BOSTON REGION METROPOLITAN PLANNING ORGANIZATION
Stephanie Pollack, MassDOT Secretary and CEO and MPO Chair
Karl H. Quackenbush, Executive Director, MPO Staff

TECHNICAL MEMORANDUM

DATE: **October 17, 2017**

TO: **Karl Quackenbush**

FROM: **Betsy Harvey**

RE: **Spatial Distribution of Crashes in EJ and Non-EJ Communities in the Boston Region MPO**

This memo describes the results of the federal fiscal year (FFY) 2017 staff-initiated research project, "Spatial Distribution of Crashes in Environmental Justice and Non-Environmental Justice Communities in the Boston Region MPO." This project explored the frequency and severity of crashes in environmental justice (EJ) communities compared with non-EJ communities in the Boston Region Metropolitan Planning Organization (MPO) area.

Environmental justice communities are transportation analysis zones (TAZs) that meet or exceed the MPO's threshold for low-income households and/or minority population—60 percent of the region's median household income, and the average minority population in the region (27.8 percent), respectively. For this study, the Central Transportation Planning Staff (CTPS) to the Boston Region MPO examined vehicle-on-vehicle, vehicle-on-bicycle, and vehicle-on-pedestrian crashes that occurred between 2010 and 2014. Our analysis used a number of different exposure, or control, measures to calculate the crash rates: population, number of trips, travel time, vehicle miles travelled (VMT), roadway miles, and lane miles. This memo presents the results of this analysis, and discusses the pros and cons of using each of the control measures. Ultimately, the information in this memo could help the MPO evaluate safety in EJ and non-EJ communities more effectively.

1 BACKGROUND

Automobile crashes are one of the leading causes of death in the United States. In 2015, more than 36,000 people died in a crash, and an additional 2,624,934 people were injured.[1] Several studies have shown that people of color and those in low-income communities are more apt to be killed in a crash than people in other demographic groups. Smart Growth America's *Dangerous by Design 2014* reported that it is 60 percent more probable that African American pedestrians

[1] "Ten Leading Causes of Death and Injury," 2017, May 2, *Centers for Disease Control and Prevention,* https://www.cdc.gov/injury/wisqars/leadingcauses.html.

would be killed in crashes than White pedestrians. This probability for Hispanics is 43 percent, and the likelihood that American Indians would be killed in crashes is an astonishing 300 percent.[2] The online platform, *Governing,* analyzed crashes between 2008 and 2012 and found that the poorest third census tracts in metro areas, in terms of per capita income, had twice the amount pedestrian fatality rates than the higher income tracts.[3] Poverty in drivers' communities among is also associated with higher crash rates. A 2009 study of California's 35 most populous counties found that fatal crashes were substantially higher in poorer counties. Socioeconomic factors were strongly correlated with motor vehicle crash risk.[4]

Studies have also found that road designs have an impact on traffic injury rates. A study of intersections in Montreal neighborhoods found that poorer neighborhoods have twice as many intersections that are major thoroughfares than do richer neighborhoods; and that these intersections have 2.4 times more pedestrian injuries than do intersections of minor streets. The intersections also had 1.3 times the number of bicyclist injuries and 3.5 times the number of motorist injuries. In addition, this study found that the intersections in the poorest census tracts have more traffic and more than twice the number of arterials as wealthier census tracts. This suggests a correlation between the design inherent in high-speed roads and the number of crashes on those roads.[5]

1.1 Exposure Measures

"Exposure" is generally defined in the literature as a measure of the potential opportunities for an event, such as a crash, to occur. However, although the theoretical definition of exposure is well understood, there is divergence among practitioners regarding operational definitions of exposure. The choice of an exposure measure reflects several factors, such as spatial scale (for example, area-wide versus specific transportation facilities), available data and data quality, and the intended purpose of the exposure measure.[6]

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[2] Warlick, Sam, 2014, August 29, "Inside Dangerous by Design: Pedestrian Fatalities Among People of Color," *Smart Growth America*, https://smartgrowthamerica.org/inside-dangerous-by-design-pedestrian-fatalities-among-people-of-color/.

[3] Maciag, Mike, "Pedestrians Dying at Disproportionate Rates in America's Poorer Neighborhoods," August 2014, *Governing*, http://www.governing.com/topics/public-justice-safety/gov-pedestrian-deaths-analysis.html.

