Motional

STPA Automation Tool

Prepared by
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Proprietary & Confidential

Outline

- Automating Analysis
- Define Purpose of the Analysis
  - Identify Losses
  - Identify System-Level Requirements
    - Identify Functions
    - Clear Unused Functional Hazards
    - Identify Unsafe Conditions
  - Identify System Constraints
  - Create Hazard Summary
    - Fill In Hazard Summary
    - Losses Traceability
    - System Constraints Traceability
- Model the Control Structure
  - draw.io Integration
- Identify Unsafe Control Actions
  - Create Unsafe Control Action Table
    - Pulls data from draw.io Control Structure Model
  - Identify Unsafe Control Actions
  - Create Controller Constraint Table
  - Unsafe Control Actions Traceability
- Identify Loss Scenarios
  - Template
- Questions?
- Tool Link

Automating Analysis

Soap Box - The Dangers of Automating Analysis

Automating Analyses can be incredibly useful

- Decrease time it takes to complete
- Reduce errors by standardizing wording
- Repeatability of analysis

However, it can also be very dangerous to automate analyses

- Over-reliance on the tool
- Reduced thinking about the problem

The goal of any analysis automation effort should be to reduce the effort to produce the analysis without affecting the quality of the analysis. This means that analysis automation tools should only automate tasks that do not require engineering effort.

Define Purpose of the Analysis

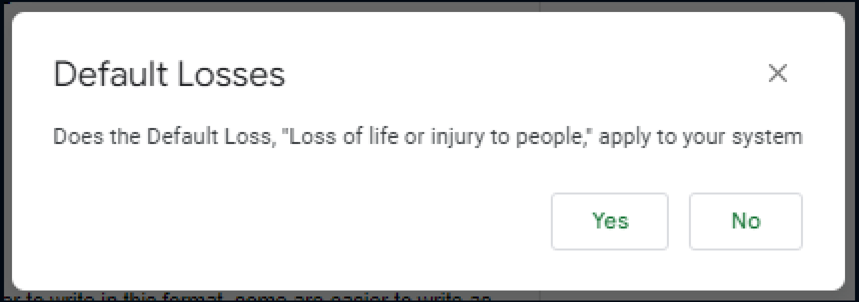
Define Purpose of the Analysis

The STPA Handbook identifies 4 steps that comprise the definition of the purpose of the STPA

1. Identify Losses
2. Identify system-level hazards
3. Identify system-level constraints
4. Refine hazards

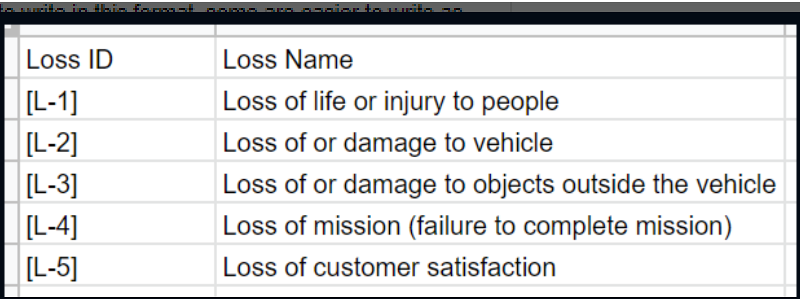
Identify Losses

The STPA Handbook, Chapter 2, identifies a set of example losses. The first function in the tool asks the user to identify which of these example losses apply to their system, then prompts the user for additional losses that they want to consider.

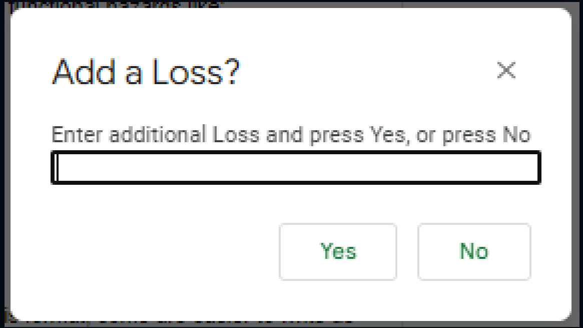


Default Losses

Does the Default Loss, "Loss of life or injury to people," apply to your system



Loss ID	Loss Name
[L-1]	Loss of life or injury to people
[L-2]	Loss of or damage to vehicle
[L-3]	Loss of or damage to objects outside the vehicle
[L-4]	Loss of mission (failure to complete mission)
[L-5]	Loss of customer satisfaction



Add a Loss?

Enter additional Loss and press Yes, or press No

Identify System-Level Hazards

The STPA Handbook identifies one method of defining hazards in the form of <System> <Unsafe Condition>

E.g., <Aircraft> <violate minimum separation standards in flight>

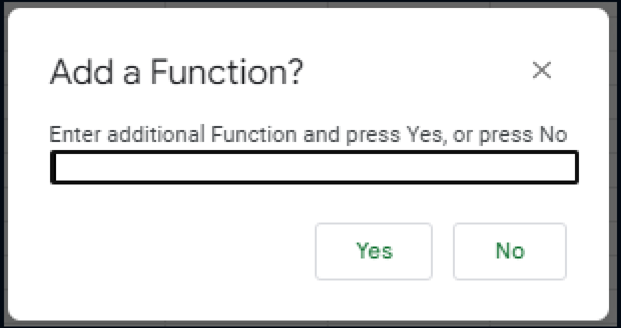
ISO-26262 uses a <Keyword> <Function> approach for identifying hazards

E.g., <Loss of> <Braking>

The STPA Automation Tool supports both methods. For the Function approach, the Identify Functions function prompts the user for their functions, prompts the user with a list of default keywords, and asks the user if they want to add keywords. It then populates a list of hazards in the <Keyword> <Function> format.

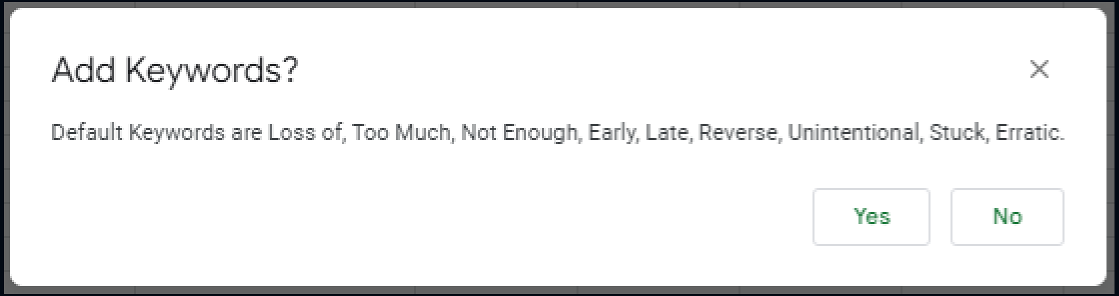
Next, the user selects which of the default functional hazards actually apply to their system and runs the Clear Unused Functional Hazards function which deletes the unused functional hazards and generates Hazard ID numbers.

