SB 747: Independent oversight is the key to making transit safety the first priority.

The SW Baseline Road crossing in Beaverton, scene of four preventable deaths on Portland's MAX system.

My name is Chris Carvalho and I want to thank you for seeing me today, co-chair Senator Beyer and co-chair McKeown and the rest of the Transportation Committee. I'm here in support of Senate Bill 747.

I've lived in Portland since 1981 and received an engineering degree from the University of California at Berkeley. I worked at Intel and Microsoft for 18 years in various capacities. I have a handicapped friend who uses MAX to get around and have accompanied him to stations on the system. We both have experienced dangerous situations that led me to look further into deaths on MAX. I started an investigation in August 2018 that continued until December that year. I looked at media accounts and reported fatalities through a public records request and researched how risks on the system impacted deaths and what could be done to reduce them. The conclusions were startling, and were published in the Portland Tribune on February 5th this year. (Exhibit 1)

Over the MAX system's 32-year history, 41 people have been killed in train collisions. The primary factor affecting non-passenger collision deaths on the MAX system is specific, highly unsafe locations. 37 percent of all fatalities happened at places where more than one death has occurred, and two locations, Gresham City Hall and the crossing of SW Baseline Rd. in Beaverton, are responsible for a fifth of all deaths. The east-west route shared by Blue and Red Line trains is the least safe segment of the system, chiefly due to being the busiest in terms of vehicle miles. It is responsible for 90.2% of all fatalities. Increased ridership appears to be the primary factor affecting the growth of fatalities over time, and efforts to improve safety are not bearing fruit. Secondarily, patterns in the nature of fatalities indicate operational and design changes throughout the system could reduce deaths by two thirds. The risk of death per vehicle or train mile for a pedestrian or cyclist by collision on the MAX system is 296 times higher than it is on a roadway around cars and trucks. Conclusions from these findings

indicate that new approaches are needed to address deaths, and could lead to a substantial reduction in the fatality rate with a minimum of cost.

Key Findings

Fatalities are continuing to increase, and are still happening at locations where recent safety upgrades have been installed. This indicates that upgrades are Band-Aid approaches and not best-practice improvements that have been demonstrated to increase safety on other cities' rail systems, such as in Boston, Pittsburgh, and Cleveland.

As we're seeing from the investigation into recent crashes of the Boeing 737 Max 8 aircraft, internal safety reviews can hide important information that has dire consequences for the operators, passengers, and families of those using transport. The truth about the jet's product design flaws and inadequate pilot training is only coming to light because independent oversight is finally happening.

TriMet says it cares about safety, yet it has knowingly withheld information from the public that can reduce injuries and deaths. Their history of interaction with the press, litigation with injured victims or families of people who were killed, and their internal culture exhibits a bias that the pedestrian is always at fault in a collision. They don't consider suicides to be a problem, even though a portion of them are preventable (Exhibit 5, Exhibit 6). Design and operational improvements to increase safety are ignored or delayed because compliance with industry standards is judged sufficient to satisfy its obligation to keep the public safe. Instead, standards compliance should be thought of as the bare minimum and a basis for more innovative efforts to deliver a safe system to the community. Only an independent review board such as the one in SB 747 can change the "business as usual" mentality that has failed to reduce death rates.

Funding for improved safety is not an issue. TriMet has always found money to expand the system, and since the Blue Line was built has raised 2.7 billion dollars to do it. The new lines carry only a quarter of total ridership, a poor return on this investment. With the vast majority of deaths happening on the Blue Line, the right priority is to first improve safety there and expand the system only after knowing how to do it in a safe manner. Otherwise, the cost of safety will balloon as more miles of unsafe track are built. In addition to the human cost of TriMet's poor attention to safety there's also a burden on taxpayers. In 2018 alone the agency's total of both industrial accident and public liability claims was $10.1 million (Exhibit 2). In Pittsburgh, a metro area with population comparable to that of Portland, their liability provision the same year was only $2.6 million, in a state where there's no cap on public liability damages (Exhibit 3).

One simple change that could reduce deaths is to stop trains at pedestrian crossings before they enter a station. Had this been done, in Ms. Sturdy's case her son would be alive today and another recent injury in Beaverton where Amy Laing's leg was severed wouldn't have happened.

Findings from the safety review required in Senate Bill 829 have not been fully implemented in ten years. If it weren't for that bill and the results of my investigation, the public would still be in the dark about the unsafe conditions on MAX. I would hope that after hearing from Ms. Sturdy and myself that you will consider going back to audit the work TriMet has done to be sure there is compliance with Senate Bill 829 because that does not appear to be the case. I have proposed a number of recommendations based on my investigation, included in your packet, which I hope the committee will consider and if you see fit, to adjust Senate Bill 747 to provide greater accountability, time deadlines for safety upgrades, and transparency that I believe is desperately needed.

Thank you very much for the opportunity to speak with you today. We can save many lives by giving safety on the MAX system the attention it deserves.

Recommendations

Two thirds of accidental deaths on MAX are preventable by implementing these recommendations, some of which are very inexpensive:

1. As mentioned above, stop trains at pedestrian crossings before entering stations, and then proceed into the station at a crawl.
2. Immediately decrease train speed limits at all sites with multiple fatalities until other safety improvements can be implemented.
3. Because the most significant relationship to fatalities is curved track, straighten curves or move curved segments underground.
4. Add more crossing gates, especially at sites with elevated fatality risk such as at angled or complex intersections.
5. Provide flashing lights and audible warnings at all pedestrian crossings that sound continuously until a train passes.
6. Evaluate signals that warn pedestrians of the direction of approaching trains to reduce the chance of an error in judgment or distraction making a person unaware of trains, especially when they are approaching from both directions.
7. Improve visibility by rerouting angled crossings and removing trees or other obstructions.
8. Begin a program of gradually moving tracks underground, elevating them, or building road underpasses or overpasses, starting at dangerous locations such as angled crossings or intersections.
9. Give Blue Line tracks highest priority for safety upgrades, with the Baseline Road crossing and Gresham City Hall station as the most critical locations.
10. Because of the strong historical correlation between ridership and fatality rate, efforts to improve safety should focus on the busiest sites and stations after places with multiple fatalities have been addressed.
11. Educate the public that train crossings are 300 times more dangerous than crossing in automobile traffic. Pedestrians, cyclists, and drivers have a false sense of security and a lack of appropriate caution around MAX stations and tracks because it's widely perceived that trains are less likely to cause deaths than cars.
12. Explore ways to limit access to restricted right-of-way including better fencing, tunneling, and motion-triggered cameras to detect trespassers.
13. Locate platforms so incoming trains are not braking from cruise speed while passing through intersections with pedestrian crossings.
14. Add pedestrian crossing request signals at dangerous intersections or track crossings such as those along East Burnside that require train and/or car traffic to stop, and warn pedestrians if a train cannot stop safely in time. These are in use at the Tuality Hospital/SE 8th Ave. MAX Station in Hillsboro. People with handicaps depend on MAX and are everywhere on the system. It's not enough to accommodate them only at a hospital stop.
15. Highway noise can make it difficult for people to hear approaching trains. Place signal lights and audible signals along the I-84 track stretch to warn people on the tracks that a train is approaching.
16. At locations such as SE 193rd & Burnside where lack of a road shoulder eliminates safe space between the road and trackway, realign streets to create a pedestrian safety zone or move track underground.
17. Look at the time of day for fatalities to find out if the sun's position, weather, or inadequate lighting could be a factor.
18. Three systems in other states have fatality rates well under half that of MAX. Practices and design at these should be examined to learn if they can be adopted in Portland.

19. If weather conditions, lighting, or sun position is found to be a factor on particular track segments, consider adding precautionary train stops or lowered speeds at the times of year and of the day when they are needed. These could be programmed into automatic signaling and speed control so delays in service only happen when risk is highest. Upgrade night lighting if needed.
20. Track blood alcohol involvement for pedestrian and cyclist deaths to determine if it is a significant factor. If found to be true, encourage intoxicated riders to take a bus, taxi, or rideshare service or travel with a sober person.
21. Improve messaging about suicide prevention through public service announcements, signage, and advertising on trains and at stations offering help for people considering using the train system as a means of suicide.
22. Implement provisions of the US Department of Transportation's rail suicide prevention initiative: https://www.volpe.dot.gov/rail-suicide-prevention
23. Provide safety materials to the public through multiple avenues (ticket apps, online, printed brochures, broadcast advertising, etc.) that educate riders and anyone near tracks or stations about risks and how to reduce them. The TriMet website only has materials for schools, and links to another nationwide site (Operation Lifesaver, https://oli.org/) which isn't tailored to specific risks on MAX. Place safety messages on the sides of trains and buses.
24. MAX has several different train types. Accident frequency by train type should be examined to see if operator visibility, braking performance, or other factors might affect fatalities. If differences are found, train types with issues should be modified or retired.
25. Investigate enclosing stations to protect them from weather and make platforms safer by keeping them warm and dry, with interior design standards. Look at using sliding glass doors at platforms to keep passengers off of the tracks and away from trains, except when the train's doors are open for boarding. The protective doors are increasingly common overseas in cities such as London, Paris and Tokyo. They are also in trial use at AirTrain stops in Queens and New Jersey. The Las Vegas monorail is the only system using them in the USA currently.
26. Add pedestrian bridges crossing I-84 to reduce trespassing on tracks. Look into the reasons why people are on that track segment in more detail. Are they homeless campers? Are they using Union Pacific railcars as hobos? Are they local residents taking a shortcut?
27. Pay special attention to known risks on the Blue Line and apply lessons learned to the proposed Barbur Blvd. line, which is planned to run down the middle of the street in a dangerous configuration.
28. Design ticketing apps so they do not need any user intervention to ride the system, reducing the chance that riders will be distracted around stations.
29. Look at placing bus and rail transit in Portland's metro area under the Port of Portland, similar to what Pittsburgh does, or under the state's transportation department, as is done in Boston. These bodies have a focus on transportation and safety, and might provide an environment more conducive to safety as a priority.
30. The law that created TriMet (Chapter 267 — Mass Transit Districts; Transportation Districts) has some troublesome provisions such as ORS 267.245 (District exempt from right of way fencing requirements) and ORS 267.230 (Exemption from public utility or railroad regulation). These give the agency wide latitude to ignore or overlook industry safety best practices. The law and its provisions should be reviewed to determine if changes can be made to improve safety in mass transit districts.
31. Provide audible warning signals at all pedestrian crossings that sound continuously when a train is approaching from either direction, stopping only when it's safe to cross. If noise abatement is a concern, use flashing lights at night and an audible warning with lights during the day. Look at alternative warning

approaches for night such as lighted strips in the pavement that flash when a train is near along with vibration that provides tactile feedback to feet, wheelchairs, or bicycles.

32. Report safety statistics for the WES system as a separate heavy-rail system to the National Transit Database. This will provide a more accurate interpretation of safety for both MAX and WES.
33. Because lawsuits are a form of independent review, audit all judgments against TriMet for findings that indicate safety failures and possible improvements.

Exhibits

TriMet must reduce MAX collision deaths

MYVIEW

By Chris Carvalho

In early morning darkness on Dec. 20, a man died on the MAX tracks in Hillsboro near Northwest Cornelius Pass Road. It was the 41st death in the system's history. It might seem easy to overlook, but it fits in perfectly with TriMet's history of collision deaths.

CARVALHO

A review of these deaths shows most happen at a few highly unsafe locations. Thirty-seven percent of all fatalities happened at just five places where more than one death has occurred. Two locations — Gresham City Hall and the crossing of Southwest Baseline Road in Beaverton — are responsible for a fifth of all deaths.

The east-west route shared by Blue and Red Line trains, where the most recent death happened, is the most dangerous segment, by far. It's responsible for 90 percent of all nonpassenger fatalities.

Having spent a lot of time helping a wheelchair-bound friend navigate MAX and hearing his stories about close calls, I started to pay more attention to pedestrian deaths.

The more I read about them in media accounts, the more similarities emerged. That led me to request records from TriMet about deaths from train collisions with people.

An inkling of suspicion turned into a three-month investigation, as my research revealed layer after layer of dangers underlying fatal crashes with pedestrians, and startling trends of similar problems nationwide. I quickly learned the public has a false sense of security and a lack of appropriate caution around MAX tracks.

Fatalities have quadrupled since the system's early years, and efforts to improve safety are not bearing fruit. Patterns indicate simple operational and design changes could reduce them by two-thirds. Nothing indicates train operators play a role in accident trends.

While we tend to think Portland's roads are unsafe compared to MAX, quite the opposite is true. The risk of death by collision per vehicle-mile for a pedestrian or cyclist on MAX tracks is nearly 300 times higher than it is on a roadway around cars and trucks.

TriMet officials haven't done enough to inform the public of how dangerous their tracks are. This safety problem is not limited to MAX; it is a nationwide one. Those who depend on the system the most, including the elderly, disabled and students, unfortunately, are in the most danger.

While transit officials are proud of MAX, its safety record is nothing to brag about. Out of 24 systems in U.S. cities with more than 5 million train-miles from 2002 through 2017, MAX has a fatality rate that's in the middle of the pack, ranking 11th in terms of safety. Pittsburgh's system has a fatality rate that's one-third that of ours. We can do better.

An inexpensive and highly effective solution is to have trains come to a stop before pedestrian crossings next to stations, then enter the station at a crawl. This one change would eliminate all deaths at stations where people cross the tracks, a 30 percent reduction.

At places with multiple fatalities away from stations, tracks could be moved underground or realigned. Other changes such as adding crossing gates, speed reduction and simplifying intersections near stations also can make the system safer.

We shouldn't call these deaths accidents; they're a failure of priorities. Before spending $2.7 billion on the Barbur Boulevard MAX extension, we should improve safety on the Blue Line route, which carries 73 percent of system traffic.

There's no excuse not to when we already know how to reduce deaths. By the time the new line is completed in 2027, 18 more people likely will be dead if nothing is done. That's an unacceptable price to pay.

A map provided by Chris Carvalho showing the location of fatalities along the MAX lines since the first one opened 42 years ago.

Chris Carvalho is a photographer and chemical engineer who lives in Aloha. Contact him at 503 329-3916 or chris@lensjoy.com; You can find a link to his research in the online version of this column.

Exhibit 1. February 5, 2019 Portland Tribune editorial. The newspaper provided the map caption and gave an incorrect figure for the opening of the system. It should be 32 years ago.

Changes in the District's public liability and industrial accident claims liabilities (reported in other liabilities on the Statement of Net Position) are as follows for the years ended June 30, 2018 and 2017:

	2018		2017	
	Industrial accident claims	Public liability	Industrial accident claims	Public liability
Liability at beginning of year	$ 5,942	$ 4,189	$ 6,573	$ 4,496
Current year claims	2,370	115	2,091	617
Changes in estimates for claims of prior periods	427	1,690	622	321
Payments of claims	(3,208)	(1,864)	(3,344)	(1,245)
Liability at end of year	$ 5,531	$ 4,130	$ 5,942	$ 4,189

Based on historical experience, the District has classified $3,324 and $3,670 of the industrial accident and public liability claims liabilities as current liabilities, at June 30, 2018 and 2017, respectively.

