The Importance of Safety Equity in Transportation System Safety

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Public transportation in the U.S. often relies on multi-modal components that represent a system of systems as exemplified by transit rail. Currently, transit rail safety is measured for individual railroads as the number of events/fatalities/injuries by productivity level (typically, revenue miles). Barriers for measuring the safety of the transit transportation system of systems include the aggregation of transit properties for a passenger's trip and the varieties of safety management systems used by transit agencies.

An alternative perspective asks how safe passengers are, instead of how safe railroads are. It posits a fundamental shift to a human-centric perspective on transportation system safety which is the foundation for determining the level of transportation safety equity outcomes. The major barrier to ensuring safety equity outcomes is a lack of safety data for subgroups of the population, based on biodemographic, socioeconomic and disability data. These data are essential for determining if safety levels are equal across subgroups of the population, or if transportation safety inequities exist. If safety outcomes differ across subgroups of the population, then root causes for the disparity need to be determined and mitigated. The public service duty is to ensure that risk interventions and safety outcomes apply equitably to all.

Introduction

The concept of equity has garnered interest in the federal government recently, as evidenced by the issuance of the President's Executive Order 13985 in 2021. During the April 2021 National Transportation Safety Board (NTSB) meeting, NTSB Chair Jennifer Homendy discussed the importance of equity as applied to public transportation systems.

The concept of transportation equity likely spans several unique areas. This paper focuses on transportation safety equity outcomes that arise from work on system safety.

Rail Transportation as a System of Systems

National rail transportation is a system of systems. However, there are different perspectives from which this national system of systems is viewed for rail transportation. For example, the Federal Transit Agency (FTA) exercises oversight of safety for each transit system individually, as illustrated in Figure 1, which shows the headquarters of rail and bus public transit agencies located in every state across the nation [Ref. 1].

Transit agencies appear to be independent safety systems. However, in most cities, the rail transit lines connect with an airport, and transit bus lines connect with transit rail lines and airports. The interconnectedness of transportation modes — and of transit agencies — establishes that the overarching transportation network is a system of systems [Ref. 2]. For example, Figure 2 provides a closer view of the Washington Metropolitan Area Transit Authority (WMATA) rail service lines in the Washington, D.C. metropolitan area, which covers parts of Washington D.C., Maryland and Virginia [Ref. 3]. Figure 3 shows the Northern Virginia WMATA transit rail lines in black, and the connecting WMATA transit bus lines [Ref. 3].

In addition, there are heavy rail lines in Virginia (the Virginia Rail Express, known as VRE) and Maryland (Maryland Area Regional Commuter train service, known as MARC) that provide commuter rail service to metropolitan Washington, D.C. from areas outside of WMATA's transit services. Both the VRE and MARC rail lines are connected with local transit agencies that provide bus services to commuters who live outside of WMATA's transit service area.

A person commuting to and from work using public transportation can engage several modes of transportation within this system of systems. For example, a commuter may leave

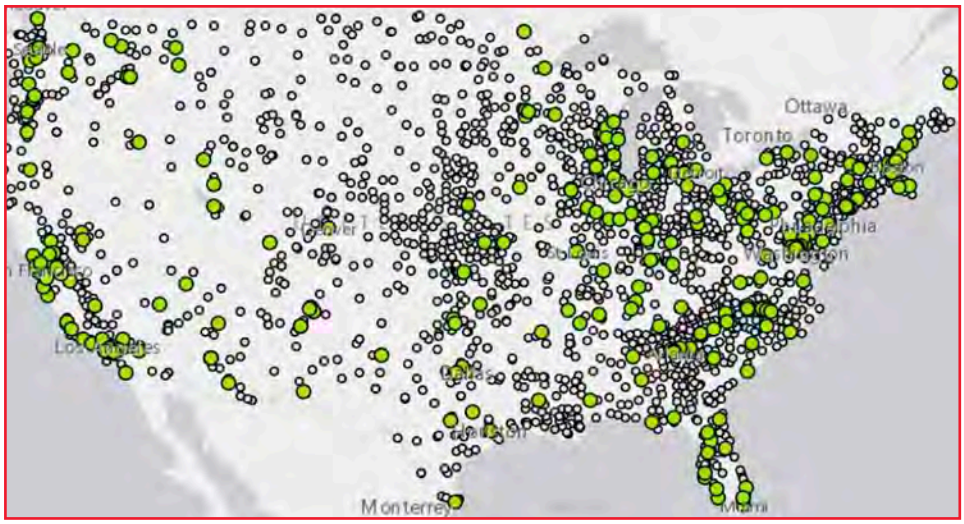

Figure 1 — National Transit Map.

their home by walking, riding a bicycle or riding in a car for the first leg of their commute. They may take a bus or train for the second part of their journey. Some may transfer to a different bus or train. The final leg of the commute may include walking to their place of work. This aggregation of travel modes presents challenges in measuring commuters' safety.

