U.S. Department of Transportation
Federal Transit Administration

Sample Safety Risk Assessment Matrices for Bus Transit Agencies

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Introduction

The Federal Transit Administration (FTA) prepared this guide to assist your transit agency in establishing a safety risk assessment matrix appropriate for the size and complexity of your operations. Choosing to adopt such a matrix may help your agency implement the Safety Risk Management process required in FTA's Public Transportation Agency Safety Plan (PTASP) regulation at 49 C.F.R. Part 673.

49 C.F.R. § 673.25(c)(1) requires each transit agency to "establish methods or processes to assess the safety risks associated with identified safety hazards." 49 C.F.R. § 673.25(c)(2) further clarifies that a safety risk assessment includes "an assessment of the likelihood and severity of the consequences of the hazards, including existing mitigations, and prioritization of the hazards based on the safety risk."

A safety risk assessment matrix provides a structured approach for addressing these requirements by helping to:

- Assess the likelihood and severity of the consequences of identified hazards;
- Determine if the safety risk is acceptable with existing mitigations, or if additional action is needed; and
- Prioritize hazards based on the safety risk of their potential consequences.

Understanding Key Terms

Definitions for key terms from 49 C.F.R. Part 673 related to safety risk assessment include:

- **Hazard** means any real or potential condition that can cause injury, illness, or death; damage to or loss of the facilities, equipment, rolling stock, or infrastructure of a public transportation system; or damage to the environment.

- **Risk** means the composite of predicted severity and likelihood of the potential effect of a hazard.

- **Risk mitigation** means a method or methods to eliminate or reduce the effects of hazards.

A hazard holds the potential that, when triggered, may result in a consequence that could cause harm or damage. The identified potential consequence may be minor or catastrophic, depending on the nature of the hazard.

Within the Part 673 Safety Risk Management process, a transit agency analyzes an identified hazard to understand its potential consequences. The agency assesses how often a potential consequence could occur (likelihood) and its harm or damage (severity). This assessment results in an understanding of the safety risk associated with the hazard and helps management decide if it needs to take action to address the safety risk. Risk mitigations reduce or eliminate safety risk associated with the potential consequences of hazards.

For example, ice on the road during winter is a hazard to bus transit operations. It is a condition with several potential consequences, including collisions, rollovers, and buses leaving the roadway involving fatalities, injuries, and destruction of property.

The risk to your operations from the hazard of ice on the road is a composite of the likelihood and severity of the hazard's potential consequences. In other words, based on how often you think your agency will experience the potential consequences of ice on the road (likelihood) and how serious you think they may be (severity), you will establish the risk for this hazard's potential consequences.

Based on this assessment, you will determine if the safety risk is acceptable or if additional risk mitigation may be necessary. Typical mitigations may include slow speed orders, snow tires, snow and ice removal, detours or snow routes, changes in curbing procedures, and defensive driving techniques, to name a few.

Using these mitigations allows your agency to reduce the risk to a level acceptable to continue passenger operations. During an ice storm, however, your agency may decide that these mitigations will not adequately reduce the risk, and your agency may opt to suspend service. In this instance, the hazard (ice on the roadway) still exists, but your agency's risk is fully mitigated because your buses are not operating over ice.

Establishing Potential Consequences for Hazards

Based on the § 673.5 definition of hazard, potential consequences for consideration in transit safety risk assessment can be defined as **an effect of a hazard involving injury, illness, or death; damage to or loss of the facilities, equipment, rolling stock, or infrastructure of a public transportation system; or damage to the environment**.

Transit agencies may choose to assess a range of consequences related to a single hazard for their level of likelihood and category of severity. For example, based on experience and subject matter expertise, your transit agency may choose to assess:

- The most common consequence,
- The worst possible consequence, and/or
- The worst credible consequence.

As an example, in the event water is leaking from the roof to the lobby floor of your transit center building, resulting in a wet floor and puddling, the **most common consequence** at your agency may be a slip resulting in a minor injury or abrasion, perhaps requiring first aid (i.e., bandage or ice).

Depending on the situation, your transit agency also may consider the hazard's **worst possible consequence** for assessment. In this example, your agency may decide that the worst possible consequence is a slip resulting in a fatality, where an individual strikes their head on the floor or on a nearby object, falling into unconsciousness and then death. Your agency may never have experienced an incident where a slip or fall has resulted in a fatality, however, your assessment team may believe it is possible based on their subject matter expertise and review of industry data.

