

Fall 2019 Risk Management Class



Risk Management Project: Driverless Trucks

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Executive Summary:

In this project, our group explores the risks associated with the automated trucking industry. Specifically, we looked at the risks face by a package handling company (i.e. DHL, FEDEX, UPS, USPS, etc.) when adopting and implementing this technology. The timeline considered in this project is the first year of the system's full implementation; assuming a completed governmental testing phase and permission prior to full implementation.

Risk events were developed using National Highway Traffic Safety Administration information as well as our group's experience in the logistical and automated trucking administration. The group's understanding is due to a combined 18 years of military logistical experience as well as the military's own project to develop this capability. While this expertise does not relate directly to placing this technology on public roads, many similarities exist. The sources of risk were identified using an end to end risk assessment on both the use of the technology as well as the technological components of the equipment (both human and mechanical sources of risk). These sources were truncated to the major sources of risk to reduce the length of this project to be more manageable given the timeline of submission. The sources were: System / Software Related, Hardware Related, Human Factor, Environmental, Terrorist or Criminal Activities. For sources, we identified 11 controls that potentially mitigated risk across various sources. Since many possible relationships between sources and controls exist, we chose to use the "Controls for Source Likelihoods" grid to assign connections.

For the budget of the project we included analysis at multiple funding levels to provide a cost-benefit analysis. It is our recommendation that management selects the \$3M funding level to achieve the highest investment leverage while still significantly reducing risk. By selecting this option, the following controls are implemented: Install back-up generators for control rooms, create pre-made media relations packages, engage employees through monthly surveys and quarterly town halls, create materials notifying customers of new technology and potential challenges, create excess capacity delivery system - Uber of delivering packages, test phase in select distribution centers, monthly performance management reviews, enhanced training, monthly map updates, include weather forecasts in delivery estimates, vehicle automatically slows and stops, two-step route approval, and add the ability to enable manual driving mode.

In this option, risk total risk reduction is significant (approximately 35%) while still maintaining acceptable levels of residual risk, 25% loss exceedance, and likelihood of losing more than \$1B. Based on these factors, we believe the \$3M funding level is the best option for management to select.

Project Summary:

In this project, our group explores the risks associated with the automated trucking industry. Specifically, we looked at the risks face by a package handling company (i.e. DHL, FEDEX, UPS, USPS, etc.) when adopting and implementing this technology. The timeline considered in this project is the first year of the system's full implementation; assuming a completed governmental testing phase and permission prior to full implementation.

Project Statistics:

Events count: 11

Source Count 29, covering sources: 22

Objective count 20, covering Objectives:15

Participants count: 7

Value of the Enterprise: \$1,400,000,000

Participants:

For this project, we thought it would be best to roleplay participants that would most likely have an objective view of the project's risks, sources of risk, and the likelihood of risk events from their particular position within the organization.

These positions included:

- Ken Gannetta: Risk Management Consultant
- Jonathon Gambrell: Risk Management Consultant
- Chief Technology Officer*
- Equipment and Maintenance Director*
- Process Management Consultant*
- Risk Management Specialist*
- Training Director*

* annotates that these participants were simulated

Risk Events:

Risk events were developed using National Highway Traffic Safety Administration information as well as our groups experience in logistical and automated trucking administration. The group's understanding is due to a combined 18 years of military logistical experience as well as the military's own project to develop this capability. While this expertise does not relate directly to placing this technology on public roads, many events are applicable. They include:

- Increased injuries and/or loss of life
- Increased damage to others' property
- Higher than normal operating costs
- Longer than average shipping delays
- System fails to operate at expected utilization rate
- Loss of vehicle or equipment
- Lost packages
- Vehicles are unable to operate
- Packages delivered to incorrect locations and require redelivery
- Data Breach
- Insufficient charging stations to support needs

Sources of Risk:

The sources of risk were identified using an end to end risk assessment on both the use of the technology as well as the technological components of the equipment (both human and mechanical sources of risk). These sources were truncated to the major sources of risk to reduce the length of this project to be more manageable given the timeline of submission. The included sources and underlining sources of risk are:

- System / Software Related:
 - Complete system failure
 - Loss of GPS signal
 - Bugs in the system
 - Inaccurate maps / routes
 - At-fault accident caused by the system
 - Truck and software are incompatible
 - Route restrictions not identified in the system
 - Unexpected / inaccurate decisions by the software
 - High number of patch / software updates
- Hardware Related
 - Battery related fire
 - Expensive system component replacement
 - Batteries don't hold advertised charge
 - Truck and hardware are incompatible
- Human Factor
 - Poorly trained maintainers
 - Poorly trained operators
 - Route approval negligence
 - Deliberate disregard for policies & procedures
 - Regulations that restrict / limit the use of driverless technology
- Environmental
 - Weather restricts road access
 - Power outage from natural events

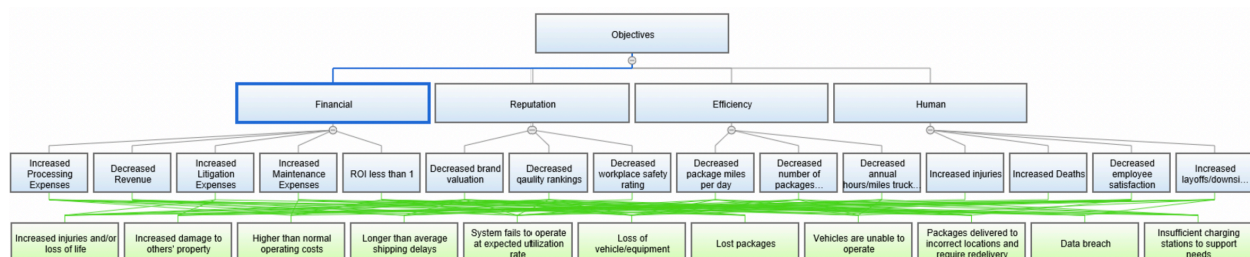
- Terrorist or Criminal Activities
 - Cyberattack
 - Vehicle Hijacking

Objectives:

Objectives were chosen due to what the group perceived as major decision factors for a business as it takes on new endeavors. These were determined using a Porter's Five Forces analysis to look at the parcel delivery industry as well as different delivery services' mission and goals statements. This was compared against required "end-states" of a project in terms of efficiency and financial burdens to determine objective categories and their respective objectives.

