Firefighting Risk Assessment

Preventing Health Risks Associated with Firefighting in Metropolitan Areas

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1. Introduction and Background

Firefighters are called to numerous dangerous settings and workplaces on behalf of the citizenry. They encounter tremendous amount of risks and their work is typical done in a dynamic environment in which the firefighters are faced with hazards. The demands placed on firefighters are sporadic, unpredictable and often under periods of intense physical and psychological stress. Due to the nature of the work performed, it is impossible to eliminate all firefighter injuries. However, a risk management system that identifies the risks, addresses the sources, and establishes clear objectives can offer methods and options to reduce injury levels.

A firefighter is a rescuer trained to extinguish fires that threaten life, property and/or the environment. The basic skills of firefighting are prevention, self-preservation, first aid, rescue and fire control. Firefighters are trained to perform scene assessments, extinguishing, salvage and overhaul, and many specializations exist, to include wildland firefighting, search and rescue, HAZMAT, fire inspection, air extinguishing and fire jumping (parachuting near active large wildfires). In most municipalities, firefighters also serve as EMTs, serving as the first responders to medical emergencies and transporting individuals to medical facilities via ambulances.

The amount of risk assumed by a firefighter will dependent on numerous factors to include municipality. Firefighters in metropolitan areas will receive more calls and experience more hazards on average than firefighters in more rural areas. Additionally, the quality of protective gear, level of training, and professionalization will vary from department to department. Many firefighters in the US are volunteers.

National Fire Protection Association Statistics Website (http://www.nfpa.org)

- 68,085 firefighter injuries were reported in the U.S in 2015. Of these, 29,130 were injuries at the fire ground (on-scene/line-of-duty).

- The number of fire ground injuries per 1,000 fires has remained relatively constant for the past 20 years, which reinforces the need for continued standards development, as well as fire prevention outreach and advocacy.

- Strain, sprain, muscular pain resulted in more than half the major types of injuries received during firefighting operations (53%) and non-firefighting injuries (60%).

- In addition to injuries, there were 8,350 documented exposures to infectious diseases (e.g., hepatitis, meningitis, HIV, other) in 2015. This amounts to 1 exposure per 2,500 emergency medical service runs by fire departments.

- There were an estimated 27,250 documented exposures to hazardous conditions (e.g. asbestos, chemicals, fumes, radioactive materials, other) in 2015. This amounts to 1 exposure per 40 hazardous condition runs by fire departments.

- In 2015, there was an estimated 16,600 collisions involving fire department emergency vehicles responding to or returning from incidents. This is the highest number of collisions since NFPA began collecting this information in 1990.

2. Initial Risk Planning and Methodology

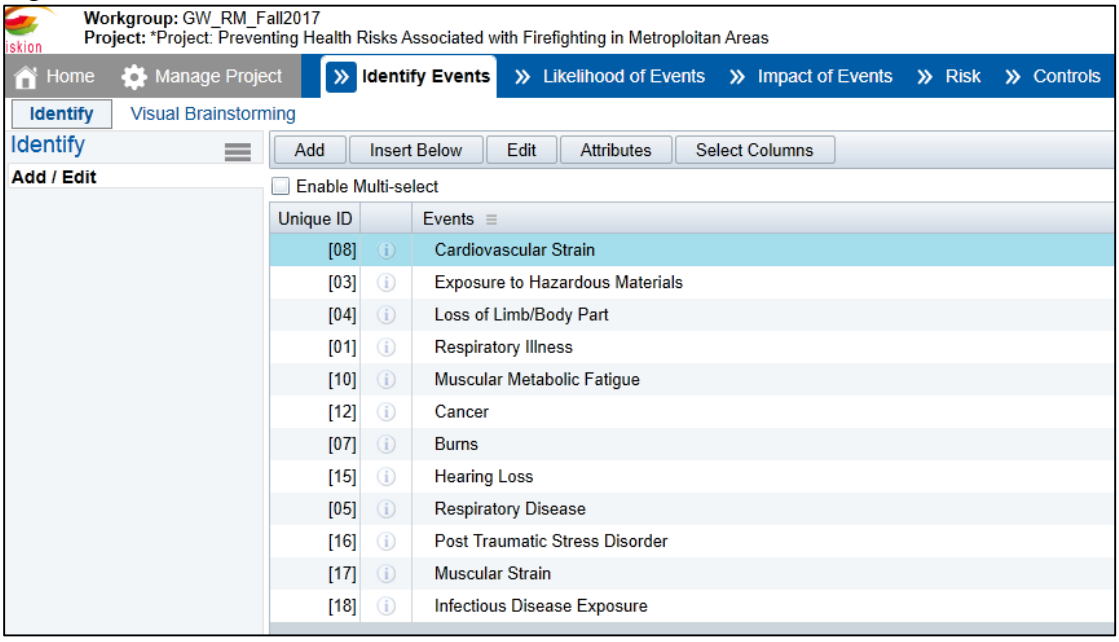
We identified, analyzed, and categorized many of the associated risks with the firefighting profession and the sources associated with these risks. Based largely on readily available statistics provided by national firefighter and fire safety organizations, associations and institutes, risk planning was initiated. We developed objectives for this project which should be addressed in a firefighter risk management plan. The analysis was focused on events that could cause injuries to firefighters through a method known as Event Focused Risk Management.

In this Event Focused Risk Management process, risk events are identified, the sources that cause these events are analyzed and objectives to mitigate the risk events are presented. This analytical process does not always start with the event and it is important to understand the difference between sources with risk events.

- Through this process, a risk event should represent a failure and should have an impact that can be analyzed and quantified.
- The objectives were identified and arranged in a hierarchy.
- Stakeholders were selected and they measured (provided their professional opinion and assessment) of the relationships, correlations and impacts amongst the risk events, and sources.
- Overall risk was derived from these measurements and objectives were derived.

2.1 Identifying Risk Events

Figure 1. Risk Event in Riskion



Based on our research of available statistics, we identified the short-term and long-term risks commonly associated with the firefighting profession. Below are the twelve risk events we assessed in our project and risk management strategy.

Cardiovascular Strain: Firefighters perform difficult work in dangerous dynamic environments. Cardiac strain refers to high heart rate, high cardiac output, and enhanced blood clotting potential which can lead to something as simple as fatigue or as serious as heart attack. Heart attacks are the leading cause (nearly half) of line-of-duty deaths among firefighters.

Exposure to Hazardous Materials: Firefighters may be exposed to hazardous materials during their firefighting duties or when called to a scene to secure, transport and/or test potentially hazardous solids, liquids or gases.

Loss of Limb/Body Part: Although highly unlikely, sources could lead to a firefighter losing one of their limbs or body parts.

Respiratory Illness: The regular exposure to smoke which occurs in firefighting may be linked with chronic respiratory related illness and deaths in firefighters.

Muscular Metabolic Fatigue: Muscle fatigue is the decline in ability of a muscle to generate force. It can be a result of vigorous exercise but abnormal fatigue may be caused by barriers to or interference with the different stages of muscle contraction. Due to the weight of the protective equipment worn and the physical strain a firefighter encounters on scenes, muscular metabolic fatigue is likely a common risk event.

Burns: A firefighter is exposed to flames and comes into contact with heated materials at a substantially larger rate than civilians. Sources such as wearing protective gear, professional training, situational awareness, and effective protocols should minimize burns as a risk event.

Hearing Loss: Noise from extrication equipment, emergency sirens, air horns, and fire apparatus engines are all potential noise exposures for firefighters. Constant exposure without adequate hearing protection could lead to long term hearing loss.

Respiratory Disease: There is likely a higher risk among firefighters of developing respiratory diseases due to chronic exposure to harsh elements. Chronic respiratory disease in fire fighters may be more common than what is found amongst the general population.

Post-Traumatic Stress Disorder: Firefighters regularly experience stressful situations and have an extremely higher statistical percentage of enduring emotional trauma than the general population.

Muscular Strain: Although usually considered a minor injury, the leading cause of work related injuries to firefighters are sprains, strains, and muscle injuries.

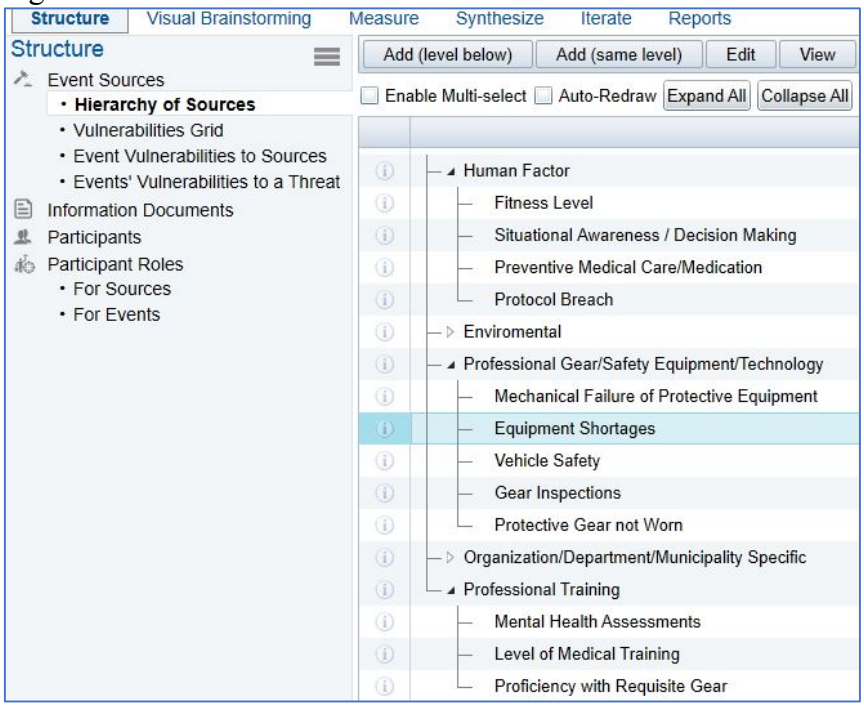
Cancer: A study by the National Institute for Occupational Safety and Health (NIOSH) published in 2015 examined whether firefighters have a higher risk of cancer due to job exposures. The firefighters in this study had a slight increase (10%) in cancer diagnoses (9%

increase) and cancer-related deaths (14% increase). Understanding the increased risks faced by firefighters can help target prevention efforts.