Current Approaches to Measuring Safety

Currently, safety is measured by metrics such as collision events, fatalities and injuries, as reported by each rail transit agency to state and federal oversight authorities. When federal agencies, such as the FTA, aggregate railroad safety data in their federal databases, the data are received and compiled using each railroad's productivity level (some measure of miles traveled) and the collision events, injuries and fatalities by classification of person (passenger, employee, etc.). For transit railroads, the FTA maintains these data in the National Transit Database (NTD), where data are aggregated by year in safety and security time series data files, shown in Figure 4. Figure 5 show events, fatalities and injuries per 100 million vehicle (train) revenue miles [Ref. 4]. The numbers shown in Figure 5 are not an extrapolation if the railroad is productive in terms of revenue vehicle miles traveled.[1] Rail transit agencies also report other safety metrics, such as collision events/fatalities/injuries per 100 million train car or passenger revenue miles, where each vehicle (train) has multiple cars and each car transports multiple passengers. These methods of reporting rail safety data may be different for each rail transit agency.

Measuring the system safety of individual transit railroads typically is done by examining the rates of collision events/fatalities/injuries per vehicle revenue mile for customers/employees/other persons. These rates are viewed as how closely they approximate zero safety events and compared across railroads.

Barriers to Measuring Safety

There is not currently a practice of measuring commuters' safety as they travel on multiple transit modes and systems. On a broader scale, there is not a current practice to measure the safety of transit transportation's national system of systems, which is essential in answering the question: *How safe is the national transit transportation system?* The barriers to doing this include the aggregation of different transit properties for a passenger's trip and the varieties of safety management systems used by transit agencies.

The aggregation of properties for a commuter's trip was discussed earlier. In addition, there may be an aggregation of transit properties and agencies, with different safety responsibilities, for one portionof a commuter's trip. These different rail properties may have different types of safety management systems in place, as there are few federal guidelines. The Federal Railroad Administration (FRA) recently issued Title 49 Code of Federal Regulations Part 270, "System Safety Program," after several delays over many years [Ref. 5]. A lack of standardized safety management systems, particularly when multiple rail transit properties are involved, creates opportunities for overlapping and gaps in system safety. An example of this came to light during the NTSB's investigation of a rail accident in Dupont, Washington [Ref. 6].

On Dec. 18, 2017, at 7:34 a.m., southbound Amtrak passenger train 501 derailed at overspeed from a bridge near Dupont, Washington on its inaugural run of the new Point Defiance Bypass. Several passenger railcars fell onto Interstate 5 and hit multiple highway vehicles (Figure 6). At the time of the accident, 77 passengers, five Amtrak employees and a Talgo technician were on the train. Of these individuals, three passengers were killed and 57 passengers and crew were transported to nearby hospitals. Additionally, eight individuals in highway vehicles were injured. The damage was estimated to be more than $25.8 million.

The Point Defiance Bypass rail project provides an example of how an aggregation of properties and agencies form a system of systems

1. Similar safety data spreadsheets are available on the FTA's NTD website for transit bus agencies, showing both the number of collision events, fatalities and injuries, and the number per 100 million vehicle revenue miles.

within passenger rail transportation (Figure 7). It was funded by the Washington State Department of Transportation (WSDOT) and federal grants administered by the FRA. WSDOT contracted with Sound Transit to complete the Bypass. Sound Transit hired and managed contractors who undertook the work. All improvements are owned by Sound Transit, which is also responsible for track operation and maintenance of the Bypass. Sound Transit contracted BNSF to dispatch trains on the bypass. WSDOT contracted Amtrak to provide operations that included training operating crews on the newly upgraded Point Defiance Bypass. Talgo manufactured and maintained the passenger trains through contracts with WSDOT. Amtrak is also the railroad of record responsible for developing operating rules, practices and procedures, as well as operating the revenue service.