[4] Males, Mike, 2009, "The Role of Poverty in California Teenagers' Fatal Traffic Crash Risk," *Californian Journal of Health Promotion*, 7(1).

[5] Morency, Patrick, et. al., 2012, "Neighborhood Social Inequalities in Road Traffic Injuries: The Influence of Traffic Volume and Road Design," *American Journal of Public Health*, 102(6).

[6] Federal Highway Administration, 2017, *Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities,* https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa17041/fhwasa17014.pdf

The present study is concerned with crashes across a large geographic area. One may categorize exposure measures for area-wide analyses into five types:

- Population (number of residents)
- Travelers (number of vehicles, pedestrians, or bicyclists)
- Trips (number of commutes)
- Distance (total miles traveled)
- Time (total travel time)[7]

With these factors in mind, we explored the following measures: population, number of trips, travel time, vehicle miles travelled (VMT), roadway miles, and lane miles. Below, we present the crash rates using these exposure measures, and discuss the benefits and challenges of each.

2 CRASHES IN THE BOSTON REGION MPO

2.1 Methodology

Data Inputs

For this analysis, we used crashes that occurred between 2010 and 2014, inclusive. Staff also identified environmental justice TAZs, using data from the 2010–2014 American Community Survey and the 2010 Decennial Census. While this designation of TAZs as either EJ or non-EJ does not take into account the actual number of people who are low-income or minority, it serves as a useful proxy by identifying communities in which crashes would more likely occur; as it is not possible to know the minority and low-income statuses for people involved in crashes. It is also a useful designation insofar as the MPO uses these thresholds to identify EJ TAZs for its several Title VI and EJ analyses, and when evaluating projects for funding in the Transportation Improvement Program (TIP).

Analysis

Exploratory in nature, this project examined crash data in order to begin to identify whether differences in crash rates, crash types, and crash severity exist between EJ TAZs and non-EJ TAZs. The first step was to identify the number of crashes in EJ TAZs, non-EJ TAZs, and all TAZs in the MPO region, by type and severity. Table 1 summarizes these data, as well as the MPO population and number of TAZs in the region.

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[7] Federal Highway Administration, 2017, *Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities,* https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa17041/fhwasa17014.pdf.

Table 1
Summary of Crashes in the Boston Region MPO, by Type and Severity, 2010–14

	EJ TAZs Count	EJ TAZs Pct. of Row Totals	Non-EJ TAZs Count	Non-EJ TAZs Pct. of Row Totals	All TAZs Count	All TAZs Pct. of Row Totals
MPO TAZs	673	34.6%	1,270	65.4%	1,943	100.0%
MPO Population	1,156,175	36.6	2,005,669	63.4	3,161,844	100.0
Fatal Crashes	168	29.7	397	70.3	565	100.0
Injury Crashes	18,312	31.0	40,700	69.0	59,012	100.0
PDO Crashes	51,023	29.0	125,033	71.0	176,056	100.0
Bicyclist Crashes	1,781	43.1	2,355	56.9	4,136	100.0
Pedestrian Crashes	3,100	49.1	3,210	50.9	6,310	100.0
Total Crashes	**69,503**	**29.5%**	**166,130**	**70.5%**	**235,633**	**100.0%**

EJ = Environmental justice. MPO = Metropolitan Planning Organization. PDO = Property damage only. TAZ = Traffic analysis zone.
Sources: 2010 Decennial Census; 2010-2014 American Community Survey; CTPS.

There are 673 EJ TAZs and 1,270 non-EJ TAZs within the MPO region (34.6 percent and 65.4 percent of all TAZs, respectively). Between 2010 and 2014, there were 235,633 crashes in the MPO region. Of these, 69,503 (29.5 percent) were in EJ TAZs, while the remainder (166,130, or 70.5 percent) were in non-EJ TAZs. Of pedestrian, bicyclist, and automobile crashes, pedestrian crashes were the most overrepresented relative to the percent of the EJ population, at 49.1 percent of all pedestrian crashes. Bicyclist crashes are similarly overrepresented, at 43.1 percent of all bicyclist crashes. These data indicate that bicyclist and pedestrian crashes are relatively more frequent in EJ communities than in non-EJ communities, which is consistent with the findings that follow. However, while this kind of information provides a useful overview of the geographic distribution of crashes within the MPO, it does not account for the actual exposure to crashes, that is, the *potential* to be involved in a crash. This can be measured in several ways, such as by time spent on the road, number of trips taken, or distance travelled, as we explain in the remainder of this memo,

