	☑	Isolation- Saftey/Caution Signs on the Work Site	Consequence	Yes	10000	10		$3,008,951
15	☑	Personal Protective Equipment and Clothing (PPE)	Consequence	Yes	50000	9		$2,679,893
01	☑	Project Management Advancement Training	Cause	Yes	250000	2		$1,440,640
13	☑	Experienced Public Relations Team	Consequence	Yes	250000	8		$1,330,827
09	☑	Project Management Advancement Training	Vulnerability	Yes	80000	11		$1,267,741
11	☑	Periodic Employee Surveys	Vulnerability	Yes	30000	8		$522,993
14	☐	Full Insurance Coverage	Consequence		300000	1		$292,690
05	☐	Emergency Spending Funds	Cause		3000000	4		$161,203
02	☐	Automated Material Inventory Forecasting Systems	Cause		270000	1		$104,218
12	☐	Emphasis on Building Customer and Supplier Relationships	Vulnerability		100000	8		$25,448
03	☑	Robust Weather Tracking	Cause	Yes	5000	3		$8,472
08	☐	Backup Power Generator	Cause		12000	1		$8,118

Figure 50. Cost vs. Savings - Manually Selected Controls for Construction of a new Sports Complex Project

Control Name	Cost of Control	Applications	Risk with each control	Stand Alone Reduction	Cost vs. Savings
Employee Training and Development Sessions	$200,000.00	11	$4,822,008.00	$6,453,665.00	$6,253,665.00
Employee Maintaining Mandatory Checklist of Processes	$20,000.00	7	$7,008,382.00	$4,267,291.00	$4,247,291.00
Regular Inspections	$150,000.00	7	$6,881,766.00	$4,393,907.00	$4,243,907.00
Building & Equipment Quality Assessments	$30,000.00	12	$7,956,256.00	$3,319,417.00	$3,289,417.00
Isolation- Saftey/Caution Signs on the Work Site	$10,000.00	10	$8,266,722.00	$3,008,951.00	$2,998,951.00
Personal Protective Equipment and Clothing (PPE)	$50,000.00	9	$8,595,780.00	$2,679,893.00	$2,629,893.00
Project Management Advancement Training (Sources)	$250,000.00	2	$9,835,033.00	$1,440,640.00	$1,190,640.00
Project Management Advancement Training (Events)	$80,000.00	11	$10,007,931.00	$1,267,742.00	$1,187,742.00
Experienced Public Relations Team	$250,000.00	8	$9,944,846.00	$1,330,827.00	$1,080,827.00
Periodic Employee Surveys	$30,000.00	8	$10,752,680.00	$522,993.00	$492,993.00
Robust Weather Tracking	$5,000.00	3	$11,267,200.00	$8,473.00	$3,473.00
Backup Power Generator	$12,000.00	1	$11,267,554.00	$8,119.00	-$3,881.00
Full Insurance Coverage	$300,000.00	1	$10,982,982.00	$292,691.00	-$7,309.00
Emphasis on Building Customer and Supplier Relationships	$100,000.00	8	$11,250,224.00	$25,449.00	-$74,551.00
Automated Material Inventory Forecasting Systems	$270,000.00	1	$11,171,455.00	$104,218.00	-$165,782.00
Emergency Spending Funds	$3,000,000.00	4	$11,114,470.00	$161,203.00	-$2,838,797.00
Total Risk with no Controls					
$11,275,673.00					

The loss exceedance curve also reflects that there is 5% probability that the loss will exceed $5.78 million with implementing the eleven manually selected controls; however, the closest point that could be mapped on the graph was $5.84 million at 4.96%, as seen in Figure 51. This value is above our risk tolerance level of 10% of the total cost of the project ($2,963,607.50). However, since 5% is low, one can say the likelihood of this $5.78 million loss is extremely low and should not be a great threat to the company's risk tolerance level and as mentioned previously, the value of risk with the manually selected controls is $621,362.00, which is below the threshold of risk acceptance.

It is also evident that the controls were very effective because as seen in Figure 52, without any controls, there is a 61.57% probability that the loss will exceed $5.93 million. The probability decreased by approximately 56% with the implementation of controls.

Figure 51. Loss Exceedance Curve with and without Manually Selected Controls – 5% Value at Risk