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Exhibit 2. Liability costs (in thousands) from TriMet's 2018 financial report, https://trimet.org/pdfs/publications/2018-audited-financial-report.pdf

PORT AUTHORITY OF ALLEGHENY COUNTY

COMPARATIVE SUMMARY OF REVENUES AND EXPENSES
(Unaudited)

	Month of June 2018			12 Month Year-to-Date		
	Budget	Actual	Variance	Budget	Actual	Variance
REVENUE :						
Passenger revenue -						
Bus, Light Rail & Incline Plane	$7,492,086	$7,481,904	($10,182)	$85,710,366	$90,488,477	$4,778,111
ACCESS program service	1,051,351	962,494	($88,857)	12,455,600	11,797,308	($658,292)
Advertising	220,834	145,584	($75,250)	2,650,000	2,822,827	$172,827
Interest income	49,000	134,515	$85,515	588,000	1,067,127	$479,127
Other income	40,851	23,239	($17,612)	490,161	748,067	$257,906
Total Operating Income	**$8,854,122**	**$8,747,736**	**($106,386)**	**$101,894,127**	**$106,923,806**	**$5,029,679**
EXPENSE :						
Wages & salaries	$14,439,857	$14,809,509	($369,652)	$159,523,564	$158,838,686	$684,878
Employee benefits	13,214,639	12,519,276	$695,363	154,126,603	148,493,092	$5,633,511
Materials & supplies	3,408,719	4,247,507	($838,788)	41,218,159	41,357,117	($138,958)
Provision for injuries & damages	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Purchased services	1,104,907	1,121,425	($16,518)	13,406,261	10,275,435	$3,130,826
Utilities	659,285	544,442	$114,843	8,515,676	7,228,995	$1,286,681
Other expense	731,897	832,771	($100,874)	9,275,783	7,473,939	$1,801,844
Interest	0	0	$0	0	0	$0
ACCESS program service	2,422,138	2,202,923	$219,215	29,065,700	27,230,401	$1,835,299
Total Expense	**$36,344,280**	**$36,505,693**	**($161,413)**	**$419,785,746**	**$403,506,615**	**$16,279,131**
Deficit before Subsidy	**($27,490,158)**	**($27,757,957)**	**($267,799)**	**($317,891,619)**	**($296,582,809)**	**$21,308,810**

Exhibit 3. Pittsburgh transit financial report shows $2.6 million liability cost in 2018:
http://www.portauthority.org/paac/Portals/0/2018budget/MonthlyIncomeStatementJune2018.pdf

The following letter was sent to Bruce Warner, the TriMet board member in my district. I never received a response. The data in the enclosed chart showed a pedestrian fatality rate that was 25 times worse for trains than for automobile collisions, a preliminary result that was later corrected to 296 times worse once my research included a more thorough examination of data. The original data used to prepare the enclosed chart was based on all urban motor vehicle deaths, including vehicle occupants. Pedestrian & bike fatalities are approximately 1/5 of total motor vehicle involved deaths. This error was corrected in my analysis published by the Portland Tribune.

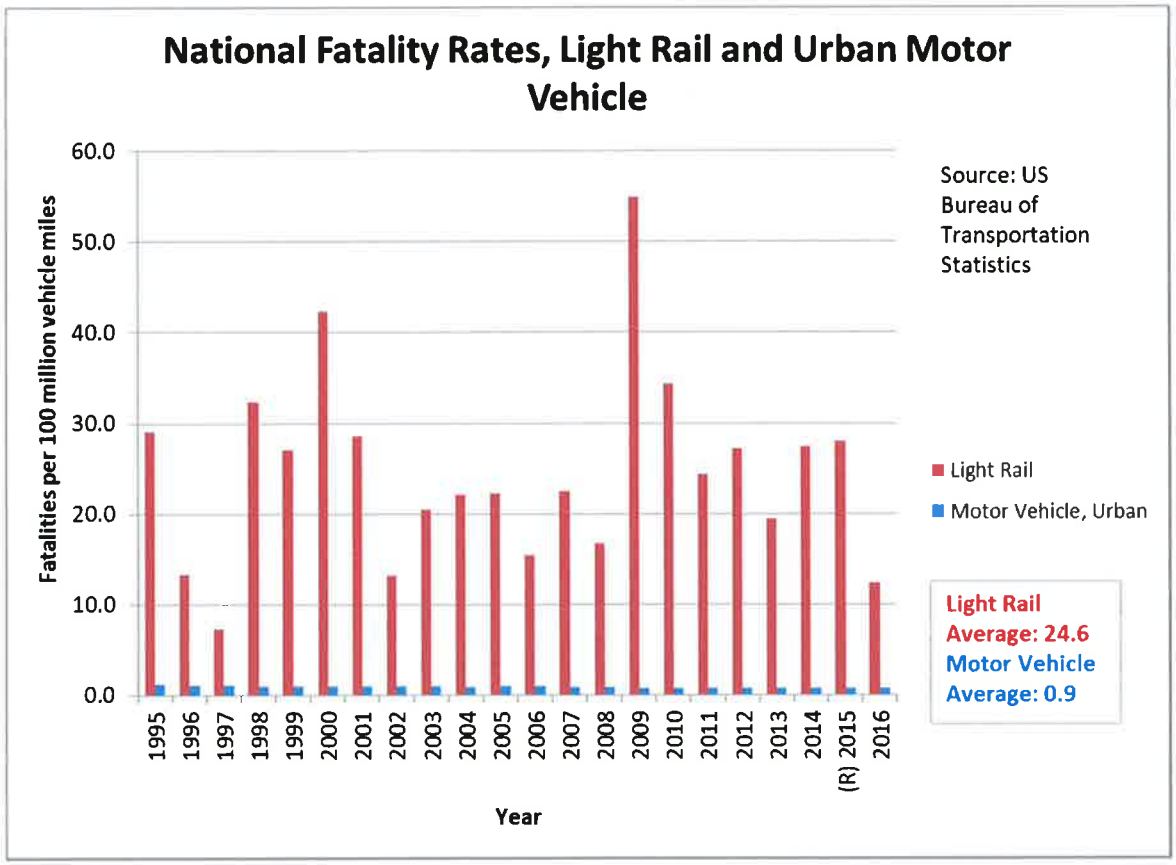
Exhibit 4. Letter to Bruce Warner, TriMet board member, outlining severity of fatality risk.

17717 SW Washington Dr.
Aloha, OR 97078
August 12, 2018

Mr. Bruce Warner
Tri-Met Board of Directors
1800 SW 1st Ave #300
Portland, OR 97201

Dear Mr. Warner:

On August 6, a teen was struck by a MAX train at Merlo Road. Earlier this year, there was a fatal train collision with a pedestrian at a marked crossing in Beaverton. Tri-Met doesn't publicly track MAX fatalities, but some data from the US Bureau of Transportation Statistics indicate that per vehicle mile, light rail nationwide has a fatality rate 25 times that of motor vehicles in urban areas. That's unacceptable for a system designed by engineers and run by professionals. Would we tolerate that from airlines?



There is a simple solution to these injuries and deaths. Trains should stop before entering the station at pedestrian crossings, and then proceed into the station at a crawl. This step would eliminate all injuries and deaths at these locations. It would add travel time, but the tradeoff would be worth it. Drivers on our roads have to stop for pedestrians; the same should be true for passenger trains at stations, where most of these incidents happen.

It might even be possible to make some improvements to tracks to allow trains to operate at higher speeds between stations, cancelling out any delay from stopping before entering the station.

Light rail isn't equivalent to freight trains. Light rail trains are smaller, carry passengers, stop frequently, and operate in close proximity to pedestrians, handicapped people, the elderly, and cyclists. The operator is responsible for the lives of both passengers and people near the tracks. The intention of light rail is to safely transport passengers. Right now, MAX is failing horribly in meeting this goal. The rules for operating light rail need to reflect these critical differences. While personal responsibility is certainly a factor in some deaths, it's not always the case. We also know that young people, the elderly, and the handicapped depend on transit yet are less able to be watchful around trains due to sensory and cognitive differences that are no fault of their own. They shouldn't be at risk of death as a consequence. In a region with a Vision Zero campaign to eliminate pedestrian deaths, light rail is not exempt. It's time to put in place a common-sense solution to stop deaths on the MAX system that are entirely preventable.

Sincerely,

Chris Carvalho

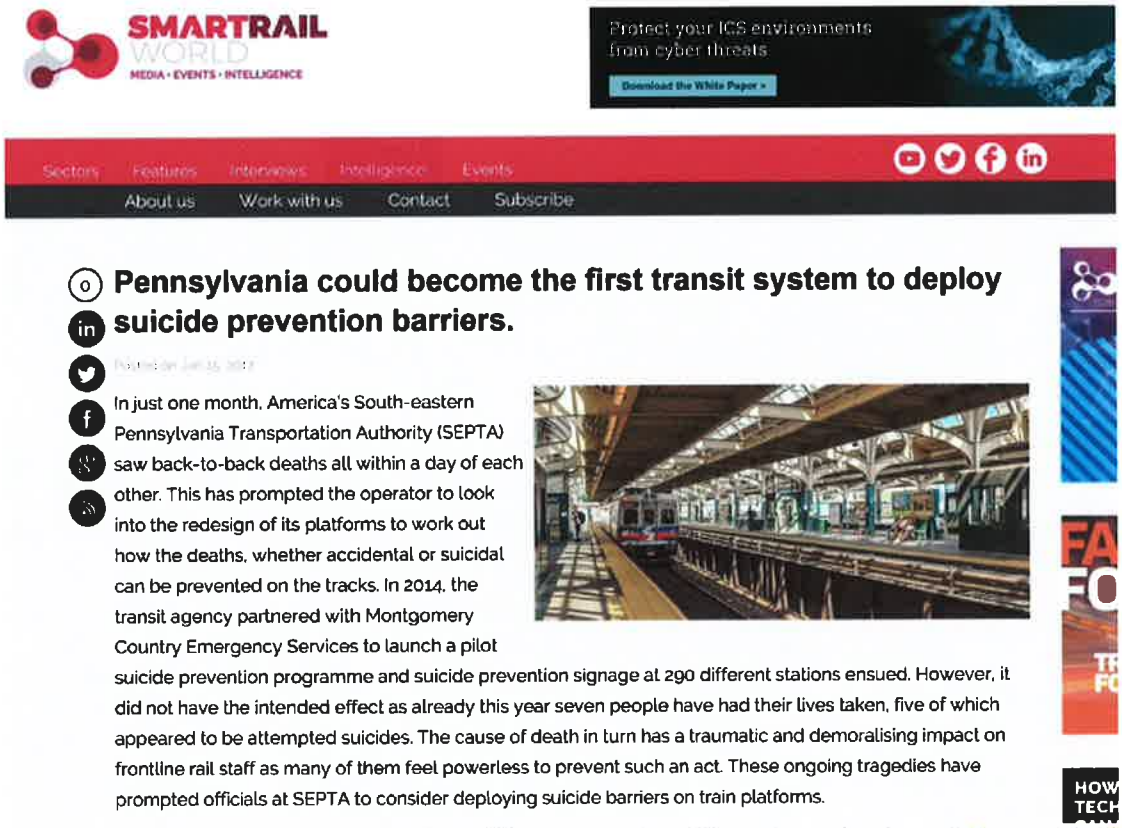


Exhibit 5. Pennsylvania plan for suicide prevention: https://www.smartrailworld.com/pennsylvania-could-become-the-first-transit-system-to-deploy-suicide-prevention-barriers

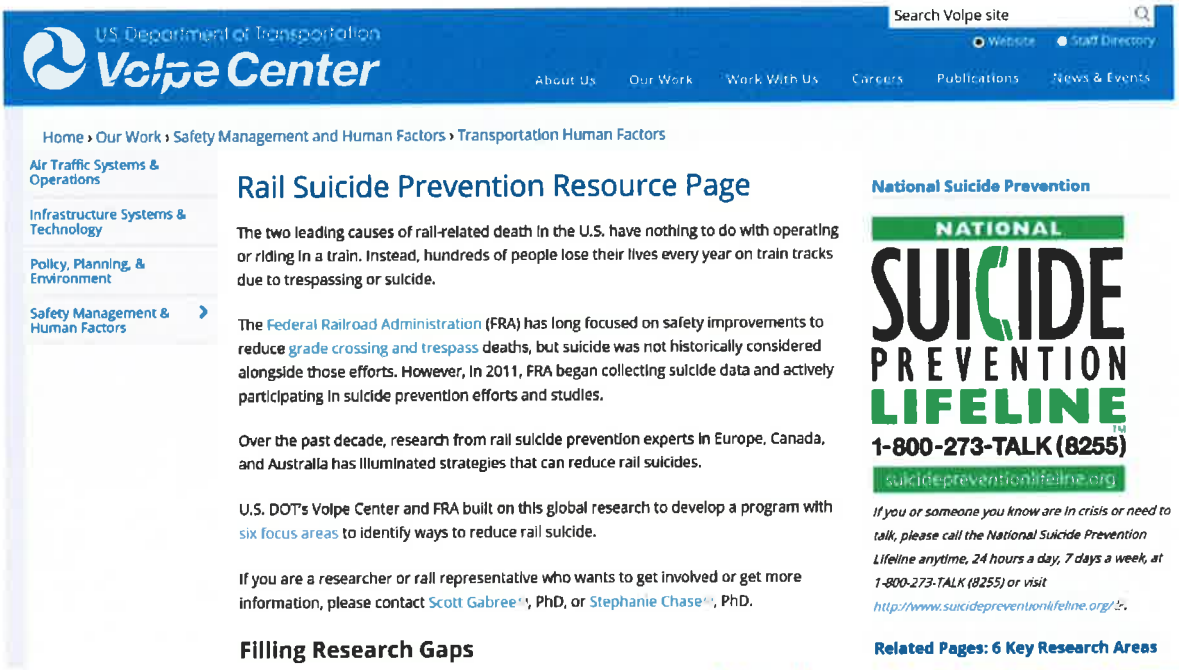


Exhibit 6. US Department of Transportation rail suicide prevention initiative: https://www.volpe.dot.gov/rail-suicide-prevention

An Analysis of Fatalities on Portland, Oregon's Light-Rail System

By Chris Carvalho, January 24, 2019 (updated March 29, 2019)

Summary

The primary factor affecting non-passenger collision deaths on the MAX system is specific, highly unsafe locations. 37 percent of all fatalities happened at places where more than one death has occurred, and two locations, Gresham City Hall and the crossing of SW Baseline Rd. in Beaverton, are responsible for a fifth of all deaths. The east-west route shared by Blue and Red Line trains is the least safe segment of the system, chiefly due to being the busiest in terms of vehicle miles. It is responsible for 90.2% of all fatalities. Increased ridership appears to be the primary factor affecting the growth of fatalities over time, and efforts to improve safety are not bearing fruit. Secondarily, patterns in the nature of fatalities indicate operational and design changes throughout the system could reduce overall fatalities by 66%. A surprising finding comparing light-rail deaths to motor vehicle deaths came from the analysis. The risk of death per vehicle (train) mile for a pedestrian or cyclist by collision on the MAX system is 296 times higher than it is on a roadway around cars and trucks. This high risk differential is not limited to MAX, it is a nationwide problem. Fatality rate trends were also examined to compare MAX with other light-rail systems. Over time, MAX fatalities and those on other large light-rail systems are increasing at a similar rate. This finding indicates that the increase in deaths is not unique to MAX. Out of 24 systems nationwide with more than 5 million train miles from 2002 through 2017, MAX has a fatality rate that's slightly better than average, ranking eleventh in terms of safety. Conclusions from these findings indicate that new approaches are needed to address deaths, and could lead to a substantial reduction in the fatality rate with a minimum of cost.

Introduction

This report investigates the history of non-passenger fatalities on the TriMet MAX light-rail system in Portland, Oregon and compares the system's fatality rate with others nationwide. Non-passenger fatalities include cyclists, motorists, pedestrians, and wheelchair users that have collided with trains. Fatality and train mileage data were obtained from TriMet through a public records request. Nationwide data came from the National Transit Database and the National Highway Traffic Safety Administration.

Methods and Disclosure

Fatality data from all sources were organized in Microsoft Excel 2010. A map of fatality locations was prepared using Google Earth Pro, and Google Maps Street View was used to examine selected fatality locations for safety concerns. This analysis did not attempt to look at police reports, the time of day of incidents, or individual investigations due to the cost of obtaining those records. MAX fatality data for the years 1986 through 2017 were included, but comparison to national statistics was limited to the years 2002-2017 because of the difficulty of obtaining earlier data. Press accounts of deaths were consulted as well as various statistics from the TriMet website, internal mileage data, court records, and safety audit reports.