Infection Disease Exposure: Based primarily in a firefighter's EMT duties and exposure to sick and wounded civilians, they encounter individuals with potential infectious diseases and need to take precautions to minimize their exposure.

2.2 Identifying Risk Sources

Figure 2. Sources in Riskion



Sources are Threats or hazards that cause an event to occur.

There are numerous sources for the risks we have identified. Although neither our risk events or risk sources are exhaustive, we believe the events and sources we address can guide us to an effective risk management strategy. We have identified five main categories, each with several sub-categories. The five main categories are: human factor; environmental; professional gear/safety equipment/technology; organization/department/municipality specific; and professional training.

Human Factor: When we address human factors in relation to fire safety, we are focused on optimizing human performance and reducing human errors or failures. A firefighter is responsible for his/her level of fitness, situational awareness, following preventive medical care and respecting the established work protocols. When these human factors are positively addressed, a firefighter very likely minimizes many (but certainly not all) negative consequences of exposure to hazards and risk events related to firefighting.

- Fitness Level

- Situational Awareness/Decision Making
- Preventive Medical Care/Medication
- Protocol Breach

Environmental: When we address environmental factors, we are looking to optimize the safety of firefighters when they encounter risks while responding to calls for service and while on scene. A fire department should understand the typical environmental risks the firefighters are exposed to and utilize their resources to maximize safety. We identified 8 sub-categories under environmental which we believe provide a fair representation of risks firefighters face.

- Level of Noise Exposure
- Thermal Environmental Exposure
- Exposure to Smoke
- Hazardous Materials
- Psychological Stress
- Crime Rate/Exposure to Violence
- Civilian Error to Line of Duty Actions
- Structure Failures

Professional Gear/Safety Equipment/ Technology: When we address professional gear and safety equipment in this project, we are focused on the performance of the gear, gear inspections and storage, and the failure on part of the firefighters to use the equipment. We identified 5 sub-categories related to professional firefighting gear which we believe provide a fair representation of risks firefighters face associated with their gear and equipment.

- Mechanical Failure of Protective Equipment
- Equipment Shortages
- Vehicle Safety
- Gear Inspection
- Protective Gear Not Worn

Organization/Department/Municipality Specific: Resources available to the public (fire extinguishers, emergency escapes, fire alarms, fire fighters visiting schools, etc.) can minimize threats to firefighters. Additionally, there are environmental factors specific and unique to each department: some departments service rural areas and others work large cities; some departments attend to twenty calls a night while others may go days between calls; some have a specialized maritime and/or air component; some work in high crime areas; some work in cities with inadequate fire prevention codes; etc. Below are five sub-categories that we identified to encompass department specific characteristics and nature of the community they service.

- City Codes
- Call Rates for Medical Services
- Calls per Shift
- Adequate Qualified Staffing
- Teamwork/Partner Failure

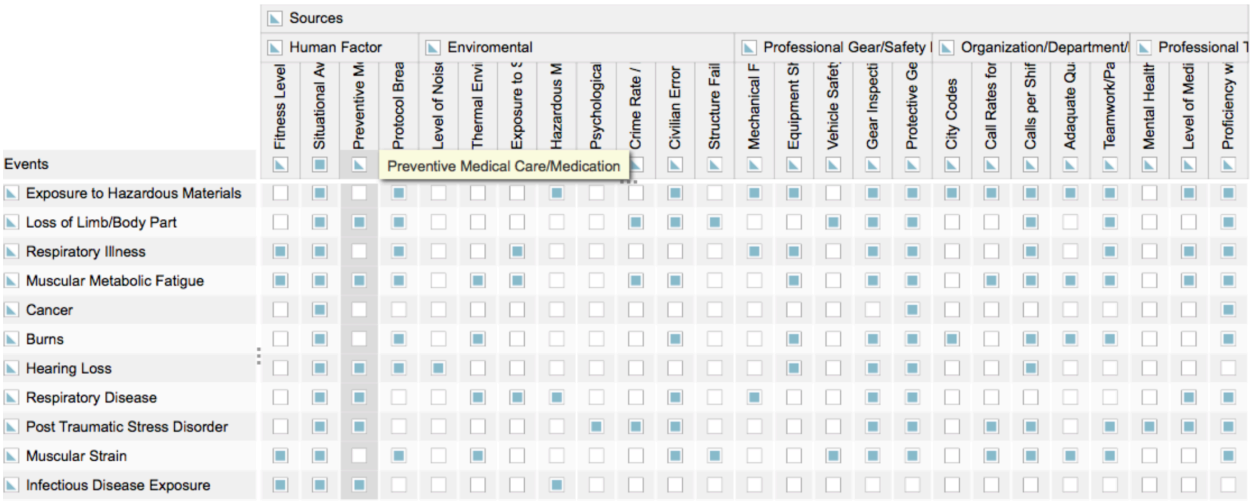
Professional Training: A clear understanding of the duties and responsibilities of the profession combined with the skills and knowledge to perform those duties and responsibilities is fundamental. Not all departments will provide the same standard of training, but a higher level of training will increase work safety. Training can be categorized in numerous ways to include initial, advanced and refresher, and will encompass a broad range of subjects for firefighters since their work is dynamic by nature.

- Standard Level of Training / Basic Training
- Mental Health Assessments
- Level of Medical Training
- Proficiency with Requisite Gear

2.3 Mapping Sources to Events:

Events and sources were identified and then Riskion was used to map sources to events. Numerous sources may contribute to an event. Additionally, an event does not necessarily require a contributing source. Figure 3 below is a vulnerability grid, where the identified sources are mapped to the sources selected.

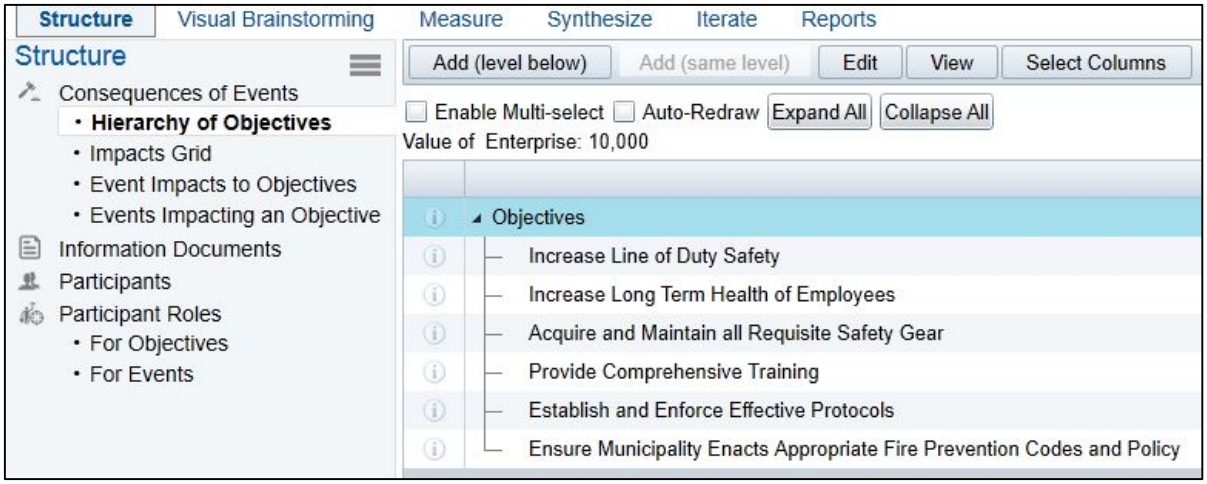
Figure 3. Vulnerabilities Grid of Events to Sources



There are several sources which contribute to each event and understanding these contribution is important. The figure above, depicts that not all the sources contributes to all the events.

2.4 Impact of Events on Objectives

Figure 4. Objectives in Riskion



In order to successfully manage the risks of firefighting and measure the sources and controls identified above, clear objectives need to be established. Below are some major objectives a fire department could set. A successful risk management plan should see positive results in these objectives.

Increase Line of Duty Safety: Active personnel who are serving the fire department and are usually on duty need to have higher safety standards which should be maintained always. The objective of having the safety of the ones who are in the line of duty should always be kept as the first and the foremost.

Increase Long Term Health of Employees: firefighters are usually exposed to extreme health dangers and are prone to chronic diseases, so their long-term health maintenance should be one of the primary objectives.

Acquire and Maintain all Requisite Safety Gear: one of the major objectives to ensure the safety and well-being of the firefighters is to ensure that all the precautionary measures are taken and a proactive approach of the security is maintained. Acquiring and maintaining appropriate gear for the firefighters is one of the basic ways to ensure meeting the objective.

Provide Comprehensive Training: Providing appropriate training to the staff is really important to ensure the well-being of the staff. It is necessary to ensure that the staff member is well on his own and can handle his risky job well.

Establish and Enforce Effective Protocols: Strong protocols need to be in place and need to be strictly followed as an objective. No one should be allowed to violate any policy that's in place and a stern reaction should be given if someone goes off-track.
Ensure Municipality Enacts Appropriate Fire Prevention Codes and policy: Every town or state usually have their own municipality codes and policy. A very important objective is to ensure that those codes and policies are strongly adhered to.

2.5 Participant Roles

For this project, we have created and incorporated participants that have roles in our risk management plan. Below are the individuals serving in a specific duty position relevant to assess certain risks associated with firefighting. These individuals have unique insight and experience to help measure the risks, identify the sources and provide risk management strategies to identify objectives that can help minimize risks to the firefighting industry.

Figure 5. Participants Identified in Riskion

Fire Chief: Senior member of the fire department. Success and failure of the department resides with this individual. The Fire Chief sets the policies of the department, leads the staff, and overseas all operations, functions and personnel.