- Financial
 - Increased processing expenses
 - Decreased revenue
 - Increased Litigation expenses
 - Increased maintenance expenses
 - Return on investment (ROI) less than 1
- Reputation
 - Decreased brand valuation
 - Decreased quality rankings
 - Decreased workplace safety rating
- Efficiency
 - Decreased package miles per day
 - Decreased number of packages delivered per day
 - Decreased annual hours/ miles trucks can operate
- Human
 - Increased injuries
 - Increased deaths
 - Decreased employee satisfaction
 - Increased layoff / downsizing

Hierarchical view of objectives with events (as shown in Riskion and in larger size in Appendix 1)



Controls for this event will be discussed later in the paper.

Measuring Risk Events and Likelihoods

Structuring Phase: In order to measure the likeliness of risk events the group used Riskion's vulnerability grid to determine what event would be affected by each source. For the participant's roles, we determined that this would be conducted using all participants because their view would likely be a contributing factor to an organization's decision on the project. We concluded that this will be the trend throughout the project given the senior level roles of the participants.

Measure Phase: The group decided to use pairwise comparison to determine the weight and likelihood of the sources due to the hierarchical nature of the sources, differing judgements among participants, and the severity in weight that each participant believes that the source will have on the project. Using the pairwise comparison tool provides the project with a derived answer using the analytical hierarchical process, or AHP. AHP assigns measurable values from an individual's feelings or personal insights. These measurable values help determine which source and sub-source may be the most likely, either filtered by participant or in aggregate. For the event phase we used Riskion's default rating scale because it seemed applicable, appropriate, and capable of accurately measuring the responses. To give a broad view of the project, the team decided to add simulated participants to provide a more substantive analysis. The views of these simulated participants were developed on the group's understanding of the participant's roles and responsibilities as well as an understanding of what the participant might believe would be the most likely source of risk as well as what event may occur due to the risk.

Synthesize and Iterate Phase: The following are reports generated by Riskion following the input of all participants. These reports provide the group with measurable insight as well as the likelihood of the risks as they relate to the sources in order to weight all opinions accurately as to not skew the decision based on one participant's heavy views.

Reports Generated through this phase of the project:

Likelihoods Due To System/Software related			Likelihoods Due To Hardware Related		
	Events	[All Participants] 7 with judgments		Events	[All Participants] 7 with judgments
[01]	Increased injuries and/or loss of life	45.58%	[01]	Increased injuries and/or loss of life	1.11%
[02]	Increased damage to others' property	29.70%	[02]	Increased damage to others' property	0.44%
[03]	Higher than normal operating costs	70.74%	[03]	Higher than normal operating costs	8.12%
[04]	Longer than average shipping delays	100.79%	[04]	Longer than average shipping delays	2.24%
[05]	System fails to operate at expected utilization rate	69.81%	[05]	System fails to operate at expected utilization rate	1.35%
[06]	Loss of vehicle/equipment	10.15%	[06]	Loss of vehicle/equipment	0.44%
[07]	Lost packages	8.05%	[07]	Lost packages	0.42%
[08]	Vehicles are unable to operate	59.27%	[08]	Vehicles are unable to operate	3.19%
[09]	Packages delivered to incorrect locations and require redelivery	16.78%	[09]	Packages delivered to incorrect locations and require redelivery	0.00%
[10]	Data breach	0.00%	[10]	Data breach	0.00%
[11]	Insufficient charging stations to support needs	6.04%	[11]	Insufficient charging stations to support needs	1.58%

Likelihoods Due To Human Factor			Likelihoods Due To Environmental		
	Events	[All Participants] 7 with judgments		Events	[All Participants] 7 with judgments
[01]	Increased injuries and/or loss of life	25.55%	[01]	Increased injuries and/or loss of life	37.71%
[02]	Increased damage to others' property	13.80%	[02]	Increased damage to others' property	0.00%
[03]	Higher than normal operating costs	54.58%	[03]	Higher than normal operating costs	0.00%
[04]	Longer than average shipping delays	38.20%	[04]	Longer than average shipping delays	142.94%
[05]	System fails to operate at expected utilization rate	52.39%	[05]	System fails to operate at expected utilization rate	25.60%
[06]	Loss of vehicle/equipment	1.38%	[06]	Loss of vehicle/equipment	0.16%
[07]	Lost packages	4.00%	[07]	Lost packages	0.00%
[08]	Vehicles are unable to operate	41.46%	[08]	Vehicles are unable to operate	12.16%
[09]	Packages delivered to incorrect locations and require redelivery	31.99%	[09]	Packages delivered to incorrect locations and require redelivery	0.00%
[10]	Data breach	3.23%	[10]	Data breach	0.00%
[11]	Insufficient charging stations to support needs	0.00%	[11]	Insufficient charging stations to support needs	18.08%

Likelihoods Due To Terrorist/Criminal		
	Events	[All Participants] 7 with judgments
[01]	Increased injuries and/or loss of life	6.22%
[02]	Increased damage to others' property	7.81%
[03]	Higher than normal operating costs	21.17%
[04]	Longer than average shipping delays	26.26%
[05]	System fails to operate at expected utilization rate	22.59%
[06]	Loss of vehicle/equipment	15.15%
[07]	Lost packages	14.70%
[08]	Vehicles are unable to operate	16.48%
[09]	Packages delivered to incorrect locations and require redelivery	0.00%
[10]	Data breach	23.75%
[11]	Insufficient charging stations to support needs	0.00%