Stations along the Blue Line route were categorized for fatality risk factors. They were compared to rank risk factors in order of importance for fatal collisions and determine if multiple factors increased the likelihood of deaths.

The analysis was conducted independently from TriMet or any other party. The author received no compensation for the work, nor was the work requested by any party.

Overview

Below is a map showing Portland's MAX system lines and fatality locations, marked as a red teardrop. Train lines are designated by the colors blue, red, green, orange, and yellow. Where lines overlap, only one color is shown for clarity. Since the trains in overlapping areas share tracks, this simplification should not have any bearing on the reason for a fatality. Prior to 2018 a total of 40 fatalities have occurred. A 41st fatality happened in 2018 near NW Cornelius Pass Road in Hillsboro. It is noted on the map but not included in the national comparisons analysis because other data are only available for years with full reporting. The 2018 fatality was examined for similarity to others regarding safety issues.

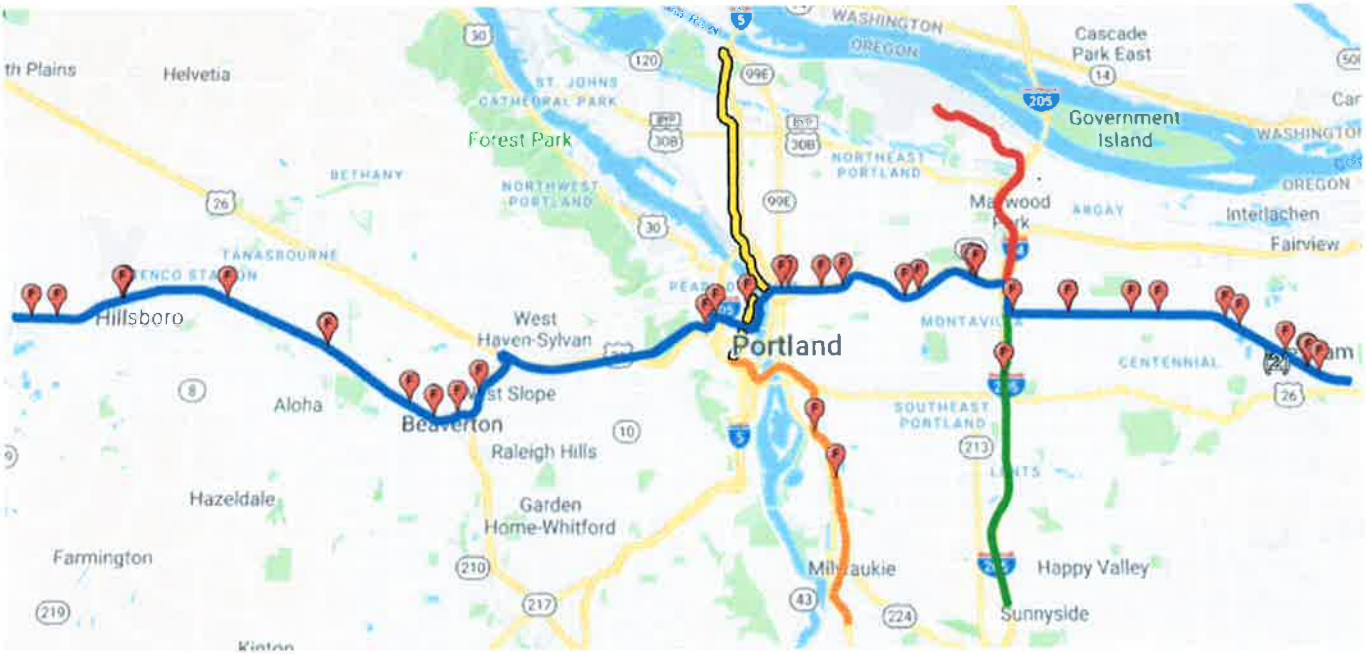


Figure 1. Map showing MAX fatality locations

It is immediately obvious that most fatalities occur on the east-west Blue and Red lines, running from Hillsboro to Gresham. Only four deaths happened on the Green, Orange, and Yellow lines. None have happened on the Red Line route from the Gateway Transit Center to the Portland Airport.

MAX Line	Number of Fatalities (1986-2018)	Percent of Total	Line Age as % of System Lifetime
Blue (Red)	37	90.2	100
Orange	2	4.9	6
Green	1	2.4	26
Yellow	1	2.4	44
Red (Airport spur)	0	0.0	52
Total	**41**		

Table 1. Fatalities by train line

This result is somewhat misleading. It does not mean that the Blue Line route is so dangerous due to any physical characteristics, though they might play a role. TriMet provided train revenue mileage data for the years 2009-2017, which can be used to establish the relative risk per train mile on each line. The Blue Line is by far the busiest line on the system. When this adjustment is made, a risk differential can be calculated to determine if fatalities are significantly different from what would be expected if all parts of the system had equivalent risk per

train mile. It shows the number of fatalities is consistent with what can be expected from train traffic levels as the primary factor impacting safety.

MAX Line	Fatalities 2009-2017	% Actual Fatalities	Train Miles	% Miles	Risk Differential
Blue (Red)	15	79%	26,561,212	73%	108%
Green	1	5%	5,325,806	15%	36%
Orange	2	11%	976,179	3%	391%
Yellow	1	5%	3,413,448	9%	56%
Total	19	100%	36,276,646	100%	

Table 2. Risk adjustment for train mile by line

Before interpreting these results, some background. The Yellow Line opened May 1, 2004. The Green Line opened Sept. 2009, and the Orange Line opened Sept. 2015. The Red line opened September 2001, but largely shares the route of the Blue Line as far as total mileage is concerned. Because there are only four total fatalities among the Green, Orange, and Yellow lines, the relative risk compared to that of the Blue Line is not meaningful because the sample size is too small to make a statistical comparison. One caution is that because two suicides occurred on the Orange Line with only three percent of the total revenue miles for the period, this represents almost a fourfold higher risk than is nominal for the entire system. While the sample size is too small to call this significant, further attention should be paid to this observation to ensure it doesn't indicate a concerning problem with that segment. Based on an annual sampling of fatality rates, the eight percent risk increase on the Blue Line route compared to the system overall represents about a 50% chance this difference is significant. So as of this time, it is premature to conclude the Blue Line route is definitely less safe compared to the other routes for reasons other than traffic miles.

There are a number of challenges to improving safety on the Blue Line route. This report will not attempt to address the importance of each one, but they are listed as areas for more detailed investigation. The Blue Line was the first MAX line constructed. The eastern segment running from Portland's city center to Gresham opened in 1986. The western segment of the Blue Line running from downtown Portland to Hillsboro opened in 1998. As the two oldest segments of the system, their design did not benefit from local experience, other than following design standards in place for light rail at the time. Design compromises to limit cost placed much of the line on surface streets. In retrospect, this decision may contribute to the high fatality rate on the Blue Line, especially at specific locations where more than one death has happened.

The Blue Line also includes a long stretch running down the center of East Burnside St. This type of alignment is notorious for high accident rates, because it places trains, cars, and pedestrians in close proximity and has many intersections crossing the tracks. A total of four pedestrian deaths between stations have happened along this route. Trains operate at higher speeds than they do in the downtown core, lengthening stopping distances. There are marked pedestrian crossings between stations, but they still have high risk due to the rapid speed of trains. Most intersections on this segment do not use crossing gates, instead relying on traffic lights. Along parts of this route, such as the fatality at SE 193rd & Burnside, there is no shoulder between the traffic lane and the track (Figure 2, below). A pedestrian crossing tracks in this situation could mistakenly cross when both a train and a car are approaching and have no safe space to escape to. While TriMet considers this spot "restricted right of way," it is not protected by fencing (impractical because there would be gaps at intersections allowing entry) and "No Trespassing" signs are easily ignored. Pedestrians likely cross the tracks unaware of the danger. Another possible contributing factor to high fatality rates is the east-west orientation of the Blue Line. It's possible that the sun reduces visibility near sunrise and sunset times for both train operators and people crossing

the rail line trying to watch for trains. To understand this factor more, the angle of the sun relative to the train for each accident needs to be examined along with weather conditions present at the time. Relatively little work has been done in the literature on this factor, but two papers indicate a significant relationship between glare and accident rates for automobile traffic. [1,2] Commonalities described below (Table 4) also point to a possible relation between fatal accidents and the sun's position or weather conditions for some locations.

Figure 2. SE 193rd & Burnside fatality location showing no safe space between traffic lane and trackway

While grade separation generally reduces fatality rates[3], the segment of the Blue Line along Interstate 84 is separated from the road system, yet has a high number of fatalities. TriMet classifies all deaths along this segment as "Train and pedestrian in restricted right of way." The reasons for this anomaly should be investigated. It's possible that there are homeless people camping near the tracks, hobos using Union Pacific railcars that share the right of way and crossing MAX tracks to access Portland streets, or local residents are using the track area for some other purpose. If there is a common thread underlying these deaths, it may be possible to reduce them without tunneling the MAX tracks. Other parts of the system with grade separation have few fatalities. Highway noise in this area may make it difficult for people to hear an oncoming train. Trains also travel at high speed in this section, up to 60 mph. The combination of high speed and east-west orientation makes it more difficult for operators to stop a train if there's a person on the tracks and visibility is limited due to the sun's glare. While there is a fence that separates the Union Pacific and MAX rights-of-way along I-84, there are places at freeway ramps, such as the onramp at NE 60th and Glisan, where it's possible for a person to easily access the MAX tracks in order to walk along them, or to leave the tracks and enter city streets.

Because the Blue Line route is the busiest on the system, it also has the highest number of deaths. The risk differential (Table 2) indicates eight percent more deaths happen on this segment than can be explained by traffic alone, with a 50% confidence level. Since 90.2 percent (79% since 2009) of all deaths happen on it and it

also appears to be slightly more dangerous per train mile than other parts of the system, it should be considered as the focus of efforts to improve safety.

There are several locations in the system where multiple deaths have occurred:

Location	Number of Fatalities	Percent of Total
Gresham City Hall	4	10%
SW Baseline Rd. Crossing	4	10%
82nd Ave.	3	7%
E. 122nd Ave.	2	5%
Hillsboro Fairplex	2	5%

Table 3. Locations with multiple fatalities

37 percent of all fatalities happened at places where more than one death has occurred, and two locations, Gresham City Hall and the crossing of SW Baseline Rd. in Beaverton, are responsible for a fifth of all deaths.

Looking closer at these two trouble spots, at the Baseline crossing (Figure 3, below) there are no traffic signals on a street where cars travel at high speed and no marked crosswalks on the street, though there are designated track crossings for pedestrians. This can cause pedestrians to focus more on auto traffic than trains. Trees limit visibility looking to the west. An angled track crossing makes it difficult to watch for trains and cars at the same time. Both the track and street heading to the west are curved, limiting visibility of oncoming car and train traffic. While pedestrians are supposed to cross the tracks at a right angle using separate sidewalks, the sidewalks are located inconveniently well away from the roadway, tempting people to take a shortcut by crossing the tracks using the bike lanes along Baseline. The angled crossing of the bike lanes lengthens the amount of time that pedestrians are in the track area, possibly making a person's judgment of the amount of time needed to cross the tracks deceptively short. Since pedestrians usually walk facing traffic, they are not blocked by crossing gates in this situation.

Fencing in the median (Figure 4, below) actually directs pedestrians to cross in the track area when the crossing gates are down and cars are stopped. This is a time when it seems safer to cross because auto traffic is halted and there's a deceptively safe space created by stopped cars while a train is approaching.

At many grade crossings with gates for cars, the bells sound for only about ten seconds, then stop.[4] This is a noise abatement measure, but it means that pedestrians or cyclists who enter the area after the bells stop have no audible warning other than the sound of the approaching train or an operator's bell or horn. A person might mistakenly believe the train has already passed in this situation, when in fact the danger of the approaching train is at its highest. It's counter-intuitive that when bells are sounding with gates down, it's actually safer to cross the track than when they are not since the bells sound well in advance of the train's arrival.

Figure 3. SW Baseline Road crossing looking west

Figure 4. Deceptively safe crossing directs pedestrians into trackway when cars are stopped at crossing gates

At the Gresham City Hall station, there are buildings and trees on both ends of the platform that restrict visibility close to where pedestrians cross tracks. Once again, there are no traffic signals where the tracks cross NW Eastman Parkway and the tracks cross NW Eastman Parkway at an angle. There is a marked crosswalk.

Figure 5. Gresham City Hall station looking west from NW Eastman Parkway

Figure 6. NW Eastman Parkway looking south, Gresham City Hall station on right

Another common factor for many deaths is the track crossing layout. Thirteen fatal incidents, or 32 percent, happened at angled, complex intersections or track crossings.

There is no clear pattern as to when fatalities happen during the year. Below (Figure 7) is a chart showing the number of fatalities per month. However, there is a possible explanation for fatalities increasing in January and June through September. Short days and cold, poor weather in January could make accidents more likely since busy times on the system are during dark hours. In the clear summer months, sun glare could be contributing to an inability of operators or pedestrians to see each other. Poorer weather in the fall and the loss of Daylight Savings Time could contribute to more deaths in October, November, and December compared to the spring months. More investigation is needed to understand if these theories have merit.

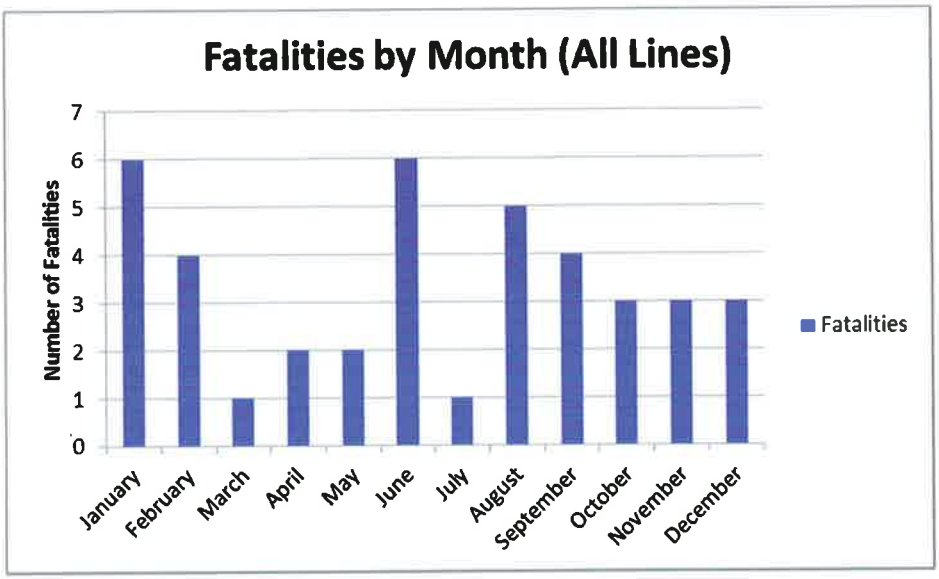


Figure 7. Summary of fatalities by month

However, there are interesting commonalities between the location of some fatalities and the time of year. Below is a list of multiple deaths happening in a short period of months at specific parts of the MAX system. This finding points to possible safety issues relating to the sun, day length, and/or weather conditions.

Location	Months	Deaths
Banfield area	Jan/Feb/Mar	3
Baseline crossing	Jun	2
E. Burnside	Aug/Sep/Oct	5

Table 4. Commonalities between deaths, location, and time of year

Fatalities appear to be increasing over time. The last year with zero deaths was 2008, and before that, in 2000. Using a linear correlation, fatality counts per year have quadrupled over the history of the system.