Your agency also may choose to assess the **worst credible consequence**, meaning the consequence that, while realistic and imaginable in your day-to-day operations, is not as extreme as the worst possible consequence. In this example, your agency may find that the worst credible consequence is a slip resulting in a major injury, such as a broken leg or arm, requiring hospitalization.

Assessing Safety Risk

For the next step, your agency may choose to assess the three potential consequences it has identified associated with the example hazard (leaking water in transit center lobby) by likelihood and severity. Figure 1 below presents a sample safety risk assessment matrix to support this assessment.

This sample matrix measures the level of safety risk in terms of severity (across the top) and likelihood (down the side). This sample matrix intentionally does not include titles for the categories of severity and the levels of likelihood, relying instead on numbers and letters. For some agencies, this approach may help to avoid bias or assumptions based on differing interpretations of the words used to define severity or likelihood by encouraging individuals to focus on the category definitions in the severity and likelihood tables instead of the labels.

For other agencies, who may prefer to use labels, Figure 2 illustrates this same sample matrix with labels assigned. There are four categories of severity: Catastrophic (1), Critical (2), Marginal (3) and Negligible (4). The five levels of likelihood are Frequent (A), Probable (B), Occasional (C), Remote (D), and Improbable (E).

Figure 1: Sample Safety Risk Assessment Matrix with No Labels

RISK ASSESSMENT MATRIX				
SEVERITY / LIKELIHOOD	1	2	3	4
A	High	High	High	Medium
B	High	High	Medium	Medium
C	High	Medium	Medium	Low
D	Medium	Medium	Low	Low
E	Medium	Low	Low	Low

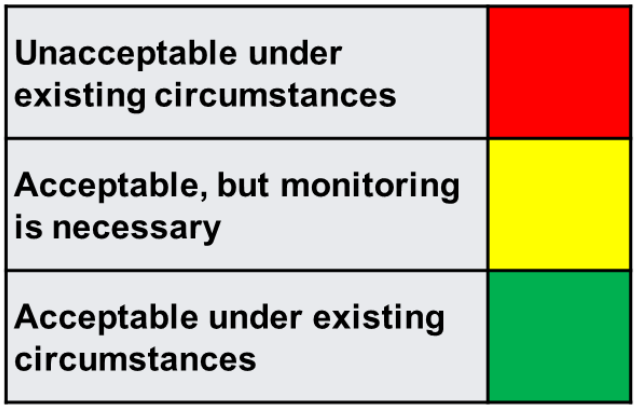
Figure 2: Sample Safety Risk Assessment Matrix with Labels

RISK ASSESSMENT MATRIX				
SEVERITY / LIKELIHOOD	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	High	Medium
Probable (B)	High	High	Medium	Medium
Occasional (C)	High	Medium	Medium	Low
Remote (D)	Medium	Medium	Low	Low
Improbable (E)	Medium	Low	Low	Low

Whichever approach your agency chooses, the matrix format will allow you to combine your assessment of severity and likelihood to determine the overall risk rating of the potential consequence of the hazard. This rating may be referred to by the combined number and letter of the column and row on the matrix (i.e.,1E) or by the combined names of the selected column and row (i.e., Catastrophic-Improbable) or by both (i.e., 1E [Catastrophic-Improbable]).

As indicated in Figure 3, the matrix format also groups these combined measures into risk categories, in this case Unacceptable (red), Acceptable with Monitoring (yellow), and Acceptable under Existing Circumstances (green).

Figure 3: Safety Risk Levels



In applying this matrix to the example of the leaking water in the transit center lobby, your agency may find that the most common consequence (slip resulting in injury requiring first aid) will be experienced only occasionally and that the relatively minor nature of the injury is marginal. This rating of Marginal (for severity) and Occasional (for likelihood) indicates a "3C" risk in the combined ratings in Figure 1. This risk rating means that the potential consequence from the hazard would be acceptable to your agency without additional action, but that monitoring is required to make sure the severity or likelihood of the hazard's potential consequences do not change.