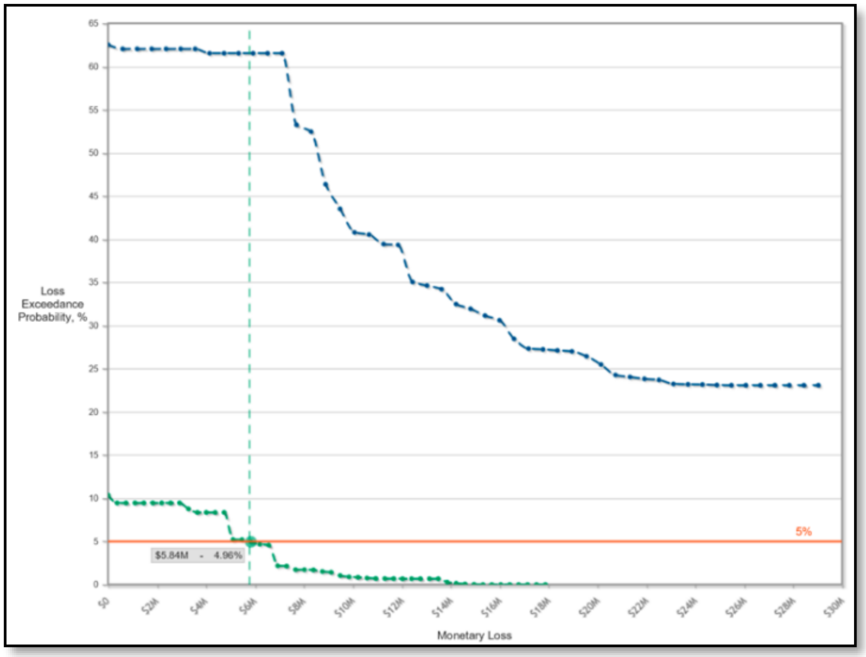
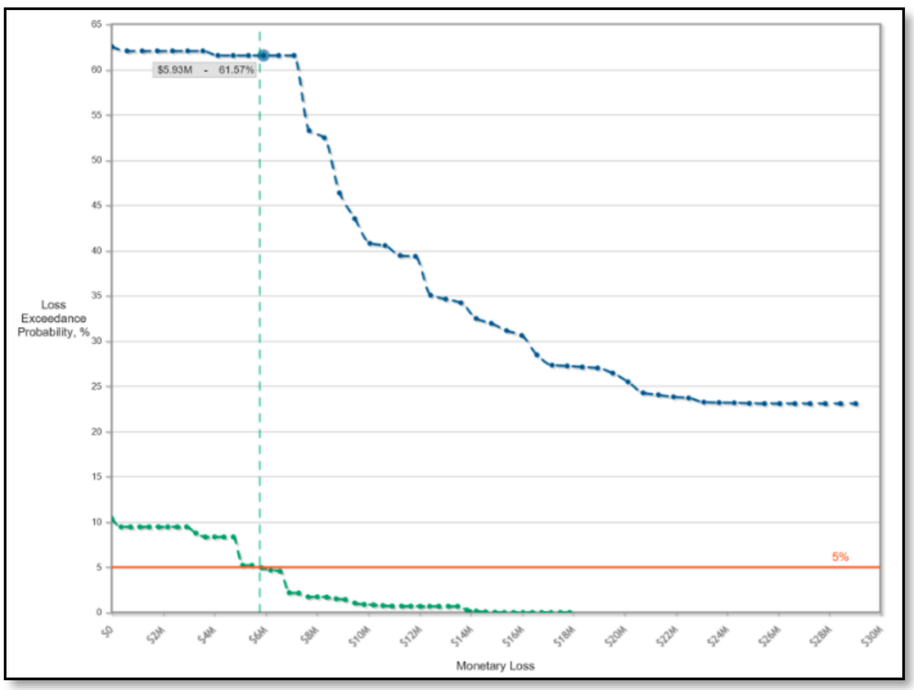


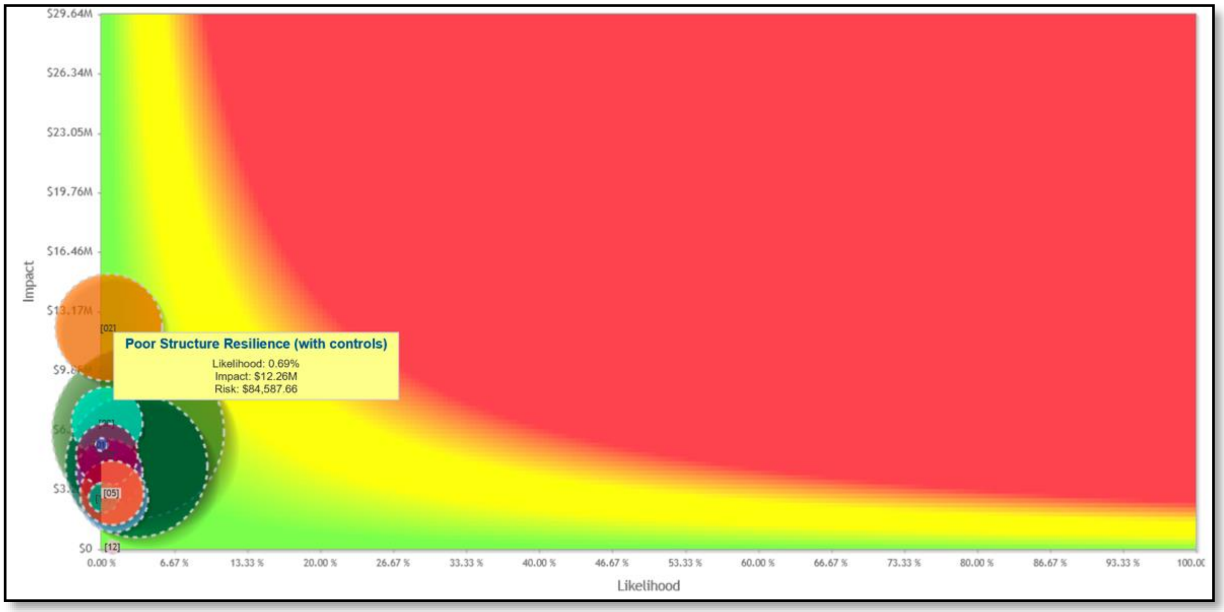
Figure 52. Loss Exceedance Curve with and without Manually Selected Controls – 5% Value at Risk