Identify System-Level Hazards



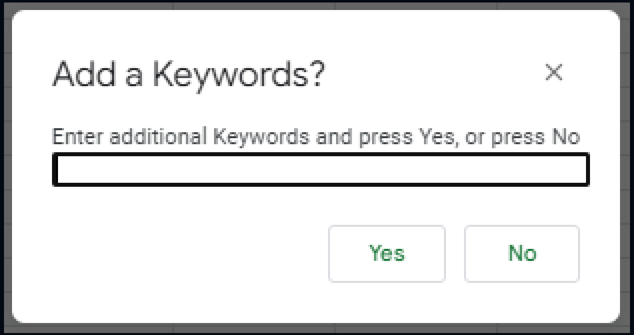
Add a Function?

Enter additional Function and press Yes, or press No



Add Keywords?

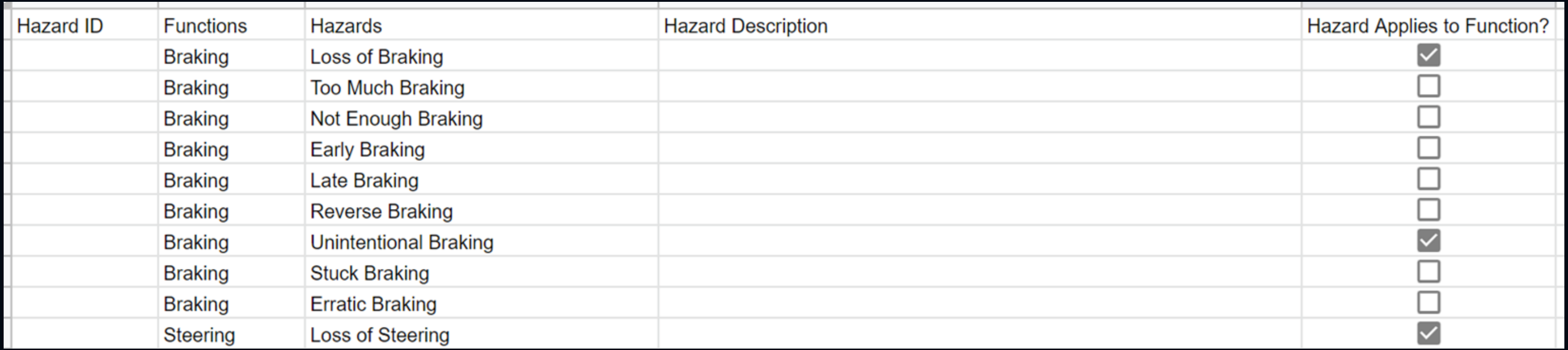
Default Keywords are Loss of, Too Much, Not Enough, Early, Late, Reverse, Unintentional, Stuck, Erratic.



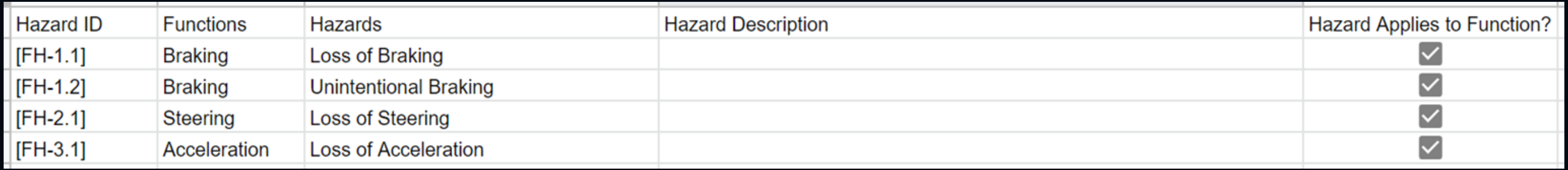
Add a Keywords?

Enter additional Keywords and press Yes, or press No

Identify System-Level Hazards



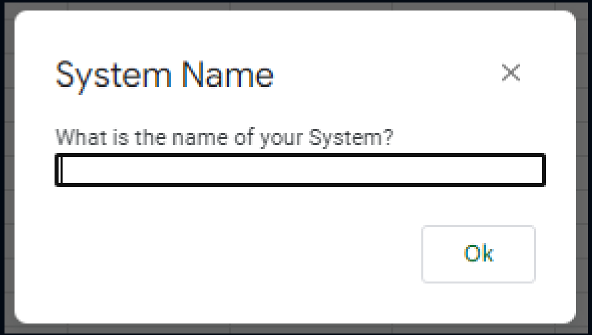
Hazard ID	Functions	Hazards	Hazard Description	Hazard Applies to Function?
	Braking	Loss of Braking		☑
	Braking	Too Much Braking		□
	Braking	Not Enough Braking		□
	Braking	Early Braking		□
	Braking	Late Braking		□
	Braking	Reverse Braking		□
	Braking	Unintentional Braking		☑
	Braking	Stuck Braking		□
	Braking	Erratic Braking		□
	Steering	Loss of Steering		☑



Hazard ID	Functions	Hazards	Hazard Description	Hazard Applies to Function?
[FH-1.1]	Braking	Loss of Braking		☑
[FH-1.2]	Braking	Unintentional Braking		☑
[FH-2.1]	Steering	Loss of Steering		☑
[FH-3.1]	Acceleration	Loss of Acceleration		☑

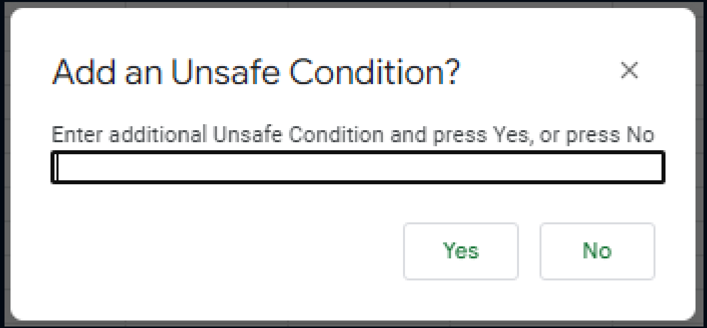
Identify System-Level Hazards

For the Unsafe Condition approach, the Identify Unsafe Conditions function prompts the user for the name of the system, then prompts the user for all of the unsafe conditions for that system. Then it asks the user if there are additional systems and repeats the process for all systems.



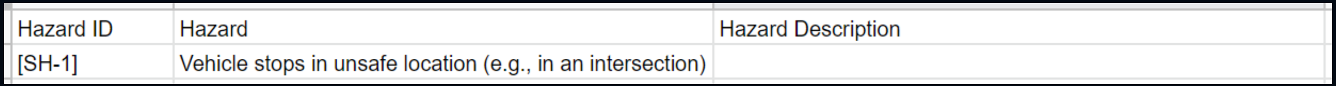
System Name

What is the name of your System?