The NTSB investigated this accident. Among the 53 findings was:

> "Had the Washington State Department of Transportation, Central Puget Sound Regional Transit Authority, Amtrak, and the Federal Railroad Administration been more engaged and assertive and had clearly defined roles and responsibilities during the preparation of the inaugural service, it would have been more likely that safety hazards, such as the speed reduction for the curve, would have been better identified and addressed."

Among the 32 new safety recommendations issued by the NTSB were:

To Amtrak:

"Work collaboratively with all host railroads and states that own infrastructure over which you operate in an effort to develop a comprehensive safety management system program that meets or exceeds the pending Federal Railroad Administration regulation, Title 49 Code of Federal Regulations Part 270, "System Safety Program." (R-19-027)

"Conduct risk assessments on all new or upgraded services that occur on Amtrak-owned territory, host railroads, or in states that own infrastructure over which you operate. (R-19-028)"

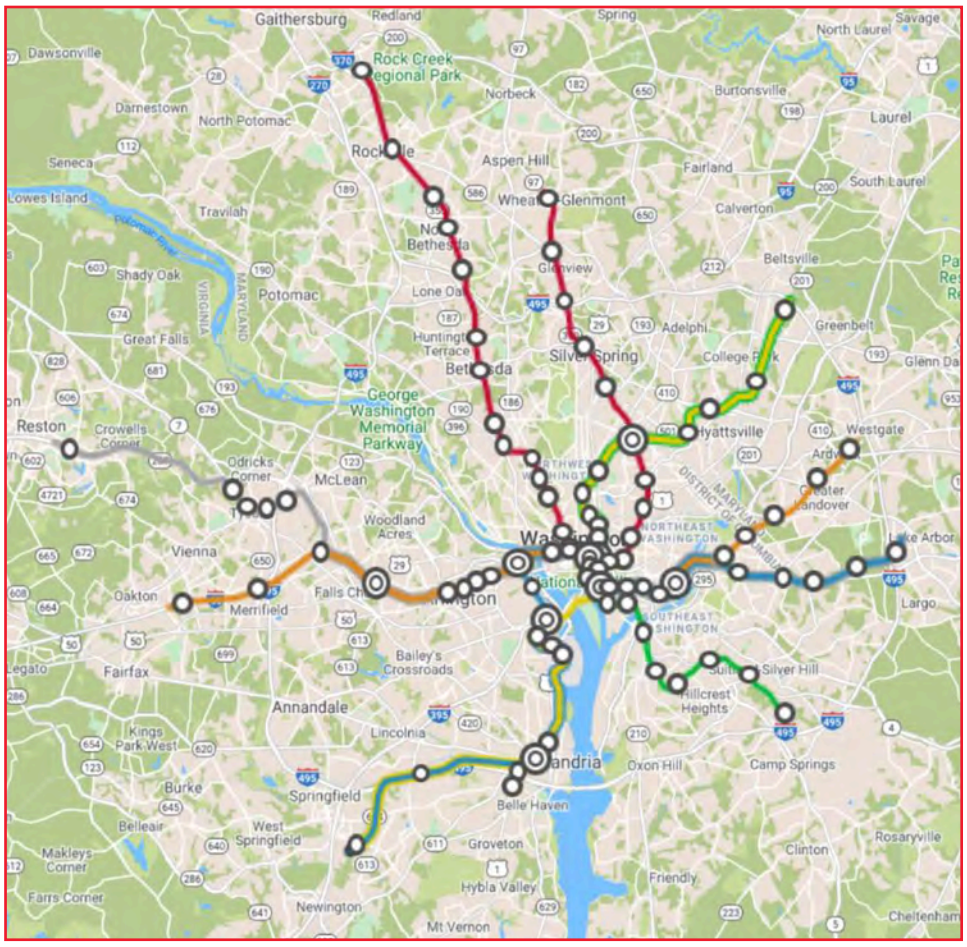

Figure 2 — WMATA Map of Washington, D.C. Transit Rail Lines

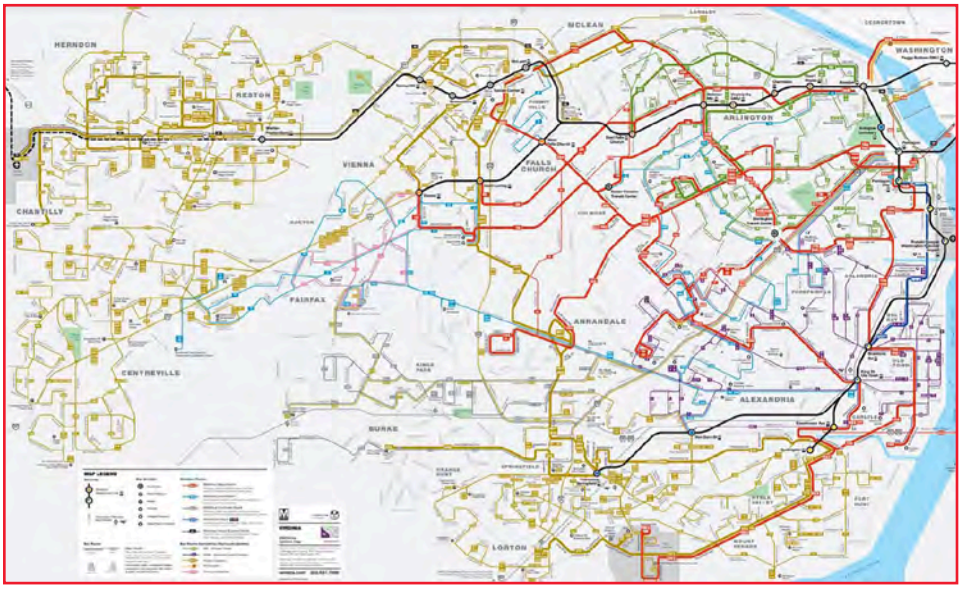

Figure 3 — WMATA Map of Northern Virginia Transit Rail and Bus Lines

Mode	Year	Train Revenue Miles	VRH	VOMS	EVENTS Collisions with Motor Vehicle	with Person	with Fixed Object	with Rail Vehicle	with Bus Vehicle	with Other	Collision Total	Derailment Total	Fire Total	Security Total	NOC Total	Event Total	FATALITIES Passenger	People waiting or leaving	Employee Operator	Employee	Total Employee	Other Worker	Other Bicyclist	Ped in Crossing	Ped Not in Crossing	Ped Crossing Tracks	Ped Walking Along Tracl	Other Vehicle Occupan	Other	Trespasser	Suicide	Total Other	Total Fatalities	INJURIES Passenger	People Waiting or Leaving