3 EXPLORING EXPOSURE MEASURES

Staff explored crash rates using different exposure measures, with the number of crashes as the nominator and the exposure measure as the denominator. The research bears out that, when available, for area-wide analyses, travel-based measures are ideal. When those are unavailable, population-based measures may be appropriate. However, differences in speed, travel distance, and travel time between modes should be considered when selecting exposure measures as they vary between modes, especially between pedestrians or bicyclists and automobiles. [8,9]

The last column in each of the remaining tables shows the ratio of EJ crash rates to non-EJ crash rates. A ratio of greater than one means that the EJ crash rate exceeds the non-EJ crash rate. These ratios show the magnitude of the difference in crash rates in EJ and non-EJ TAZs, and allow for comparison of the exposure measures.

3.1 Population as Exposure

The population of a given area, or of a particular demographic group, is a simple proxy for exposure. It rests on the assumption that the population equals the number of people—driving, walking, or bicycling—who use the roadway network and therefore are exposed to the potential for crashes. However, it assumes that actual exposure is the same across the population, which it is not, as neither time spent on the road nor distance traveled is accounted for. It also does not account for workers who commute to the city and for tourists, both of which are significant in several communities in the region, especially Boston.

Because the denominator (population) is the same for all modes, it can be used to compare the risk between walking or bicycling and driving.[10] Data for these are also easy to acquire and are available at many geographic scales. In this analysis, because the number of crashes was far lower than the population, the result was multiplied by 10,000 to get the number of crashes per 10,000 people. These results are shown in Table 2.

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[8] *Estimating Pedestrian Accident Exposure,* May 2010, *Safe Transportation Education and Research Center,* http://www.path.berkeley.edu/sites/default/files/publications/PRR-2010-32.pdf.

[9] Guler, Illgin, and Offer Grembel, August 2016, "Use of Different Exposure Metrics for Understanding Multi-modal Travel Injury Risk," *International Journal of Transportation Science and Technology*, 5(1), pp. 28-37.

[10] Federal Highway Administration, 2017, *Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities,* https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa17041/fhwasa17014.pdf

Table 2
Crashes, Injuries, and Fatalities per 10,000 People in the Boston Region MPO, 2010–14

	EJ TAZs	Non-EJ TAZs	All TAZs	Ratio of EJ: Non-EJ Crash Rate
Population	**1,156,175**	**2,005,669**	**3,161,844**	**N/A**
Fatal Crashes	1.45	1.98	1.79	0.73
Auto	0.89	1.46	1.25	0.61
Pedestrian	0.50	0.46	0.47	1.09
Bicyclist	0.06	0.06	0.06	0.93
Injury Crashes	158.38	202.92	186.64	0.78
Auto	128.82	184.62	164.21	0.70
Pedestrian	17.91	11.10	13.59	1.61
Bicyclist	11.65	7.20	8.83	1.62
PDO Crashes	441.31	623.40	556.81	0.71
Auto	556.57	801.92	712.20	0.69
Pedestrian	26.81	16.00	19.96	1.68
Bicyclist	17.77	10.38	13.08	1.71
All Crashes	**601.15**	**828.30**	**745.24**	**0.73**
Auto	**556.57**	**801.92**	**712.20**	**0.69**
Pedestrian	**26.81**	**16.00**	**19.96**	**1.68**
Bicyclist	**17.77**	**10.38**	**13.08**	**1.71**

EJ = Environmental justice. MPO = Metropolitan planning organization. N/A = Not applicable or available. PDO = Property damage only. TAZ = Traffic analysis zone.
Sources: 2010 Decennial Census; CTPS.

Using population as the exposure measure shows that crash rates are higher in non-EJ TAZs compared with EJ TAZs, for all modes combined. Interestingly, pedestrian and bicyclist crash rates are higher in EJ TAZs, except for fatal bicyclist crashes. Across all modes, the ratio of EJ to non-EJ TAZ crash rates are higher for injury and property damage only (PDO) crashes than for fatal crashes, which indicates that these types of crashes are relatively more frequent than fatal crashes in EJ TAZs than in non-EJ TAZs.