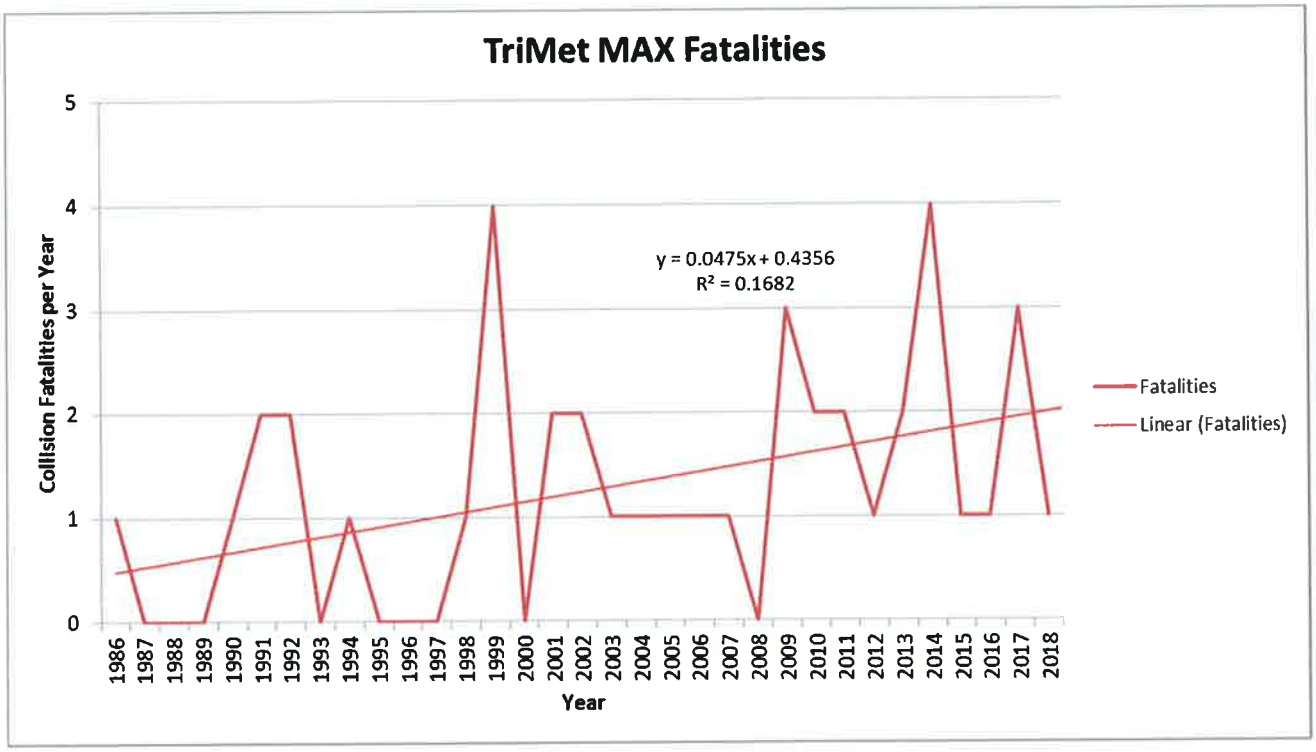


Figure 8. Fatality trend by year

The increase is not simply due to the addition of more train lines. Only four fatalities have occurred on north-south lines, and in 1999 which had four fatalities, only the Blue Line was in operation. Nor is it explained by population changes. During the time period of the chart, the metro area's population increased by 72%.[5]

The most likely contributing factor to the increase in fatalities is the number of boarding rides.[6] Both have approximately doubled from 2000 to 2017. It does make sense that all other things being equal, if the number of people boarding trains increases then fatalities should also increase. However, if the two track in lockstep, efforts to improve safety are not bearing fruit. It's important to note that correlation does not imply causation, but no other known factor increases significantly over the time period examined.

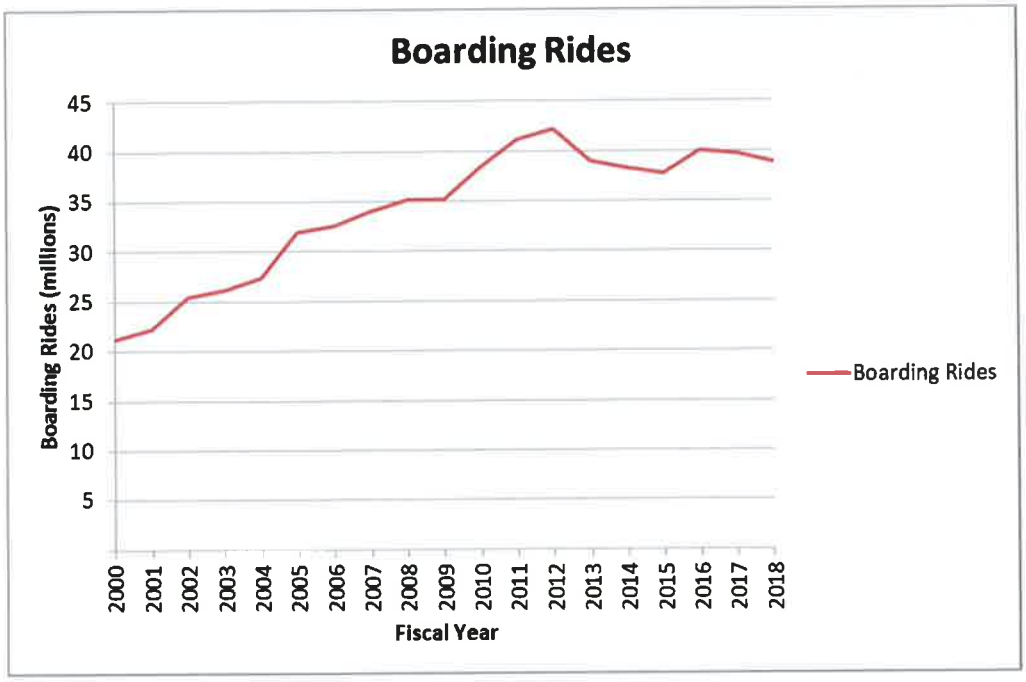


Figure 9. Annual MAX boarding ride counts

TriMet also introduced new work rules in June 2013 to eliminate back-to-back shifts for train operators in an effort to reduce fatigue. However, this change appears to have had no effect on the fatality rate. The fatality rate is increasing while the collision rate remains relatively constant. (Figure 10, below)

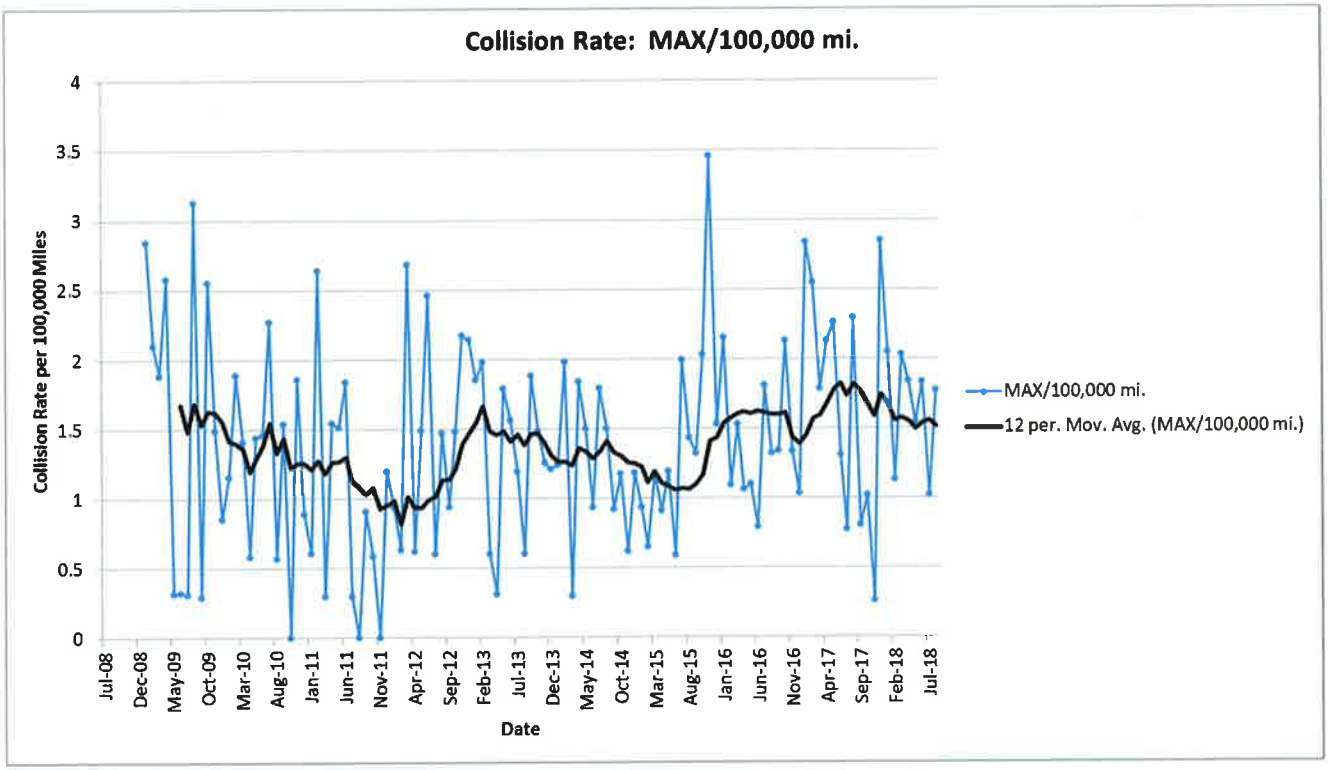


Figure 10. MAX collision rate by month with 12-month moving average

A December 2016 compliance audit by Michael T. Flanigon found that rule violations for train operators tripled from 2006 to 2016.[7] However, the violations were not tied to any fatalities. There was a non-injury collision with a car in February 2013 at a Hillsboro rail crossing from one violation.

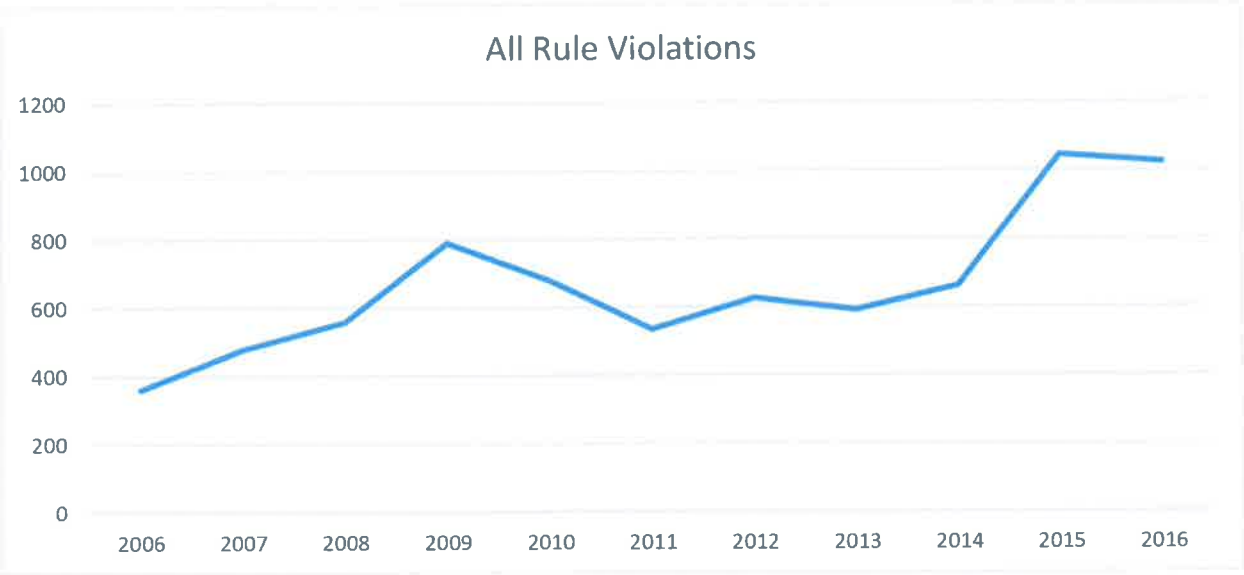


Figure 11. (Flanigon) MAX Operating Rule Violation Trend (note: 2016 is a partial year)

From 2000 until now, the average train speed has steadily decreased from 20.8 to 18.2 miles per hour. Slower speeds should improve safety, but they too don't seem to be having a positive effect.

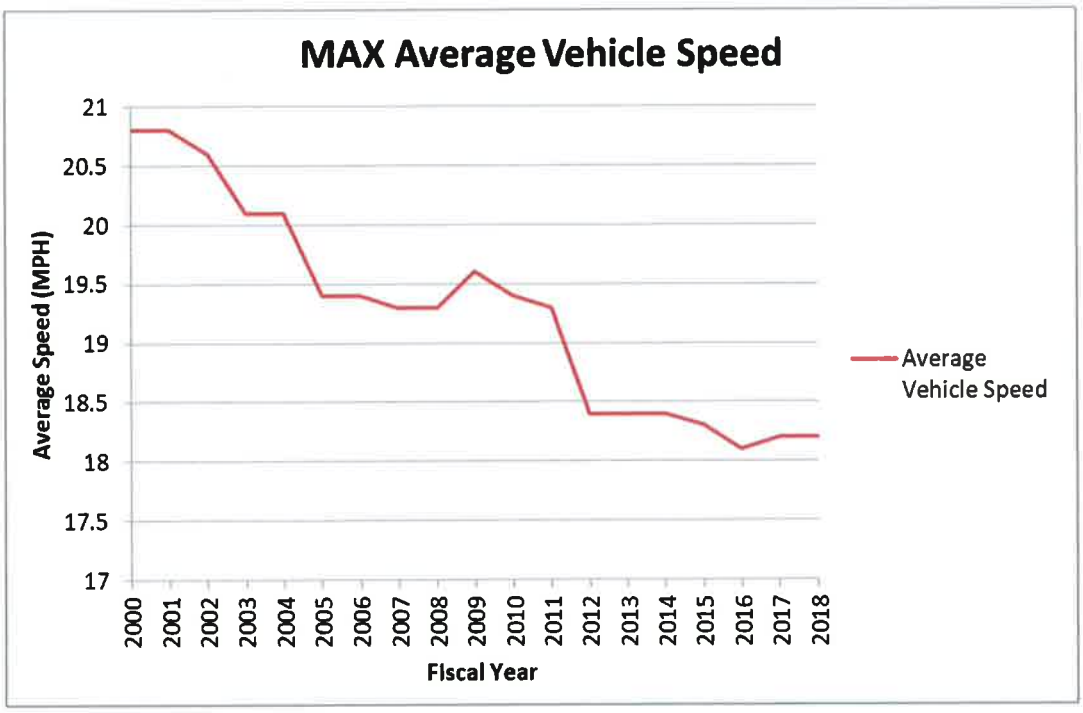


Figure 12. System-wide average vehicle speed

Below are some locations of fatalities that illustrate difficult design decisions on urban streets. In these situations, the best known practice to improve safety is to move tracks underground.

The Goose Hollow/SW Jefferson St. MAX Station is an example of a fatality location where tall buildings restrict visibility and there are no crossing gates. The low barrier along the left side of Jefferson along the sidewalk in the distance is easily jumped by pedestrians. It's an example of a difficult design decision where a taller barrier would reduce trespassing onto the tracks, but it would prevent a person in danger from jumping out of the path of an oncoming train.

Figure 13. Goose Hollow/SW Jefferson St. MAX Station showing visibility issues and pedestrian/traffic conflicts

NE 7th & Holladay is another example of a fatality with close proximity of trains and pedestrians with buildings on street corners limiting visibility. Downtown, there are many such locations that are dangerous.

Figure 14. NE 7th & Holladay station

Seemingly small issues with station infrastructure can contribute to unsafe situations and might go unnoticed as contributing to some accidents. At the Beaverton Transit Center there is a section of bump tiles that's been installed improperly, leaving a raised edge that's difficult for wheelchair users to move over safely. The position of the edge makes it possible a wheelchair user could be trapped in the track area in front of a moving train.