Firefighting Academy Commander: This individual is responsible for managing the training of all new members of the department and likely overseas all refresher training and the incorporation of new tactics, techniques and procedures.

Senior Firefighter: On the job or "hands on" training is often the premier learning method and skills and knowledge are often perishable. A senior member of the department that is participating in calls for service is likely best suited to provide the most accurate assessment of the needs of the department.

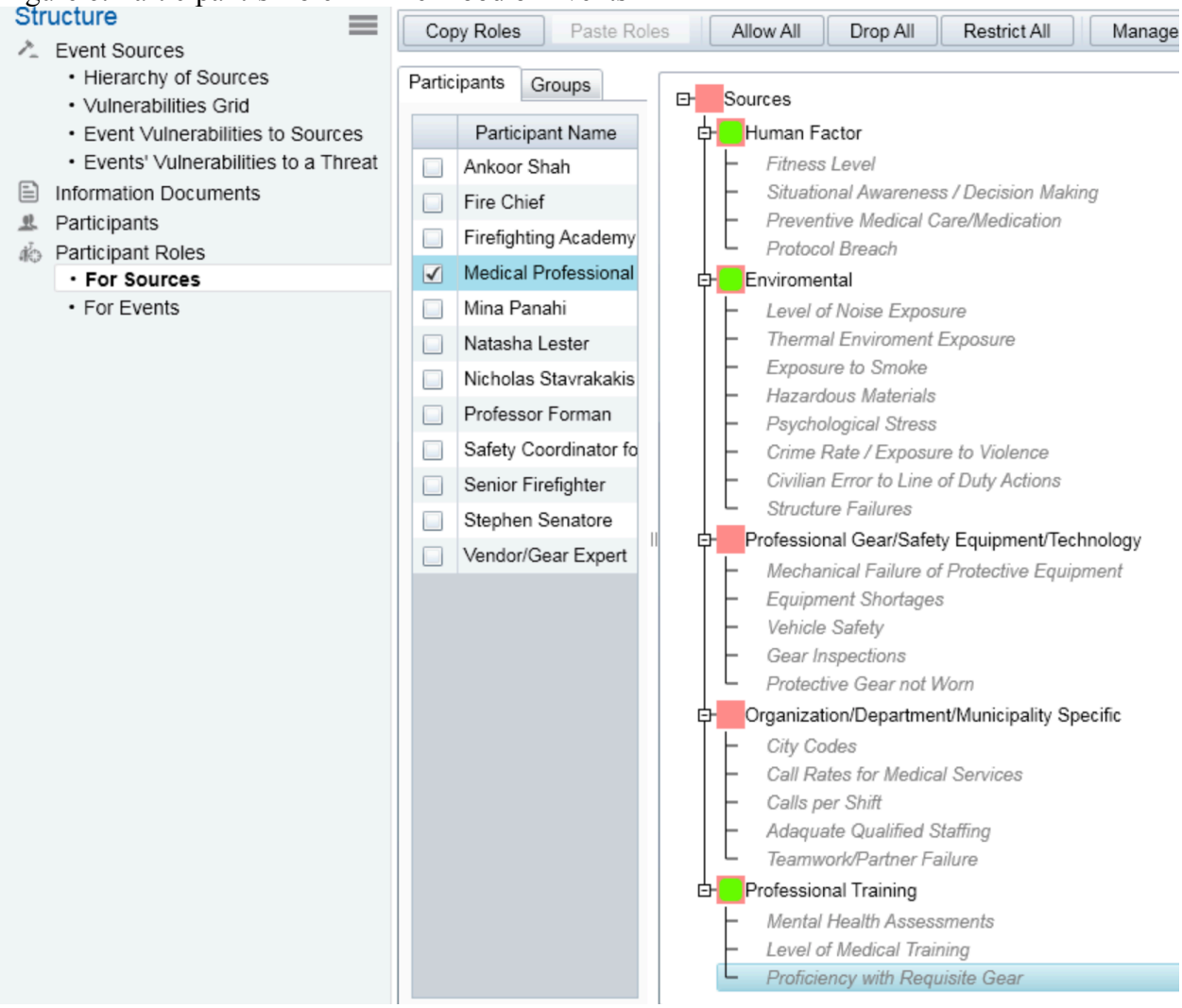
Vendor/Gear Expert: Companies focused on fire safety are constantly improving their products and developing new gear. Having a representative from the private sector provide a review and critique of the current authorized personal safety gear could be useful. Vendor recommendations to a fire department could highlight areas they need to invest more resources and highlight deficiencies. Additionally, a vendor could develop specialized gear that may be unique to a certain department.

Medical Professional: A firefighter in a typical department responds to numerous calls for service in an emergency medical capacity. They serve as the first responders to a wide range of medical situations, which account for the majority of their calls for service in most departments.

Since they spend more time providing patient care than fighting fires, initial and refresher training on medical matters should be a focus. A medical professional should participate in a department's risk management strategy. A medical professional can refine and update the department's training and provide recommendations to increase firefighter safety.

Safety Coordinator for the Municipality: The individual responsible for overall safety issues should be a participant. Not every municipality has a safety coordinator, but larger municipalities and cities generally do. This person is responsible for overseeing overall public safety.

Figure 6. Participant's Role in Likelihood of Events



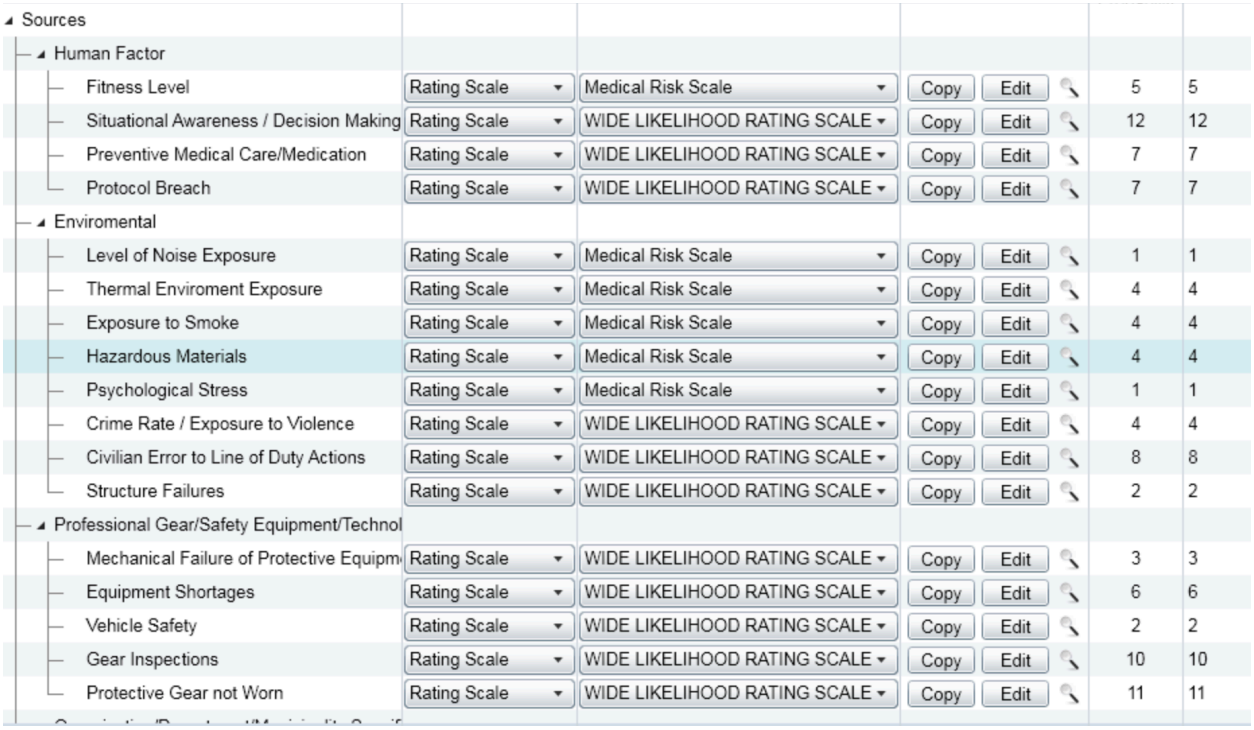
Different participants play different roles when evaluating sources and events. Evaluators are constrained by their level of expertise and their area of business. The green highlighted boxes in the evaluation of sources above, shows the Medical Professional evaluating the medical area whereas the red boxes are the ones which they cannot evaluate.

3. Measurement Method

There are several ways to measure risk, but the problem is that all risk measuring tools are limited by nominal, ordinal or interval data to calculate the likelihood of any event to occur and do not create ratio scale models in which ratio scaling is usually mathematically related to the other ratio and hence creating an in-depth understanding of the results. Riskion by using analytical hierarchy measurement methods gives the results in the ratio scales which can derive meaningful values for risk, impact, and likelihood.

The measurement methods were assessed for sources and events which mixed with pairwise comparison, pairwise with given probability, and medical scale. This assessment helped to data and judgment to be made in ratio scale numbers. Participant made their own judgment in this assessment which cannot be perfect but these judgments are helping to identify the risk.

3.1 Measurement Methods for Events – Likelihood of Events



▲ Sources						
▲ Human Factor						
Fitness Level	Rating Scale	Medical Risk Scale	Copy	Edit	5	5
Situational Awareness / Decision Making	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	12	12
Preventive Medical Care/Medication	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	7	7
Protocol Breach	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	7	7
▲ Enviromental						
Level of Noise Exposure	Rating Scale	Medical Risk Scale	Copy	Edit	1	1
Thermal Enviroment Exposure	Rating Scale	Medical Risk Scale	Copy	Edit	4	4
Exposure to Smoke	Rating Scale	Medical Risk Scale	Copy	Edit	4	4
Hazardous Materials	Rating Scale	Medical Risk Scale	Copy	Edit	4	4
Psychological Stress	Rating Scale	Medical Risk Scale	Copy	Edit	1	1
Crime Rate / Exposure to Violence	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	4	4
Civilian Error to Line of Duty Actions	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	8	8
Structure Failures	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	2	2
▲ Professional Gear/Safety Equipment/Technol						
Mechanical Failure of Protective Equipm	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	3	3
Equipment Shortages	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	6	6
Vehicle Safety	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	2	2
Gear Inspections	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	10	10
Protective Gear not Worn	Rating Scale	WIDE LIKELIHOOD RATING SCALE	Copy	Edit	11	11

In the figure above, the method used for measuring the event likelihood are shown.