Bus	2019	0	221,466,722	90,910	###	520	206	0	48	29	6,228	0	165	676	7,905	**14,974**	6	6	3	0	3	1	4	6	11	0	2	37	8		11	79	**95**	8,632	3,201
Bus	2020	0	221,466,722	90,910	###	355	129	0	38	20	4,523	0	168	506	5,659	**10,856**	7	7	4	1	5	0	6	11	6	0	2	47	10		4	86	**109**	5,123	2,570
Bus	2021	0	221,466,722	90,910	292	27	14	0	3	2	338	0	18	30	436	**822**	0	0	0	0	0	0	0	0	0	0	0	7	1		0	8	**8**	348	173
Rail	2002	127,859,788	33,502,218	9,495	314	92	22	0		242	670	21	1,670	39	5,477	**7,877**	7	33			3	1							7	25	13	45	**89**	2,602	2,457
Rail	2003	129,050,924	33,478,139	9,628	229	66	7	0		379	681	19	1,518	31	4,148	**6,397**	3	15			2	0							12	20	15	47	**66**	1,027	3,104
Rail	2004	133,217,864	34,618,135	9,954	237	59	12	0		314	622	51	1,573	55	4,832	**7,133**	8	10			4	0							19	27	14	60	**82**	1,123	4,038
Rail	2005	135,044,425	35,547,190	10,001	430	70	14	0		180	694	50	1,763	35	4,172	**6,713**	8	14			3	0							8	17	7	32	**57**	841	3,315
Rail	2006	137,428,615	36,263,416	10,083	92	60	2	4		537	695	72	1,643	31	4,883	**7,324**	4	2			3	1							12	11	8	31	**51**	1,543	3,487
Rail	2007	140,302,891	36,968,973	10,252	86	83	2	7		519	697	82	1,939	25	5,343	**8,086**	6	7			2	0							14	23	14	51	**66**	2,429	2,901
Rail	2008	140,483,004	37,946,030	10,378	88	103	4	14		8	217	39	1,684	170	7,734	**9,844**	1	12	1	2	3	0	1	3	6	0	2	3	30		43	88	**104**	601	7,097
Rail	2009	142,682,893	38,467,821	10,508	97	152	0	12		6	267	27	1,361	254	7,900	**9,809**	11	15	1	3	4	0	3	4	5	6	8	3	21		63	113	**142**	686	7,363