As seen in Figure 47, with the implementation of all the controls, all the likelihood of all the events decreased tremendously, specifically, 'Poor Structure Resilience' decreased to a 0.69% likelihood and a $9.82 million impact; as a result, this event posed a risk threat to the project of $67,724.20.

As seen in Figure 53, with the implementation of the eleven manually selected controls, the likelihood of occurrence remains at 0.69%, however the impact increased to $12.26 million and the risk increased to $84,587.66, which is expected, since five of the controls were removed.

Figure 53. Risk Heat Map with Manually Selected Controls

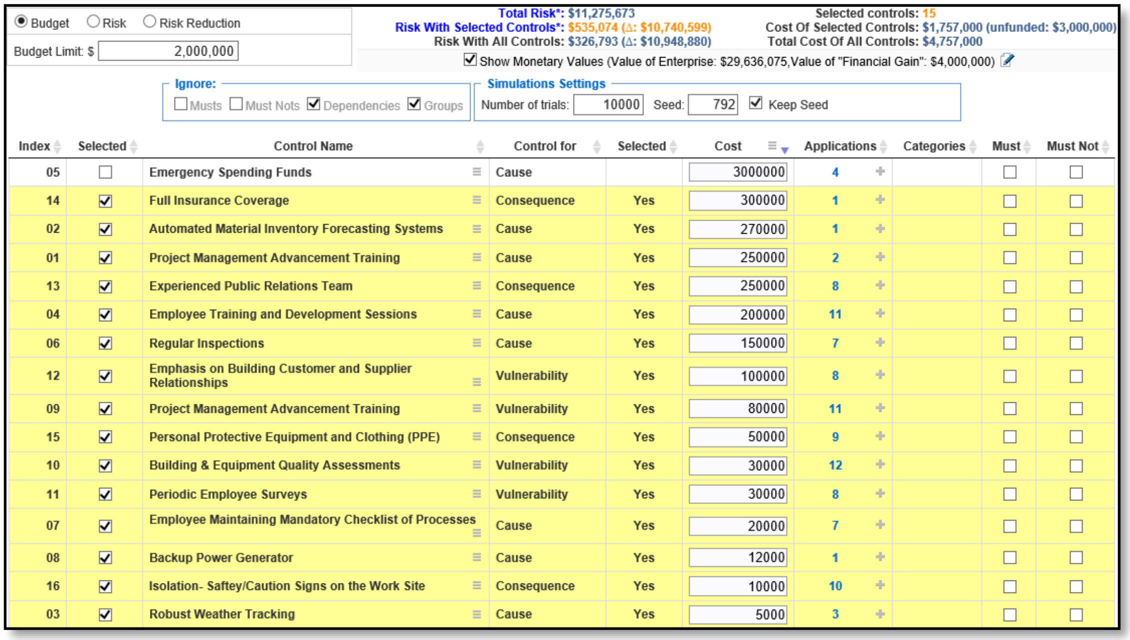


7.2 Optimization of Risk Controls

The cost of the project is $29,636,075.00 with the implementation all 16 controls valued at $4,757,000.00, which saves $10,948,880 worth of risk. However, in the event that the project has to operate within a strict budget where only $2 million can be allocated towards implementing controls, the optimization function can assist with deciding which combination of controls are most valuable while staying within the budget. Riskion allows us to input a value for the budget, and once we click the optimize button, it shows us a list of the best combination of controls while staying within the budget.

As seen in Figure 54, with a $2 million budget, with simulated results, fifteen of the sixteen controls were selected at the cost of $1,757,000.00. These optimized risks save $10,740,599.00 while using all 16 controls valued at approximately $2 million more, would only save an additional $208,281.00. The control that was removed was ‘Emergency Spending Funds’ which directly controlled the event ‘Unexpected Overspending’.