When assessing the worst possible consequence, your agency may find an improbable likelihood of a slip with such a consequence, but the fatal severity of the consequence may be potentially catastrophic. Therefore, with a risk rating of Catastrophic (severity) and Improbable (likelihood) – or 1E on the matrix in Figure 1 – the risk from the water leak also would be acceptable to your agency without additional action, but monitoring is required to make sure the hazard's potential consequences do not change. With a risk level of 1E, monitoring may become particularly important. For example, should the leak expand to a nearby stairwell, then the likelihood of a serious fall may increase to Occasionally, resulting in an unacceptable risk rating of 1C that must be mitigated through additional action, such as closing off part of the lobby and the stairwell while repairing the leaking roof.

Finally, when assessing the worst credible consequence associated with the leaking water on the lobby floor, your agency may find that the severity of the injury (requiring hospitalization) is Critical, and the likelihood of such a fall is Occasional. With this risk rating of 2C on the matrix, your agency may choose to accept the risk with monitoring. As with the worst possible consequence, based on the results of monitoring, your agency also may decide additional action is warranted. For example, if it will be raining all week, increasing the exposure (and therefore likelihood) of employees and members of the public to the wet floor, your agency may increase the assessment of the likelihood of a slip to Probable. With a new risk rating of 2B, the risk is no longer acceptable without action. To mitigate the risk, your agency may decide to put up temporary barricades or signs to direct pedestrian traffic away from the leaking water, institute a mopping and water control initiative for the lobby and develop a plan to repair the roof.

Designing a Safety Risk Assessment Matrix

Now that we have reviewed a simple example for how to use a generic safety risk assessment matrix, your agency may consider how it wants to design its own matrix, including the categories of severity it would like to include, the levels of likelihood it may prefer, and the criteria for each respective severity category and likelihood level.

Your agency may choose to develop these risk assessment tools with discussion and review by the Accountable Executive (AE), agency leadership and executive management, and key staff. Ultimately, your agency may use these tools to determine when to take action to mitigate the potential consequences of a hazard. Given the potential importance of these tools to your agency's safety risk mitigation initiatives, active engagement of your agency's AE, leadership and executive management, and key staff may support their development and use.

Selecting Severity Categories and Criteria

When defining consequence severity categories for your agency, it is important to consider the full range of potential impacts on your operations. As discussed earlier, Part 673 identifies a series of potential criteria for populating consequence categories, including:

- Death,
- Injury,
- Illness,
- Damage to the facilities, equipment, rolling stock, or infrastructure of a public transportation system,
- Loss of the facilities, equipment, rolling stock, or infrastructure of a public transportation system, and
- Damage to the environment.

Your agency may find severity categories most useful when they provide meaningful distinctions between levels. Your agency may find it easier to assess severity when distinct safety outcomes are in different categories. For example, following this approach, an injury resulting in permanent disability would be in a different severity category from an injury requiring first aid. A consequence with multiple fatalities would be in a different category from a consequence with a single fatality or no fatalities.

In addition, using multiple different criteria – from the list in the definition of hazard specified in Part 673 – to define severity within each category offers multiple ways to justify each risk assessment's severity. For example and as illustration only, in your most severe category, your agency may choose to include criteria such as multiple fatalities, an injury or illness resulting in permanent disability, loss of property damage greater than $250,000, forced system-wide shutdown for 4 or more hours, and irreversible environmental damage that violates law or regulation.

The table below provides illustrative examples to support the establishment of criteria for severity categories at your agency:

Consequences	Considerations for Categories of Severity
Death	Number of fatalities, types of fatalities, priority given to fatalities occurring under specific conditions (i.e., striking passengers versus pedestrians or bicyclists versus trespassers)
Injury	Number of injuries, types of injuries, priority for passenger and employee injuries or other injuries, full or partial disability, hospitalization, lost workdays, first aid
Illness	Full or partial disability, hospitalization, lost workdays
Property Damage	Range of dollar values, total or partial destruction of vehicle or infrastructure element
Loss of Service	System-wide shutdown, partial shutdown, significant limitations on service
Damage to the Environment	Extent of damage (reversible, reversible with mitigation, irreversible), legal determination regarding failure to comply with environmental regulations

Other criteria also could be important to your agency and added to this list, such as loss of reputation or loss of organizational capability, although these criteria may not be directly related to safety performance. You also may place different levels of priority on consequences, for example, by assigning property damage involving transit agency property a greater consequence than other types of property damage.

Also, depending on the types of hazards you identify, your agency may choose to establish two or more sets of severity categories and criteria. For example, one set of categories and criteria may be used for bus operations, another for bus maintenance, and a third for all hazards related to pedestrians and bicyclists, which may be a major safety focus for your agency. While the specific measures or data used for these categories will be different across the matrices, your agency may choose to keep a similar proportional relationship between its severity categories across its matrices. This will ensure consistent understanding for the AE and agency leadership and executive management.