Medical Risk rating scale: This specific measurement scale is a custom-made scale created to determine the likelihood of events to the hierarchy of the sources. The scale is assessed by the Riskion comparison method. The medical risk likelihood rating scale below can help in accurately figuring out the differences between intensities. Other scales with the names as “wide likelihood rating scale” and “default Rating Scale” used with different likelihoods from another assessment. These scales help to measure the events with specifying intensities.

Intensity Name	Likelihood
certain	1.0000
Highly likely	0.8188771
highly unlikely	0.2380905
impossibl	0.007442
somewhat likely	0.60731
somewhat unlikely	0.3613891
Very likely	0.720204

3.2 Measurement method for Sources-Likelihood of Events

◢ Sources	Pairwise Compari	
— ◢ Human Factor	Pairwise of Probal	Wide Pairwise of Probabilities Scale t
— Fitness Level		
— Situational Awareness / Decision Making		
— Preventive Medical Care/Medication		
— Protocol Breach		
— ◢ Enviromental	Pairwise with Give	Thermal Enviroment Exposure: 0.9
— Level of Noise Exposure		
— Thermal Enviroment Exposure		
— Exposure to Smoke		
— Hazardous Materials		
— Psychological Stress		
— Crime Rate / Exposure to Violence		
— Civilian Error to Line of Duty Actions		
— Structure Failures		
— ◢ Professional Gear/Safety Equipment/Technol	Pairwise Compari	
— Mechanical Failure of Protective Equipm		
— Equipment Shortages		
— Vehicle Safety		
— Gear Inspections		
— Protective Gear not Worn		
— ◢ Organization/Department/Municipality Specifi	Pairwise Compari	
— City Codes		

In the figure above, three different methods used for calculating the likelihood of sources are shown: Pairwise Comparison, pairwise of probability, and Pairwise with a Given Likelihood.

Pairwise of probabilities: This method helps us to examine a wide range of values that we believe are linked with the happening of any event. The best use and advantage of this method is that it can come up with a list of consistent results of the likelihoods as long as the range is known.

Pairwise Comparison: In an assigned category, the importance of each source can be derived by this method using ratio scale likelihoods.

Pairwise with Given Likelihood: This method is similar to pairwise comparison but it has a given likelihood which can be manually entered in Riskion. The given likelihood is based on historical data.

3.3 Likelihood of Sources Impact

Having clear objectives is critical for any risk management strategy. For purposes of this project, the objectives we identified are the steps we believe a firefighting organization can take to reduce risks to firefighters. Using Riskion, we assessed every objective's impact to our identified sources, measuring the objectives ability to reduce risk. Through Riskion, we used an impact rating scale. The participants assessed the objectives impact on the events by selecting a level of likelihood (considerable, moderate, low, extreme, etc.). This process was completed for every identified objective by every participant.

Measuring Events Respect to Objectives

After establishing the measurement scales, the defined participants were asked to share their independent opinion by providing their ratings on all the elements within the categories they were assigned based upon their roles. The feedback received was later used to create the final analysis.

3.4 Evaluation

For the evaluation of the likelihood of the events and impacts of events, the figures illustrate the total number of evaluations that each participant conducted on two pairwise comparisons of the likelihood of events and impact of events. The results of the evaluations are discussed later in the report.

Overall Evaluation Progress for Likelihood of Events

Participant Name	Email Address	Evaluation Progress	Last Judgment Time	Actions
Nicholas Stavrakakis	**nstavrakakis@gwu.edu**	**100.0%(274/274)**	**11/2/2017 12:33:13 AM**	
Mina Panahi	**minapnh@gwu.edu**	**100.0%(281/281)**	**11/2/2017 12:27:56 AM**	
Stephen Senatore	**senatore@gwu.edu**	**100.0%(281/281)**	**11/2/2017 12:26:39 AM**	
Fire Chief	FireChief@gmail.com	100.0%(281/281)	11/2/2017 12:29:15 AM	
Firefighting Academy Commander	FirefightingAcademyCO@gmail.com	100.0%(281/281)	11/2/2017 12:30:57 AM	
Safety Coordinator for County	CountySafetyCoordinator@gmail.com	100.0%(163/163)	11/2/2017 12:36:29 AM	
Professor Forman	**forman@gwu.edu**	**0.0% (0/281)**		
Ankoor Shah	anshah@gwu.edu	0.0% (0/281)		
Natasha Lester	natashaagard@gwu.edu	0.0% (0/136)		
Medical Professional	MedicalProfessionals@gmail.com	0.0% (0/260)		

The above picture shows the number of participants and the total steps which assigned for them to use their judgment independently. It shows that the number of steps is different for each participant.

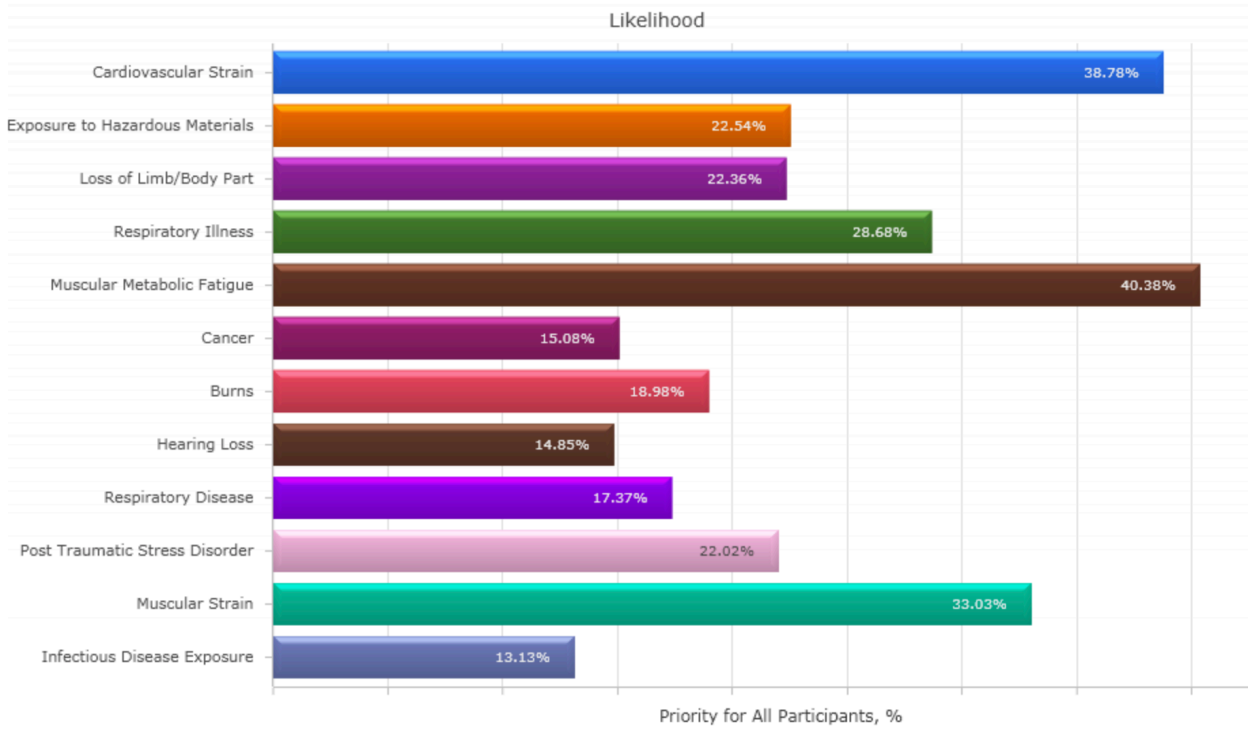
4. Risk Analysis and Synthesized Results

After completing the evaluations, the results received by riskion were reviewed to analyze the results for the outliers or any unexpected outcomes. The synthesized tab is defined in Riskion to show all the measurements in depth by using a different type of figures. Synthesis is the most important aspect. The results were mathematically meaningful because they are derived as ratio scale measurements. Riskion helped us to examine results by using sensitivity analysis. Dynamic and performance sensitivity analysis was used to analyze our evaluation results and helped to check if any of the results were an extreme outlier or have serious variation between the participants.