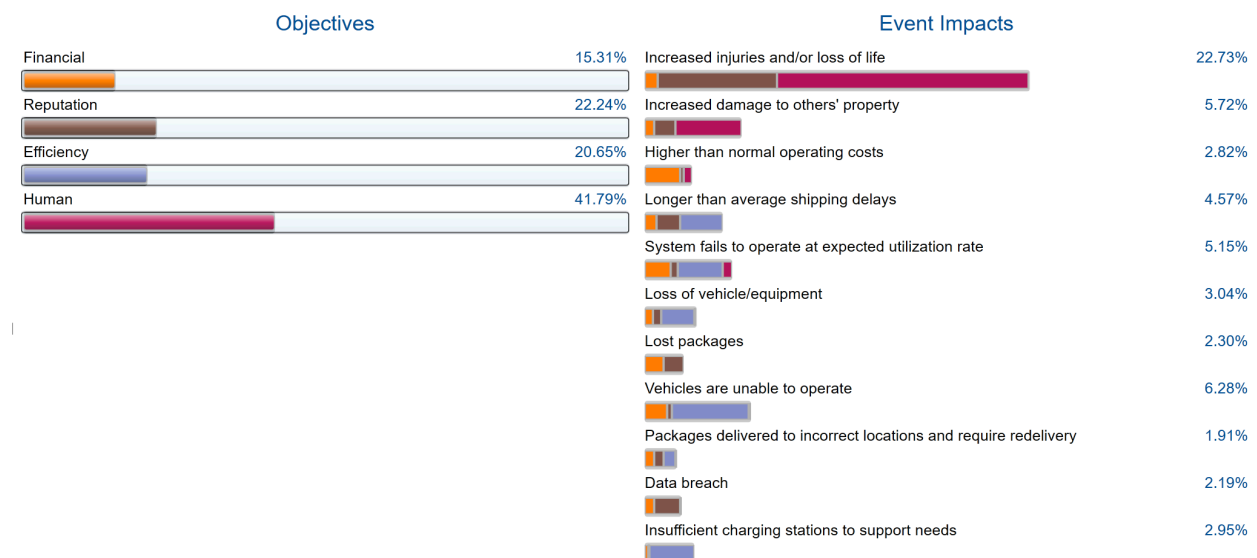
Report Phase: Looking at these charts provides a detailed look at each source of risk and how that overarching source is judged towards each event, determining a likelihood. It is clear that software related issues are provide the project with a significant amount of risk across most of the events with an average risk of 37.81%

across all events. Human nature and environment are second and third most likely sources, respectively, which could have an impact on the project. These reports provide a great visual display and allow for decision makers to have a better understanding of the sources of risk, events which may occur, and the likelihood of the event based on the source.

Measuring and Synthesizing Risk Event Impacts

Structure Phase: The group set up a Hierarchy of Objectives using the objectives list and hierarchy outlined in the introductory section of the project. Like the risk events, we used Riskon's Consequence Grid to develop what event would affect each objective. This was done to shorten the length of the respondents required amount of questions, reducing question fatigue and ensuring that the weighted averages of the relationships would not be skewed by nullified data and questions would be asked in the proper context.

Measure Phase / Synthesize and Iterate Phase: Similar to the Risk likeliness phase, we used both pair-wise and rating scaled measurement techniques for the objectives and events, respectively. This is done for the same reasons explained above. The following report is one of the reports generated by Riskon given the input from the participants.



Reporting Phase: The reports above indicate that the largest risk from this project confirms our group's early suspicion that the human factor is going to cause the largest issue to this endeavor. By measuring the objectives against the impacts, it was clear that any injury or loss of life would be catastrophic to the firm. This likelihood is high due to the unpredictable nature of humans sharing the road with the automated trucks.

Accidents happen today even in optimum road conditions by drivers either making poor or impaired decisions.

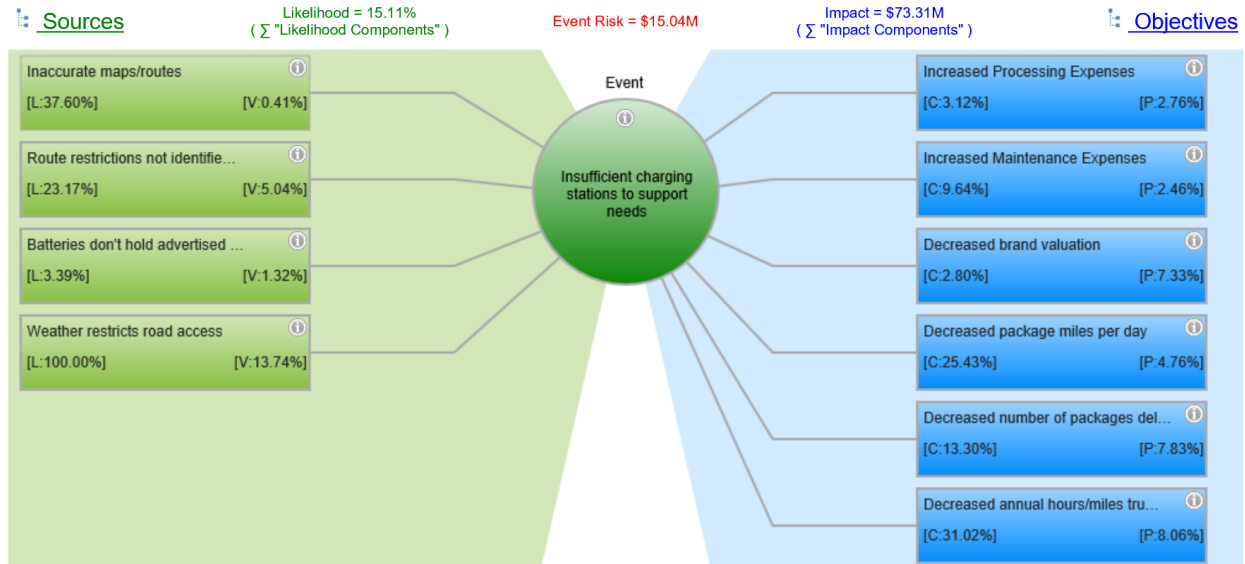
Examining and Communicating Event and Total Risks

Graphic depiction is a useful tool needed to assist in the communication of risk to leadership. At this stage, we have values related to likelihoods of events (as determined by sources and the impact those events have on objectives. These relationships can be expressed in two ways, on a high level through the likelihood, impacts, and risks table, and through individual event bow-tie diagrams.

The table, as seen below, is effective at communicating the overall likelihood, impact, and risk of an event. It does not, however, show in detail how each source contributes to an event, or how events contribute to objectives. It is very useful as a snapshot of uncontrolled risks.