Add an Unsafe Condition?

Enter additional Unsafe Condition and press Yes, or press No



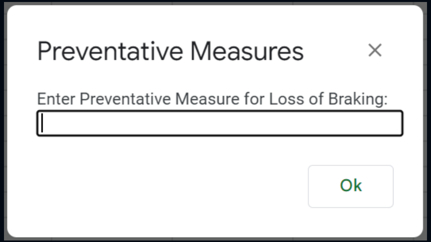
Hazard ID	Hazard	Hazard Description
[SH-1]	Vehicle stops in unsafe location (e.g., in an intersection)	

Identify System Constraints

The Identify System Constraints function prompts the user for the preventative measure for <Keyword> <Function> hazards, prompts the user to invert the condition for <System> <Unsafe Condition> hazards, and prompts the user for any additional system constraints.

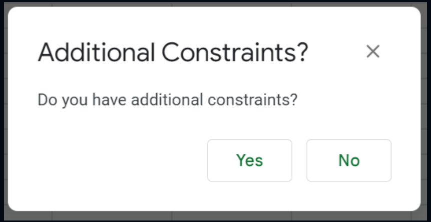
After the prompts, the function populates the system constraints table.

Identify System Constraints



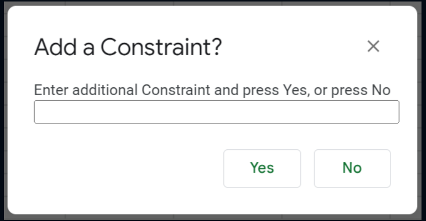
Preventative Measures

Enter Preventative Measure for Loss of Braking:



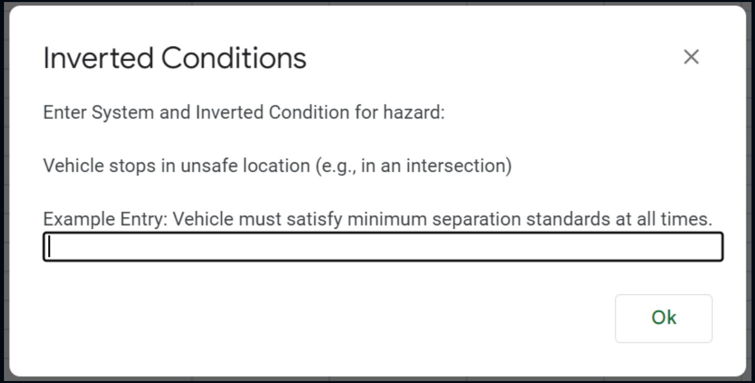
Additional Constraints?

Do you have additional constraints?



Add a Constraint?

Enter additional Constraint and press Yes, or press No

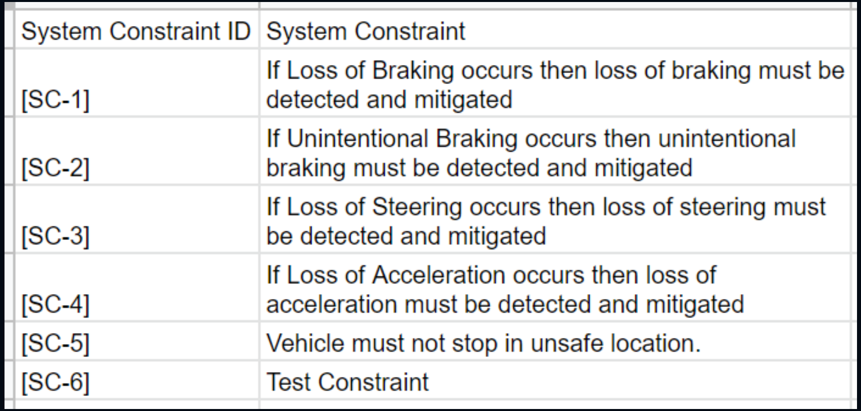


Inverted Conditions

Enter System and Inverted Condition for hazard:

Vehicle stops in unsafe location (e.g., in an intersection)

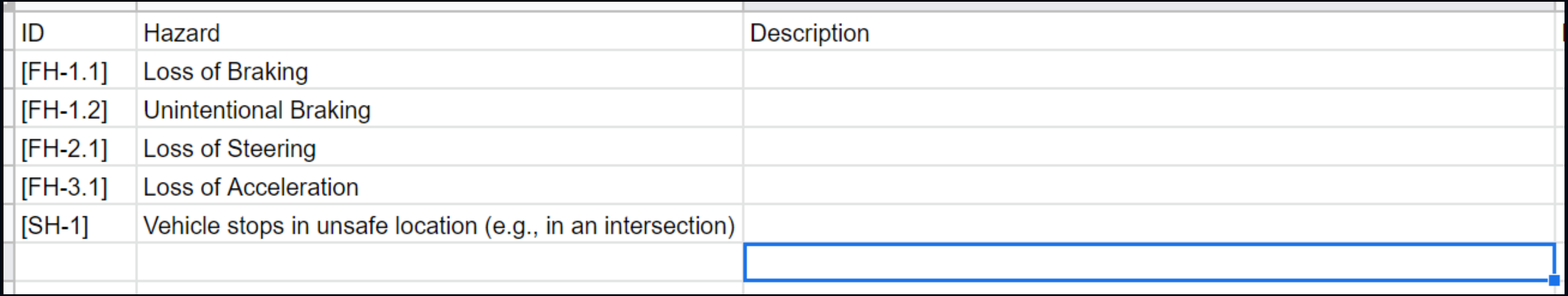
Example Entry: Vehicle must satisfy minimum separation standards at all times.



System Constraint ID	System Constraint
[SC-1]	If Loss of Braking occurs then loss of braking must be detected and mitigated
[SC-2]	If Unintentional Braking occurs then unintentional braking must be detected and mitigated
[SC-3]	If Loss of Steering occurs then loss of steering must be detected and mitigated
[SC-4]	If Loss of Acceleration occurs then loss of acceleration must be detected and mitigated
[SC-5]	Vehicle must not stop in unsafe location.
[SC-6]	Test Constraint

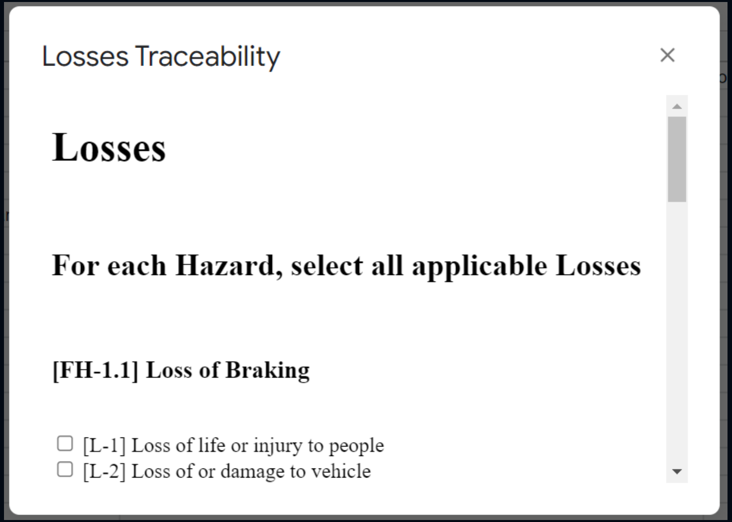
Create Hazard Summary

There are three functions to create the hazard summary. The first function populates the hazards from the Functional Hazards and System Hazards tabs into the Hazard Summary tab. The other two functions help the user populate the Losses Traceability and System Constraint Traceability for all of the hazards.