Figure 15. Bump tiles at Beaverton Transit Center showing a trap risk for wheelchair users

This issue was first observed in August 2015. It was reported to TriMet, but still hasn't been resolved as of the date of publication of this report. While no fatality from this situation has happened, it is a sign that the safety culture at TriMet can improve because an obvious area of risk with a simple solution hasn't been addressed for a long time since being discovered.

Comparison to National Data

Data from the National Transit Database were examined to see how MAX compares to other light-rail systems.[8] Only systems with more than 5 million total train miles in the years 2002-2017 were included. Deaths of employees and passengers were excluded for consistency. The MAX fatality rate is 32% lower than the average for these systems (Figure 16, below.)

There were discrepancies between the data from the US Transit Database and records provided by TriMet. One death was under-reported in 2002 and again in 2006. In 2013, a death on the WES heavy-rail line was reported as a light-rail death. In 2014, one death was over-reported, classified as "other vehicle occupant." For the period 2002-2017, two deaths were under-reported and two were over-reported, so the total cancels out. While the result doesn't change the outcome of this analysis, the discrepancies should be corrected. Because heavy-rail design tends to be safer, including WES fatalities and miles in federal reports makes overall safety look better than it is.

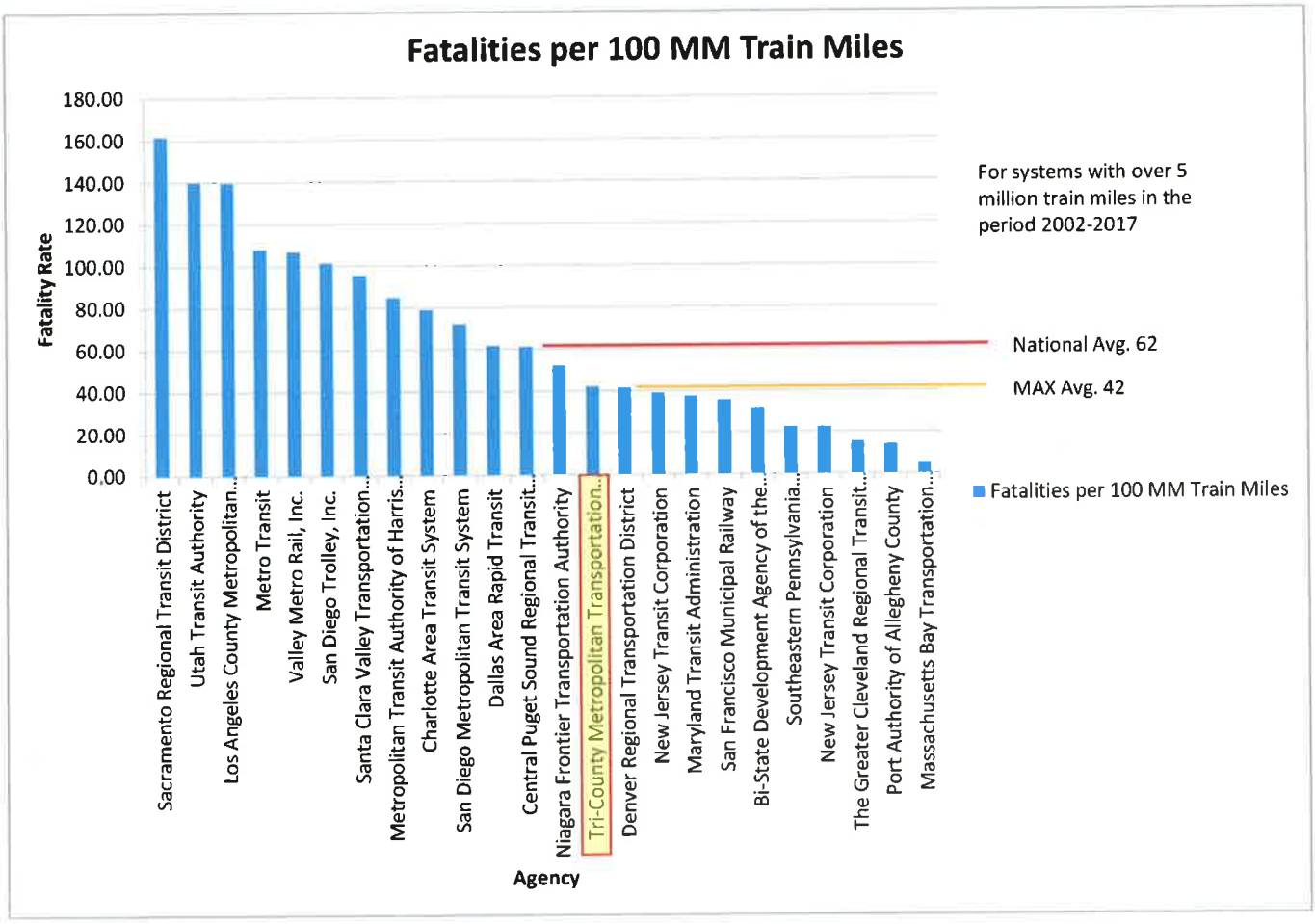


Figure 16. Average fatality rates per 100 million train miles for MAX and other light-rail systems in large cities

Fatality rate trends were also examined to compare MAX with other light-rail systems and to automobile traffic. Over time, MAX fatalities and those on other large light-rail systems are increasing at a similar rate. This finding indicates that the increase in deaths is not unique to MAX. In the chart (Figure 17) below, notice that motor vehicle non-passenger fatalities[9] are plotted on a separate axis with a range that is 100 times smaller than for light rail. Also note that the data were adjusted by train revenue mile, so increases in the number of train miles due to growth are not responsible for the observed increase. When considering automobile-caused fatalities for pedestrians and cyclists, national figures were used instead of those for Portland only because the national numbers were broken out for pedestrians and cyclists, which are roughly 1/5 of total automobile-caused deaths. Also, even though Portland streets are considered to be 10-15% more dangerous than streets nationwide for pedestrians, danger can vary widely by geography within an urban area so the national data offer a larger sample size. The slightly higher local difference in Portland doesn't alter the overall conclusion of substantially higher fatality risk for trains vs. automobiles. The automobile-caused fatality statistics exclude suicides, so the figures for MAX and light rail nationwide were also adjusted to exclude them.

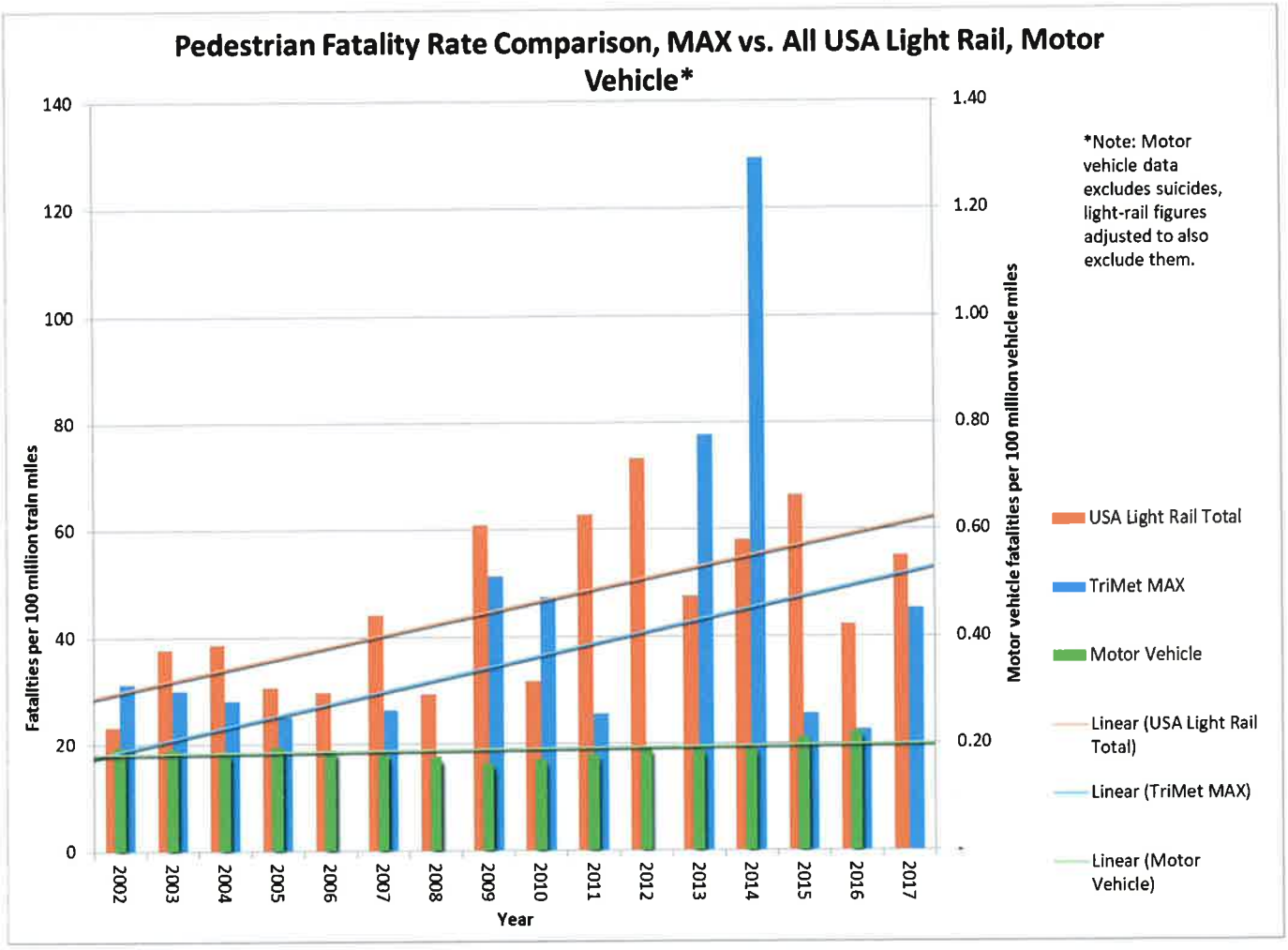


Figure 17. Comparison of MAX fatality history with light-rail systems nationwide and non-occupant motor vehicle deaths (pedestrians and cyclists)

While rail transit has always been considered and promoted as a safer mode of travel for passengers than using an automobile, quite the opposite is true for people who are not physically on a train. When MAX fatality rates per vehicle mile are compared to those for automobiles, a troubling picture emerges. The risk of death per vehicle (train) mile for a pedestrian or cyclist by collision on the MAX system is 296 times higher than it is on a roadway around cars and trucks, based on a five-year moving average calculated in 2017 of the data in Figure 17. This indicates a glaring need for safety improvements on MAX and for light-rail systems in general. This is an interesting finding when considering that MAX train operators are highly trained professionals subject to drug testing and routine medical exams. The likely cause for MAX fatality rates being so much higher than for auto traffic is not train operators, it is system design and operational procedures.

To be fair, there is high variability in the light-rail annual fatality rate for Portland. However, the nationwide data have a much larger sample size and we know MAX historically has a fatality rate that's about average for large systems. The same calculation for the national data gives a risk that's 266 times higher than for auto traffic, and is likely an accurate estimate. The wide disparity between train-caused fatalities and those from automobiles cannot be discounted.

While it's common sense that automobiles can swerve and they can also stop more quickly than trains, few people understand how these two factors contribute to the tremendous difference in risk between trains and autos for pedestrians and cyclists. There is a widespread misconception among the public that street traffic is far

more dangerous than crossing at a MAX station, when the opposite is true by a large margin. One way to intuitively understand the high risk of train collisions is that most of us who drive have not had a collision causing a pedestrian death, nor do we know of friends this has happened to. However, a high percentage of MAX operators have or will experience in their careers a collision causing death. This may not be the best marketing message for TriMet, but it offers an opportunity to make progress on reducing the fatality risk. Informing the public to exercise care around the system and understand which situations have the most risk should also have a positive effect on fatal accidents.

Fatality Breakdown

Looking at the circumstances of MAX fatalities as classified by TriMet, the top three are people in the restricted right of way, people at or near a station, and suicide.

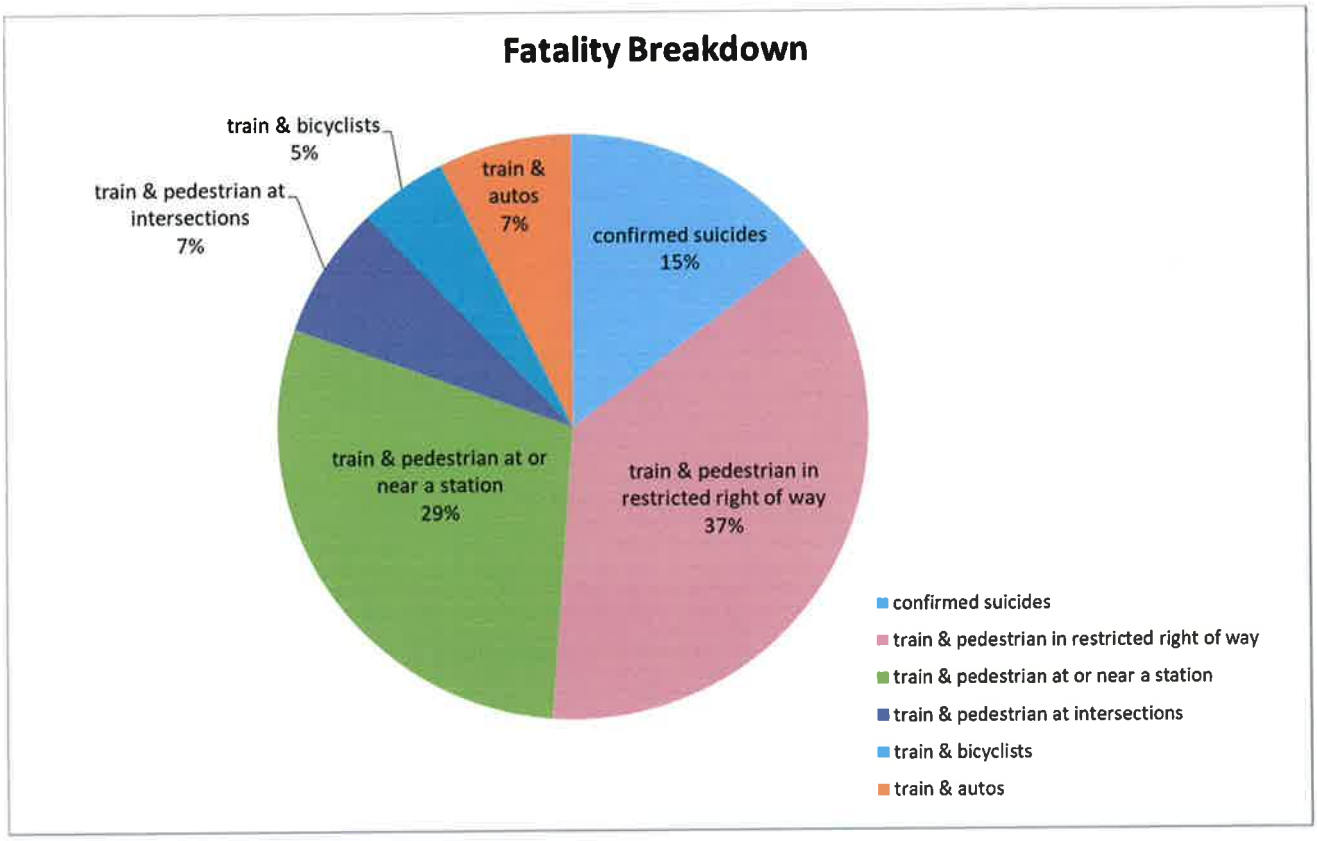


Figure 18. Breakdown of fatality types

Suicides make up 15% of fatalities on MAX. They are considered hard to prevent on transit systems, but those who attempt it have common characteristics.[10]

Suicide on Subway Systems: Shared characteristics of attempters
Male
20 to 30 years of age
Single or unmarried at the time of incident
Living alone
Receiving in-patient treatment
Serious and chronic mental illness
At least one previous attempt (sometimes involving the subway)
An expressed desire to commit suicide

Table 5. Profile of those likely to attempt suicide on subway systems

Preventability of Fatalities

As fatalities were examined, it became clear that many were preventable through design changes at stations and intersections or grade crossings, or by modifying the operational procedure to have a train operator stop before pedestrian crossings at either end of a station and then enter the station at a crawl. This change would allow operators to safely stop if a pedestrian were in the crossing area or in an unsafe location on the platform. Today, trains only brake as they approach a station and come to a stop at the platform. Each fatality was graded as preventable or not if those changes were made. The result: 67% of deaths could be prevented by design improvements or stopping the train at pedestrian crossings and then entering the station at a crawl. This figure still has uncertainty because TriMet did not provide detailed investigations of each incident. However, at the very least these changes should be seriously considered as it could greatly reduce fatality risk on the system.