3.2 Trips as Exposure

Using trips as the exposure measure indicates how likely a person is to be in a crash based on the number of trips taken within a geographic area. Exposure based on trips—whether pedestrian, bicyclist, or vehicle—is an appropriate metric for assessing crash rates in a large region. It is also a useful measure for examining trips by purpose. However, it does not account for the distance traveled or time spent traveling, which vary depending on the mode.[11] This

[11] Federal Highway Administration, 2017, *Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities,* https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa17041/fhwasa17014.pdf

measure assumes that all modes are exposed to risk equally, regardless of the trip length or duration. This is problematic when comparing driving with bicycling or walking, as the latter two take longer to cover the same distance as the former, therefore increasing exposure. Using a trip-based exposure measure would not account for these differences and would treat the risk for each mode the same. Therefore, if trips are used as the exposure measure, crash rates should only be compared within modes. A time- or distance-based measure is better at highlighting the differences between modes.[12] Therefore, crash rates based on trips are divided here into auto trips and bicyclist/pedestrian trips.

The number of trips taken within a given area is typically a difficult statistic to get, especially for a region-wide analysis. This indicator is more feasible for studies that look at a section of roadway, as counting technologies can be employed. However, the MPO's travel demand model estimates trip productions for the Long-Range Transportation Plan (LRTP), which could be used to estimate the number of trips completed within the MPO over the course of the five years for which crash data are collected. In this analysis, base year trips from 2012 (as produced for the 2015 LRTP) were used, and included all trip purposes and modes. In accordance with the population growth method used in the LRTP, the annual growth rate of 7.7 percent was applied to trips in 2010, 2011, 2013, and 2014, the years immediately preceding and following 2012. Trips were broken out by mode, and were identified as produced in either an EJ or non-EJ TAZ. Although it does not account for all trips that go through a TAZ, trip productions are a simple way of identifying trips within EJ and non-EJ TAZs. (Calculating all trips going through, starting in, and ending in each TAZ would be prohibitively time-consuming, and was thus not practical for this exercise.) These results are shown in Tables 3 and 4.

Table 3 shows crash rates using auto trips as the exposure measure. Crash rates for fatal, injury, and PDO crashes were all higher in non-EJ TAZs. The ratio for EJ and non-EJ injury crashes is closer to one than for fatal crashes, which indicates that there is a greater risk of being in a crash in an EJ TAZ than in a non-EJ TAZ.

[12] Guler, Illgin, and Offer Grembel, August 2016, "Use of Different Exposure Metrics for Understanding Multi-modal Travel Injury Risk," *International Journal of Transportation Science and Technology*, 5(1), pp. 28-37.

Table 3
Crashes, Injuries, and Fatalities per 10 Million Auto Trips, 2010–14

	EJ TAZs	Non-EJ TAZs	MPO Region	Ratio of EJ: Non-EJ Crash Rate
Auto Trips[1]	6,133,432,228	11,898,519,482	18,031,951,710	N/A
Fatal Crashes	0.17	0.25	0.22	0.68
Injury Crashes	24.28	31.12	28.79	0.78
PDO Crashes	80.46	103.81	95.87	0.78
All Crashes	**104.92**	**135.17**	**124.88**	**0.78**

[1]Trips are for a five-year period, between 2010 and 2014, which aligns with the time frame for the crash data. To calculate the number of trips over five years, the annual population growth rate of 7.7% (as identified for the 2015 LRTP) was applied to each of the two years preceding and the two years following the 2012 base year for which trips were gathered from the 2015 LRTP.
EJ = Environmental justice. LRTP = Long-Range Transportation Plan. N/A = Not applicable or available.
PDO = Property damage only TAZ = Traffic analysis zone.
Sources: 2010 Decennial Census; CTPS.

Table 4 shows the crash rates based on non-auto (bicycle and pedestrian trips). Rates are higher in non-EJ TAZs for all types of crashes. However, once again the ratio of EJ to non-EJ crashes is higher for injury crashes than for fatal crashes, which indicates that there is a greater risk of being in a crash in an EJ TAZ than in a non-EJ TAZ. The PDO and injury crash rates for non-auto trips are also lower than for auto trips.