ID	Hazard	Description
[FH-1.1]	Loss of Braking	
[FH-1.2]	Unintentional Braking	
[FH-2.1]	Loss of Steering	
[FH-3.1]	Loss of Acceleration	
[SH-1]	Vehicle stops in unsafe location (e.g., in an intersection)	

Create Hazard Summary



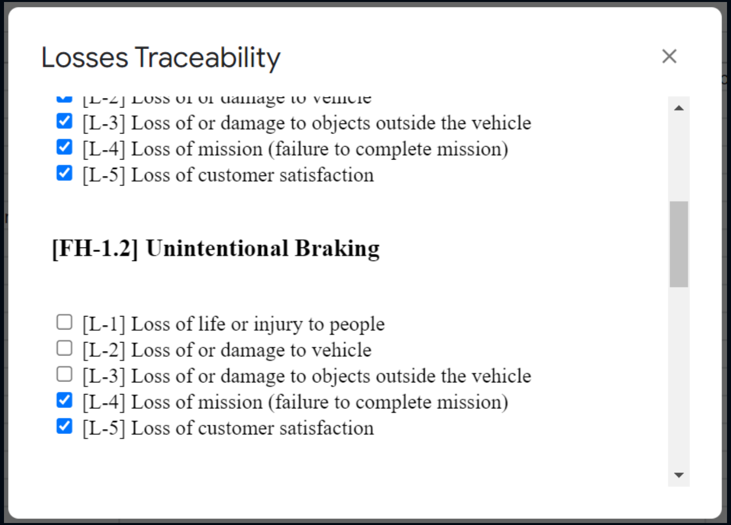
Losses Traceability

Losses

For each Hazard, select all applicable Losses

[FH-1.1] Loss of Braking

☐ [L-1] Loss of life or injury to people
☐ [L-2] Loss of or damage to vehicle



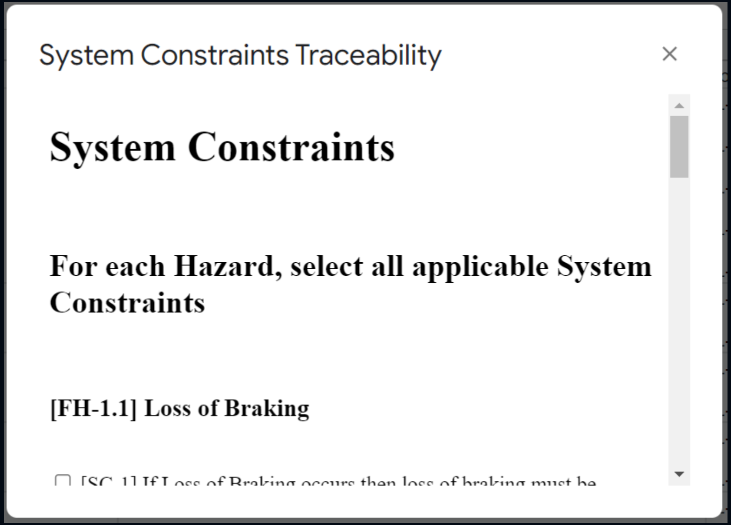
Losses Traceability

☑ [L-2] Loss of or damage to vehicle
☑ [L-3] Loss of or damage to objects outside the vehicle
☑ [L-4] Loss of mission (failure to complete mission)
☑ [L-5] Loss of customer satisfaction

[FH-1.2] Unintentional Braking

☐ [L-1] Loss of life or injury to people
☐ [L-2] Loss of or damage to vehicle
☐ [L-3] Loss of or damage to objects outside the vehicle
☑ [L-4] Loss of mission (failure to complete mission)
☑ [L-5] Loss of customer satisfaction