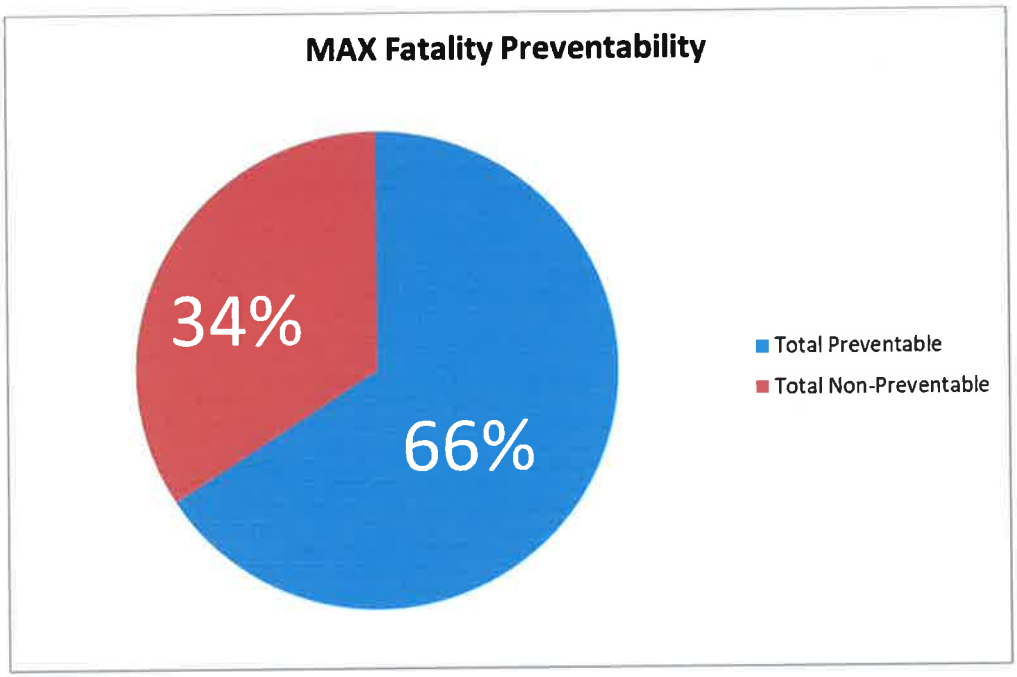


Figure 19. Estimated preventability of fatalities appearing to be the result of operational and/or design issues

To further understand risk factors for fatalities, likely risk factors were identified at each station along the Blue Line and then analyzed for frequency and multiple risk factor convergence. Stations were grouped into two populations: those without fatalities and those with them. Next, the statistical significance of the percentage of stations in each group with a particular factor present was calculated. The results are ranked in Figure 20 below. The most significant factors (> 70% confidence level) were a curved track, no crossing gates, and a complex intersection. Other factors had less than a 70% confidence level. It is likely that in the future, some factors might increase in confidence level because currently there are about twice the number of stations without fatalities as those with them, limiting the sample size in the latter group. A curved road is likely significant as it is present at the Baseline Road crossing, but was not a station site so it was excluded from the analysis.

Other lines were not included for this analysis because much lower ridership and fatality counts on them likely make a comparison invalid. Collisions far from stations in the restricted right of way were also not included because the risk factors at those locations are likely quite different compared to stations, especially train speed. At those sites, more detail is needed than was provided in the records request for this analysis such as the exact location of the incident, the time of day, train speed, and lighting conditions.

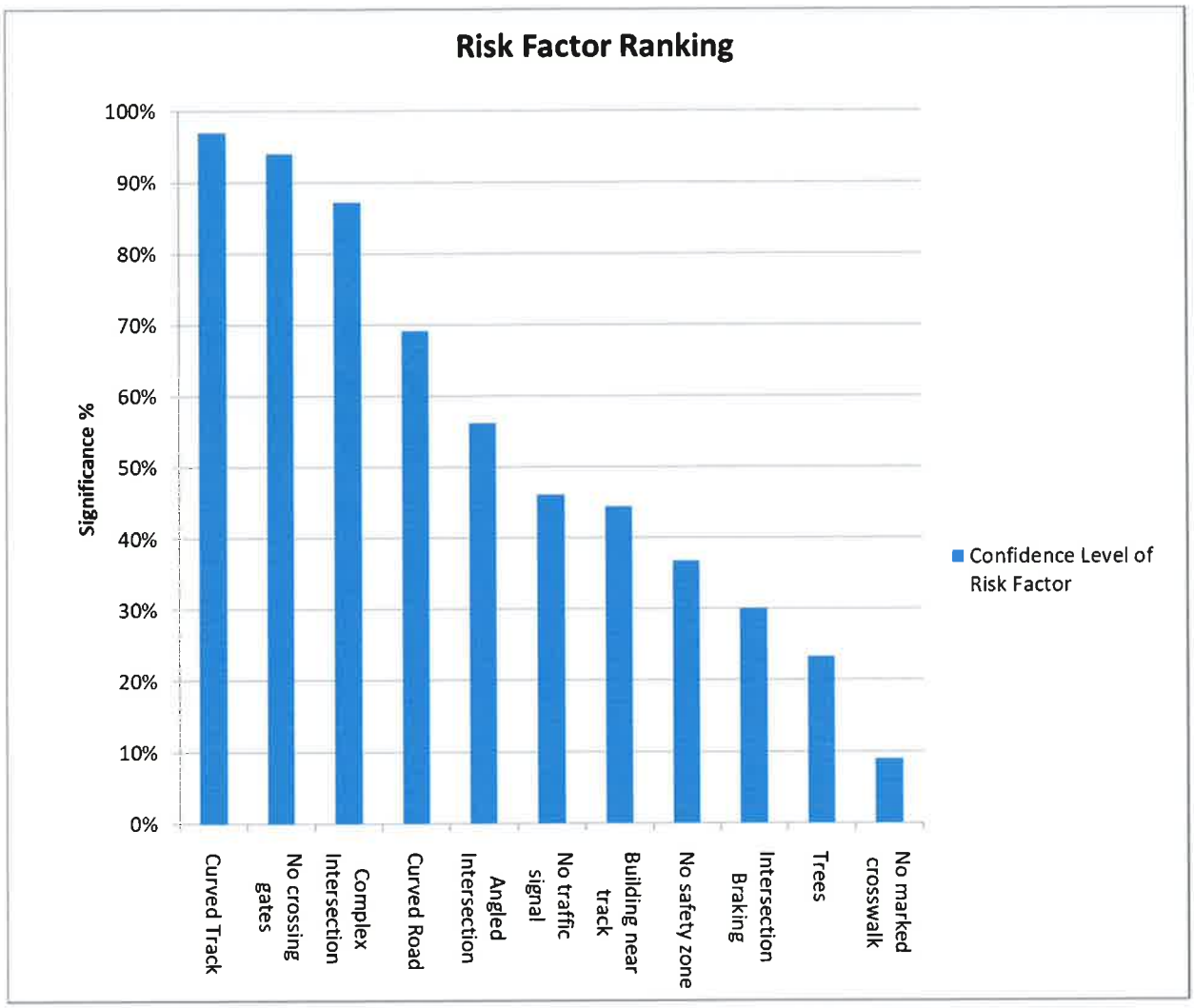


Figure 20. Significance ranking of fatality risk factors at Blue Line stations

The number of individual risk factors at stations with and without fatalities is summarized in Figure 21 below. This is not an exhaustive list of risk factors. Two that are likely important but not accounted for include train speed and number of riders per day at a station. TriMet did not supply those data in the records request, but they should be included in a future examination of risk in order to inform safety upgrade decisions.

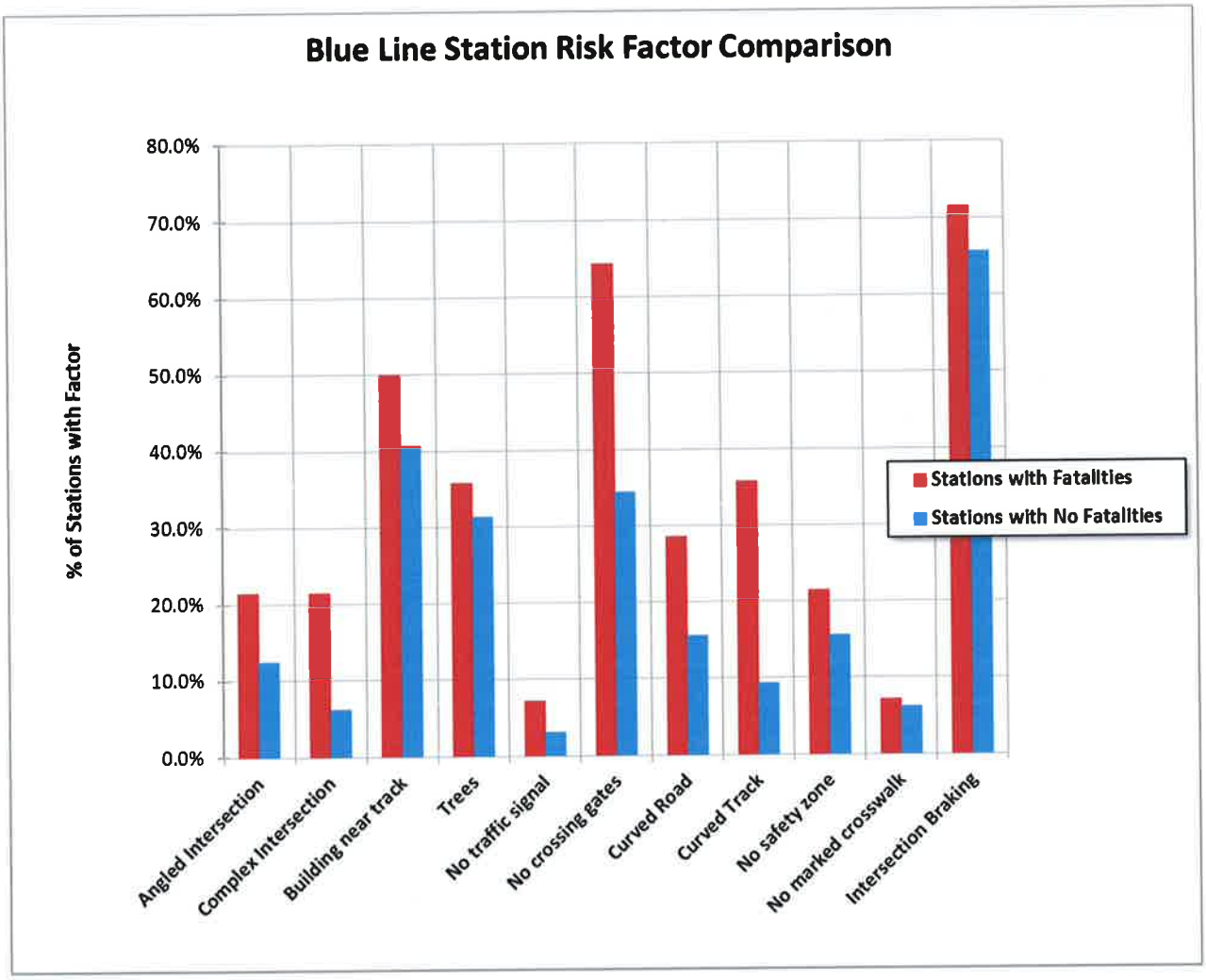


Figure 21. Risk factor breakdown for stations with and without fatalities

Along East Burnside and in downtown Hillsboro, tracks run down the center of the street. Most stations are designed so that the eastbound platform is located at the southeast side of the intersection and the westbound platform is at the northwest side (Figure 22, below). This configuration requires a train operator to be braking from cruise speed while crossing an intersection. Pedestrians who see an approaching train might be tempted to dart in front of it to catch it. The risk of a collision is greater in this situation than if the platform positions were switched to have the eastbound platform at the southwest side and the westbound platform at the northeast side. Braking would then happen mostly on restricted right of way. Acceleration through the intersection on departure would be slower, allowing more reaction time for an operator to avoid a collision, and the operator could verify the intersection and crosswalks were clear before accelerating from a stop. There would be no temptation for pedestrians to rush in front of a train to catch it. This layout change would eliminate the need to stop at some pedestrian crossings along the route, saving travel time and allowing the use of that measure elsewhere on the system where it's needed due to design constraints.

While there was only 30% significance found for intersection braking, the actual risk is difficult to quantify because it is highly dependent on train speed and different stations have different exposure to the issue depending on the platform distance from the intersection, the location of each platform relative to the intersection, and varying degrees of grade separation. In downtown Portland most stations will have braking through intersections on both sides of the platforms in both track directions, but train speeds are much lower. A

more thorough risk analysis with detailed data would likely identify a higher confidence level for this risk factor. One way to further quantify risk from this design would be to include nonfatal injuries, as it would greatly increase the sample size for statistical comparison.

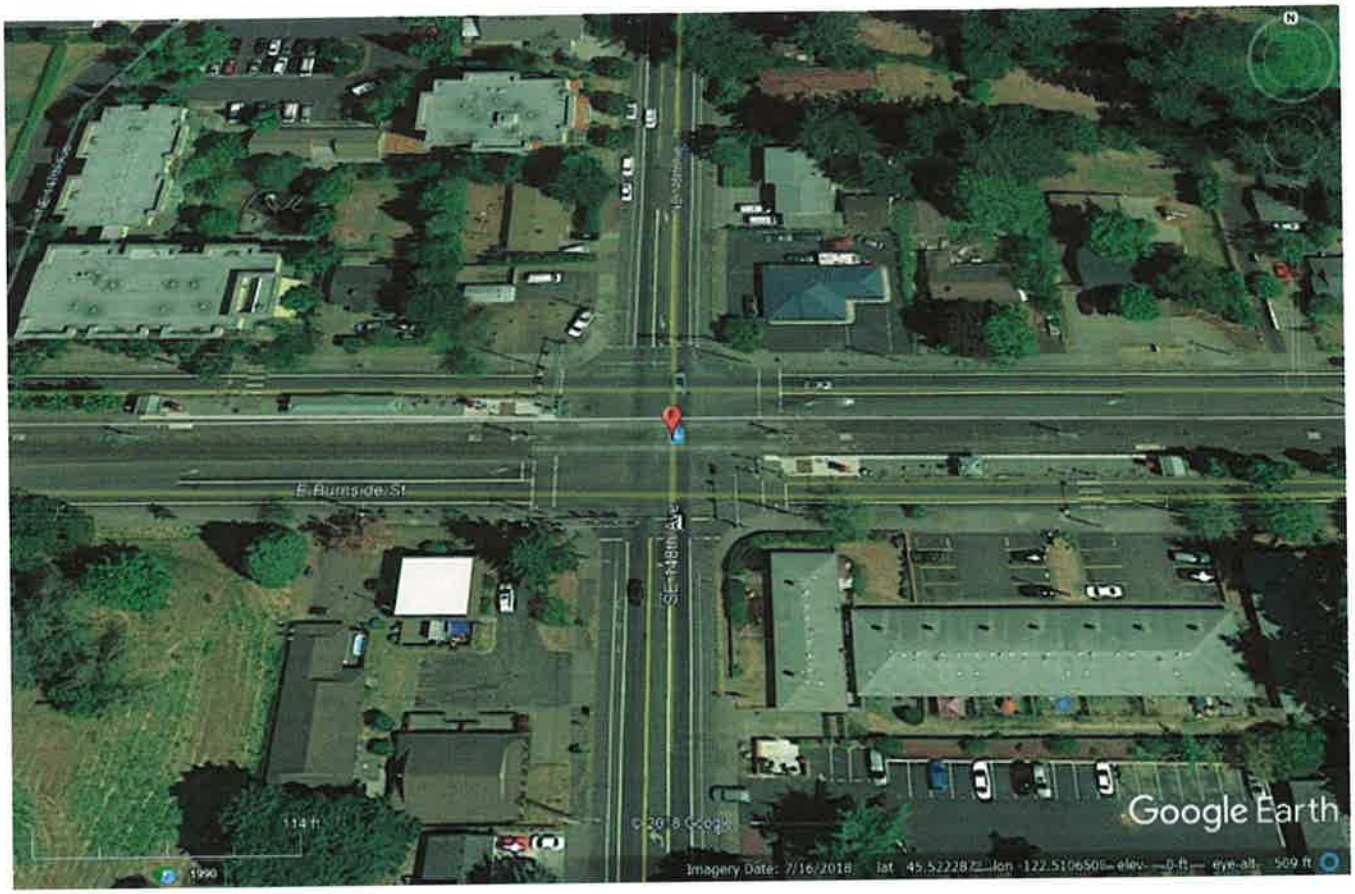


Figure 22. Station configuration along East Burnside showing high-risk layout requiring braking through intersections

The number of risk factors was higher at stations with fatalities compared to those without them at 96.4% confidence (Figure 23, below).