4.1 Likelihood of Events Synthesized Results

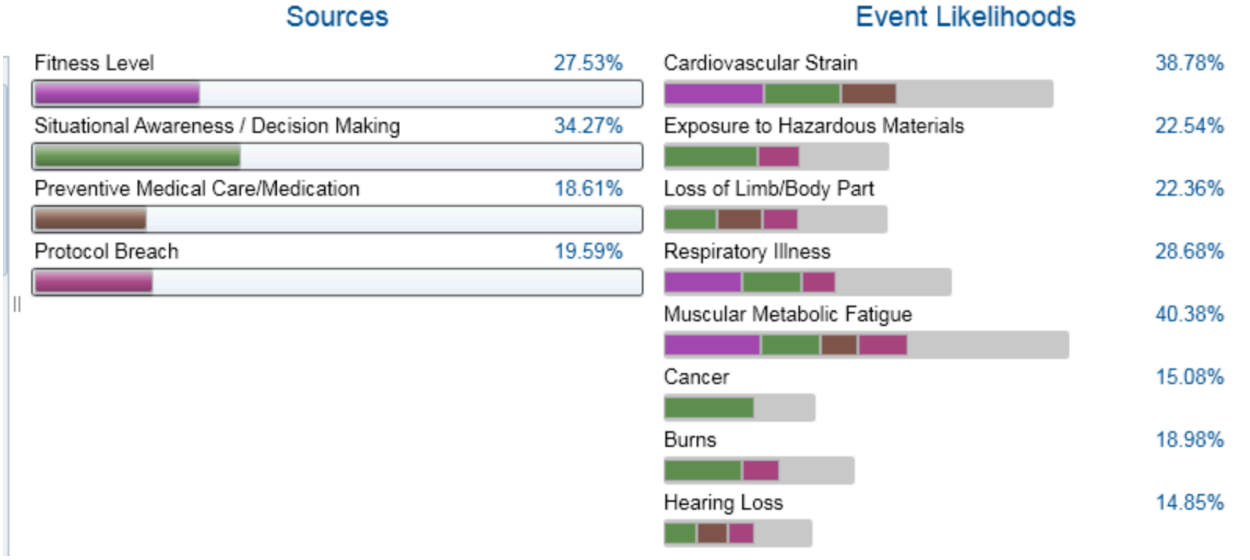
As stated above, estimating the likelihood of a source impacting an event is not an easy task. Additionally, identifying the likelihood of specific events occurring by analyzing the major risks is also a large task. In this project, our assessments produced a value for the likelihood of our events occurring. The figure below displays the likelihood of events sorted by priority or likelihood of occurrence. Although the percentages themselves may be high, we assess with very high confidence that the events are in the correct order.

Likelihood of Events



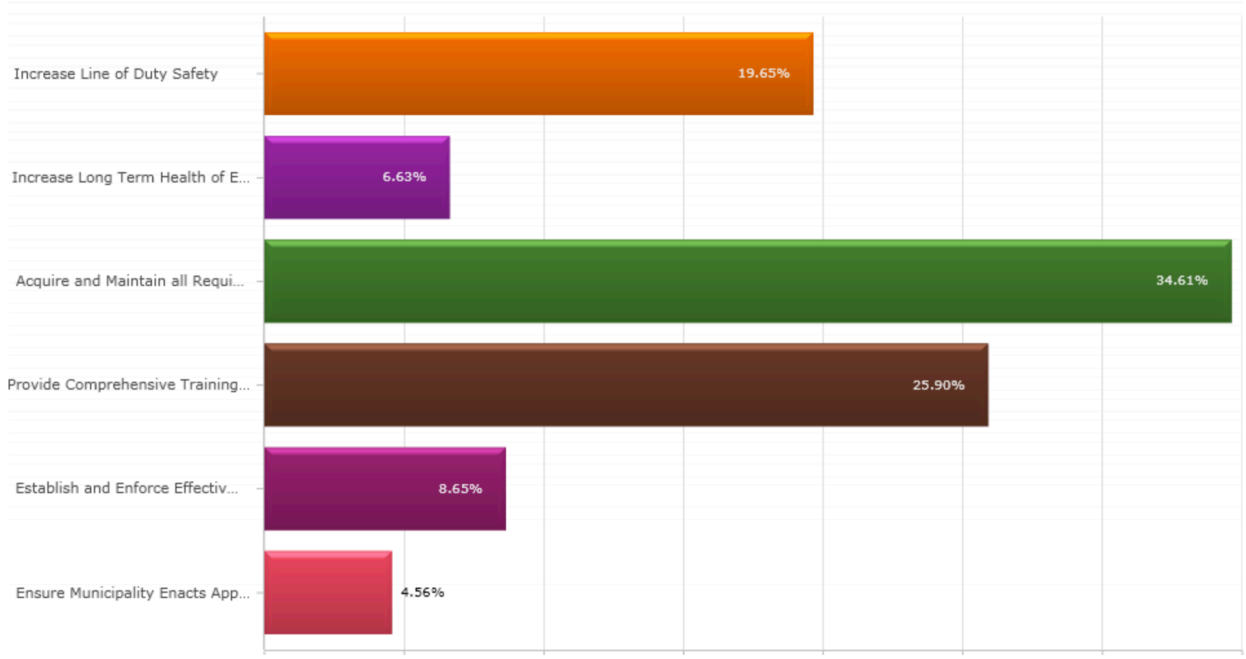
The figure shows the normalized aggregated results from the all the participants' judgments Muscular Metabolic Fatigue has the highest percentage of 40.38% followed by Cardiovascular strain posed the percentage of threat at 38.78%, and exposure to hazardous materials and loss of limbs or any other body part at 22.54% and 22.36% respectively.

Dynamic Sensitivity of Event Likelihood-Sources



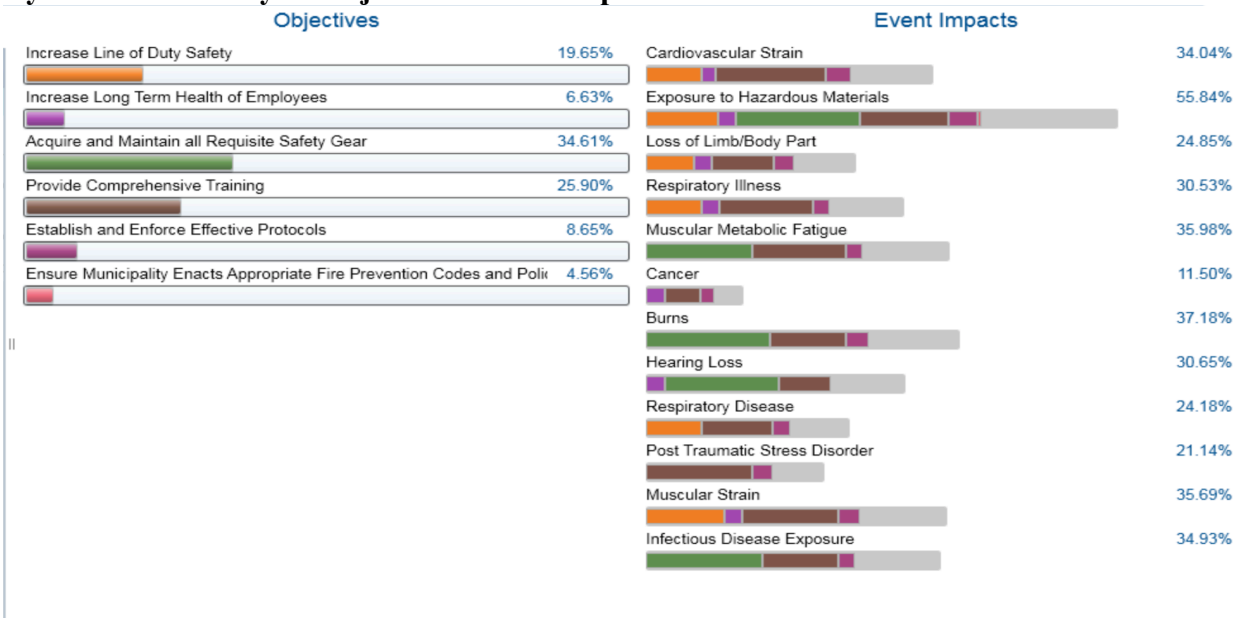
4.2 Objectives Impact on Events Synthesized Results

The synthesized result of the objective impact on events are shown in the figure below.



This figure shows that acquire and maintain all the safety gear has the highest priority of with respect to objective 34.61% followed by Providing comprehensive training for firefighter with 25.90%.

Dynamic Sensitivity of Objectives-Event Impact

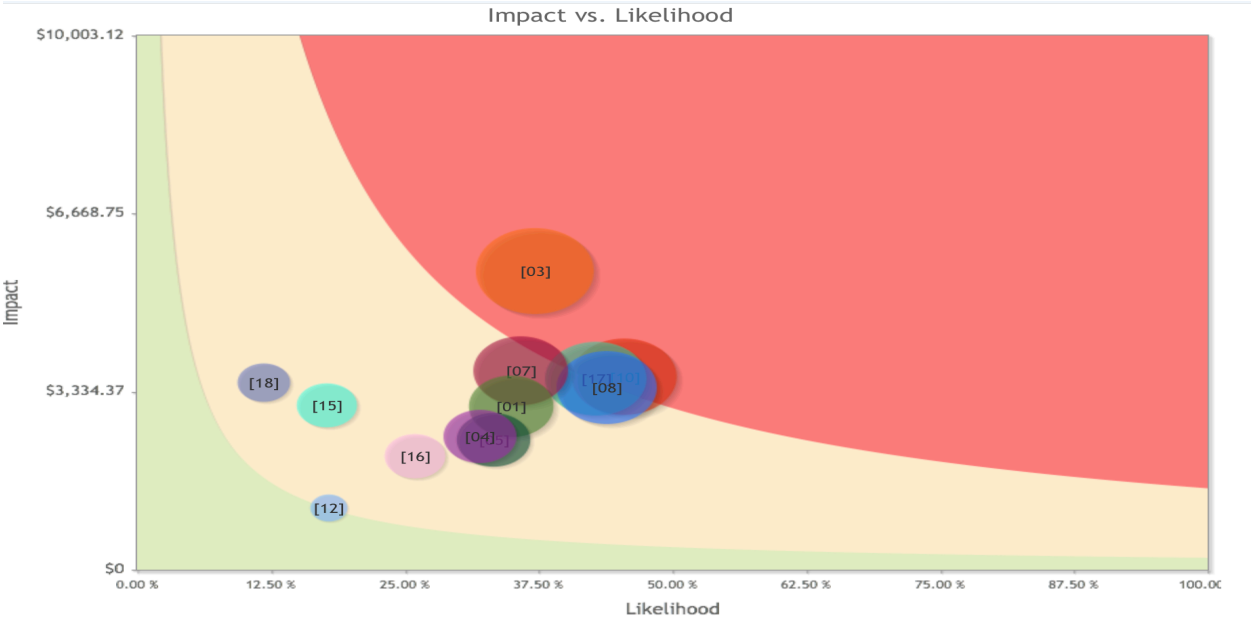


4.3 Risk Map

We used risk maps to help visualize our assessments. The risk maps show all of the sources normalized and relative to each other. The size of the bubble in the chart displays the relative

likelihood of the event from its contributing sources. The risk map in Figure below is a snapshot of the sources impact vs. likelihood. This map has different risk regions: Red zone (over 15%), Yellow zone (2%-15%), and under 2% as green part. The figure shows that those bubbles in the red zone have the highest value of risk so it helped us to find out where is the critical part to apply controls within its given budget.