Create Hazard Summary



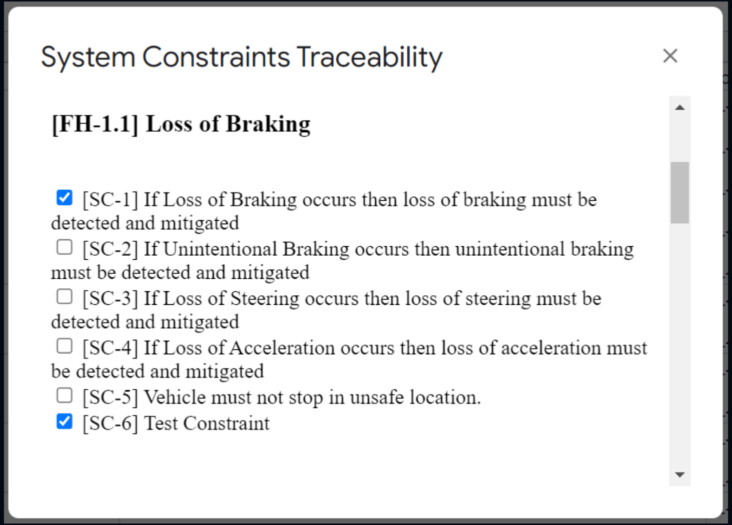
System Constraints Traceability

System Constraints

For each Hazard, select all applicable System Constraints

[FH-1.1] Loss of Braking

□ [SC-1] If Loss of Braking occurs then loss of braking must be

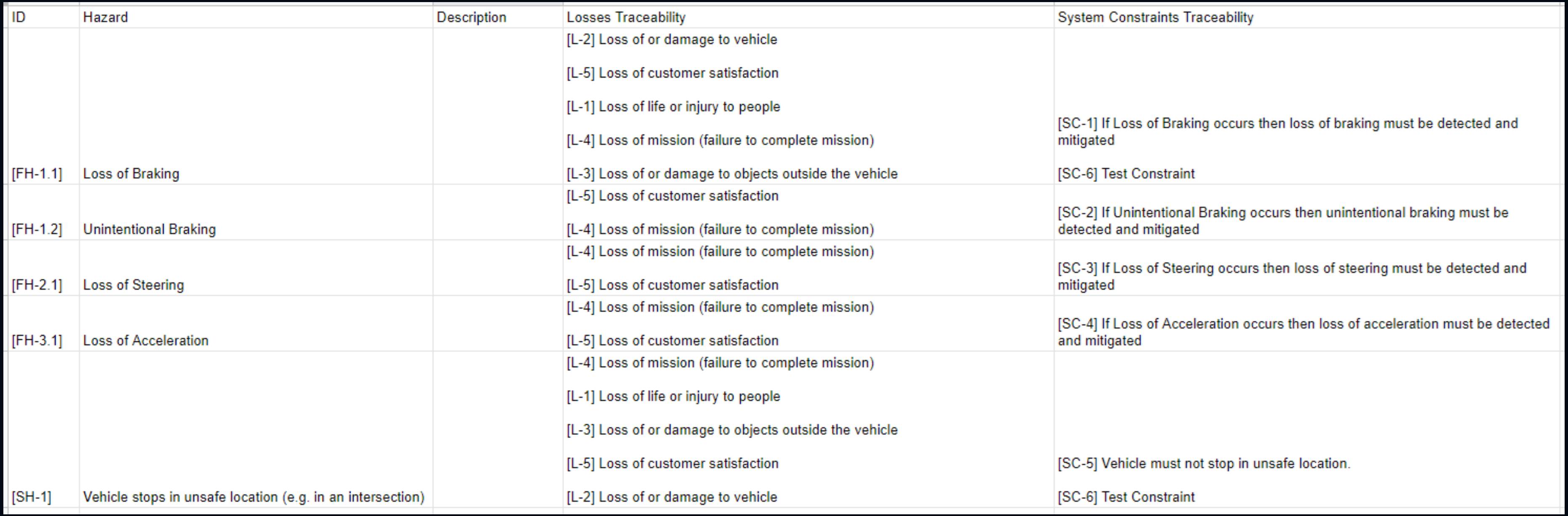


System Constraints Traceability

[FH-1.1] Loss of Braking

☑ [SC-1] If Loss of Braking occurs then loss of braking must be detected and mitigated
□ [SC-2] If Unintentional Braking occurs then unintentional braking must be detected and mitigated
□ [SC-3] If Loss of Steering occurs then loss of steering must be detected and mitigated
□ [SC-4] If Loss of Acceleration occurs then loss of acceleration must be detected and mitigated
□ [SC-5] Vehicle must not stop in unsafe location.
☑ [SC-6] Test Constraint

Create Hazard Summary



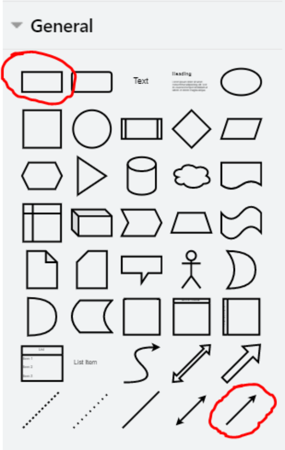
ID	Hazard	Description	Losses Traceability	System Constraints Traceability
[FH-1.1]	Loss of Braking		[L-2] Loss of or damage to vehicle [L-5] Loss of customer satisfaction [L-1] Loss of life or injury to people [L-4] Loss of mission (failure to complete mission) [L-3] Loss of or damage to objects outside the vehicle	[SC-1] If Loss of Braking occurs then loss of braking must be detected and mitigated [SC-6] Test Constraint
[FH-1.2]	Unintentional Braking		[L-5] Loss of customer satisfaction [L-4] Loss of mission (failure to complete mission)	[SC-2] If Unintentional Braking occurs then unintentional braking must be detected and mitigated
[FH-2.1]	Loss of Steering		[L-4] Loss of mission (failure to complete mission) [L-5] Loss of customer satisfaction	[SC-3] If Loss of Steering occurs then loss of steering must be detected and mitigated
[FH-3.1]	Loss of Acceleration		[L-4] Loss of mission (failure to complete mission) [L-5] Loss of customer satisfaction	[SC-4] If Loss of Acceleration occurs then loss of acceleration must be detected and mitigated
[SH-1]	Vehicle stops in unsafe location (e.g. in an intersection)		[L-4] Loss of mission (failure to complete mission) [L-1] Loss of life or injury to people [L-3] Loss of or damage to objects outside the vehicle [L-5] Loss of customer satisfaction [L-2] Loss of or damage to vehicle	[SC-5] Vehicle must not stop in unsafe location. [SC-6] Test Constraint

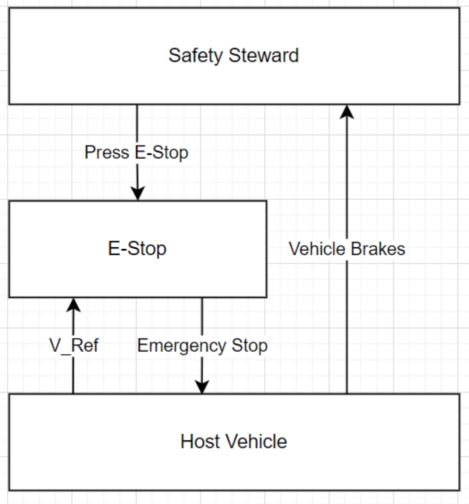
Model the Control Structure

Model the Control Structure

The STPA Automation Tool integrates with draw.io for modeling the Control Structure. Create the Control Structure Model using rectangles for items in the system (e.g., controllers, controlled processes, etc.) and directional connectors for control actions, feedback, and data. Label all rectangles and directional connectors.

Once the Control Structure is modeled, export as an image (PNG, JPEG, SVG) to pull into the STPA Automation Tool. Then export as XML and save to Google Drive to be able to automatically create the Unsafe Control Actions Table from the Control Structure Model.





Identify Unsafe Control Actions

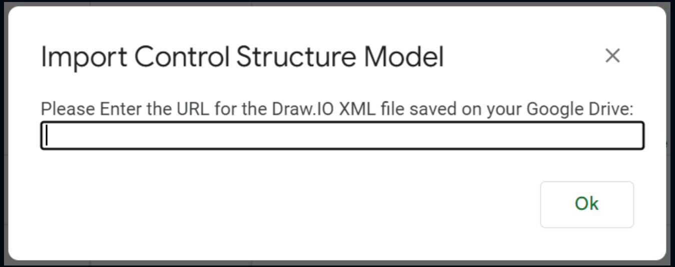
Identify Unsafe Control Actions

The STPA Automation Tool can automatically extract the information from the draw.io Control Structure Model. Select the Create Unsafe Control Actions function, and enter the URL where the XML file was saved in Google Drive.

The tool reads the XML file and extracts the directional connectors and the source and destination rectangles to create the table.

