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HAZARD ANALYSIS FOR A1-01282019 EVENT
JANUARY 28, 2019
TRAIN #25 LRV #316 SINGLE VEHICLE R-LINE TRAIN

BY:
REGIONAL TRANSPORTATION DISTRICT SAFETY DIVISION
MARCH 14, 2019

HISTORY

On January 28, 2019, at approximately 7:17 AM, a Regional Transportation District (RTD) Light Rail Vehicle (LRV) entered a curve at approximately four times the permitted speed (based on event data recorder-EDR information); the posted permitted speed for the curve is 10 MPH. The location of the curve is East Exposition Ave at South Sable Boulevard in Aurora, CO. As a result of the vehicle speed into the curve, Train #25 (hereafter #25) derailed from the A-Track (inside curve) and crossed over the B-Track (outside curve). During this event, the LRV tilted towards the outside of the curve (to the left); this resulted in the LRV body or structure contacting the concrete pavement. This tilt placed significant forces/weight onto the left side door structures and LRV body; the doors, stepwells, and body were flexed damaging the door structures. Passengers inside the LRV were subjected to significant forces; these forces affected passengers' ability to remain standing and seated. One passenger contacted the trailing door set (left rear door) multiple times (based on door damage on interior); at some point during the derailment, the passenger was ejected from the moving LRV through the door and onto the snow covered concrete pavement. This passenger had her left leg (above the foot/ankle and below the knee) pinned between the pavement and the LRV doorframe; the crushing forces amputated the passenger's lower leg.

INVESTIGATION

During the investigation of A1-01282019 (Colorado Public Utilities Commission accident tracking identifier), it was determined that speed was the single contributor to this event; the track infrastructure and the LRV were in operational condition without defects. Human factors were the singular causation of the derailment of #25 (reference report A1-01282019 for additional information). During the investigation, it was determined by the Regional Transportation District that the event met criteria that may necessitates a Corrective Action Plan (CAP).

HAZARD ANALYSIS AND HAZARD RISK INDEX

The RTD Safety Division conducted the investigation of A1-01282019 (LRV derailment of vehicle 316); information and documentation from all Light Rail Operations Divisions were requested and reviewed during the investigation. Two other parallel but independent investigations occurred with RTD's investigation; one was from Delta V, an accident reconstruction/investigation entity and the other was with the Aurora Police Department Traffic Section. Conclusions as to the cause of the event were identical in all three cases.

To determine the appropriate Hazard Risk Indices for a similar event occurrence, data was reviewed for the R-Line service only; the data included the number of round-trips completed since the inception of the R-Line system, the number of round trips from January 2018 to 2019, the number of round trips completed on a Monday for the same time frame, and finally, for #25 on the day of the event.

Due to the extent of injuries with the passengers from #25, one of which received serious bodily injuries (SBI) the most appropriate severity category would be "critical" or "2" on the Mil-Std 882E; the Mil-Std 882E matrix provides a means to categorize events on the severity or consequences of an occurrence versus the probability or likelihood of occurrences. The next task was to determine the likelihood or probability that an event such as A1-01282019 would occur. Anecdotal information was readily available but empirical data was required to adequately evaluate then classify the occurrence into the Mil-Std 882E Hazard Risk Index; RTD's Rail Operations Transportation Division was able to provide the data to conduct this analysis.

TRAIN #25-RUN #2*
If the analysis were to focus solely on the train involved in the January 28, 2019, event, it would indicate that this was the second run (second round trip) from Peoria Station to Lincoln Station (R-Line route); the data to evaluate would then be two trips through the Sable/Exposition curve with one trip resulting in a derailment. This would provide a probability of occurrence as 1 in 2 or 0.5; this would result in an HRI of 2A or frequent critical events. RTD train service data does not support this conclusion and therefore a classification of 2A is not justified.

AVERAGE MONDAY R-LINE SERVICE**
If the analysis were to focus solely on the services (runs or trips) provided on an average (non-holiday) Monday, there would be approximately 63 round trips for R-Line trains. This would provide a probability of occurrence of 1 in 63 or 0.01587; the HRI would then be 2B or probable critical events. Again, the RTD can demonstrate that the data does not support this conclusion and therefore a classification of 2B is not justified.