Figure 54. Controls Selected with a Budget Scenario of $2 Million for Controls



Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
05	☐	Emergency Spending Funds	Cause		3000000	4		☐	☐
14	☑	Full Insurance Coverage	Consequence	Yes	300000	1		☐	☐
02	☑	Automated Material Inventory Forecasting Systems	Cause	Yes	270000	1		☐	☐
01	☑	Project Management Advancement Training	Cause	Yes	250000	2		☐	☐
13	☑	Experienced Public Relations Team	Consequence	Yes	250000	8		☐	☐
04	☑	Employee Training and Development Sessions	Cause	Yes	200000	11		☐	☐
06	☑	Regular Inspections	Cause	Yes	150000	7		☐	☐
12	☑	Emphasis on Building Customer and Supplier Relationships	Vulnerability	Yes	100000	8		☐	☐
09	☑	Project Management Advancement Training	Vulnerability	Yes	80000	11		☐	☐
15	☑	Personal Protective Equipment and Clothing (PPE)	Consequence	Yes	50000	9		☐	☐
10	☑	Building & Equipment Quality Assessments	Vulnerability	Yes	30000	12		☐	☐
11	☑	Periodic Employee Surveys	Vulnerability	Yes	30000	8		☐	☐
07	☑	Employee Maintaining Mandatory Checklist of Processes	Cause	Yes	20000	7		☐	☐
08	☑	Backup Power Generator	Cause	Yes	12000	1		☐	☐
16	☑	Isolation- Saftey/Caution Signs on the Work Site	Consequence	Yes	10000	10		☐	☐
03	☑	Robust Weather Tracking	Cause	Yes	5000	3		☐	☐

The loss exceedance curve also reflects that there is 5% probability that the loss will exceed $5.04 million with implementing the optimized combination of controls with a $2 million budget; however, the closest point that could be mapped on the graph was $5.11 million at 4.45%, as seen in Figure 55. Similarly, this value is above our risk tolerance level of 10% of the total cost of the project ($2,963,607.50). However, the value of risk with the combination of controls at $2 million is $535,074.00, which is below the threshold of risk acceptance.

It is also evident that the controls were very effective because as seen in Figure 56, without any controls, there is a 61.57% probability that the loss will exceed $5.33 million. The probability decreased by approximately 56% with the implementation of controls.

Figure 55. Loss Exceedance Curve with and without Optimized set of Controls with $2 Million budget – 5% Value at Risk

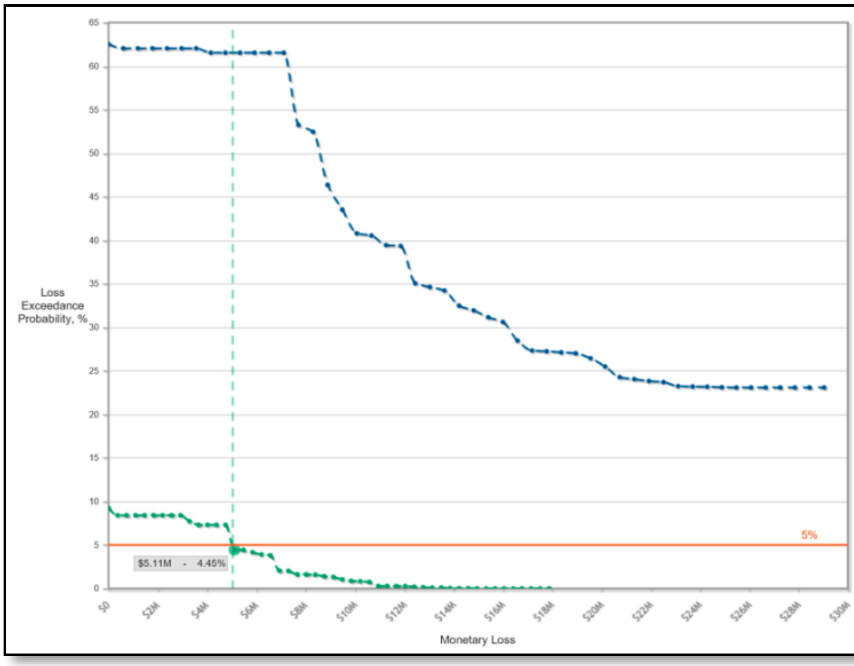
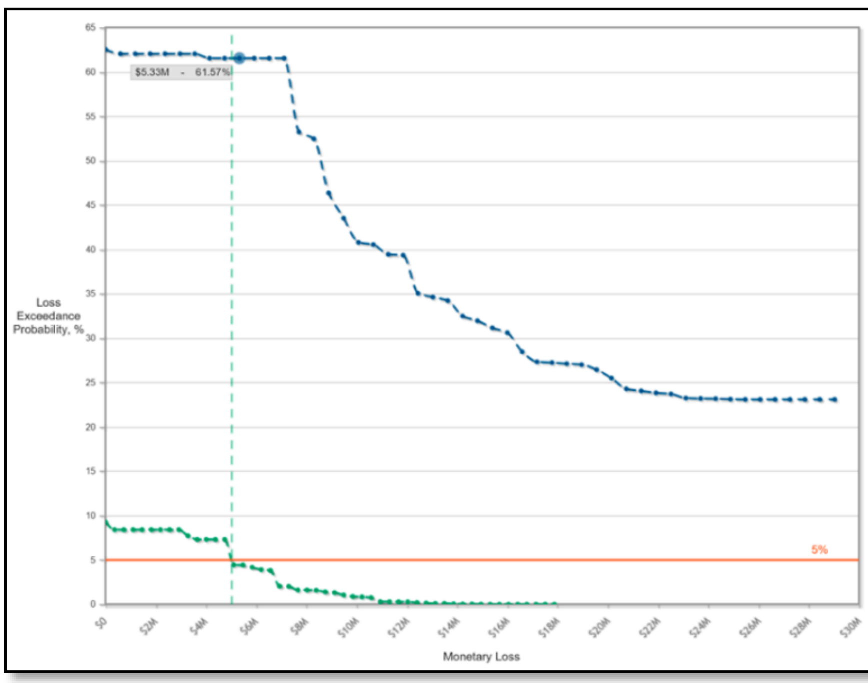
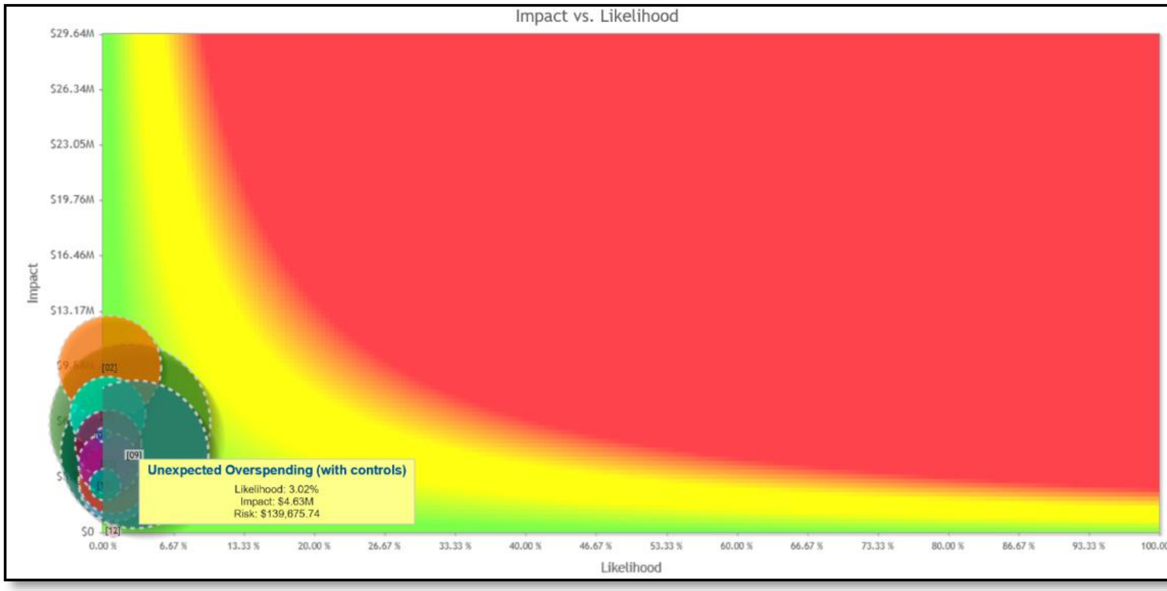