Rail	2010	139,612,092	37,842,395	10,502	132	161	3	6		11	313	31	1,364	144	7,613	**9,732**	4	21	0	3	3	0	2	1	3	3	8	3	17		57	94	**122**	2,411	5,556
Rail	2011	138,193,836	37,721,024	10,408	116	208	3	7	1	6	341	44	1,316	598	7,141	**9,440**	2	23	0	0	0	0	1	5	1	5	7	1	28		57	105	**130**	699	6,987
Rail	2012	140,776,527	38,596,091	10,688	136	205	2	9	2	10	364	38	1,263	722	6,976	**9,363**	3	35	0	1	1	0	0	2	2	8	11	9	20		59	111	**150**	679	5,470
Rail	2013	147,257,434	39,988,724	10,749	142	183	4	7	2	6	344	35	1,137	600	7,856	**9,972**	7	17	0	4	5	0	6	1	3	5	7	7	25		67	121	**149**	690	7,424
Rail	2014	148,747,379	40,010,179	10,867	157	183	5	3	0	9	357	36	1,157	648	6,404	**8,602**	9	23	0	0	0	0	5	3	0	9	12	4	9		61	103	**135**	737	6,194
Rail	2015	152,586,914	41,015,893	11,092	602	275	18	26	3	6	930	63	1,328	709	6,245	**9,275**	7	13	0	1	1	1	2	5	3	11	9	8	20		65	123	**145**	715	5,891
Rail	2016	156,277,909	41,678,653	11,185	690	260	7	28	8	9	1,002	72	1,448	779	6,145	**9,446**	4	31	0	2	2	0	2	4	1	0	5	7	19		75	113	**150**	649	5,948
Rail	2017	158,707,443	42,469,636	11,269	281	285	6	32	6	9	619	88	1,473	902	4,897	**7,979**	10	25	0	1	1	2	4	7	2	0	6	9	22		63	113	**151**	916	4,213
Rail	2018	157,263,544	42,589,160	11,250	297	313	10	32	1	9	662	81	1,358	1,050	4,955	**8,106**	9	22	0	5	5	1	2	5	4	0	4	2	40		80	197	**174**	792	4,377
Rail	2019	160,296,363	43,301,993	11,418	255	332	19	31	5	5	647	68	1,226	1,354	4,864	**8,159**	9	32	0	1	1	0	3	6	3	0	5	6	46		62	131	**173**	895	4,409
Rail	2020	160,296,363	43,301,993	11,418	200	271	10	26	0	5	512	67	1,398	834	3,053	**5,864**	17	24	1	3	4	0	0	1	2	0	9	7	65		56	140	**185**	493	2,660

Figure 4 — Transit Rail Safety Data, Reported to the FTA by Rail Transit Agencies, Aggregated by Year.