MONDAY SERVICE R-LINE FOR JANUARY 2018 TO JANUARY 2019***
If the analysis were to focus solely on the amount of service provided for one year of Mondays (round trips from Peoria to Lincoln), the data would indicates 3312 round trips. This provides a probability of occurrence of 1 derailment in 3312 or 0.0003; the HRI would then be 2C on the high end and approaching 2D on the low end of probability. The RTD data does not support this conclusion and therefore the classification of 2C/D is not justified.

R-LINE SERVICE FOR JANUARY 2018 TO JANUARY 2019****
Using data from January 2018 to January 2019 provides significantly more data points, a more realistic view of the level of service provided by the R-Line; the data indicates that there were approximately 26,052 round trip runs completed in the one year timeframe. This would provide a probability of occurrence of 1 derailment in 26,052 or 3.8384E-05 or 0.000038384; the HRI would be 2D on the high end and 2E on the low end of probability. The classification of 2D/E is more appropriate when the context of service levels are accounted for in the data analysis; additionally, if consideration is given to the number of R-Line service runs since inception this classification is justifiable.

R-LINE SERVICE SINCE INCEPTION OF ALIGNMENT***
Service for the R-Line began in 2016; RTD is now approaching the third year of service for that alignment. If data were to be considered for the entire time the R-Line has been in service there are approximately 53,607 round trips completed. This would yield a probability of occurrence of 1 derailment in 53,607 or 1.87E-5 or 0.0000187. This would place the probability near the improbable range (low end) but not at the level of remote; this equates to 2E to 2D. Once again, the data supports a classification of 2D/E as more representative for the HRI categorization.

CONCLUSION
Based on data received from RTD Rail Operations Transportation Division, the appropriate categorization within the Mil-Std 882E matrix is 2D/E for a derailment at the Sable/Exposition curve. This data combined with the results of the investigation indicating human factors as the sole cause for the January 28, 2019, event indicate a system that is overall safe; the likelihood of a similar event cannot be dismissed, but is remote at best based on the available data.

Human factors are the most difficult to manage or change; information from the investigation showed a strong familiarity with the alignment by the Operator involved. RTD has determined the "why" for the January 28, 2019, event; it was speed. The "what" and "how" of what lead the Operator to enter the Sable/Exposition curve at nearly four-times the posted speed limit may never be fully determined or understood. Corrective actions taken by RTD may have little influence in changing the HRI from a 2D/E to a full 2E for human factors.

Risk Analysis for A1-01282019 January 28, 2019

Item	Hazard Description	Hazard Cause	Hazard Effect	Hazard Category and Probability	Hazard Resolution/Reduction
1	Light Rail Vehicle (LRV) derails while navigating an embedded track curve; speed of LRV exceeds posted limit.	All causes researched and eliminated except for one-Human Factors	LRV derails from track way, travels across concrete pavement to contact adjacent track way	2A/B* 2B** 2C/D*** 2D/E**** 2E/D*****	Human Factors for causation difficult to manage. Training program evaluation and modification if/as necessary, efficiency checks (random/scheduled-announced/unannounced

To determine the appropriate severity category as defined in Table I for a given hazard at a given point in time, identify the potential for death or injury, environmental impact, or monetary loss. A given hazard may have the potential to affect one or all of these three areas.

Table I Severity Categories

SEVERITY CATEGORIES		
Description	**Severity Category**	**Mishap Result Criteria**
Catastrophic	1	Could result in one or more of the following: death, 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: 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 work day(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 work day, minimal environmental impact, or monetary loss less than $100K.

To determine the appropriate probability level as defined in Table II for a given hazard at a given point in time, assess the likelihood of occurrence of a mishap. Probability level F is used to document cases where the hazard is no longer present. No amount of doctrine, training, warning, caution, or Personal Protective Equipment (PPE) can move a mishap probability to level F.

Table II Probability Levels

PROBABILITY LEVELS			
Description	Level	Specific Individual Item	Fleet or Inventory
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced.
Probable	B	Will occur several times in the life of an item.	Will occur frequently.
Occasional	C	Likely to occur sometime in the life of an item.	Will occur several times.
Remote	D	Unlikely, but possible to occur in the life of an item.	Unlikely, but can reasonably be expected to occur.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item.	Unlikely to occur, but possible.
Eliminated	F	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.	Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.

Assessed risks are expressed as a Risk Assessment Code (RAC) which is a combination of one severity category and one probability level. For example, a RAC of 1A is the combination of a Catastrophic severity category and a Frequent probability level. Table III assigns a risk level of High, Serious, Medium, or Low for each RAC.

Table III Risk Assessment Matrix

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