No. ▼	Event		All Participants		
			Likelihood Simulated	Impact, \$ Simulated	Risk, \$ Simulated
[11]	Insufficient charging stations to support needs	≡	<div><div></div>20.51%</div>	<div><div></div>73,313,507</div>	<div><div></div>15,038,276</div>
[10]	Data breach	≡	<div><div></div>26.80%</div>	<div><div></div>56,626,113</div>	<div><div></div>15,176,553</div>
[09]	Packages delivered to incorrect locations and require redelivery	≡	<div><div></div>41.50%</div>	<div><div></div>50,715,799</div>	<div><div></div>21,048,852</div>
[08]	Vehicles are unable to operate	≡	<div><div></div>76.46%</div>	<div><div></div>164,096,957</div>	<div><div></div>125,464,802</div>
[07]	Lost packages	≡	<div><div></div>25.16%</div>	<div><div></div>54,351,828</div>	<div><div></div>13,672,846</div>
[06]	Loss of vehicle/equipment	≡	<div><div></div>24.21%</div>	<div><div></div>75,768,779</div>	<div><div></div>18,342,608</div>
[05]	System fails to operate at expected utilization rate	≡	<div><div></div>84.82%</div>	<div><div></div>137,095,541</div>	<div><div></div>116,282,827</div>
[04]	Longer than average shipping delays	≡	<div><div></div>98.01%</div>	<div><div></div>135,121,371</div>	<div><div></div>132,434,139</div>
[03]	Higher than normal operating costs	≡	<div><div></div>81.91%</div>	<div><div></div>68,503,737</div>	<div><div></div>56,114,004</div>
[02]	Increased damage to others' property	≡	<div><div></div>41.96%</div>	<div><div></div>139,052,462</div>	<div><div></div>58,348,753</div>
[01]	Increased injuries and/or loss of life	≡	<div><div></div>69.06%</div>	<div><div></div>625,304,021</div>	<div><div></div>431,866,053</div>
Total Risk (Average Loss)					Simulated \$1,003,789,717

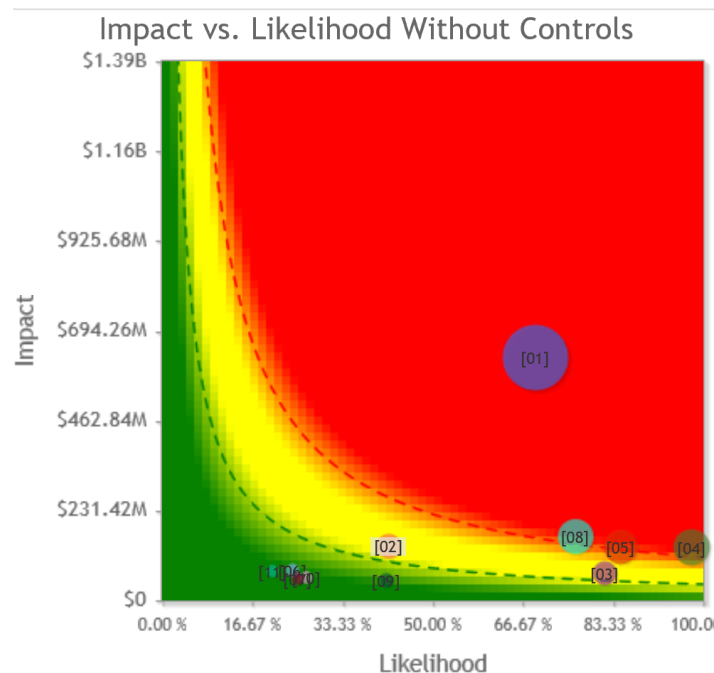
Bow-tie diagrams, on the other hand, provide exact information about how each source contributes to events and how those events contribute to objectives. For simplicity, we've included an example bow-tie diagram for the event "insufficient charging stations to support needs." As seen in this diagram, we are able to see precisely how the four associated events contribute to the event firing, and how the event impacts the six associated objectives. These are very useful for drilling down into an event's structure, but should only be used for deeper analysis due to the total volume of bow-tie diagrams.



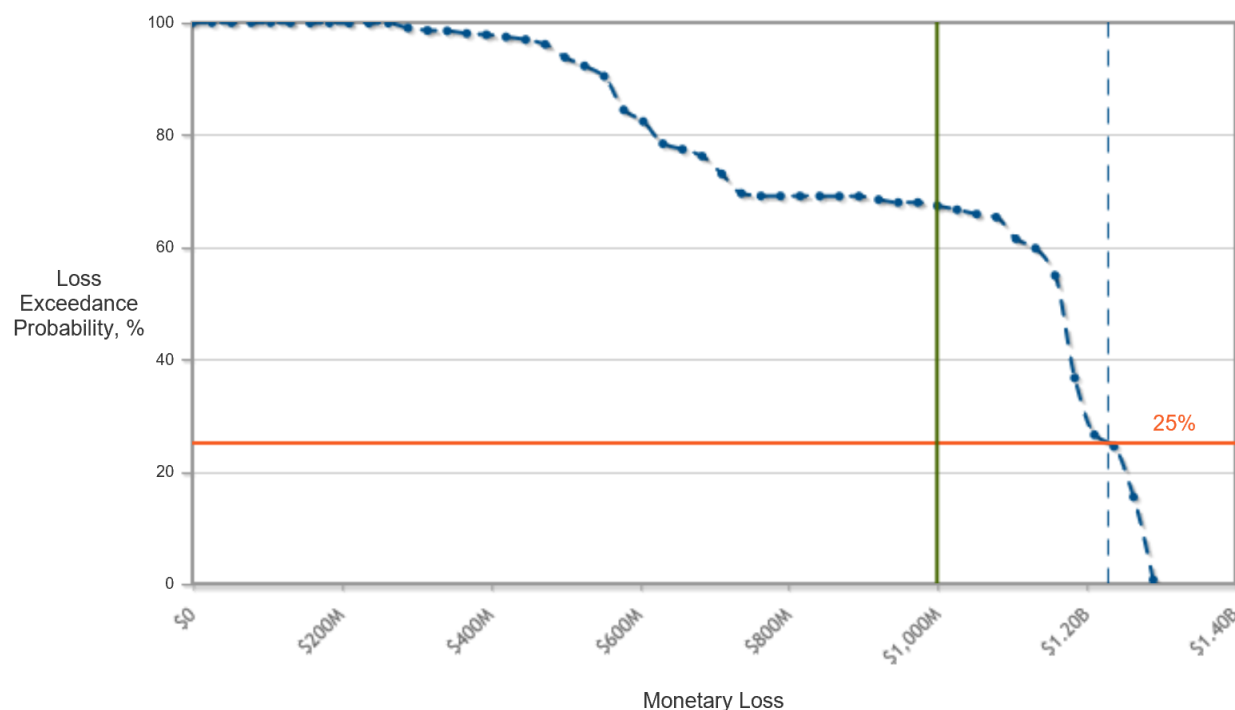
To visualize this better, we generated a heat map using the following parameters as a percentage of the value of the enterprise (\$1.4B):

- Risk over 8% - Red
- Risk between 3% and 8% - Yellow
- Risk under 3% - Green

The heat map shows us very clearly that the largest risk event is “increased injuries/loss of life” (circle 01 in purple). There are three other events (04, 05, and 08) that also fall within the region for risk greater than 8%, showing us there is significant uncontrolled risk present in the project.