Figure 56. Loss Exceedance Curve with and without Optimized set of Controls with $2 Million budget – 5% Value at Risk



As seen in Figure 57, with the optimized set of controls, the risk heat map is also adjusted. The risk event 'Unexpected Overspending' previously had a 0.60% likelihood, a $4.56 million impact and a risk threat valued at $27,365.51. It now has a 3.02% likelihood and a $4.63 million impact; as a result, this event now poses a risk threat to the project of $139,675.74.

Figure 57. Risk Heat Map with Optimized set of Controls with $2 Million budget



As seen in Figure 58, with a $1 million budget for the controls, with simulated results, ten of the sixteen controls were selected at the cost of $995,000.00. These optimized risks save $10,647,660.00 while using all 16 controls valued at approximately $3 million more, would only save an additional $301,220.00.

Figure 58. Controls Selected with a Budget Scenario of $1 Million for Controls

(●) Budget ( ) Risk ( ) Risk Reduction
Budget Limit: $ 1,000,000

Total Risk*: $11,275,673
Risk With Selected Controls*: $628,013 (Δ: $10,647,660)
Risk With All Controls: $326,793 (Δ: $10,948,880)

Selected controls: 10
Cost Of Selected Controls: $995,000 (unfunded: $3,762,000)
Total Cost Of All Controls: $4,757,000

☑ Show Monetary Values (Value of Enterprise: $29,636,075,Value of "Financial Gain": $4,000,000)

Ignore: ☐ Musts ☐ Must Nots ☑ Dependencies ☑ Groups

Simulations Settings: Number of trials: 10000 Seed: 792 ☑ Keep Seed

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
05	☐	Emergency Spending Funds	Cause		3000000	4		☐	☐
14	☐	Full Insurance Coverage	Consequence		300000	1		☐	☐
02	☐	Automated Material Inventory Forecasting Systems	Cause		270000	1		☐	☐
01	☑	Project Management Advancement Training	Cause	Yes	250000	2		☐	☐
13	☑	Experienced Public Relations Team	Consequence	Yes	250000	8		☐	☐
04	☑	Employee Training and Development Sessions	Cause	Yes	200000	11		☐	☐
06	☑	Regular Inspections	Cause	Yes	150000	7		☐	☐
12	☐	Emphasis on Building Customer and Supplier Relationships	Vulnerability		100000	8		☐	☐
09	☐	Project Management Advancement Training	Vulnerability		80000	11		☐	☐
15	☑	Personal Protective Equipment and Clothing (PPE)	Consequence	Yes	50000	9		☐	☐
10	☑	Building & Equipment Quality Assessments	Vulnerability	Yes	30000	12		☐	☐
11	☑	Periodic Employee Surveys	Vulnerability	Yes	30000	8		☐	☐
07	☑	Employee Maintaining Mandatory Checklist of Processes	Cause	Yes	20000	7		☐	☐
08	☐	Backup Power Generator	Cause		12000	1		☐	☐
16	☑	Isolation- Saftey/Caution Signs on the Work Site	Consequence	Yes	10000	10		☐	☐
03	☑	Robust Weather Tracking	Cause	Yes	5000	3		☐	☐