Overall Risk Map for Impact vs. Likelihood



4.4 Overall Likelihoods, Impacts, and Risks without Controls

The overall risk is calculated by multiplying the likelihood by the impact of an event. The likelihood and impact were rated by the participants by using the methods that were mentioned earlier in the report. In Riskion the total risk aggregated to become $12,468.99 million for all the events and the loss is expected to be $5547.98 which it cannot be possible when the total financial value of the enterprise is $10K million dollar. The events, sources, and objectives are all inter-related, and that is the reason why a mismatch occurs. By simulating an event, these problems can be solved as random numbers are generated.

No.	Event	Likelihood		All Participants Impact, $		Risk, $	
		Computed ▲	Simulated	Computed	Simulated	Computed	Simulated
[18]	Infectious Disease Exposure	11.86%	11.00%	3,492.91	2,311.83	414.36	254.30
[15]	Hearing Loss	17.78%	12.50%	3,064.73	2,218.47	544.86	277.31
[12]	Cancer	17.94%	14.30%	1,150.36	698.84	206.40	99.93
[16]	Post Traumatic Stress Disorder	26.02%	20.40%	2,114.23	1,091.53	550.11	222.67
[04]	Loss of Limb/Body Part	32.05%	21.50%	2,484.74	1,650.67	796.32	354.89
[05]	Respiratory Disease	33.38%	22.80%	2,417.61	1,584.70	807.03	361.31
[01]	Respiratory Illness	34.98%	21.70%	3,052.61	1,883.08	1,067.80	408.63
[07]	Burns	35.91%	25.10%	3,717.83	2,576.20	1,335.14	646.63
[03]	Exposure to Hazardous Materials	37.24%	25.20%	5,583.72	3,969.15	2,079.44	1,000.23
[17]	Muscular Strain	42.93%	27.00%	3,568.55	2,184.27	1,532.05	589.75
[08]	Cardiovascular Strain	43.92%	29.00%	3,404.31	2,090.14	1,495.29	606.14
[10]	Muscular Metabolic Fatigue	45.59%	29.60%	3,597.87	2,453.34	1,640.18	726.19
	Total Risk (Computed)					**$12,468.99**	
	Total Loss (Simulated)						**$5,547.98**

5. Identifying Controls:

Controls required for this case are identified as a brainstorm activity by group which are defined below:

Regular Gear Inspection: Through regular and routine inspections of personal protective gear, firefighting equipment and emergency response vehicles, the chances of equipment failures and malfunctions will decrease.

Physical Fitness Program: By emphasizing the importance of physical fitness and allowing time during duty hours to exercise, many of the risks associated with firefighting can be minimized. Increasing the fitness and health level of a firefighting department will decrease overall health and safety risks to the department and members.

Progressive and Extensive Initial Training (Academy): Initial onboarding training needs to be comprehensive. The training that occurs at the fire academies sets the baseline standard for employees and ensures all members are adequately qualified to perform all basic duties and responsibilities.

Quarterly Refresher Training: All employees should be required to attend refresher training. Some skills and practices taught in the fire academy may not be utilized regularly and many skills are perishable. Additionally, new and improved ways of doing business are always developed, so this would be a great forum to expose the work force to them.

Internal Safety Gear Enforcement: Employees do not always use the assigned protective gear. Policies need to exist and enforcement needs to occur to ensure all employees are following safety gear policies.

Calls for Service Management: The firefighters are exposed to additional risks with every call for service. Adequate staffing and call management can better ensure members are not over tasked, limit sustained exposure and minimize error caused by fatigue and carelessness.

Mental Health Assessments: Regular mental health assessments can identify mental health threats to members and identify employees possibly in the need of further mental health treatment.

Periodic Medical Screenings: Regular assessments conducted by a mental health professional can identify current health issues and may identify concerns and risks only identifiable through a health screening.

Universal Protocol Enforcement: Departments should have well established and understood Standard Operating Procedures or Protocols, and they need to be enforced by leaders and supervisors within the departments.

Community Fire Prevention Policies: Resources available to the public (fire extinguishers, emergency escapes, fire alarms, fire fighters visiting schools, etc.) can provide first line safety to the public since fire fighter response time can never be zero.

Adequate Funding and Priority for Gear Acquisition: Communities need to adequately fund their fire department so they can provide the most reliable and advanced safety gear to their members. Departments need to budget effectively for appropriate gear quality and availability.

Human Resource / Staffing Controls: Many fire departments are understaffed. Staffing constraints can cause additional risks to the individual firefighters.

Teambuilding Events: Having trust in your partners and having realistic baseline standards for members builds confidence in the department.

Medical First Responder Refresher Courses: Since many calls for service for fighters is medical in nature, it is critical for the departments to be current on emergency medical care procedures and constant refreshing on perishable patient care skills.

Periodic Driver's Training: Many firefighters are injured while responding to service calls. Periodic training should be provided on emergency vehicle response procedures and safety protocols.

5.1 Controls in Riskion

After identifying the controls for the potential risk events, then the decision made to apply them to the threat sources, vulnerabilities, and consequences in Riskion to prevent or reduce the potential and uncertain loss. Controls determine to prevent some undesirable factors to reach a desirable state in the project. The cost of each controls is defined and added in the Riskion.

Control register for "*Project: Preventing Health Risks Associated with Firefighting in Metroploitan Areas"

Selected controls: 15
Cost Of Selected Controls: $102 (unfunded: $0)
Total Cost Of All Controls: $102

Index	Control Name	Control for	Selected	Cost	Applications	Categories
01	Regular Gear Inspection	Threat	Yes	1	9	
02	Physical Fitness Program	Threat	Yes	5	4	
03	Internal Safety Gear Enforcement	Threat	Yes	30	10	
04	Progressive and Extensive Initial Training (Academy)	Vulnerability	Yes	10	57	
05	Quarterly Refresher Training	Vulnerability	Yes	5	64	
06	Mental Health Assessments	Vulnerability	Yes	5	68	
07	Adequate Funding for Gear Acquisition	Vulnerability	Yes	10	69	
08	Human Resource / Staffing Controls	Vulnerability	Yes	10	63	
09	Calls for Service Management	Consequence	Yes	1	12	
10	Periodic Medical Screenings	Consequence	Yes	10	3	
11	Universal Protocol Enforcement	Consequence	Yes	1	2	
12	Community Fire Prevention Policies	Consequence	Yes	1	3	
13	Team Building Events	Consequence	Yes	5	3	
14	Medical First Responder Refresher Courses	Consequence	Yes	2	4	
15	Periodic Driver's Training	Consequence	Yes	6	3	

Measurement for Controls

Measurement Methods for Controls for Threats

Control Name	Human Factor							
	Fitness Level	Situational Awareness / Decision Making	Preventive Medical Care/Medication	Protocol Breach	Level of Noise Exposure	Thermal Enviroment Exposure	Exposure to Smoke	H
1. Regular Gear Inspection					Direct	Direct	Direct	
2. Physical Fitness Program	Direct							
3. Internal Safety Gear Enforcement					Direct	Direct	Direct	

6. Controls Optimization and Efficiency Frontier Curve

Decision making is the way to choose the best alternative i.e. scenario among several alternatives to achieve the overall objectives. The overall objective of this case study is to decrease the risks associated with firefighter in Metropolitan areas by assuming an appropriate budget selection to increase the safety of them. Expert choice Companion help to this assessment in selecting the best possible alternative budget selection after using Riskion software to identify the risk amount. The total budget of $75 million with an enterprise value of $10K million to maintain and implement the defined controls. In the optimization below, we can see that the focus is on greatest risk reduction from $12,468.99 to $2,154.74 million which are double counted in Riskion. Controls selected by Riskion are in total of 11and this selection, does not include those controls which performed a stand-alone reduction analysis.

Controls optimization for "*Project: Preventing Health Risks Associated with Firefighting in Metroploitan Areas"

Budget | Risk | Risk Reduction

Budget Limit: $ 75

Total Risk: $12,468.99
Risk With Selected Controls: $2,154.74 (Δ: $10,314.25)
Risk With All Controls: $1,808.83 (Δ: $10,660.16)
Total Risk Reduction: $8,271.92

Selected controls: 10
Cost Of Selected Controls: $75 (unfunded: $27)
Total Cost Of All Controls: $102

Ignore: Musts | Must Nots | Dependencies | Groups

Search:

Index	Control Name	Control for	Selected	Cost	Applications	Categories	S.A. Reduction	Must	Must Not
01	Regular Gear Inspection	Threat	Yes	1	9		$1,946.82		
02	Physical Fitness Program	Threat		5	4		$1,533.80		
03	Internal Safety Gear Enforcement	Threat	Yes	30	10		$3,379		
04	Progressive and Extensive Initial Training (Academy)	Vulnerability	Yes	10	48		$3,256.42		
05	Quarterly Refresher Training	Vulnerability	Yes	5	56		$2,710.04		
06	Mental Health Assessments	Vulnerability	Yes	5	60		$3,194.35		
07	Adequate Funding for Gear Acquisition	Vulnerability	Yes	10	59		$2,025.11		
08	Human Resource / Staffing Controls	Vulnerability	Yes	10	56		$1,686.86		
09	Calls for Service Management	Consequence	Yes	1	12		$1,467.59		
10	Periodic Medical Screenings	Consequence		10	3		$580.70		
11	Universal Protocol Enforcement	Consequence	Yes	1	2		$347.38		
12	Community Fire Prevention Policies	Consequence		1	3		$169.96		
13	Team Building Events	Consequence		5	3		$770.70		

6.1 Efficient Frontier for Controls Optimization

Efficient frontier could be seen as another method for selecting the controls through Riskion. The software helps in understanding that if more money is spent on controls then the risk to face would eventually come down. In this case this method is used to help in deciding the optimal controls to apply in which amount of budget.