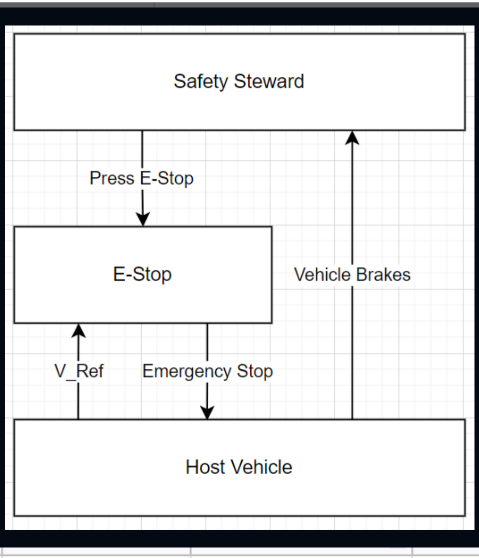
Select the Arrow Type for each directional connector from the drop down menu

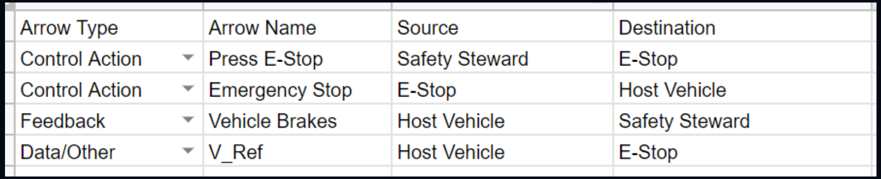
- Control Action
- Feedback
- Data/Other



Import Control Structure Model

Please Enter the URL for the Draw.IO XML file saved on your Google Drive:

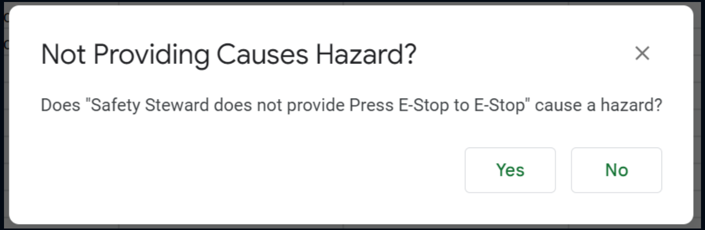




Arrow Type	Arrow Name	Source	Destination
Control Action	Press E-Stop	Safety Steward	E-Stop
Control Action	Emergency Stop	E-Stop	Host Vehicle
Feedback	Vehicle Brakes	Host Vehicle	Safety Steward
Data/Other	V_Ref	Host Vehicle	E-Stop

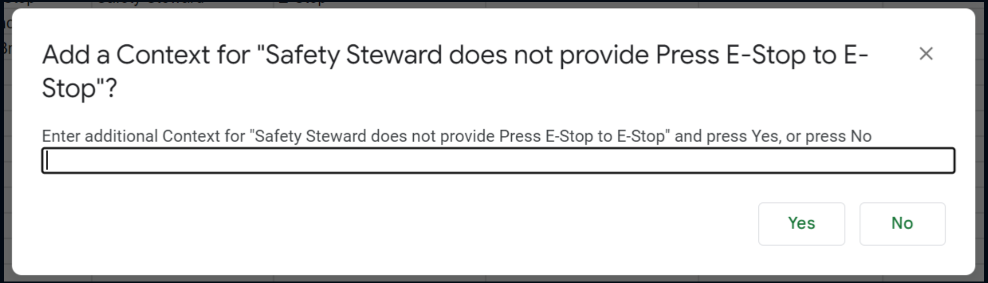
Identify Unsafe Control Actions

The Identify Unsafe Control Actions function guides the user through the set of potential Unsafe Control Actions, and if the Unsafe Control Action applies to their system, asks the user to enter the context that makes it an unsafe control action.



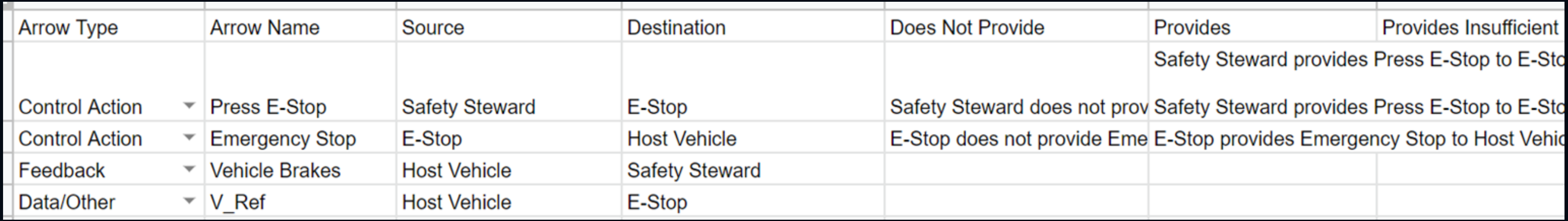
Not Providing Causes Hazard?

Does "Safety Steward does not provide Press E-Stop to E-Stop" cause a hazard?



Add a Context for "Safety Steward does not provide Press E-Stop to E-Stop"?

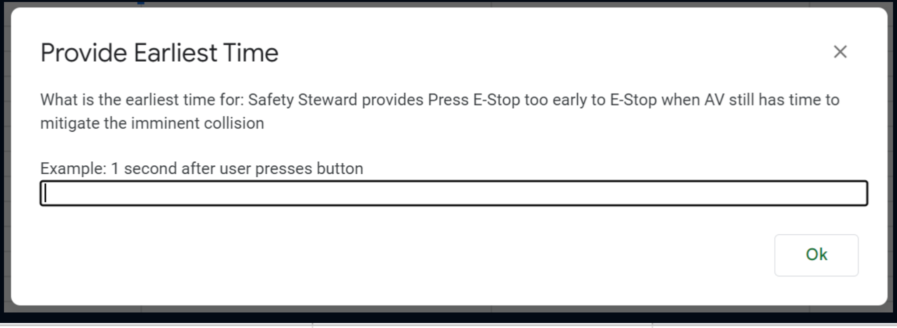
Enter additional Context for "Safety Steward does not provide Press E-Stop to E-Stop" and press Yes, or press No



Arrow Type	Arrow Name	Source	Destination	Does Not Provide	Provides	Provides Insufficient
Control Action	Press E-Stop	Safety Steward	E-Stop	Safety Steward does not prov	Safety Steward provides Press E-Stop to E-Sto Safety Steward provides Press E-Stop to E-Sto	
Control Action	Emergency Stop	E-Stop	Host Vehicle	E-Stop does not provide Eme	E-Stop provides Emergency Stop to Host Vehic	
Feedback	Vehicle Brakes	Host Vehicle	Safety Steward			
Data/Other	V_Ref	Host Vehicle	E-Stop			