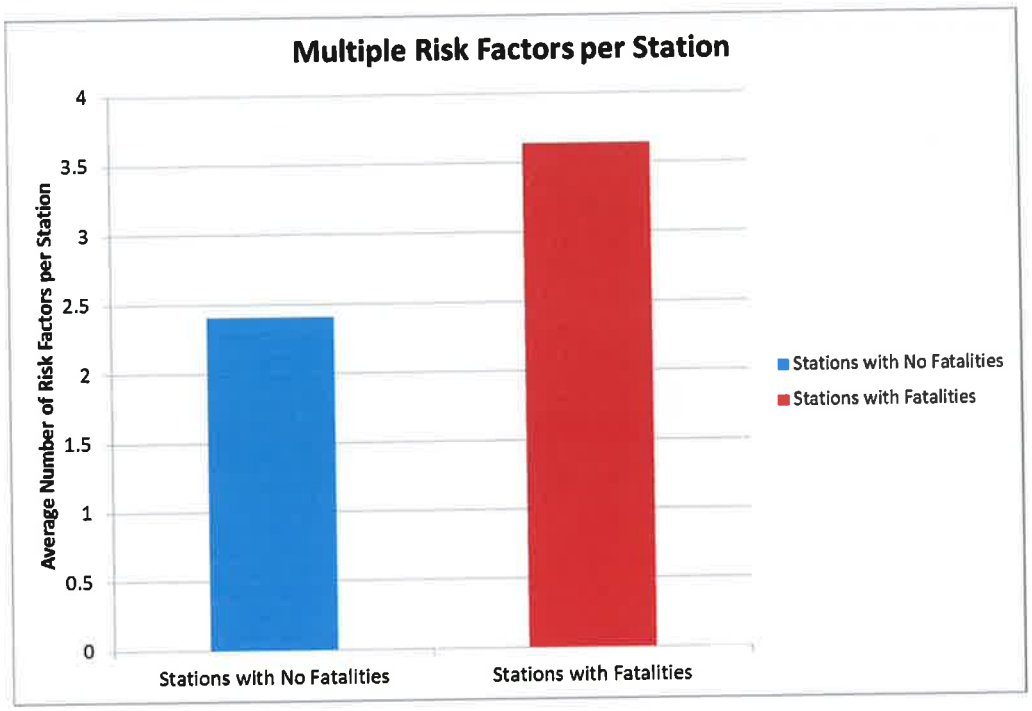


Figure 23. Significance of multiple risk factors at stations

Note: Redacted information in the remainder of this section is confidential to TriMet.

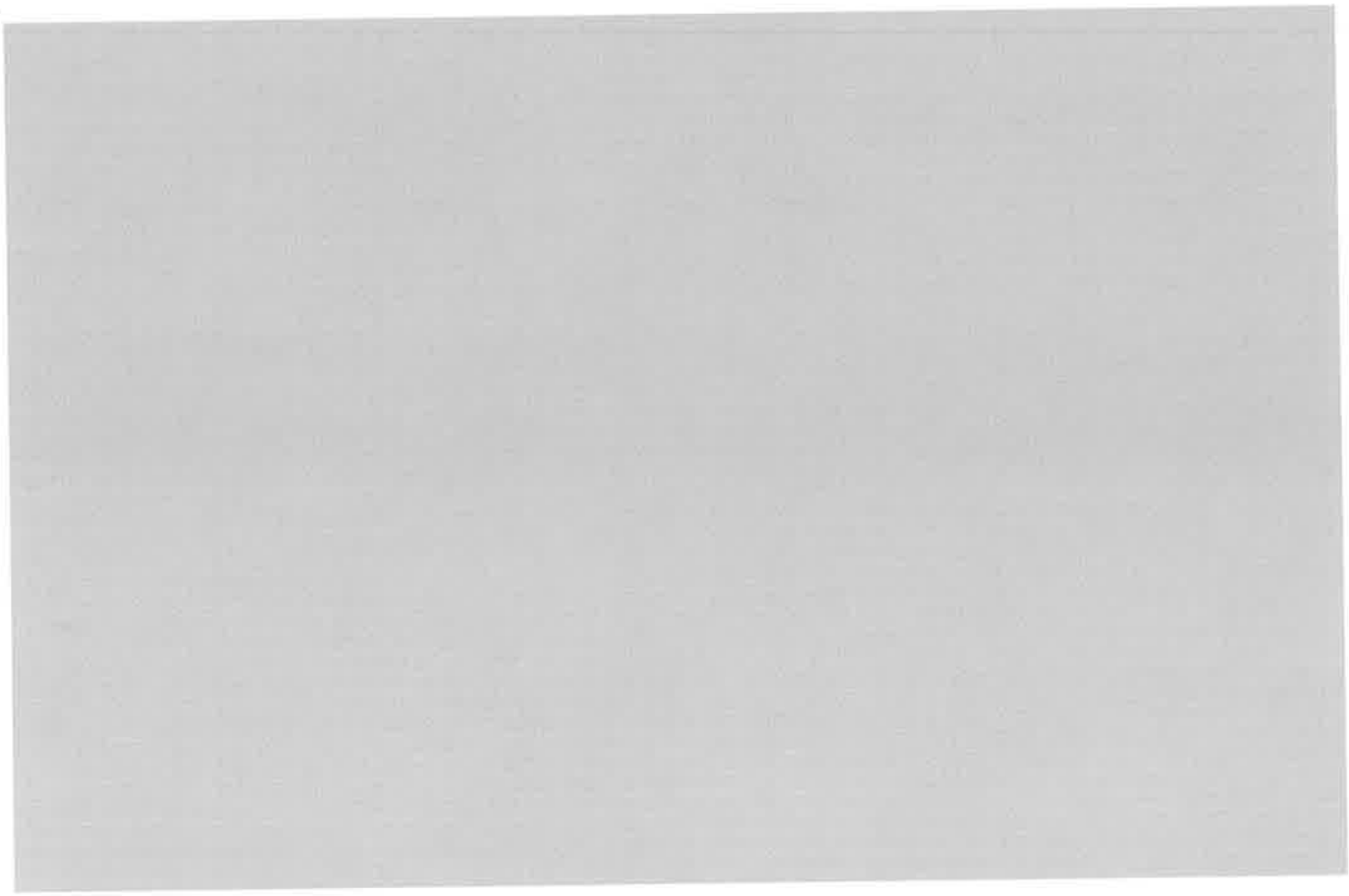


Figure 24.

Discussion

Historically, light-rail system design and operations have borrowed from heavy-rail systems. However, there are major differences between the two. Freight trains have much longer stopping distances, so they include grade separation, crossing gates with bells and lights, and loud horns. They also are much louder due to their powerful diesel locomotives and heavy weight, providing a warning to pedestrians. Freight trains are mostly separated from cars and pedestrians, and people do not congregate around freight trains at or between stations. Use of crossing gates is nearly universal at urban intersections. From 2007-2013, heavy rail's fatality rate for cars and pedestrians was 1.95 deaths per 100 million train miles, and light rail's rate was 10.7 times higher[3] at 20.8 (Appendix B). Also note that the death rate for MAX is double this rate at 42, and the group of larger systems of which MAX is a part has an average fatality rate of 62, about 30 times higher than heavy rail. Given the promotion of light rail as a transit alternative in U.S. cities, there needs to be significant effort devoted to improving its safety, especially when heavy rail has demonstrated a markedly better safety record.

Light rail operates in close proximity to cars, cyclists, and pedestrians. It also is specifically targeted toward people with some kind of physical limitation that impacts their ability to drive. Unfortunately, people with handicaps are much more likely to also be at risk for accidents around a light-rail station. People who are intoxicated are urged to take mass transit rather than drive, and this is wise. However, once again this kind of impairment increases accident risk at a station. An estimated 34 percent of fatal automobile-pedestrian crashes nationwide each had a pedestrian with a blood alcohol content of .08 grams per deciliter (g/dL) or higher.[11] Another study that specifically looked at train-pedestrian deaths found in 80% of them the pedestrian had a

blood alcohol level of greater than 0.099 g/dL.[12] Ironically, a person who's responsible about not driving when impaired is putting one's own life at greater risk as a passenger around light-rail tracks.

Because stations are gathering points for people, there is a high density of pedestrian crossings that increase risk. Light-rail segments often operate along the center of wide boulevards, something that is almost never done with heavy-rail tracks. The trains are quieter, and because they often are near residential areas tend to avoid use of their horns. Crossing gates are installed with much lower frequency than for heavy-rail tracks. Taken together, all of these differences point out that light rail needs to be designed and operated with high regard for pedestrians, cyclists, wheelchair users, and people with handicaps or other impairments. The statistics strongly suggest this is not true today.

The nationwide trend of increasing fatalities has been noted by other states and the Federal Railroad Administration. A 2008 report reached similar conclusions to those expressed here. In particular, they noted more research is needed into effective devices for alerting pedestrians to trains, better crossing design, improved public education efforts, and measures to take into account pedestrians' tendency to ignore train crossing warnings and to take the shortest distance possible through a rail corridor, regardless of risk.[13] Ten years later, very little in the way of results has been achieved as death rates continue to rise.

Members of the public might object to safety improvements that increase travel time or inconvenience riders, often emphasizing "personal responsibility." This kind of thinking denies the reality that transit users include handicapped or elderly riders, the fact that a greater proportion of system users have handicaps because they cannot drive and rely on mass transit, and teenage passengers may not have the level of maturity or experience to behave safely on the tracks. Teenagers may be more likely to be distracted by mobile devices, and because many do not drive, they depend on public transit for getting to and from school or other events. Paradoxically, the trend of moving ticketing to mobile apps could have the effect of increasing distraction around stations if passengers need to check their devices in order to issue a ticket. Ticketing apps should be designed so that they are completely automatic and do not require any user intervention to ride the system.

While changing operations to have trains stop at crossings before entering the station will increase travel times, there is such a compelling improvement to fatality rates that it is likely a worthwhile tradeoff. It's worth noting that the City of Portland is currently executing a "Vision Zero" campaign where speed limits are being reduced on surface streets to make them safer for cyclists and pedestrians. If this is an important goal for the city even though it makes travel slower for auto traffic, stopping trains at crossings should also be implemented on the MAX system if it becomes safer as a result. This change would be very inexpensive compared to the alternatives of tunneling or elevating track, or building road underpasses.

Recommendations

Looking at fatality history and safety across the system produces a long list of possible recommendations. While it's unlikely they all need to be implemented, all should be examined and as many as possible should be tested here or researched on other systems around the world to evaluate their effectiveness. The best should be implemented. These are presented below, in rough priority order.

1. Stop trains at pedestrian crossings before entering stations, and then proceed into the station at a crawl.
2. Immediately decrease train speed limits at all sites with multiple fatalities until other safety improvements can be implemented.
3. Because the most significant relationship to fatalities is curved track, straighten curves or move curved segments underground.

4. Add more crossing gates, especially at sites with elevated fatality risk such as at angled or complex intersections.
5. Provide flashing lights and audible warnings at all pedestrian crossings that sound continuously until a train passes.
6. Evaluate signals that warn pedestrians of the direction of approaching trains to reduce the chance of an error in judgment or distraction making a person unaware of trains, especially when they are approaching from both directions.
7. Improve visibility by rerouting angled crossings and removing trees or other obstructions.
8. Begin a program of gradually moving tracks underground, elevating them, or building road underpasses or overpasses, starting at dangerous locations such as angled crossings or intersections.
9. Give Blue Line tracks highest priority for safety upgrades, with the Baseline Road crossing and Gresham City Hall station as the most critical locations.
10. Because of the strong historical correlation between ridership and fatality rate, efforts to improve safety should focus on the busiest sites and stations after places with multiple fatalities have been addressed.
11. Educate the public that train crossings are 300 times more dangerous than crossing in automobile traffic. Pedestrians, cyclists, and drivers have a false sense of security and a lack of appropriate caution around MAX stations and tracks because it's widely perceived that trains are less likely to cause deaths than cars.
12. Explore ways to limit access to restricted right-of-way including better fencing, tunneling, and motion-triggered cameras to detect trespassers.
13. Locate platforms so incoming trains are not braking from cruise speed while passing through intersections with pedestrian crossings.
14. Add pedestrian crossing request signals at dangerous intersections or track crossings such as those along East Burnside that require train and/or car traffic to stop, and warn pedestrians if a train cannot stop safely in time. These are in use at the Tuality Hospital/SE 8th Ave. MAX Station in Hillsboro.
15. Place signal lights and audible signals along the I-84 track stretch to warn people on the tracks that a train is approaching.
16. At locations such as SE 193rd & Burnside where lack of a road shoulder eliminates safe space between the road and trackway, realign streets to create a pedestrian safety zone or move track underground.
17. Look at the time of day for fatalities to find out if the sun's position, weather, or inadequate lighting could be a factor.
18. Three systems in other states have fatality rates well under half that of MAX (Figure 16, above). Practices and design at these should be examined to learn if they can be adopted in Portland.
19. If weather conditions, lighting, or sun position is found to be a factor on particular track segments, consider adding precautionary train stops or lowered speeds at the times of year and of the day when they are needed. These could be programmed into automatic signaling and speed control so delays in service only happen when risk is highest. Upgrade night lighting if needed.
20. Track blood alcohol involvement for pedestrian and cyclist deaths to determine if it is a significant factor. If found to be true, encourage intoxicated riders to take a bus, taxi, or rideshare service or travel with a sober person.
21. Improve messaging about suicide prevention through public service announcements, signage, and advertising on trains and at stations offering help for people considering using the train system as a means of suicide.
22. Implement provisions of the US Department of Transportation's rail suicide prevention initiative: https://www.volpe.dot.gov/rail-suicide-prevention

23. Provide safety materials to the public through multiple avenues (ticket apps, online, printed brochures, broadcast advertising, etc.) that educate riders and anyone near tracks or stations about risks and how to reduce them. The TriMet website only has materials for schools, and links to another nationwide site (Operation Lifesaver, https://oli.org/) which isn't tailored to specific risks on MAX. Place safety messages on the sides of trains and buses.
24. MAX has several different train types. Accident frequency by train type should be examined to see if operator visibility, braking performance, or other factors might affect fatalities. If differences are found, train types with issues should be modified or retired.
25. Investigate enclosing stations to protect them from weather and make platforms safer by keeping them warm and dry, with interior design standards. Look at using sliding glass doors at platforms to keep passengers off of the tracks and away from trains, except when the train's doors are open for boarding.[14] The protective doors are increasingly common overseas in cities such as London, Paris and Tokyo. They are also in trial use at AirTrain stops in Queens and New Jersey. The Las Vegas monorail is the only system using them in the USA currently. (Figure 25, below)

Figure 25. Platform edge doors at Kwai Hing Station of Hong Kong MTR. By Hokachung - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=15843556

26. Add pedestrian bridges crossing I-84 to reduce trespassing on tracks. Look into the reasons why people are on that track segment in more detail. Are they homeless campers? Are they using Union Pacific railcars as hobos? Are they local residents taking a shortcut?
27. Pay special attention to known risks on the Blue Line and apply lessons learned to the proposed Barbur Blvd. line, which is planned to run down the middle of the street in a dangerous configuration.
28. Design ticketing apps so they do not need any user intervention to ride the system, reducing the chance that riders will be distracted around stations.
29. Look at placing bus and rail transit in Portland's metro area under the Port of Portland, similar to what Pittsburgh does, or under the state's transportation department, as is done in Boston. These bodies have

a focus on transportation and safety, and might provide an environment more conducive to safety as a priority.