Selecting Levels of Likelihood and Criteria

Likelihood measures how often you think something will happen over a specific period of time or sample. Calendar days, weeks, months, years or decades are often used as time periods to support assessments of likelihood in safety risk assessment.

Using samples may support more specific likelihood assessments based on available data. For example, your agency may choose to assess how often something will occur per a standardized measure of vehicle revenue miles, unlinked passenger trips, or the number of specific infrastructure elements related to the hazard and its unique potential consequences, for example the number of wheelchair lift deployments per month. Another commonly used sample is operating hours or the number of hours during which your agency provides service over a specific time period, i.e., 500 operating hours per month or 60,000 operating hours per year.

Process cycles provide another type of sample. In this instance, the number of occurrences may be shown in relation to the amount of time required to complete a specific process (i.e., complete an average bus route at your agency) or the hours of an employee's average career or the time required to perform a specific maintenance activity. Samples also may include life cycles, which typically cover all stages of the planning, design, operations, maintenance and disposal of a component, vehicle, sub-system, system or infrastructure element, and may equate to a range of time periods, i.e., 5 years, 12 years, 25 year, 30 years, or 100 years, depending on the nature of the hazard and its potential consequences.

Having multiple criteria available for assessing likelihood may expand your agency's capability to conduct safety risk assessment. The table below provides illustrative examples for consideration at your agency:

Likelihood	Considerations for Levels of Likelihood
Frequent	***Continuously experienced.*** Depending on the nature of the hazard, the potential consequence can be expected to occur more than once per month. Examples of how this can be depicted include: • Potential consequence will be experienced by system more than once per month, • Potential consequence will be experienced by system more than once per 500 operating hours, • Potential consequence will be experienced by system more than once per 50,000 unlinked passenger trips, • Potential consequence will be experienced by system more than once per 40,000 vehicle revenue miles. • Potential consequence will be experienced by individual bus operator more than ten times in his/her career (52,000 hours), and • Potential consequence will be experienced more than once per year throughout vehicle life cycle. Larger systems may choose to standardize this level of likelihood in terms of events (potential consequences) per operating hour, with the Mean Time Between Events (MTBE) as less than 1,000 operating hours. This approach reflects guidance previously provided by FTA in its *Hazard Analysis Guidelines for Federal Transit Projects* (2000).

Likelihood	Considerations for Levels of Likelihood
	For special situations, such as safety risk assessments focused on pedestrian and bicycle safety issues, depending on the nature of the assessment, frequent may be defined as once or more per day or week, or more frequently if using observational data from specific locations for specific observational periods.
Probable	***Will occur frequently.*** Depending on the nature of the hazard, the potential consequence may be experienced less than once per month but more than once per year. Examples of how this can be depicted include: • Potential consequence will be experienced less than once per month but more than once per year, • Potential consequence will be experienced once per 500 to 6,000 operating hours, • Potential consequence will be experienced once per 50,000 to 600,000 unlinked passenger trips, • Potential consequence will be experienced once per 40,000 to 480,000 vehicle revenue miles, • Potential consequence will be experienced by bus operator more than five times but less than 10 times in his/her career, and • Potential consequence will be experienced once per year throughout vehicle life cycle. Larger systems may choose to standardize this level of likelihood in terms of events per hour, with the MTBE equal to or greater than 1,000 operating hours and less than 100,000 operating hours. This approach reflects guidance previously provided by FTA in its *Hazard Analysis Guidelines for Federal Transit Projects* (2000). For special situations, such as safety risk assessments focused on pedestrian and bicycle safety issues, depending on the nature of the assessment, probable may be defined as once per week or month, or more frequently if using observational data from specific locations for specific observational periods.
Occasional	**Will occur several times**. Depending on the nature of the hazard, the potential consequence may be experienced less than once per year but more than once per decade. Examples of how this can be depicted include: • Potential consequence will be experienced less than once per year but more than once per decade, • Potential consequence will be experienced once per 6,000 operating hours to 60,000 operating hours, • Potential consequence will be experienced once per 600,000 to 6,000,000 unlinked passenger trips, • Potential consequence will be experienced once per 480,000 to 4,800,000 vehicle revenue miles, • Potential consequence will be experienced by bus operator more than once but less than five times in his/her career, and • Potential consequence will be experienced at least once every two years throughout vehicle life cycle.