The loss exceedance curve also reflects that there is 5% probability that the loss will exceed $5.90 million with implementing the optimized combination of controls with a $1 million budget; however, the closest point that could be mapped on the graph was $5.84 million at 5.06%, as seen in Figure 59. Similarly, this value is above our risk tolerance level of 10% of the total cost of the project ($2,963,607.50). However, the value of risk with the combination of controls at $1 million is $628,013.00, which is below the threshold of risk acceptance.

It is also evident that the controls were very effective because as seen in Figure 60, without any controls, there is a 61.57% probability that the loss will exceed $5.93 million. The probability decreased by approximately 56% with the implementation of controls.

Figure 59. Loss Exceedance Curve with and without Optimized set of Controls with $1 Million budget – 5% Value at Risk

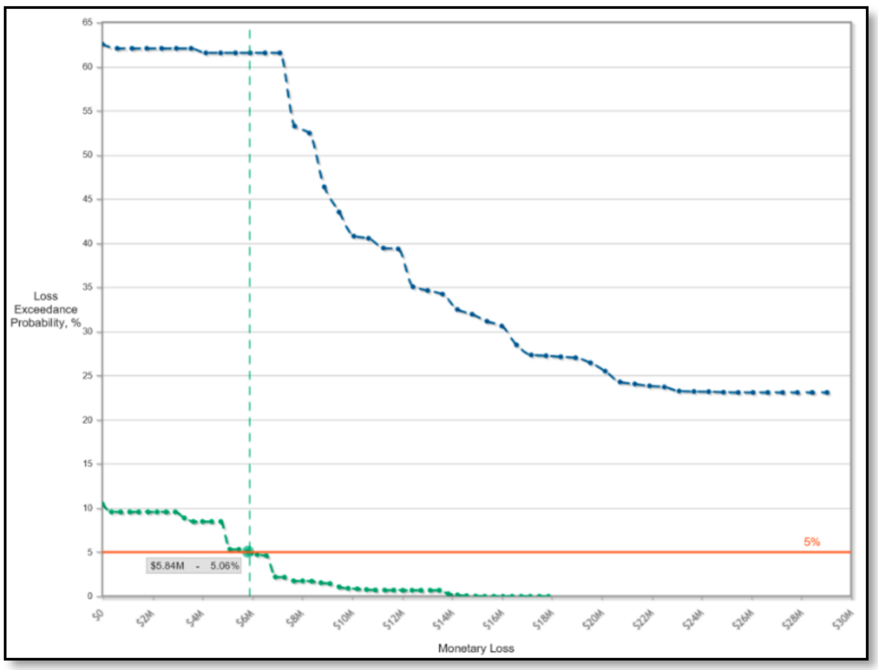
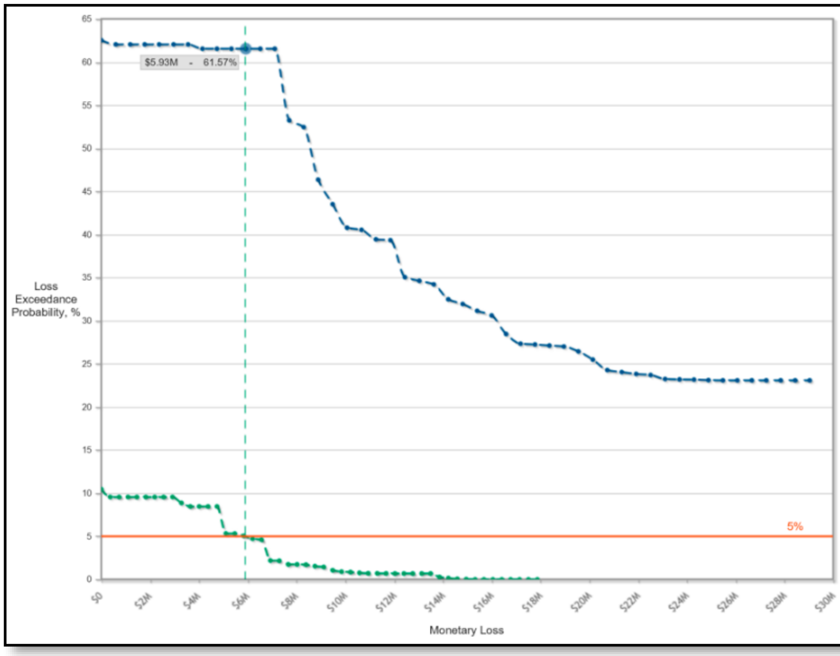
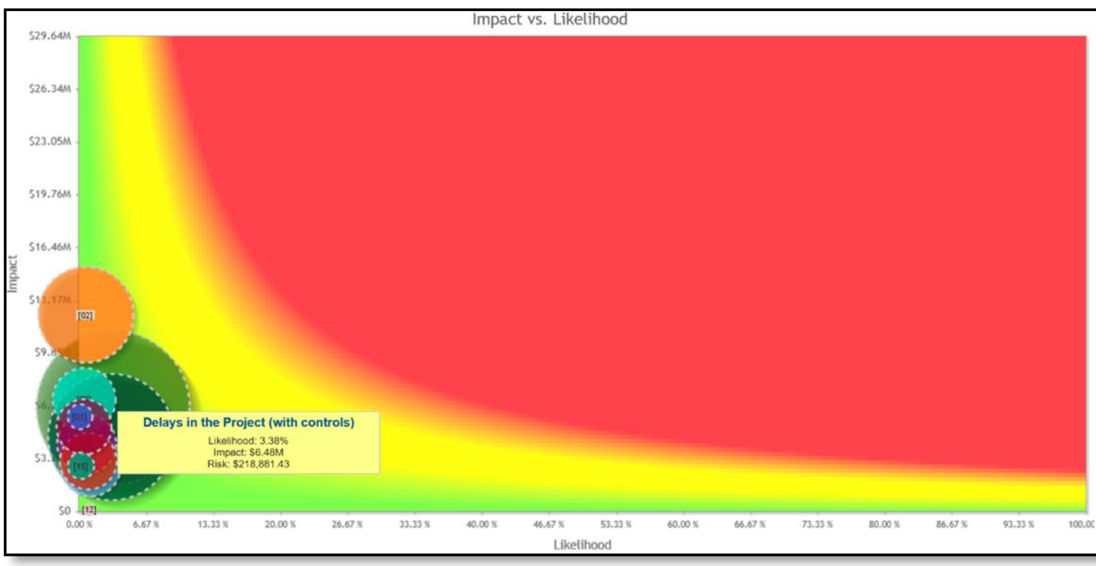