Identify Unsafe Control Actions

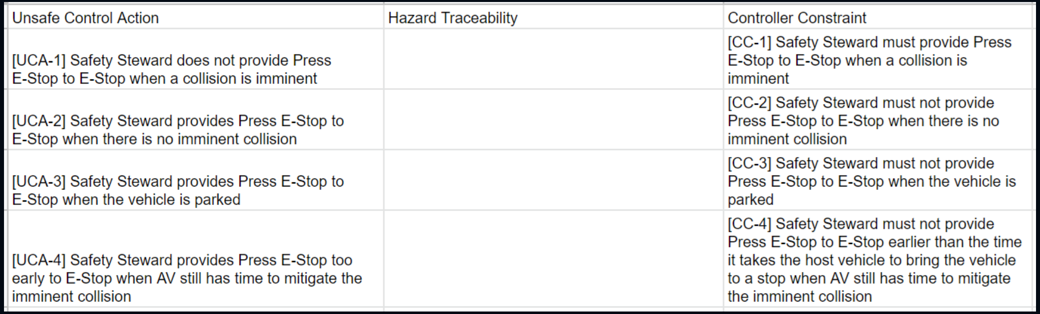
The Create Control Constraints function guides the user through developing the Control Constraints for each Unsafe Control Action. It prompts the user for limits of how much or time when appropriate for the Unsafe Control Action.



Provide Earliest Time

What is the earliest time for: Safety Steward provides Press E-Stop too early to E-Stop when AV still has time to mitigate the imminent collision

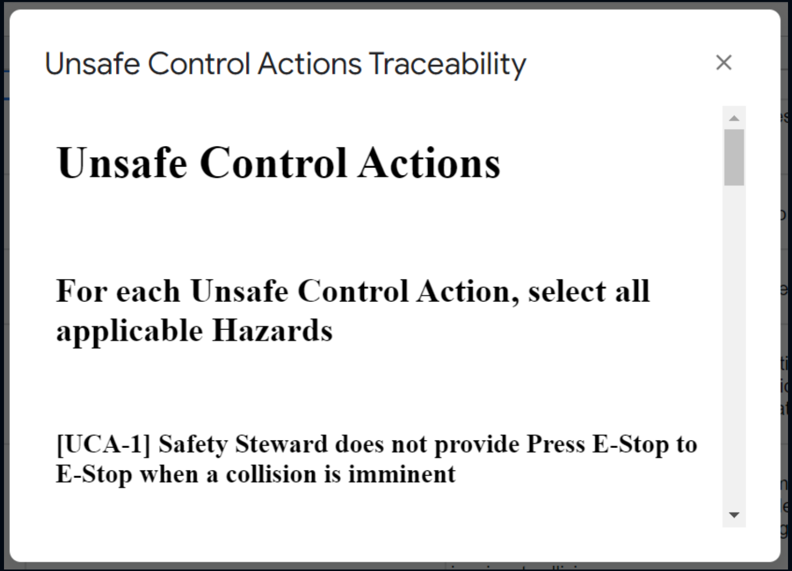
Example: 1 second after user presses button



Unsafe Control Action	Hazard Traceability	Controller Constraint
[UCA-1] Safety Steward does not provide Press E-Stop to E-Stop when a collision is imminent		[CC-1] Safety Steward must provide Press E-Stop to E-Stop when a collision is imminent
[UCA-2] Safety Steward provides Press E-Stop to E-Stop when there is no imminent collision		[CC-2] Safety Steward must not provide Press E-Stop to E-Stop when there is no imminent collision
[UCA-3] Safety Steward provides Press E-Stop to E-Stop when the vehicle is parked		[CC-3] Safety Steward must not provide Press E-Stop to E-Stop when the vehicle is parked
[UCA-4] Safety Steward provides Press E-Stop too early to E-Stop when AV still has time to mitigate the imminent collision		[CC-4] Safety Steward must not provide Press E-Stop to E-Stop earlier than the time it takes the host vehicle to bring the vehicle to a stop when AV still has time to mitigate the imminent collision

Identify Unsafe Control Actions

The Unsafe Control Actions Traceability function guides the user through tracing the Unsafe Control Actions to the Hazards.

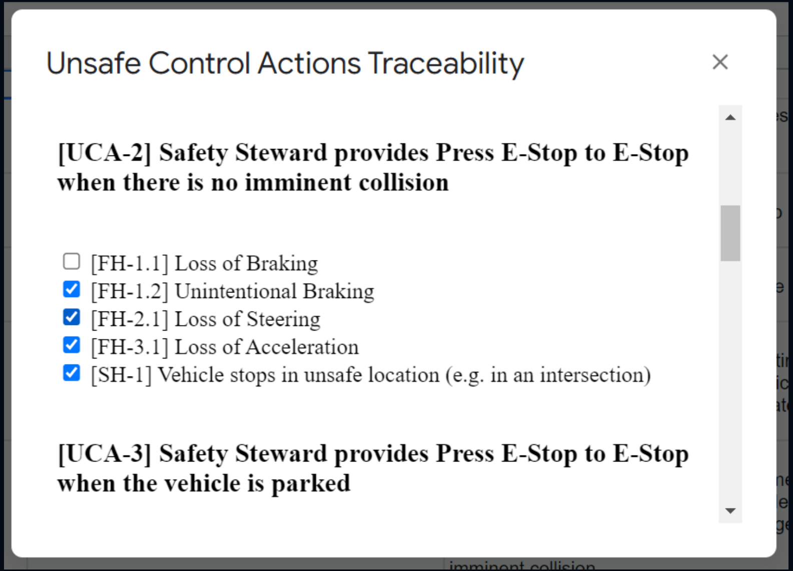


Unsafe Control Actions Traceability

Unsafe Control Actions

For each Unsafe Control Action, select all applicable Hazards

[UCA-1] Safety Steward does not provide Press E-Stop to E-Stop when a collision is imminent