Table 4
Crashes, Injuries, and Fatalities per 10 Million Non-Auto (Bicycle and Pedestrian) Trips, 2010–14

	EJ TAZs	Non-EJ TAZs	MPO Region	Ratio of EJ: Non-EJ Crash Rate
Non-Auto Trips[1]	1,002,175,317	596,364,846	1,598,540,164	N/A
Fatal Crashes	0.65	1.76	1.06	0.37
Injury Crashes	34.11	61.57	44.35	0.55
PDO Crashes	16.67	28.02	19.93	0.60
All Crashes	**51.43**	**88.74**	**65.35**	**0.58**

[1]Trips are for a five-year period, between 2010 and 2014, which aligns with the time frame for the crash data. To calculate the number of trips over five years, the annual population growth rate of 7.7% (as identified for the 2015 LRTP) was applied to each of the two years preceding and the two years following the 2012 base year for which trips were gathered from the 2015 LRTP.
EJ = Environmental justice. LRTP = Long-Range Transportation Plan. N/A = Not applicable or available.
PDO = Property damage only. TAZ = Traffic analysis zone.
Sources: 2010 Decennial Census; CTPS.

3.3 Travel Time as Exposure

Time-based exposure measures indicate how likely a person is to be in a crash based on the length of time spent traveling. Because people tend to travel similar amounts of time regardless of mode, but distance covered differs significantly between modes, auto travel should be separated from bicycling and walking.

Drivers will have greater exposure in terms of distance and generally would travel further during the same time interval than would other modes.[13] Table 5 shows crash rates for auto travel, as derived from the 2015 LRTP 2012 base year over a hypothetical five-year period. As pedestrian and bicyclist travel times were not available, those crashes are not analyzed here.

The results in Table 5 show that, overall, crash rates are higher in non-EJ TAZs than in EJ-TAZs. However, it also shows that the risk of being in an injury crash is higher in EJ TAZs than in non-EJ TAZs, which is consistent with the other findings in this memo.

Table 5
Crashes, Injuries, and Fatalities per 1,000 Hours of Auto Trips, 2010–14

	EJ TAZs	Non-EJ TAZs	MPO Region	Ratio of EJ: Non-EJ Crash Rate
Total Travel Time (minutes)[1]	**476,830**	**744,366**	**1,221,196**	**N/A**
Fatal Crashes	0.22	0.39	0.32	0.55
Injury Crashes	21.24	49.74	42.52	0.63
PDO Crashes	103.50	165.94	141.56	0.62
All Crashes	**134.95**	**216.07**	**184.40**	**0.62**

[1]Travel time is from the 2015 LRTP base year (2012) and is over a five-year period.
EJ = Environmental justice. LRTP = Long-Range Transportation Plan. N/A = Not applicable or available.
PDO = Equivalent property damage only. TAZ = Traffic analysis zone.
Sources: 2010 Decennial Census; CTPS.

3.4 Vehicle Miles Traveled (VMT) as Exposure

VMT indicates the crash risk based on the distance traveled. Using VMT as an exposure measure is ideal for large areas, assuming that risk is equal over the distance traveled. However, it does not take into account the time spent traveling. It should not be used to compare risk between modes with significantly different travel speeds, such as walking and driving.[14] VMT was not available for bicycling and walking, so only auto crash rates are analyzed here.

Table 6 shows crashes per 10,000,000 VMT per square mile. Staff calculated VMT over a hypothetical five-year period from the 2012 base year from the 2015 LRTP. Daily VMT resulting from the model run was expanded out to five years—2010 through 2014. The results in Table 6 show that the crash rates are lower in EJ TAZs than in non-EJ TAZs for all crash severities. But once again, the ratio of

[13] Guler, Illgin, and Offer Grembel, August 2016, “Use of Different Exposure Metrics for Understanding Multi-modal Travel Injury Risk,” *International Journal of Transportation Science and Technology*, 5(1), pp. 28-37.
[14] Federal Highway Administration, 2017, *Synthesis of Methods for Estimating Pedestrian and Bicyclist Exposure to Risk at Areawide Levels and on Specific Transportation Facilities,* https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa17041/fhwasa17014.pdf

non-EJ to EJ crashes is higher for injury crashes and PDO crashes than for fatal crashes, indicating that these types of crashes are relatively more frequent in EJ TAZs than are fatal crashes.