Likelihood	Considerations for Levels of Likelihood
	Larger systems may choose to standardize this level of likelihood in terms of events per hour, with the MTBE equal to or greater than 100,000 operating hours and less than 1,000,000 operating hours. This approach follows guidance previously provided by FTA in its *Hazard Analysis Guidelines for Federal Transit Projects* (2000). For special situations, such as safety risk assessments focused on pedestrian and bicycle safety issues, depending on the nature of the hazard, occasional may be defined as once per month or quarter, or more frequently if using observational data from specific locations for specific observational periods.
Remote	**Unlikely, but can reasonably be expected to occur**. Depending on the nature of the hazard, the potential consequence may be experienced less than once per decade but more than once in the life of the system. Examples of how this can be depicted include: • Potential consequence will occur once in the life of the system, • Potential consequence will be experienced once per 60,000 operating hours to 180,000 operating hours • Potential consequence will be experienced once per 6,000,000 to 18,000,000 unlinked passenger trips, • Potential consequence will be experienced once per 4,800,000 to 14,400,000 vehicle revenue miles, • Potential consequence will be experienced by bus operator once in his/her career, and • Potential consequence will be experienced once throughout vehicle life cycle. Larger systems may choose to standardize this level of likelihood in terms of events per hour, with the MTBE greater than 1,000,000 operating hours and less than 100,000,000 operating hours. This approach reflects guidance previously provided by FTA in its *Hazard Analysis Guidelines for Federal Transit Projects* (2000). For special situations, such as safety risk assessments focused on pedestrian and bicycle safety issues, depending on the nature of the hazard, remote may be defined as once per quarter or year, or more frequently if using observational data from specific locations for specific observational periods.
Improbable	**Unlikely to occur but possible**. Depending on the nature of the hazard, the potential consequence likely will not be experienced in the life of the system but is possible. Examples of how this can be depicted includes: • Potential consequence likely will not occur in the life of the system, • Potential consequence will be experienced by bus operator less than once in his/her career, and • Potential consequence will be experienced less than once throughout vehicle life cycle. Larger systems may choose to standardize this level of likelihood in terms of events per hour, with the MTBE greater than 100,000,000 hours. This approach reflects guidance previously provided by FTA in its *Hazard Analysis Guidelines for Federal Transit Projects* (2000). For special situations, such as safety risk assessments focused on pedestrian and bicycle safety issues, depending on the nature of the hazard, remote may be defined as once per year or decade, or more frequently if using observational data from specific locations for specific observational periods.

Sample Matrices

To support your agency in designing its own safety risk assessment matrix, this guide contains three illustrative, sample matrices for your agency's consideration:

- The **Simple Matrix in Appendix A** has three categories for severity: Catastrophic, Serious and Marginal and three levels for likelihood: Frequent, Occasional and Remote.
- The **Standard Matrix in Appendix B** contains four categories for severity: Catastrophic, Critical, Marginal and Negligible and five levels for likelihood: Frequent, Probable, Occasional, Remote and Improbable.
- The **Subject-Specific Matrix in Appendix C** presents categories of severity and likelihood levels focused on assessing potential consequences of hazards related to pedestrian and bicycle safety.

Appendices A and B present proposed criteria for consideration based on the potential consequences listed in the definition of hazard in Part 673 and the levels of likelihood discussed in this guide. Appendix C illustrates how additional data and information collected on specific locations and the behaviors of bus operators, pedestrians and bicyclists can be incorporated into the safety risk assessment process. FTA's sample matrices can be tailored and modified by your agency based on your unique operations and considerations.

All three matrices also include a proposed safety risk index to assess the composite severity and likelihood rankings. Each agency may choose to establish their own index appropriate to the size and complexity of their operations.

For all three sample matrices, FTA's illustrative, sample safety risk index includes:

Safety Risk Index	Criteria by Index
HIGH	Unacceptable – Action Required: Safety risk must be mitigated or eliminated.
MEDIUM	Undesirable – Management Decision: Executive management must decide whether to accept safety risk with monitoring or require additional action.
LOW	Acceptable with Review: Safety risk is acceptable pending management review.

Based on engagement with the AE and agency leadership and executive management, this matrix may be revised to reflect their guidance and preferences. For example, an additional safety risk index row may be added between High and Medium or additional levels of management review and approval may be specified.