Mode	Year	Average Service Ratios Trip Length: PMT/UPT	Load Factor: PMT/VRM	Revenue Speed: VRM/VRH	Trips per Hour: UPT/VRH	Average EVENT rates per 100m VRM Collisions with Motor Vehicle	with Person	with Fixed Object	with Rail Vehicle	with Bus Vehicle	with Other	Collision Total	Derailment Total	Fire Total	Security Total	NOC Total	Event Total	Average FATALITY rates per 100m VRM Passenger	People waiting or leaving	Employee Operator	Employee	Total Employee	Other Worker	Other Bicyclist	Ped in Crossing	Ped Not in Crossing	Ped Crossing Tracks	Ped Walking Along Tracks	Other Vehicle Occupa	Other	Suicide	Total Other	Total Fatalities	Average INJURIES rates per 100m VRM Passenger	People Waiting or Leaving
Rail	2008	4.72	25.40	19.30	103.76	12.0	14.1	0.5	1.9		1.1	29.6	5.3	230.0	23.2	1,056.2	**1,344.4**	0.1	1.6	0.1	0.3	0.4	0.0	0.1	0.4	0.8	0.0	0.3	0.4	4.1	5.9	12.0	**14.2**	82.1	969.3
Rail	2009	4.80	25.05	19.39	101.27	13.0	20.4	0.0	1.6		0.8	35.8	3.6	182.5	34.1	1,059.2	**1,315.2**	1.5	1.9	0.1	0.4	0.5	0.0	0.4	0.5	0.7	0.8	1.1	0.4	2.8	8.4	15.2	**1.9**	92.0	987.2
Rail	2010	4.63	25.03	19.27	104.25	18.1	22.1	0.4	0.8		1.5	42.9	4.3	187.1	56.4	1,044.1	**1,334.7**	0.5	2.9	0.0	0.4	0.4	0.0	0.3	0.1	0.4	0.4	1.1	0.4	2.3	7.8	12.9	**16.7**	330.7	762.0
Rail	2011	4.75	26.83	19.10	107.81	16.1	28.9	0.4	1.0	0.1	0.8	47.3	6.1	182.7	83.0	991.3	**1,310.4**	0.3	3.2	0.0	0.0	0.0	0.0	0.1	0.7	0.1	0.7	1.0	0.1	3.9	7.9	14.6	**18.0**	97.0	969.9
Rail	2012	4.69	26.91	18.95	108.70	18.6	28.0	0.3	1.2	0.3	1.4	49.8	5.2	172.6	98.7	953.6	**1,279.9**	0.4	4.8	0.0	0.1	0.1	0.0	0.0	0.3	0.3	1.1	1.5	1.2	2.7	8.1	15.2	**20.5**	92.8	747.7
Rail	2013	4.72	26.83	18.90	107.34	18.8	24.2	0.5	0.9	0.3	0.8	45.5	4.6	150.4	79.4	1,039.4	**1,319.3**	0.9	2.2	0.0	0.5	0.5	0.0	0.8	0.1	0.4	0.7	0.9	0.9	3.3	8.9	16.0	**19.7**	91.3	982.2
Rail	2014	4.68	27.22	18.99	110.33	20.7	24.1	0.7	0.4	0.0	1.2	47.0	4.7	152.3	85.3	842.9	**1,132.2**	1.2	3.0	0.0	0.0	0.0	0.0	0.7	0.4	0.0	0.2	1.6	0.5	1.2	8.0	13.6	**17.8**	97.0	815.3
Rail	2015	4.74	26.32	19.05	105.88	77.0	35.2	2.3	3.3	0.4	0.8	119.0	8.1	169.9	90.7	799.2	**1,186.9**	0.9	1.7	0.0	0.1	0.1	0.1	0.3	0.6	0.4	0.4	1.2	1.0	2.6	8.3	15.7	**18.6**	91.5	753.9
Rail	2016	4.77	26.34	18.91	104.32	87.5	33.0	0.9	3.6	1.0	1.1	127.1	9.1	183.7	98.8	779.6	**1,198.5**	0.5	3.9	0.0	0.3	0.3	0.0	0.3	0.5	0.1	0.0	0.6	0.9	2.4	9.5	14.3	**19.0**	82.3	754.7
Rail	2017	4.63	24.94	18.88	101.61	35.1	35.6	0.7	4.0	0.7	1.1	77.2	11.0	183.7	112.5	610.9	**995.3**	1.2	3.1	0.0	0.1	0.1	0.2	0.5	0.9	0.2	0.0	0.7	1.1	2.7	7.9	14.1	**18.8**	114.3	525.5
Rail	2018	4.56	23.90	18.87	98.83	37.0	38.9	1.2	4.0	0.1	1.1	82.4	10.1	169.0	130.7	646.6	**1,008.7**	1.1	2.7	0.0	0.6	0.6	0.1	0.2	0.6	0.5	0.0	0.5	0.2	50.	10.0	17.0	**21.7**	98.6	544.7
Rail	2019	4.60	23.94	18.93	98.46	31.1	40.5	2.3	3.8	0.6	0.6	78.9	8.3	149.6	165.2	593.4	**995.4**	1.1	3.9	0.0	0.1	0.1	0.0	0.4	0.7	0.4	0.0	0.6	0.7	5.6	7.6	16.0	**21.1**	109.2	537.9
Rail	2020	4.60	23.94	18.93	98.46	24.4	33.1	1.2	3.2	0.0	0.6	62.5	8.2	170.6	101.7	372.5	**715.4**	2.1	2.9	0.1	0.4	0.5	0.0	0.0	0.1	0.2	0.0	1.1	0.9	7.9	6.8	17.1	**22.6**	60.1	324.5
Rail	2021	4.60	23.94	18.93	98.46	1.6	2.9	0.1	0.4	0.0	0.0	5.0	0.0	14.6	7.7	35.4	**62.7**	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.4	0.5	1.1	**1.5**	6.0	30.6