Efficient Frontier for "*Project: Preventing Health Risks Associated with Firefighting in Metroploitan Areas"

Options: Ensure funded controls remain funded as budget increases | Grid View Mode | Detailed tooltips

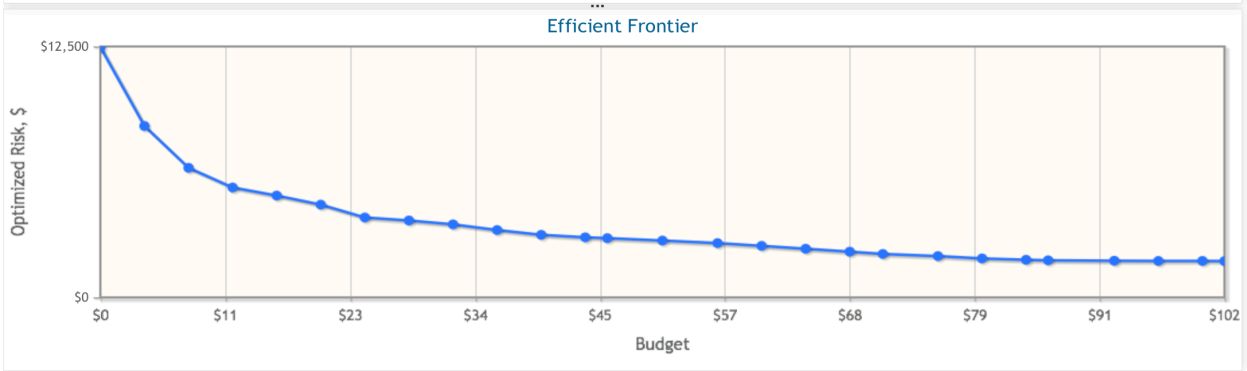
Delta when optimizing for Increasing Budgets: Specified Amount: 4 | Approx. # of Increments: 26 | All Solutions, Δ: 1

X-axis range: From: To:

Ignore: Musts | Must Nots | Groups | Dependencies

Base Case includes: Groups

Index	Events/Budget	$0	$4	$8	$12	$16	$20	$24	$28	$32	$36	$40	$44	$48	$52	$56
	Risk with Selected Controls	124.69	85.4	64.56	54.75	50.72	46.21	39.8	38.31	36.38	33.56	31.17	29.93	29.51	28.32	27.05
	Funded Cost	$0	$4	$8	$12	$16	$20	$24	$28	$32	$36	$40	$44	$46	$51	$56
1.	Regular Gear Inspection		FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDED	FUNDE
2.	Physical Fitness Program						FUNDED		FUNDED			FUNDED	FUNDED	FUNDED	FUNDED	FUNDE

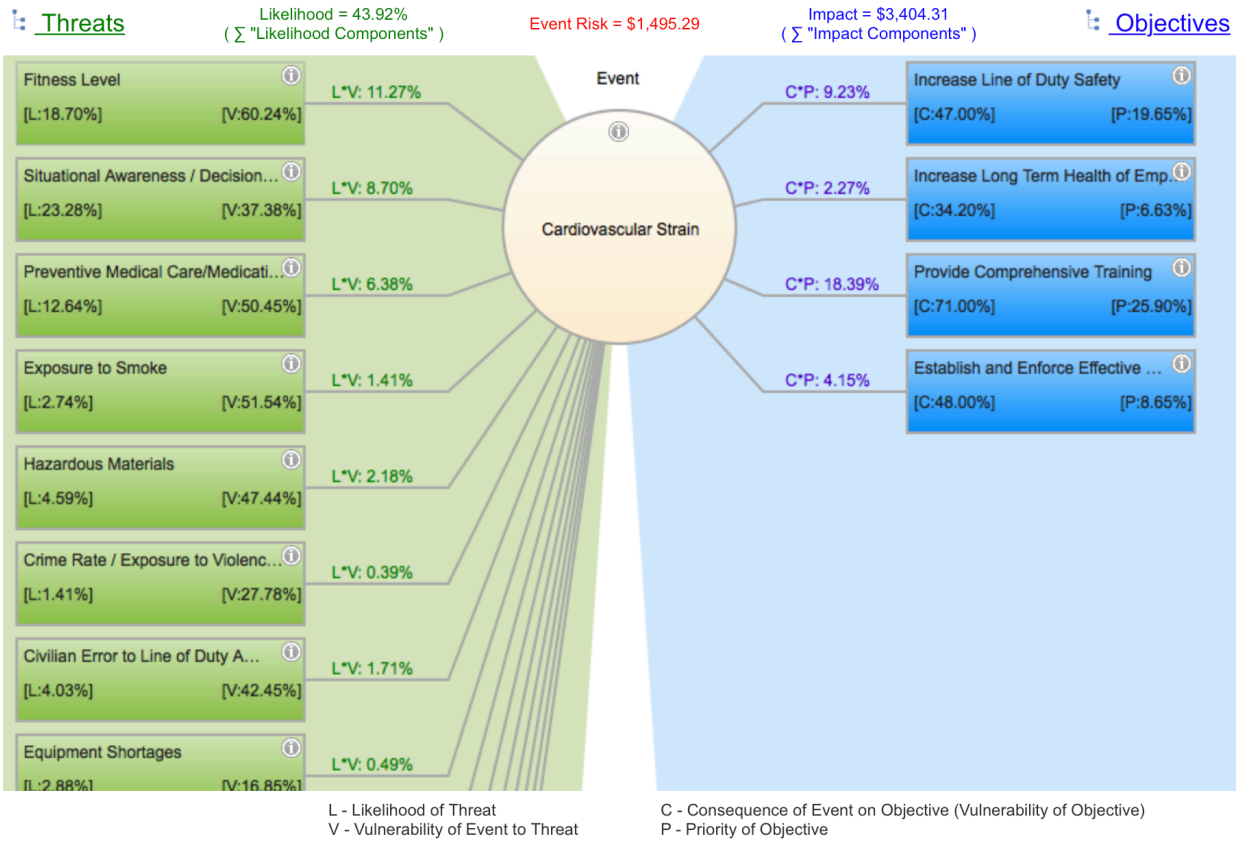


The figure shows that as much as the budget is increasing more controls would be applied, so the graph is becoming more flatten and efficient. The majority of the controls are applied in the beginning to reduce the overall risk in this case.

6.2 Bow Tie Diagrams without Controls

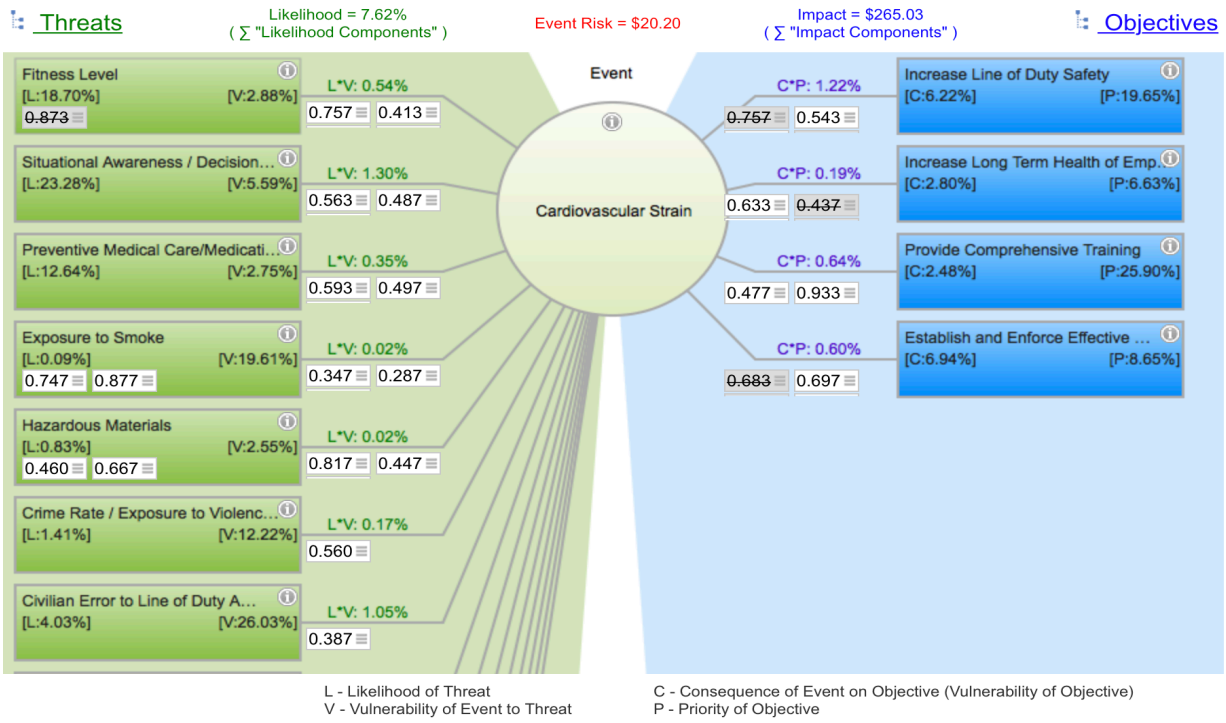
The bow-tie diagram shows any threat that can lead onto impacting the objectives. The likelihood being 43.92% and the impact being $3404.31 for the event of "cardiovascular strain" is a result of multiple threats combining to pose an event risk of $1,495.29. By using the bow-tie diagram, the team was able to analyze the risk events. This figure helps to identify the total number of threats to that added up to create that event along with the objectives that would be affected by the particular event.