Turning our attention to the loss exceedance curve, we see two key pieces of information. First, 25% loss exceedance is over \$1.2 billion. This means there is a 25% chance that in the first year of implementation, this system will lose \$1.2 billion. Second, the probability of loss of \$1 billion is over 67%. These figures highlight the need for implementing controls.



Controlling/Mitigating Risk

Structuring Phase: In this phase of the controlling and mitigating risk section, we first chose to create a list of controls for mitigating the sources listed in earlier in this report. For sources, we identified 11 controls that potentially mitigated risk across various sources. Since many possible relationships between sources and controls exist, we chose to use the “Controls for Source Likelihoods” grid to assign connections. Below is the completed grid.

Control Name	Sources																			
	System/Software related										Hardware Related									
	<input type="checkbox"/> Complete system failure	<input type="checkbox"/> Loss of GPS signal	<input type="checkbox"/> Bugs in the system	<input type="checkbox"/> Inaccurate map/routes	<input type="checkbox"/> At-fault accident caused by the system	<input type="checkbox"/> Truck and software are incompatible	<input type="checkbox"/> Route restrictions not identified in the system	<input type="checkbox"/> Unexpected/inaccurate decision by software	<input type="checkbox"/> High number of patch/software updates	<input type="checkbox"/> Battery related fire	<input type="checkbox"/> Expensive system component replacement	<input type="checkbox"/> Batteries don't hold advertised charge	<input type="checkbox"/> Truck and hardware are incompatible	<input type="checkbox"/> Poorly trained maintainers	<input type="checkbox"/> Poorly trained operators	<input type="checkbox"/> Route approval negligence	<input type="checkbox"/> Deliberate disregard for policies & procedures	<input type="checkbox"/> Regulations that restrict/inhibit the use of diversionary technology	<input type="checkbox"/> Weather restricts road access	<input type="checkbox"/> Power outage from natural events
<input type="checkbox"/> 01. Test phase in select distribution centers	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 02. Monthly performance management reviews	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 03. Enhanced training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 04. Monthly map updates	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 05. Prescreen fleet for compatibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 06. Include weather forecasts in delivery estimates	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 07. Install dual-mode GPS (ground and satellite)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 08. Semi-annual cyber security tests	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> 09. Put a dummy in the driver's seat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> 10. Removable steering wheels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> 11. Monthly software updates	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

We compiled controls for events and objectives in a similar manner. In this instance, we derived eight controls for events and eight controls for objectives. Like sources, these controls potentially spanned across multiple events or objectives. Because of the many relationship possibilities that exist in this case, we applied controls across each event and objective using the appropriate grid to ensure thoroughness and completeness. Because each event and objective each have a separate grid to apply controls, we won't display the results here (total of 22 grids).

Measure Phase: Unlike the previous sections, for controlling and mitigating risk we chose to seek input only from those participants with knowledge of the control and event or objective it applied to. For example, we excluded the Training Director from providing input to technology related judgements such as software or hardware controls. Below is the grid of role applications.

Control Name	<input type="checkbox"/> Professor Forman (forman@uwu.edu)	<input checked="" type="checkbox"/> Jon Gambrell (jgambrell@uwu.edu)	<input checked="" type="checkbox"/> Kenneth Gannetta (kgannetta@uwu.edu)	<input type="checkbox"/> Nicholas Stavrakakis (nstavrakakis@uwu.edu)	<input type="checkbox"/> Process Management Consultant (Processes@uwu.edu)	<input type="checkbox"/> Risk Management Specialist (Risk@uwu.edu)	<input type="checkbox"/> Chief Technology Officer (Tech@uwu.edu)	<input type="checkbox"/> Training Director (Training@uwu.edu)	<input type="checkbox"/> Equipment & Maintenance Director (Trucks@uwu.edu)
Controls for Sources									
<input type="checkbox"/> Test phase in select distribution centers	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Monthly performance management reviews	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Enhanced training	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Monthly map updates	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Prescreen fleet for compatibility	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Include weather forecasts in delivery estimates	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Install dual-mode GPS (ground and satellite)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Semi-annual cyber security tests	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Put a dummy in the driver's seat	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Removable steering wheels	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Monthly software updates	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Controls for Events									
<input type="checkbox"/> Install back-up generators for control rooms	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Vehicle automatically slows and stops	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Two-step route approval	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Remote vehicle shutdown	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Automatic fire suppression systems	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Enable manual driving mode	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Install hybrid generators to supply in vehicle charge	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Two data centers capable of supporting network	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Controls for Consequences									
<input type="checkbox"/> Create an interest bearing settlement fund	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Retain in-house legal team	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Create pre-made media relations packages	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Engage employees through monthly surveys and quarterly town halls	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Institute policies to eliminate layoffs from driverless trucking program	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Create materials notifying customers of new technology and potential upsets and downsides	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> Create excess capacity delivery system - User of delivering packages	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/> Maintain manual driving mode for trucks	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

We also chose to allow participants to directly input the effectiveness of the control rather than using pairwise comparisons. It was our belief that participants selected had enough experience to accurately evaluate the effectiveness of each control in

percentage form. Additionally, we felt that conducting pairwise comparisons for controls would create too many measurement questions which could dissuade participants from completing the activity.

Effectiveness: The overall effectiveness for each control as they relate to sources, events, and objectives is the result of combined input from all applicable participants. The final combined effectiveness rates are located in Riskion under Controls → Effectiveness. We do not include the results for each control in this report due to the size/volume of each report.

Optimize: We realize that implementing all controls may not be feasible or affordable. With this in mind, we selected what we believe are the “must have” controls that need to be implemented. Our list of “must haves” is below.