Figure 60. Loss Exceedance Curve with and without Optimized set of Controls with $1 Million budget – 5% Value at Risk



As seen in Figure 61, with the optimized set of controls, the risk heat map is also adjusted. The risk event 'Delays in the Project' previously had a likelihood of 1.63%, an impact of $6.51 million and a risk of $106,145.99. It now has a 3.38% likelihood and a $6.48 million impact; as a result, this event now poses a risk threat to the project of $218,881.43.

Figure 61. Risk Heat Map with Optimized set of Controls with $1 Million budget



7.3 Efficient Frontier Curve

After optimization of controls at a $2 million budget and a $1 million budget, the efficient frontier gives an idea of the most effective combination of controls at each budget level. As the budget level increases, the monetary value of risk decreases until it becomes stagnant. This feature also helps us to visualize diminishing returns on risk investments.

As seen in Figure 62, it is not efficient to spend more money on additional controls after $1.76 million. The risk value between the budget of $2 million and $3.75 million remains stagnant, which means that it is most efficient to spend $1.76 million on risk controls to reduce the risk to a value of $536,412.96. To decrease the value of risk any further you would have to spend at least $4 million on the implementation of controls. At $4 million, the risk value decreases to $420,832.28. This combination of controls can be seen at the optimization at $2 million budget, where only $1.76 million was spent on the controls. As seen in Figure 54, this reduces risk to $535,074.00, which is well below the risk tolerance of the company.

Figure 62. Efficient Frontier Curve

Index	Controls/Budget	$1.25M	$1.50M	$1.75M	$2M	$2.25M	$2.50M	$2.75M	$3M	$3.25M	$3.50M	$3.75M	$4M	$4.25M	$4.50M	$4.75M
	Risk with Selected Controls, $	589,757.91	$551,231.01	$548,267.41	$536,412.98	$536,412.98	$536,412.98	$536,412.98	$536,412.98	$536,412.98	$536,412.98	$536,412.98	$420,832.28	$382,305.38	$343,778.48	$340,814.87
	Funded Cost	1.19M	$1.46M	$1.75M	$1.76M	$1.76M	$1.76M	$1.76M	$1.76M	$1.76M	$1.76M	$1.76M	$4M	$4.19M	$4.46M	$4.75M
1.	Project Management Advancement Training	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED
2.	Automated Material Inventory Forecasting Systems		FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED			FUNDED	FUNDED

7.4 Comparison of Risk Values at Different Levels of Selected Combinations of Controls

As seen in Table 6, a comparison of all the previously analyzed levels of controls have been depicted below. The highest value of risk was found to be $11,275,673.00, which resulted from the implementation of no controls. Since controls helps us mitigate our risk exposure and it is done to reduce the potential harm, if there are no controls, the value of risk of the project is expected to be the highest. If all 16 identified controls were to be implemented the value of risk was found to be $326,793.00, which was the at its lowest. Evidently, if there are no budget constraints and the company is able to implement all possible controls, the value of risk will be at its minimum.