Appendix A: Simple Matrix

Severity Categories		
Description	**Severity Category**	**Criteria**
Catastrophic	1	Could result in death, permanent total disability, loss exceeding $250,000, system shutdown lasting 4 or more hours, or irreversible severe environmental damage that violates law or regulation.
Serious	2	Could result in permanent partial disability, injury or occupational illness that may result in hospitalization of at least one person, property damage exceeding $25K but less than $250,000, system shutdown lasting between 10 minutes and 4 hours, or reversible environmental damage causing a violation of law or regulation.
Marginal	3	Could result in injury or occupational illness resulting in one or more lost workday(s), property damage up to $25,000, system shutdown of less than 10 minutes, or mitigatable environmental damage without violation of law or regulation.

Likelihood Levels			
Description	**Level**	**Individual item**	**System or Vehicle Fleet**
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced. Potential consequence may occur more than once in 500 operating hours.
Occasional	B	Will occur several times in the life of an item.	Will occur several times. Potential consequence may be experienced once in 500 to 60,000 operating hours.
Remote	C	Unlikely to occur in the life of an item.	Unlikely but possible. Potential consequence may be experienced once in 60,000 to 1,800,000 operating hours.

Risk Assessment Matrix			
Likelihood/Severity	**Catastrophic (1)**	**Serious (2)**	**Marginal (3)**
Frequent (A)	HIGH (1A)	HIGH (2A)	MEDIUM (3A)
Occasional (B)	HIGH (1B)	MEDIUM (2B)	LOW (3B)
Remote (C)	HIGH (1C)	MEDIUM (2C)	LOW (3C)

Safety Risk Index	Criteria by Index
HIGH	Unacceptable – Action Required: Safety risk must be mitigated or eliminated.
MEDIUM	Undesirable – Management Decision: Executive management must decide whether to accept safety risk with monitoring or require additional action.
LOW	Acceptable with Review: Safety risk is acceptable pending management review.

Appendix B: Standard Matrix

Severity Categories		
Description	**Severity Category**	**Criteria**
Catastrophic	1	Could result in one or more of the following: multiple deaths, permanent total disability, irreversible significant environmental impact or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: death, permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost workday(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost workday, minimal environmental impact, or monetary loss less than $100K.

Likelihood Levels			
Description	**Level**	**Individual item**	**System or Vehicle Fleet**
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced. Potential consequence may be experienced more than once in 500 operating hours.
Probable	B	Will occur several times in the life of an item.	Will occur frequently. Potential consequence may be experienced once between 500 and 6,000 operating hours.
Occasional	C	Likely to occur sometime in the life of an item.	Will occur several times. Potential consequence may be experienced once between 6,000 and 60,000 operating hours.
Remote	D	Unlikely, but possible to occur in the life of an item.	Unlikely but can reasonably be expected to occur. Potential consequence may be experienced once between 60,000 and 180,000 operating hours.
Improbable	E	So unlikely, it can be assumed occurrences may not be experienced in the life of an item.	Unlikely to occur, but possible.

Risk Assessment Matrix				
Likelihood/ Severity	**Catastrophic (1)**	**Critical (2)**	**Marginal (3)**	**Negligible (4)**
Frequent (A)	HIGH	HIGH	HIGH	MEDIUM
Probable (B)	HIGH	HIGH	MEDIUM	MEDIUM
Occasional (C)	HIGH	MEDIUM	MEDIUM	LOW
Remote (D)	MEDIUM	MEDIUM	LOW	LOW
Improbable (E)	LOW	LOW	LOW	LOW

Safety Risk Index	Criteria by Index
HIGH	Unacceptable – Action Required: Safety risk must be mitigated or eliminated.
MEDIUM	Undesirable – Management Decision: Executive management must decide whether to accept safety risk with monitoring or require additional action.
LOW	Acceptable with Review: Safety risk is acceptable pending management review.

Appendix C: Subject-Specific Matrix

Appendix C provides an example of how to develop a matrix focused on a single subject: assessing safety risk related to the potential consequences of hazards surrounding bus vehicle interaction with pedestrians and bicyclists. As a result, this matrix goes beyond the basic severity and likelihood information in Appendices A and B to demonstrate how survey information and observational data could be incorporated into a safety risk assessment.