- Test phase in select distribution centers – A system of this size and complexity requires some form of test prior to organization wide roll-out. Failure to do so opens the organization to potentially avoidable problems that otherwise may have been corrected.
- Install back-up generators in control rooms – Implementation of this controls drastically reduces the impact of power outage events on the operation of the system. Installing back-up generators also potentially reduces the need to have a second, fully capable back-up control system.
- Enable manual driving mode – This control provides the opportunity to manually operate all vehicles in the organization’s fleet. Manual operation may be applied to actual distribution of packages, recovering disabled vehicles, and placing vehicles into service bays.

Following selection of our “must haves,” we then turned our attention to potential dependencies that may exist between controls. These dependencies mean that if one control were implemented, the dependent control must be implemented with it. In this activity, we determined the following dependencies exist.

- “Vehicle automatically slows and stops” with “Maintain manual driving mode”
- “Monthly map updates” with “Monthly software updates”

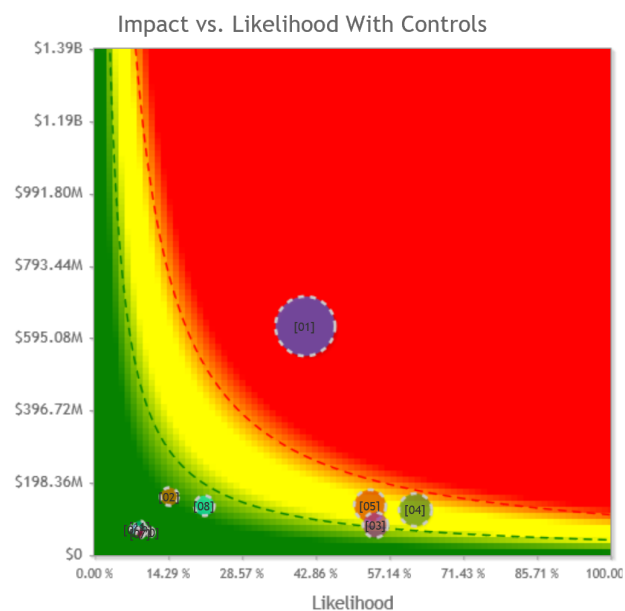
Finally, to optimize our controls we decided to set a budget limit of \$5,000,000. In this way, we can restrict the allocation of resources to approximately 15% of the value of the enterprise. Given the constraints of “must haves,” dependencies, and budget, Riskion selected controls that reduce total risk from \$1 billion to \$500 million. The optimal solution generated is below.

Total Risk*: \$1,003,789,717
Risk With Selected Controls*: \$533,981,146 (Δ: \$469,808,571)
Risk With All Controls: \$459,054,757 (Δ: \$544,734,959)

Selected controls: 16
Cost Of Selected Controls: \$4,950,000 (unfunded: \$122,150,000)
Total Cost Of All Controls: \$127,100,000

Index	Selected	Control Name	Control for	Selected	Cost	Applications	Categories	Must	Must Not
01	<input checked="" type="checkbox"/>	Install back-up generators for control rooms	Vulnerability	Yes	300000	4		<input checked="" type="checkbox"/>	<input type="checkbox"/>
02	<input type="checkbox"/>	Create an interest bearing settlement fund	Consequence		1000000	3		<input type="checkbox"/>	<input type="checkbox"/>
03	<input type="checkbox"/>	Retain in house legal team	Consequence		1000000	2		<input type="checkbox"/>	<input type="checkbox"/>
04	<input checked="" type="checkbox"/>	Create pre-made media relations packages	Consequence	Yes	20000	10		<input type="checkbox"/>	<input type="checkbox"/>
05	<input checked="" type="checkbox"/>	Engage employees through monthly surveys and quarterly town halls	Consequence	Yes	15000	5		<input type="checkbox"/>	<input type="checkbox"/>
06	<input type="checkbox"/>	Institute policies to eliminate layoffs from driverless trucking program	Consequence		2000000	6		<input type="checkbox"/>	<input type="checkbox"/>
07	<input type="checkbox"/>	Create materials notifying customers of new technology and potential upsides and downsides	Consequence		100000	7		<input type="checkbox"/>	<input type="checkbox"/>
08	<input checked="" type="checkbox"/>	Create excess capacity delivery system - Uber of delivering packages	Consequence	Yes	750000	10		<input type="checkbox"/>	<input type="checkbox"/>
09	<input type="checkbox"/>	Maintain manual driving mode for trucks	Consequence		500000	2		<input type="checkbox"/>	<input type="checkbox"/>
10	<input checked="" type="checkbox"/>	Test phase in select distribution centers	Source	Yes	1000000	8		<input checked="" type="checkbox"/>	<input type="checkbox"/>
11	<input checked="" type="checkbox"/>	Monthly performance management reviews	Source	Yes	10000	2		<input type="checkbox"/>	<input type="checkbox"/>
12	<input checked="" type="checkbox"/>	Enhanced training	Source	Yes	100000	2		<input type="checkbox"/>	<input type="checkbox"/>
13	<input checked="" type="checkbox"/>	Monthly map updates	Source	Yes	125000	2		<input type="checkbox"/>	<input type="checkbox"/>
14	<input checked="" type="checkbox"/>	Prescreen fleet for compatability	Source	Yes	80000	2		<input type="checkbox"/>	<input type="checkbox"/>
15	<input checked="" type="checkbox"/>	Include weather forecasts in delivery estimates	Source	Yes	150000	1		<input type="checkbox"/>	<input type="checkbox"/>
16	<input checked="" type="checkbox"/>	Install dual-mode GPS (ground and satellite)	Source	Yes	1500000	1		<input type="checkbox"/>	<input type="checkbox"/>
17	<input checked="" type="checkbox"/>	Semi-annual cyber security tests	Source	Yes	250000	1		<input type="checkbox"/>	<input type="checkbox"/>
18	<input type="checkbox"/>	Put a dummy in the driver's seat	Source		300000	1		<input type="checkbox"/>	<input type="checkbox"/>
19	<input checked="" type="checkbox"/>	Removable steering wheels	Source	Yes	250000	1		<input type="checkbox"/>	<input type="checkbox"/>
20	<input type="checkbox"/>	Monthly software updates	Source		750000	3		<input type="checkbox"/>	<input type="checkbox"/>
21	<input checked="" type="checkbox"/>	Vehicle automatically slows and stops	Vulnerability	Yes	100000	3		<input type="checkbox"/>	<input type="checkbox"/>
22	<input checked="" type="checkbox"/>	Two-step route approval	Vulnerability	Yes	50000	3		<input type="checkbox"/>	<input type="checkbox"/>
23	<input type="checkbox"/>	Remote vehicle shutdown	Vulnerability		500000	1		<input type="checkbox"/>	<input type="checkbox"/>
24	<input type="checkbox"/>	Automatic fire supression systems	Vulnerability		2000000	2		<input type="checkbox"/>	<input type="checkbox"/>
25	<input checked="" type="checkbox"/>	Enable manual driving mode	Vulnerability	Yes	250000	3		<input checked="" type="checkbox"/>	<input type="checkbox"/>
26	<input type="checkbox"/>	Install hybrid generators to supply in vehicle charge	Vulnerability		5000000	1		<input type="checkbox"/>	<input type="checkbox"/>
27	<input type="checkbox"/>	Two data centers capable of supporting network	Vulnerability		100000000	2		<input type="checkbox"/>	<input type="checkbox"/>