Manual selection of controls was carried out based on the input and analysis from management from what they felt were the most effective controls. Their analysis included the comparison of the stand-alone reduction values to the cost of the controls. In the event that the cost of the controls valued more than the individual monetary value of risk being mitigated, these controls were seen as a loss for the company and as a result, the mangers did not select these controls. Based on the manually selected controls, $1,075,000.00 was spent on the controls, and the residual risk was $621,362.00.

In the event that there are budget constraints, optimization at 2 different budget levels were conducted. At a $2 million budget, the cost of controls was $1,757,000.00 to reduce the risk by $10.74 million, which resulted in residual risk at $535,074.00. At a $1 million budget, the cost of controls was $995,000.00 to reduce the risk by $10.65 million, which resulted in residual risk at $628,013.00. Even though the residual risk at a budget of $2 million is lower, it is more cost effective to go with the $1 million budget. As seen in Table 7, the comparison between the two levels show that the difference between the cost of the controls of both budgets are $762,000.00, and you would be spending $762,000.00 more to only save $92,939.00.

Since it was decided that the best optimization was found at the budget level of $1 million, this can be compared to the manually selected controls. At a $1 million budget, the cost of controls was $995,000.00 to reduce the risk by $10.65 million, which resulted in residual risk at $628,013.00. With the manually selected controls, the cost of controls was $1,075,000.00 to reduce the risk by $10.65 million, which resulted in residual risk at $621,362.00. Even though the residual risk with the manually selected controls is lower, it is more cost effective to go with the $1 million budget. As seen in Table 8, the comparison between the two levels show that the difference between the cost of the controls of both levels are $80,000.00, and you would be spending $80,000.00 more to only save $6,651.00.

Out of all the combination of controls, the most cost-effective option would be the optimization at $1 million budget. Since these are financial estimations and calculations, it is always within the company's power to spend an extra amount to cover all bases, especially with a project valued at $29,636,075.00. From the analysis of the most cost-effective set of controls, it is evident that the '1 million' budget should be chosen. However, since this property is part of an educational institution, there may be factors other than financial factors that may have to be considered as a risk threat that needs to be controlled, even though it may not have a big financial impact. Given this fact, the final decision lies with the Management and Leadership teams, using their informed judgement to choose the most applicable set of controls, based on the objectives, vision and mission of the company. The Riskion software provides a platform and acts as a tool to study and analyze risks and the corresponding controls and their monetary and non-monetary effect. From this, they should be able to select the best group of controls that will be the most efficient, productive and effective in mitigating, avoiding, eliminating or transferring risk.

Table 6. Comparison of Combination of Controls

Levels of Selected Controls	Cost of Controls	Risk Reduction (Simulated)	Value of Risk (Simulated)
No Controls	$0.00	$0.00	$11,275,673
All Controls	$4,757,000.00	$10,948,880.00	$326,793.00
Manually Selected	$1,075,000.00	$10,654,310.00	$621,362.00
Optimization at $2 Million Budget	$1,757,000.00	$10,740,599.00	$535,074.00
Optimization at $1 Million Budget	$995,000.00	$10,647,660.00	$628,013.00
Optimization at $1.76 Million Budget	$1,745,000.00	$10,726,348.00	$549,325.00

Table 7. Comparison of Optimization at the two Budget Levels

Difference between Optimization Levels	Cost of Controls	Value of Risk (Simulated)
Optimization at $2 Million Budget	$1,757,000.00	$535,074.00
Optimization at $1 Million Budget	$995,000.00	$628,013.00
Difference	$762,000.00	$92,939.00

Table 8. Comparison of Optimization $1 Million Budget Level and Manually Selected Controls

Difference between Optimization levels at $1 Million & Manually Selected	Cost of Controls	Value of Risk (Simulated)
Optimization at $1 Million Budget	$995,000.00	$628,013.00
Manually Selected	$1,075,000.00	$621,362.00
Difference	$80,000.00	$6,651.00

8. Recommendation and Conclusion

After exploring the possibilities of the construction process and the hypothetical risks involved in this process, we were able to learn the likelihood of the sources, vulnerability of the risk events to the sources, consequences of risk events on the objectives, the controls and how well they positively and negatively influences each other. It is clear that a project of this magnitude and dollar value entails a large amount of risk; however, with highly experienced and qualified experts providing key judgements and measurements along with having a great team, these risks can be controlled.

Based on our hypothetical results, ‘Poor Structure Resilience’ was the most impactful risk event with human factor objectives - ‘No Death or Casualties’ and ‘Injury-Free’ being the highest priority of the objectives which is very evident in a construction project. With a full understanding of the risks involved in this project, and the associated cost to control these risks, the likelihood of the occurrence of sources, the vulnerability of the risk events and their impact on the objectives, the risk threats were decreased tremendously. In addition, with the selection and implementation of the most effective set of controls costing $ 1M, the risk residue is well within the risk tolerance of the organization.

With the proper knowledge and understanding of risk assessment concepts and use of Riskion or other Risk Management software and tools, management teams are able to assess and control risks faced in projects resulting in minimum loss.