30. The law that created TriMet (Chapter 267 — Mass Transit Districts; Transportation Districts) has some troublesome provisions such as ORS 267.245 (District exempt from right of way fencing requirements) and ORS 267.230 (Exemption from public utility or railroad regulation). These give the agency wide latitude to ignore or overlook industry safety best practices. The law and its provisions should be reviewed to determine if changes can be made to improve safety in mass transit districts.
31. Provide audible warning signals at all pedestrian crossings that sound continuously when a train is approaching from either direction, stopping only when it's safe to cross. If noise abatement is a concern, use flashing lights at night and an audible warning with lights during the day. Look at alternative warning approaches for night such as lighted strips in the pavement that flash when a train is near along with vibration that provides tactile feedback to feet, wheelchairs, or bicycles.
32. Report safety statistics for the WES system as a separate heavy-rail system to the National Transit Database. This will provide a more accurate interpretation of safety for both MAX and WES.

Advice to the Public

Disclaimer: *The information below is based on the best available knowledge at the time of publication. Reducing risk is not a guarantee of safety. Use your own common sense when considering these guidelines. The reader accepts all responsibility for one's personal safety.*

People using the MAX system or anyone traveling along its tracks should keep in mind the following advice to minimize their risk of a fatal accident:

- The Blue Line/Red Line route, exclusive of the spur from the Gateway Transit Center to the Portland Airport, is the most dangerous. People should be especially careful along this route and at its stations.
- The most dangerous spots on the system, the Baseline Road crossing and Gresham City Hall, have in common reduced visibility of trains, angled road crossings, and no traffic signals. There is also high risk when pedestrians walk facing traffic in the street at a grade crossing, as train crossing gates do not block access to the track in that situation. Those on foot or bike need to keep in mind the extremely high accident risk at locations with these attributes.
- Know what makes a station unsafe. Higher fatality risk is linked to curved track, no crossing gates, angled or complex intersections, and curved road. Use more care at these spots.
- The two most dangerous accident categories anywhere on the system are being at or near a station and being in the restricted right of way. Appropriate caution is required at stations and of course being in the restricted right of way is irresponsibly unsafe. Never cross between stations except at marked crossings. Even those are high risk due to faster train speed.
- From history, it is clear that people around stations underestimate the level of care needed to be safe. **The risk of death when crossing MAX tracks is close to 300 times greater than it is crossing a street in auto traffic.** Tracks can be crossed safely, but one must be highly vigilant.
- At tracks and stations, never let your guard down, never get distracted, and never engage in horseplay.
- People with impairments or handicaps should be especially cautious along the Blue Line, and should ask others for help or have an attendant present at stations.
- Do not take rail transit while intoxicated. Instead, get home safely on a taxi, rideshare service, or bus, and minimize time walking on streets.
- One death and a serious injury are linked to possible distraction from mobile devices. Make it a habit to put devices away until safely on the platform or on the train.
- If you have a choice of stations, always take the one that has full grade separation (no track crossings to walk over, even on the platform).
- While there are fewer fatalities on the Orange, Green, Yellow, and Red line airport spur, that is partly due to them having lower ridership compared to the Blue Line. Your personal risk on any route is still almost the same.
- If you're considering suicide, please get help. A train operator will bear a lifetime of emotional scars from a suicide attempt.
- Obey all warning signals. They might seem frustrating at times, but they work the way they do to keep you safe. Their timing and placement are from decades of experience with many accidents.
- Put yourself in the place of the train operator. Be especially careful in bad weather, at night, and during sunrise or sunset times when sun glare is present.

Conclusion

Fatality rates on the MAX system are 32% lower than the average for US light-rail systems with more than 5 million total train miles in the years 2002-2017, but specific locations are highly unsafe. 37 percent of all fatalities happened at places where more than one death has occurred, and two locations, Gresham City Hall and the crossing of SW Baseline Rd. in Beaverton, are responsible for a fifth of all deaths. The east-west combined segment for the Blue and Red lines has the highest geographic fatality risk owing mostly to the high level of train traffic on the route. Comparison to national data and examination of Portland's fatality records strongly suggest that most non-passenger deaths on the system are the result of shortcomings in design and operational procedures, not from train operators. Fatalities per train mile on MAX and for systems nationwide are rising at similar rates. Increased ridership appears to be the primary factor affecting the growth of fatalities over time, and efforts to improve safety are not bearing fruit. Conclusions from these findings indicate that new approaches are needed to address deaths, and could lead to a substantial reduction in the fatality rate with a minimum of cost. The risk of death per vehicle (train) mile for a pedestrian or cyclist by collision on the MAX system is 296 times higher than it is on streets from cars and trucks.

The simplest, least expensive, and most likely effective improvement to safety is to have trains stop completely before pedestrian crossings near each station, and then to enter the station at a crawl. This change would prevent nearly all collisions at or near stations. Three systems in other states have fatality rates well under half that of MAX. Practices and design at these should be examined to learn if they can be adopted in Portland. The most significant risk factors for fatalities are curved track, no crossing gates, and complex intersections. Redesign work should focus on eliminating these factors throughout the system. Improved education of the public on safety is important to help people reduce risk around the tracks and correct misconceptions about the safety of light-rail transit.

Appendix A

TriMet MAX Fatality Data

Fatality records are listed below. Original data provided by TriMet were annotated in red with details of site specifics that could be accident factors. A judgment of whether or not stopping the train before any pedestrian crossings at each station could have prevented a fatality was also added by the author and was not part of the data provided by the agency. Shading in the Location column indicates the train line color. Because the Blue and Red lines share the same route for most of their mileage and no deaths have occurred on the Red Line spur to the Portland Airport, all incidents on the shared east-west route are indicated as Blue Line trains.

FY	Detail	Date	Year	Count	Location	Type
FY86	Pedestrian walking in ROW	7/28/1986	1986	1	Halsey & Banfield Freeway	Train & pedestrian in restricted right of w
			1986 Total	1		
FY90	Pedestrian walking in ROW	1/1/1990	1990	1	NE 21st & Banfield Freeway	Train & pedestrian in restricted right of w
			1990 Total	1		
FY91	Collision with vehicle	1/16/1991	1991	1	NE Holladay & MLK	Train & automobile
FY91	Pedestrian in ROW	3/2/1991	1991	1	NE 53rd & Banfield Freeway	Train & pedestrian in restricted right of w
			1991 Total	2		
FY92	Pedestrian walking in ROW	2/25/1992	1992	1	NE 29th & Banfield Freeway	Train & pedestrian in restricted right of w
FY92	Pedestrian walking in ROW	6/22/1992	1992	1	NE 82nd Avenue EB	Train & pedestrian in restricted right of w
			1992 Total	2		
FY94	Pedestrian in limited access ROW	5/1/1994	1994	1	NE 60th & Banfield Freeway	Train & pedestrian in restricted right of w
			1994 Total	1		
FY99	Bicyclist in ROW	9/20/1998	1998	1	Cedar Hills Boulevard	Train & bicyclists
			1998 Total	1		
FY99	Pedestrian walking in ROW	6/5/1999	1999	1	East of FairPlex	Train & pedestrian in restricted right of w
FY99	Pedestrian at intersection	6/14/1999	1999	1	Baseline Road	Train & pedestrian at intersections (angle sight lines)
FY00	Rider at crossing in station area	8/2/1999	1999	1	Millikan Way	Train & pedestrian at or near a station
FY00	Pedestrian walking in ROW	10/11/1999	1999	1	Adjacent to Hwy 217 (Hwy 217 & Walker)	Train & pedestrian in restricted right of w
			1999 Total	4		
FY01	Suicide at station	4/9/2001	2001	1	Fair Complex station	Suicide
FY02	Suicide in ROW	10/20/2001	2001	1	East of Beaverton TC	Suicide
			2001 Total	2		
FY02	Pedestrian stepped onto tracks in front of train	1/4/2002	2002	1	Main St./Gresham	Train & pedestrian in restricted right of w intersection)
FY02	Rider fell into side of moving train	2/8/2002	2002	1	PGE Park (18th and Yamhill)	Train & pedestrian at or near a station
			2002 Total	2		
FY03	Bicyclist hit by train	6/23/2003	2003	1	Gresham City Hall	Train & bicyclists
			2003 Total	1		
FY05	Passenger in wheelchair rolled off platform and was pulled	8/1/2004	2004	1	NE 148th & Burnside	Train & pedestrian at or near a station

	under train					
			2004 Total	1		
FY06	Pedestrian walking in ROW walked into front corner of train	9/28/2005	2005	1	SE 193rd & Burnside	Train & pedestrian in restricted right of w between traffic lane and track)
			2005 Total	1		
FY06	Pedestrian walked in front of train	5/14/2006	2006	1	SE 188th & Burnside	Train & pedestrian at or near a station (nc angled, complex intersection)
			2006 Total	1		
FY08	Pedestrian walking in ROW	11/19/2007	2007	1	NE 82nd Avenue EB	Train & pedestrian in restricted right of w
			2007 Total	1		
FY09	Collision with vehicle	1/24/2009	2009	1	SE 10th & Washington (Hillsboro)	Train & automobile (no crossing gates, tr
FY09	Pedestrian stepped in front of train	4/27/2009	2009	1	West of Goose Hollow	Train & pedestrian in restricted right of w crossing gates)
FY10	Rider stepped in front of train	11/22/2009	2009	1	Gresham City Hall	Train & pedestrian at or near a station
			2009 Total	3		
FY10	Pedestrian walking in ROW	2/17/2010	2010	1	Wallula Cut	Train & pedestrian in restricted right of w
FY10	Pedestrian stepped in front of train at intersection	2/26/2010	2010	1	175th & Baseline	Train & pedestrian at intersections (angle sight lines)
			2010 Total	2		
FY11	Elderly rider leaned against moving train and fell	1/28/2011	2011	1	NW 6th & Davis St Station	Train & pedestrian at or near a station
FY11	Male moved into path of train at station	6/27/2011	2011	1	E 122nd Station	Suicide
			2011 Total	2		
FY13	Suicide in ROW	9/8/2012	2012	1	near SW Baseline Rd crossing	Suicide
			2012 Total	1		
FY14	Pedestrian stepped in front of train - accidental	9/5/2013	2013	1	near NE 7th and Holladay	Train & pedestrian at or near a station (nc buildings may obstruct visibility)
FY14	Pedestrian walked in front of train	12/22/2013	2013	1	At SE Division St Station	Train & pedestrian at or near a station
			2013 Total	2		
FY15	Pedestrian crossing against light, fell into side of moving train	8/7/2014	2014	1	E 122nd Station	Train & pedestrian at or near a station (nc
FY15	Woman in mobility device and son went between two cars of moving train	8/16/2014	2014	2	Gresham City Hall	Train & pedestrian at or near a station

FY15	Pedestrian leaned into EB trackway	10/10/2014	2014	1	160th & Burnside	Train & pedestrian in restricted right of w requires pedestrians to walk parallel to tr moving trains. Guardrails are installed.
			2014 Total	4		
FY16	Minor in restricted ROW	11/29/2015	2015	1	ROW 300 ft south of Bybee	Suicide
			2015 Total	1		
FY16	Male trespassed across eastbound trackway and tripped over chain into westbound trackway	1/10/2016	2016	1	Hillsboro Central	Train & pedestrian at or near a station
			2016 Total	1		
FY17	Pedestrian ran in front of train at intersection	6/5/2017	2017	1	Baseline near 175th	Train & pedestrian at intersections (angle sight lines)
FY18	Collision with vehicle	8/6/2017	2017	1	SE 99th & Burnside	Train & automobile (no crossing gates, tre
FY18	Suicide in ROW	12/1/2017	2017	1	ROW near 17th & McLoughlin Blvd.	Suicide (angled, complex intersection)
			2017 Total	3		
FY19	Male struck by eastbound train 4:47 am 50 yds. west of the NW Cornelius Pass Rd. train overpass on restricted right of way	12/20/2018	2018	1	ROW between Quatama and Orenco/NW 231st stations	Train & pedestrian in restricted right of w (trees obscure view, in darkness, no fenci lighting)
			2018 Total	1		
			Grand Total	41		
			Total Preventable	27		65.9%
			Total Non-Preventable	14		34.1%

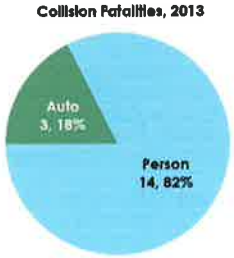
Fatality Breakdown

6	confirmed suicides
15	train & pedestrian in restricted right of way
12	train & pedestrian at or near a station
3	train & pedestrian at intersections
2	train & bicyclists
3	train & autos

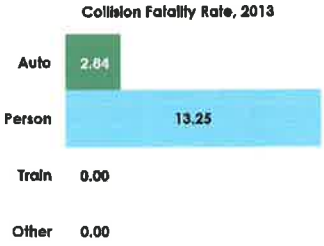
Appendix B

From "Rail Safety Statistics Report." US Department of Transportation. December 2016.

Light Rail and Streetcar Collision Fatalities by Collision Type and Rates per 100M VRM



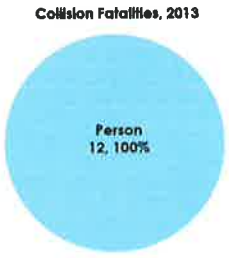
	'11	'12	'13	Avg	Trend
Auto	0	7	3	3.3	
Person	22	16	14	17.3	
Train	0	0	0	0.0	
Other	0	1	0	0.3	



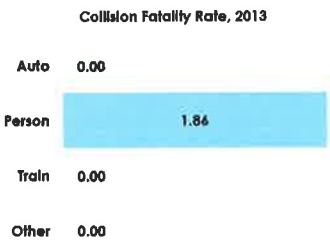
	'11	'12	'13	Avg	Trend
Auto	0.00	7.11	2.84	3.35	
Person	23.40	16.26	13.25	17.44	
Train	0.00	0.00	0.00	0.00	
Other	0.00	1.02	0.00	0.34	

Figure 42 Light Rail and Streetcar Collision Fatalities by Collision Type and Rates per 100M VRM

Heavy Rail Collision Fatalities by Collision Type and Rates per 100M VRM



	'11	'12	'13	Avg	Trend
Auto	0	0	0	0.0	
Person	6	19	12	12.3	
Train	0	0	0	0.0	
Other	2	0	0	0.7	



	'11	'12	'13	Avg	Trend
Auto	0.00	0.00	0.00	0.00	
Person	0.96	3.03	1.86	1.95	
Train	0.00	0.00	0.00	0.00	
Other	0.32	0.00	0.00	0.11	

Figure 37 Heavy Rail Collision Fatalities by Collision Type and Rates per 100M VRM

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