Figure 5 — Transit Rail Safety Data, Reported by Rail Transit Agencies and Shown per 100 Million Vehicle Revenue Miles.

The NTSB also reiterated four safety recommendations to the FRA, including:

"Enact Title 49 Code of Federal Regulations Part 270, 'System Safety Program,' without further delay. (R-17-17)" [Ref. 6]

With no federal standard for rail safety management systems and no federal requirements, a passenger rail line that includes operations from a system of systems without overarching safety oversight may have multiple versions of safety metrics and risk assessments.

Transportation Safety Equity

The previous sections provided an overview of passenger rail transportation system of systems, the types of metrics used to measure the safety of railroads, and barriers to measuring the safety of rail transportation within a system of systems. They also included the aggregation of different rail properties responsible for safety of passengers' commutes and the lack of standards for safety management systems and risk assessments. However, there are other perspectives for viewing the national system of systems for rail transportation.

Figure 6 — Aerial View of the Point Defiance Bypass Rail Accident near Dupont, Washington.

For example, one perspective asks how safe passengers are instead of how safe the railroads are. This question shifts the fundamental focus to a human-centric perspective of transportation system safety and is the foundation for determining whether transportation safety outcomes are equitable.

Current rail safety metrics are designed to determine the safety of railroads based on safety outcomes such as collision events/injuries and fatalities per million revenue miles traveled. A human-centric approach is concerned with the safety of the people who use the transportation system. For transit systems, this requires looking at safety metrics and safety risks to the person during their commute from home to work, and on the return trip, inclusive of all transportation modes used. As such, safety risk assessments must be multimodal where applicable. This shifts the safety question from how safe individual rail properties are to how safe the transportation system is for the people who use it.

Transportation safety equity is concerned with ensuring that safety outcomes are equitable for all groups of people within a population of users. Groups may be stratified on socioeconomic and biodemographic factors. If safety outcomes are different among groups, then root causes for the safety disparity need to be determined and mitigated. Although safety features and risk mitigations are not designed to discriminate among any subgroup of a user population, safety outcomes may vary across subgroups and form safety inequities.

Barriers to Determining Transportation Safety Equity

A difficulty in determining safety levels across subgroups of the population is lack of data. The FTA does not require biodemographic, socioeconomic or disability information on people injured or killed on railroad property. Therefore, accident reports to federal agencies from railroad properties often lack important details on demographic and disability information, even when that information is available from police investigations and medical examiner reports. This information is important in determining the effects of safety hazards on the most vulnerable groups within the population and the lack of these accident details in federal databases may mask potential safety issues.

Safety inequities arise for diverse reasons; for example, as unintended consequences of transportation policies, new technologies, or risk assessment and safety management schemes. Regardless, the public service duty remains — to ensure that risk interventions apply equitably to all and to ensure transportation safety equity for all, regardless of the modes of transportation used.

Currently, we do not know if any socioeconomic/biodemographic groups are injured at a higher population percentage rate than others, so we do not know if existing safety controls are operating equitably. We do not know that because we are not collecting the data. Solving this problem is compelling and necessary to ensure that transportation safety does, demonstrably, mean safety for all.