With these optimized controls in place, we arrive at reduced risk levels as shown in the heat map below. Preserving the parameters we set in place earlier, we see that our largest risk (01) has reduced significantly in terms of likelihood, but not so much in terms of impacts. Clearly the controls implemented are focused on mitigating likelihood and not impact. Events 04 and 05 are mitigated into the yellow region (between 3% and 5%) while event 08 is mitigated all the way down the green region (under 3%).



Efficient Frontier: With the optimal solution in mind given the total allowable control budget, we next chose to evaluate possible combinations of controls and budget that lie within the efficient frontier. This process looks at thousand of potential combinations to provide options that optimize controls with budget at various steps within the overall budget. To run this report, we elected to provide five options (including a \$0 option) for management to choose from when decided which controls to implement.

Controls/Budget	\$0	\$2M	\$3M
Risk Reduction, \$	\$0	\$245.14M	\$369.51M
Funded Cost	\$0	\$2M	\$2.97M
Expected Savings, \$	\$0	\$243.14M	\$366.54M
Investment Leverage	0	122.88	124.41
Risk with Selected Controls, \$	\$1B	\$758.65M	\$634.28M
25% loss exceedance	\$1.23B	\$1.11B	\$996.34M
Likelihood of losing more than \$1,000M	67.30%	39.60%	24.61%
Funded controls		12. Install back-up generators for control rooms 22. Create pre-made media relations packages 23. Engage employees through monthly surveys and quarterly town halls 1. Test phase in select distribution centers 2. Monthly performance management reviews 3. Enhanced training 6. Include weather forecasts in delivery estimates 13. Vehicle automatically slows and stops 14. Two-step route approval 17. Enable manual driving mode	12. Install back-up generators for control rooms 22. Create pre-made media relations packages 23. Engage employees through monthly surveys and quarterly town halls 25. Create materials notifying customers of new technology and potenti... 26. Create excess capacity delivery system - Uber of delivering packag... 1. Test phase in select distribution centers 2. Monthly performance management reviews 3. Enhanced training 4. Monthly map updates 6. Include weather forecasts in delivery estimates 13. Vehicle automatically slows and stops 14. Two-step route approval 17. Enable manual driving mode
Controls/Budget	\$0	\$4M	\$5M
Risk Reduction, \$	\$0	\$378.44M	\$469.81M
Funded Cost	\$0	\$3.95M	\$4.95M
Expected Savings, \$	\$0	\$374.49M	\$464.86M
Investment Leverage	0	95.81	94.91
Risk with Selected Controls, \$	\$1B	\$625.35M	\$533.98M
25% loss exceedance	\$1.23B	\$1.03B	\$918.31M
Likelihood of losing more than \$1,000M	67.30%	26.98%	14.48%
Funded controls		12. Install back-up generators for control rooms 22. Create pre-made media relations packages 23. Engage employees through monthly surveys and quarterly town halls 1. Test phase in select distribution centers 2. Monthly performance management reviews 3. Enhanced training 4. Monthly map updates 5. Prescreen fleet for compatability 6. Include weather forecasts in delivery estimates 7. Install dual-mode GPS (ground and satellite) 8. Semi-annual cyber security tests 13. Vehicle automatically slows and stops 14. Two-step route approval 17. Enable manual driving mode	12. Install back-up generators for control rooms 22. Create pre-made media relations packages 23. Engage employees through monthly surveys and quarterly town halls 26. Create excess capacity delivery system - Uber of delivering packag... 1. Test phase in select distribution centers 2. Monthly performance management reviews 3. Enhanced training 4. Monthly map updates 5. Prescreen fleet for compatability 6. Include weather forecasts in delivery estimates 7. Install dual-mode GPS (ground and satellite) 8. Semi-annual cyber security tests 10. Removable steering wheels 13. Vehicle automatically slows and stops 14. Two-step route approval 17. Enable manual driving mode

As seen in the results, options are provided at \$0, \$2M, \$3M, \$4M, and \$5M. Each option includes a unique set of controls at the specified funding level with varying results impacting risk reduction, investment leverage, residual risk, 25% loss exceedance, and likelihood of losing \$1B.

Risk Management Decision Making

Analysis of Efficient Frontier: To decide the best funding option we compared the five provided choices against one another in terms of performance. The table below summarizes top performer in each category (highlighted in green).

Controls/Budget	\$0	\$2M	\$3M	\$4M	\$5M
Risk Reduction, \$	\$0	\$245.14M	\$369.51M	\$378.44M	\$469.81M
Funded Cost	\$0	\$2M	\$2.97M	\$3.95M	\$4.95M
Expected Savings, \$	\$0	\$243.14M	\$366.54M	\$374.49M	\$464.86M
Investment Leverage	0	122.88	124.41	95.81	94.91
Risk with Selected Controls, \$	\$1B	\$758.65M	\$634.28M	\$625.35M	\$533.98M
25% loss exceedance	\$1.23B	\$1.11B	\$996.34M	\$1.03B	\$918.31M
Likelihood of losing more than \$1,000M	67.30%	39.60%	24.61%	26.98%	14.48%

As seen in the table, the \$5M option performs best in 5 of the 7 listed categories. It performs particularly well in reducing the likelihood of losing more than \$1B, reducing that category from 67.30% to 14.48% (10.13% better than the next highest performer, \$3M option). One area that the \$5M option is outperformed in is investment leverage. It's our opinion that this is an extremely important category as it effectively determines the "bang for your buck" portion of implementing controls. Just like ROI with determining the efficiency of an investment, investment leverage is a measure of risk reduction versus funded cost. In this category, the \$3M option is the best choice.