Example of Cardiovascular Strain Event in Bow-Tie Diagram



6.3 Bow Tie Diagrams with Controls

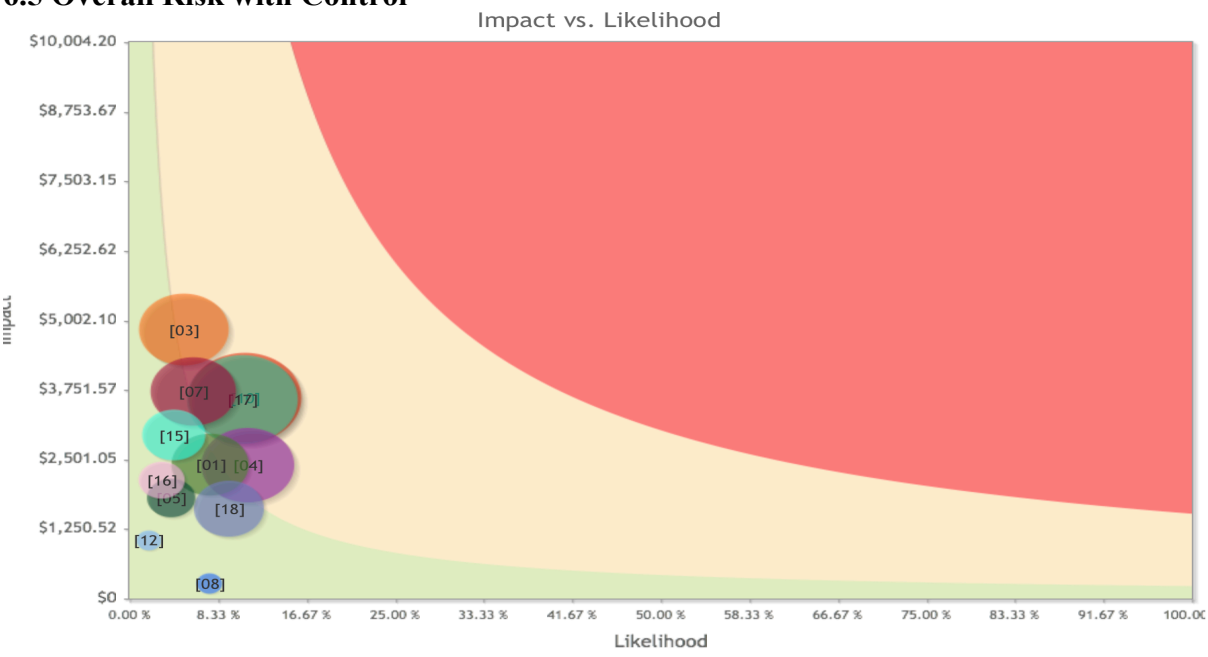
Once the controls have been put in place and properly implied, the cumulative effect can be viewed in the bow-tie diagram. The white boxes show the impact of different controls on their respective threats and objectives. The information was useful as it helped in determining the reduction in risk after using multiple controls. The controls can be used as a test to see how an extra control can reduce event risk by turning each of them on or off to see the result.



6.4 Risk Map with Control

Once all the controls have been added, a new risk map is created to show how those controls affect the overall project risk. The figure below shows how there has been a significant reduction in risk despite the fact that there are still so many events with high percentages. Extra controls can help in minimizing the events until they fall down to a point where they do not affect the organization anymore.

6.5 Overall Risk with Control



The figure shows that the overall risk shown in section 4.3 had a significant decrease to an acceptable value by applying controls.

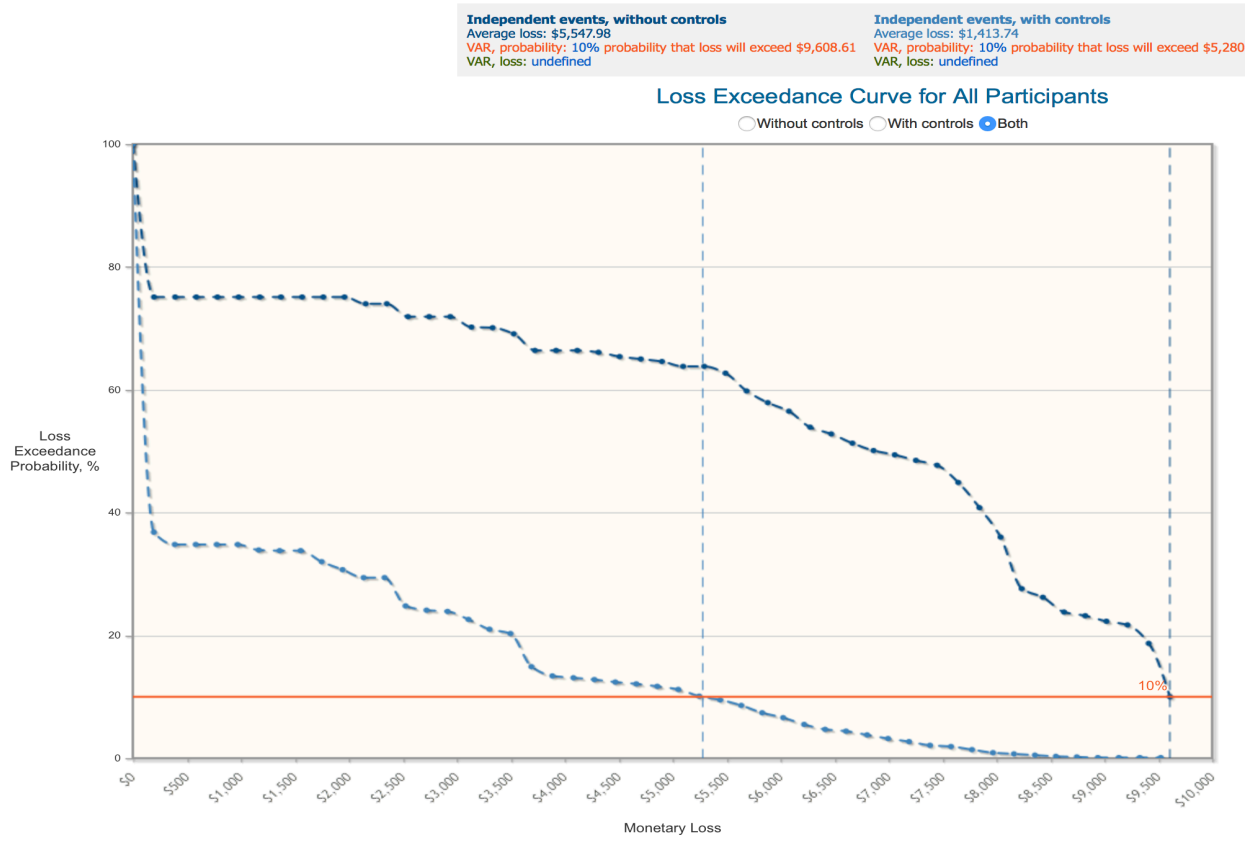
6.6 Overall Likelihoods, Impacts, and Risks After Applying Controls

The final assessment of risk, likelihood, and impact after applying the controls optimization is helped to review all the values between the considered budget. The figure below demonstrates the simulated risk with the implementation of controls with $75 million budget have the total loss reduction of $4,228.51 million and remaining of $1,319.47 million with total enterprise value of $10K million.

No.	Event	All Participants Likelihood Computed ▲	Likelihood Simulated	Impact, $ Computed	Impact, $ Simulated	Risk, $ Computed	Risk, $ Simulated
[12]	Cancer	1.85%	1.50%	1,041.44	999.76	19.30	15
[16]	Post Traumatic Stress Disorder	3.11%	3.20%	2,114.23	1,832.83	65.67	58.65
[05]	Respiratory Disease	3.98%	2.70%	1,801.78	1,669.74	71.69	45.08
[15]	Hearing Loss	4.25%	2.90%	2,922.83	2,742.59	124.13	79.54
[03]	Exposure to Hazardous Materials	5.18%	3.10%	4,820.70	4,417.06	249.49	136.93
[07]	Burns	6.08%	3.90%	3,717.83	3,375.67	226.14	131.65
[08]	Cardiovascular Strain	7.62%	5.80%	265.03	259.79	20.20	15.07
[01]	Respiratory Illness	7.71%	3.70%	2,396.99	2,090.13	184.74	77.33
[18]	Infectious Disease Exposure	9.45%	9.30%	1,606.17	1,586.77	151.79	147.57
[17]	Muscular Strain	10.68%	7.00%	3,568.55	3,373.06	381.22	236.11
[10]	Muscular Metabolic Fatigue	10.92%	7.10%	3,597.87	3,329.57	392.95	236.40
[04]	Loss of Limb/Body Part	11.21%	6.20%	2,385.47	2,260.35	267.42	140.14
	Total Risk Reduction (Computed)					**$10,314.25**	
	Total Residual Risk (Computed)					**$2,154.74**	
	Total Loss Reduction (Simulated)						**$4,228.51**
	Total Residual Loss (Simulated)						**$1,319.47**
	Cost of Selected Controls						**$75**

6.7 Loss Exchange Curve with and without Controls

Loss exchange curve is another way to show the simulated risk before control and after applying control in the same graph. This cumulative mirror frequency chart is used to compare the probability of the loss before implying the controls and after implying adequate control on the organization. So, the graph shows that there is a 10% probability that the amount of loss before applying the controls will exceed $9608.61 million, whereas the loss would decrease to $5280 million after the controls are in place



7. Conclusion

When concluding, it can be seen, very clearly that firefighting in metropolitan areas has a high loss of $5,547,98 but this amount of loss would be reduced by applying controls with budget of 75 million dollars to $1,413,74 million. A recommendation for this project is to increase the budget for implying more controls in the organization. These added controls can be checked if the added controls fail to reduce the losses, then the likelihood of the events as well as the impact needs to be rechecked. If the controls fail and the risk is high as well then, the project would not be feasible unless the profits in the future are really high too.

References

National fire protection Association. (n.d.). National Fire Protection Association Statistics. Retrieved from http://www.nfpa.org