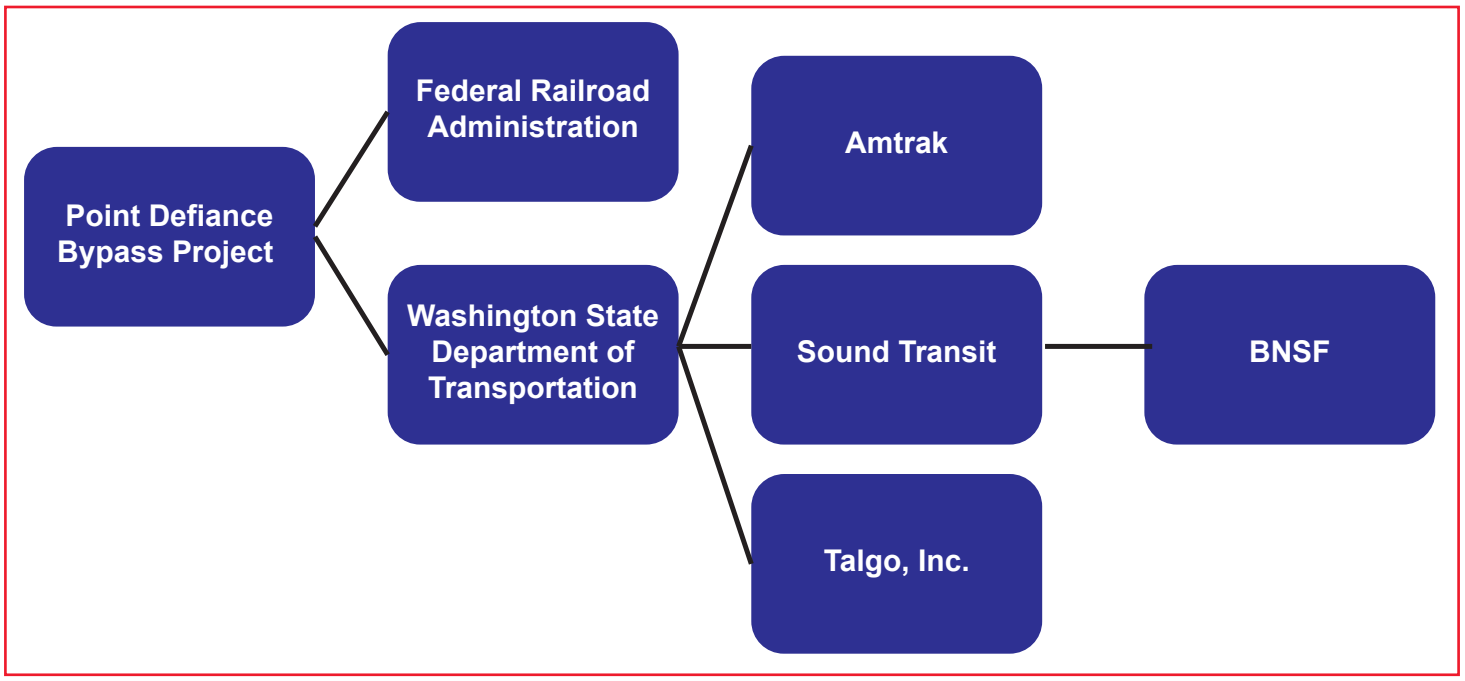

Figure 7 — Rail Properties and Oversight Agencies for the Point Defiance Bypass in Dupont, Washington.

Executive Order 13985 is geared toward improving federal databases through disaggregation of data. With this, it may be possible to determine if safety levels are equal across all subgroups of the population or if there are existing transportation safety inequities and disparities.

If disproportionally high adverse safety outcomes are identified, then methods to mitigate or avoid the associated risks through engineered or administrative risk controls can be developed and implemented.

Conclusion

Modern transit transportation systems are a complex system of systems, with commuters often engaging in multiple modes of transportation during their travels to and from work. Current methods of tracking safety metrics for individual rail and bus agencies do not capture the safety risks and outcomes of the individual commuter throughout multiple, and perhaps multi-modal, legs of a journey. Nor do current safety databases support safety analyses of the commuting population's subgroups, based on biodemographics, socioeconomics or disabilities.

Ensuring the safety of travelers will require developments in safety assessments that recognize and account for the inherent system of systems nature of public transportation and are supported by public safety databases with disaggregated safety outcomes of collision events/fatalities/injuries for all subgroups of the population, stratified by biodemographic, socioeconomic and disability data.

These changes in safety assessments and databases reflect a shift to a human-centric perspective on transportation safety, which asks how safe the passengers are, instead of how safe the railroads or buses are. A human-centric perspective is fundamental to determining if transportation safety is, indeed, equitable for all.

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