In this example, which is illustrative only, appropriate data and information could be obtained from site visits, engineering assessments and from actively monitoring specific intersections and locations to identify features that may indicate a greater likelihood or severity of the potential consequences resulting from buses, pedestrians and bicyclists moving through the same location. This may include evidence of:

- High traffic volume, multiple lanes of traffic, vehicles turning in multiple directions, high average vehicle speeds, lack of traffic signals or crosswalks, absence of a bicycle lane, inability of buses to curb, narrowing lanes, cars parked along roadway and poor lighting;
- High levels of observed bus-bicycle or bus-pedestrian conflicts, where one or both parties has to suddenly change speed or direction to avoid the other, resulting in hard braking, swerving or stopping for the bus or bicycle and abruptly stopping for the pedestrian; and
- High levels of observed bus-bicycle or bus-pedestrian avoidance, where there is a change in direction or speed caused by an interaction between parties, typically involving slowing, soft stopping, or non-sudden changes of direction by buses and bicyclists and non-sudden stopping or maneuvering around buses or bicycles by pedestrians.

Designing a matrix like this one provides the opportunity to bring additional data and information into the safety risk assessment process. While your agency, in its entire history, may have only experienced one or two fatalities or serious injuries resulting from bus-pedestrian or bus-bicycle interaction, using this additional data may help you identify and prioritize locations where additional mitigations would further reduce safety risk. In addition, use of this information can possibly shed more light on the potential safety risk associated with a particular location.

Severity Categories		
Description	**Severity Category**	**Criteria**
Catastrophic	1	More than one pedestrian-bus or bicycle-bus collision has occurred at location in last 5 years, no bike lane, location experiences high level of traffic volume and/or high pedestrian or bicycle volume, average-to-high vehicle speeds, multi-lane street, presence of turning vehicle traffic, traffic light, on-street parking and/or narrowing of lane, in commercial area.
Critical	2	One pedestrian-bus or bicycle-bus collision has occurred at location in last five years; no bike lane, location experiences moderate-to-high traffic volume and/or moderate-to-high pedestrian volume, average vehicle speeds, crosswalk and stop sign, two lanes, vehicles turning one-way, on-street parking or narrowing or lane.
Marginal	3	No pedestrian-bus or bicycle-bus collisions have occurred at location in last five years; bike lane, location experiences moderate traffic volume and moderate pedestrian volume, low-to-average vehicle speeds, includes traffic signals, one lane, vehicles turning one-way, no on-street parking.
Negligible	4	No pedestrian-bus or bicycle-bus collisions have occurred at location in last five years; bike lane, location experiences low traffic volume and low pedestrian volume, low-to-average vehicle speeds, traffic signals, raised median, no on-street parking.

Likelihood Levels			
Description	**Level**	**Bus Conflict/Avoidance**	**Location**
Frequent	A	Continuously experienced.	More than 100 instances of bus-pedestrian or bus-bicycle conflict or avoidance documented during observation period at location.
Probable	B	Will occur frequently.	No fewer than 50 and no greater than 100 instances of bus-pedestrian or bus-bicycle conflict or avoidance documented during observation period at location.
Occasional	C	Will occur several times.	No fewer than 10 and no greater than 50 instances of bus-pedestrian or bus-bicycle conflict or avoidance documented during observation period.
Remote	D	Unlikely but can reasonably be expected to occur.	Fewer than 10 instances of bus-pedestrian or bus-bicycle conflict or avoidance documented during observation period.
Improbable	E	Unlikely to occur, but possible.	Zero instances of bus-pedestrian or bus-bicycle conflict or avoidance documented during observation period.

Risk Assessment Matrix				
Likelihood/ Severity	**Catastrophic (1)**	**Critical (2)**	**Marginal (3)**	**Negligible (4)**
Frequent (A)	HIGH	HIGH	HIGH	MEDIUM
Probable (B)	HIGH	HIGH	MEDIUM	MEDIUM
Occasional (C)	HIGH	MEDIUM	MEDIUM	LOW
Remote (D)	MEDIUM	MEDIUM	LOW	LOW
Improbable (E)	LOW	LOW	LOW	LOW

Safety Risk Index	Criteria by Index
HIGH	Unacceptable – Action Required: Safety risk must be mitigated or eliminated.
MEDIUM	Undesirable – Management Decision: Executive management must decide whether to accept safety risk with monitoring or require additional action.
LOW	Acceptable with Review: Safety risk is acceptable pending management review.