When looking at these two options against each other in terms of 25% loss exceedance, we see only a slight difference between them. Specifically, what we see in the \$5M option is that there is a 25% of losing more than \$918M against the \$3M option at \$996M. While \$80M is not a small sum, the difference is low. Combine this with the results in the category "likelihood of losing more than \$1B," and we see an interesting result. From these comparisons we can infer that the \$5M funding option performs well at mitigating risk beyond \$1B, but performs similarly to the \$3M option up to roughly \$900M in risk.

Recommendation: It is our recommendation that management selects the \$3M funding level to achieve the highest investment leverage while still significantly reducing risk. By selecting this option, the following controls are implemented:

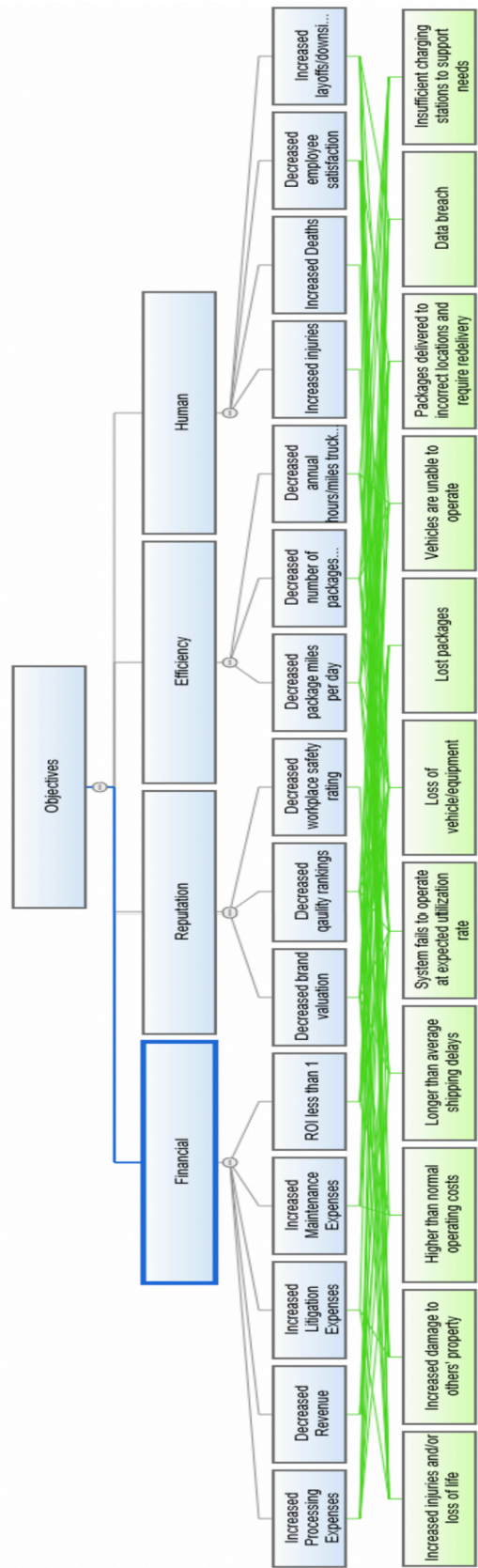
- 12. Install back-up generators for control rooms
- 22. Create pre-made media relations packages
- 23. Engage employees through monthly surveys and quarterly town halls

- 25. Create materials notifying customers of new technology and potential challenges
- 26. Create excess capacity delivery system - Uber of delivering packages
- 1. Test phase in select distribution centers
- 2. Monthly performance management reviews
- 3. Enhanced training
- 4. Monthly map updates
- 6. Include weather forecasts in delivery estimates
- 13. Vehicle automatically slows and stops
- 14. Two-step route approval
- 17. Enable manual driving mode

In this option, risk total risk reduction is significant (approximately 35%) while still maintaining acceptable levels of residual risk, 25% loss exceedance, and likelihood of losing more than \$1B. Based on these factors, we believe the \$3M funding level is the best option for management to select.

Appendix 1: Project Hierarchical View

Project's Hierarchical View



Appendix 2 : Report on Source Likelihood

Likelihood of Sources

Sources	Local Likelihood	Global Likelihood
Sources	100.00%	100.00%
System/Software related	100.00%	100.00%
Complete system failure	6.50%	6.50%
Loss of GPS signal	95.00%	95.00%
Bugs in the system	25.87%	25.87%
Inaccurate maps/routes	37.43%	37.43%
At-fault accident caused by the system	8.08%	8.08%
Truck and software are incompatible	24.36%	24.36%
Route restrictions not identified in the system	23.27%	23.27%
Unexpected/inaccurate decision by software	12.80%	12.80%
High number of patches/software updates	32.47%	32.47%
Hardware Related	100.00%	100.00%
Battery related fire	0.50%	0.50%
Expensive system component replacement	3.80%	3.80%
Batteries don't hold advertised charge	3.44%	3.44%
Truck and hardware are incompatible	1.87%	1.87%
Human Factor	100.00%	100.00%
Poorly trained maintainers	21.92%	21.92%
Poorly trained operators	17.82%	17.82%
Route approval negligence	45.54%	45.54%
Deliberate disregard for policies & procedures	20.00%	20.00%
Regulations that restrict/limit the use of driverless technology	25.52%	25.52%
Environmental	100.00%	100.00%
Weather restricts road access	129.15%	129.15%
Power outage from natural events	50.00%	50.00%
Terrorist/Criminal	100.00%	100.00%
Cyberattack	25.00%	25.00%
Vehicle Hijacking	13.22%	13.22%

Appendix 3: Likelihood of Events

Likelihood of Events

Events	Global Likelihood
Increased injuries and/or loss of life	10.63%
Increased damage to others' property	4.73%
Higher than normal operating costs	14.14%
Longer than average shipping delays	28.40%
System fails to operate at expected utilization rate	15.71%
Loss of vehicle/equipment	2.50%
Lost packages	2.49%
Vehicles are unable to operate	12.13%
Packages delivered to incorrect locations and require redelivery	4.46%
Data breach	2.47%
Insufficient charging stations to support needs	2.35%