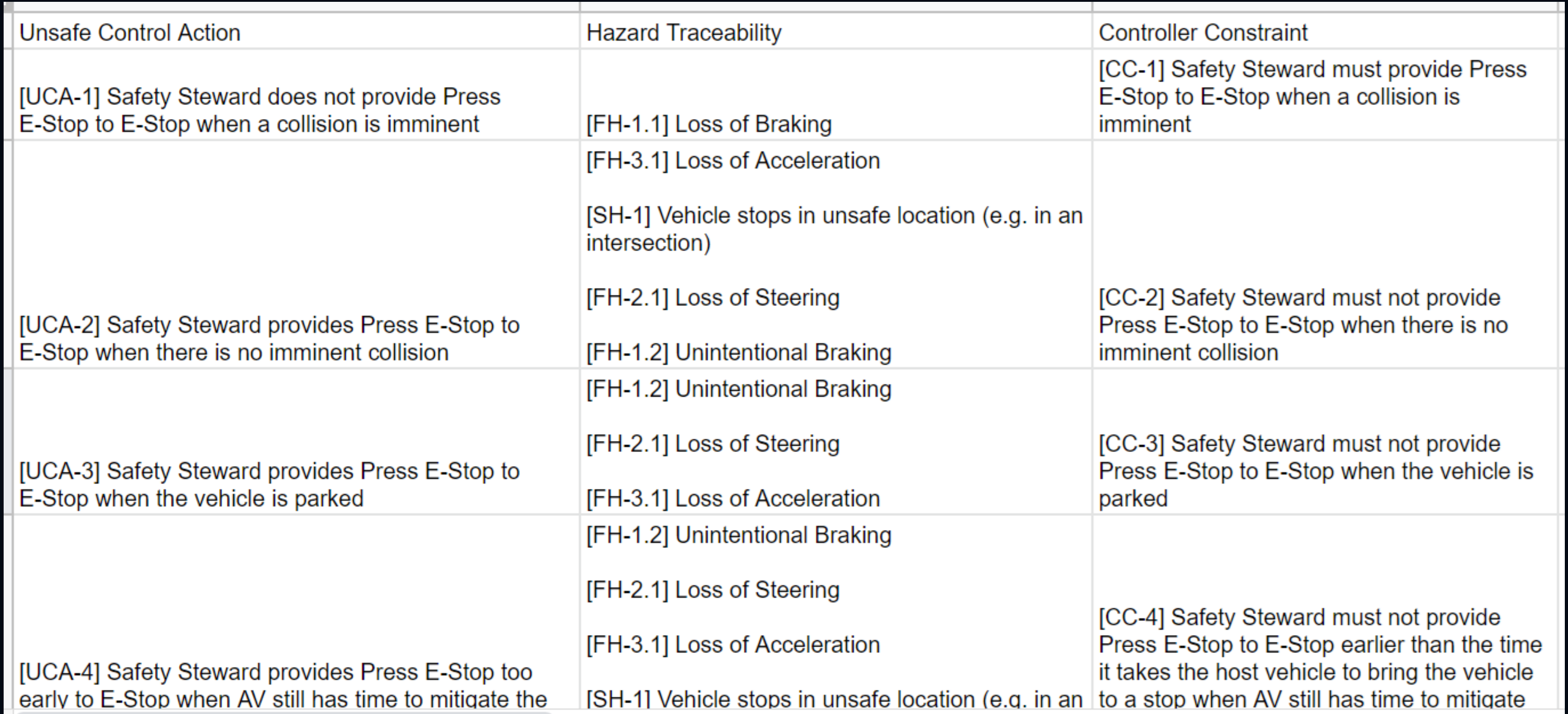
Unsafe Control Actions Traceability

[UCA-2] Safety Steward provides Press E-Stop to E-Stop when there is no imminent collision

□ [FH-1.1] Loss of Braking
☑ [FH-1.2] Unintentional Braking
☑ [FH-2.1] Loss of Steering
☑ [FH-3.1] Loss of Acceleration
☑ [SH-1] Vehicle stops in unsafe location (e.g. in an intersection)

[UCA-3] Safety Steward provides Press E-Stop to E-Stop when the vehicle is parked

Identify Unsafe Control Actions

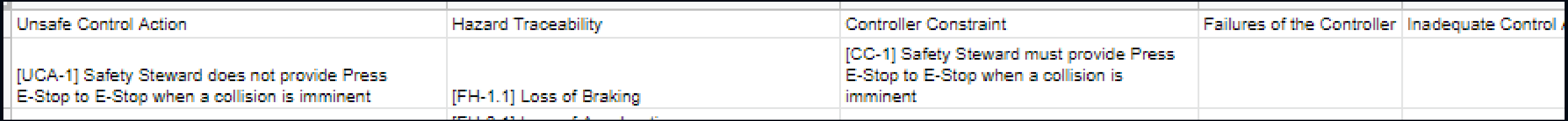


Unsafe Control Action	Hazard Traceability	Controller Constraint
[UCA-1] Safety Steward does not provide Press E-Stop to E-Stop when a collision is imminent	[FH-1.1] Loss of Braking	[CC-1] Safety Steward must provide Press E-Stop to E-Stop when a collision is imminent
[UCA-2] Safety Steward provides Press E-Stop to E-Stop when there is no imminent collision	[FH-3.1] Loss of Acceleration [SH-1] Vehicle stops in unsafe location (e.g. in an intersection) [FH-2.1] Loss of Steering [FH-1.2] Unintentional Braking	[CC-2] Safety Steward must not provide Press E-Stop to E-Stop when there is no imminent collision
[UCA-3] Safety Steward provides Press E-Stop to E-Stop when the vehicle is parked	[FH-1.2] Unintentional Braking [FH-2.1] Loss of Steering [FH-3.1] Loss of Acceleration	[CC-3] Safety Steward must not provide Press E-Stop to E-Stop when the vehicle is parked
[UCA-4] Safety Steward provides Press E-Stop too early to E-Stop when AV still has time to mitigate the	[FH-1.2] Unintentional Braking [FH-2.1] Loss of Steering [FH-3.1] Loss of Acceleration [SH-1] Vehicle stops in unsafe location (e.g. in an	[CC-4] Safety Steward must not provide Press E-Stop to E-Stop earlier than the time it takes the host vehicle to bring the vehicle to a stop when AV still has time to mitigate

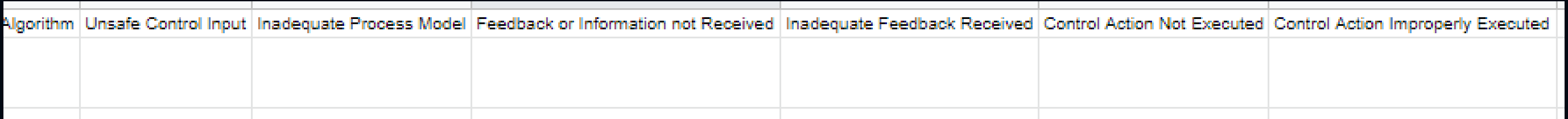
Identify Loss Scenarios

Identify Loss Scenarios

This is the most important part of the analysis. Since it requires in-depth engineering analysis, no automation is provided. However, a template is provided as part of the Controller Constraints tab where the analysis can be performed.



Unsafe Control Action	Hazard Traceability	Controller Constraint	Failures of the Controller	Inadequate Control
[UCA-1] Safety Steward does not provide Press E-Stop to E-Stop when a collision is imminent	[FH-1.1] Loss of Braking	[CC-1] Safety Steward must provide Press E-Stop to E-Stop when a collision is imminent		



Algorithm	Unsafe Control Input	Inadequate Process Model	Feedback or Information not Received	Inadequate Feedback Received	Control Action Not Executed	Control Action Improperly Executed

Questions?

Tool Link

https://docs.google.com/spreadsheets/d/1RR04D2UPmyZAtwojIzfkY6jHOefAmNMFTsNcd0-hk7c/copy