Table 6
Crashes per 10,000,000 VMT per Square Mile, 2010–14

	EJ TAZs	Non-EJ TAZs	MPO Region	Ratio of EJ: Non-EJ Crash Rate
VMT per Square Mile[1]	242,943,750,888	286,558,419,035	529,502,169,923	N/A
Fatal Crashes	0.00	0.01	0.01	0.42
Injury Crashes	0.61	1.29	0.98	0.47
PDO Crashes	2.03	4.31	3.26	0.47
All Crashes	**2.65**	**5.61**	**4.25**	**0.47**

[1]VMT was calculated for five years from the 2015 LRTP base year (2012).
EJ = Environmental justice. LRTP = Long-Range Transportation Plan. N/A = Not applicable or available.
PDO = Property damage only. TAZ = Traffic analysis zone. VMT = Vehicle miles traveled.
Sources: 2010 Decennial Census; CTPS.

3.5 Roadway Miles and Lane Miles as Exposure

Roadway miles and lane miles are not typically used as exposure measures as they do not indicate the overall level of travel activity as do other exposure measures. Rather, they provide some information about the risk of the roads in a given area, which reflect, to some degree, the type of road (for example, arterial), traffic volumes, and other design elements of the particular roadways. This kind of analysis could help identify potential characteristics of roads in an area that could affect the number and severity of crashes. Although this shows only an association and not causation, the results could help MPO staff better understand the roadway environment in EJ neighborhoods compared with non-EJ neighborhoods, the safety challenges in those neighborhoods, and identify ways that the MPO could best address them. This kind of analysis, rather than showing just the effects of crashes on roadway users, also adds a spatial dimension and points to the safety of the road environment in the TAZs in which the crashes occur, and therefore the experience of residents who are exposed to the built environment every day. TAZs with a higher rate of crashes per lane or road mile might have more dangerous roads, which would affect residents' quality of life.

Tables 7 and 8 show the number of crashes, injuries, and fatalities for every 10 roadway miles and every 10 lane miles, respectively. The first rows contain the total road/lane miles, which is the denominator for the automobile crashes, while the second rows contain the road/lane miles for roads with either full or partial access—those that permit bicyclist and pedestrian use—which is the denominator for bicyclist and pedestrian crashes. Because these denominators differ, auto crashes cannot be combined with bicyclist and pedestrian crashes; therefore, crash rates are not stated for all crashes.

The results in Table 7 show that, per mile of road, EJ TAZs have more crashes across all crash types. For bicyclist and pedestrian crashes, the crash rate is at least two times those in non-EJ TAZs. This indicates that people driving, walking, or bicycling in EJ TAZs are more likely to be in a crash than those driving, walking, or bicycling in non-EJ TAZs. Especially with regard to pedestrian and bicyclist infrastructure, this may be worth further investigation by the MPO.

Table 7
Crashes, Injuries, and Fatalities per 10 Roadway Miles, 2010–14

	EJ TAZs	Non-EJ TAZs	MPO Region	Ratio of EJ: Non-EJ Crash Rate
Road Miles	2,358.66	10,125.76	12,484.42	N/A
Full and Partial Access Miles	2,205.48	9,472.02	11,677.50	N/A
Fatal Crashes				
Auto[1]	0.44	0.29	0.32	1.51
Pedestrian and Bicyclist[2]	0.29	0.11	0.15	2.66
Injury Crashes				
Auto[1]	63.15	36.57	41.59	1.73
Pedestrian and Bicyclist[2]	15.50	3.88	6.07	4.00
PDO Crashes				
Auto[1]	209.24	121.98	138.47	1.72
Pedestrian and Bicyclist[2]	7.58	1.60	2.73	4.74
All Crashes				
Auto[1]	**272.82**	**158.84**	**180.37**	**1.72**
Pedestrian and Bicyclist[2]	**23.37**	**5.59**	**8.95**	**4.18**

[1]Controlled by total roadway miles. [2]Controlled by roadway miles with full or partial access, on which pedestrians and bicyclists are permitted to travel.
EJ = Environmental justice. N/A = Not applicable or available. PDO = Property damage only. TAZ = Traffic analysis zone. VMT = Vehicle miles traveled.
Sources: 2010 Decennial Census; CTPS.

Similarly, Table 8 shows the number and severity of crashes by mode per 10 lane miles. Analyses of lane miles take into account the number of lanes on a road and the potential danger of a particular road (the more lanes a road has, the faster the cars likely would travel). The results show that across all modes and severity, crashes are more common in EJ TAZs than in non-EJ TAZs. In fact, the ratio between crashes in EJ and non-EJ TAZs is higher than when roadway miles are used as the exposure measure. (Although the crash rates will always be lower with lane miles than with road miles—there are more lane than road miles—the magnitude of the difference between crashes in EJ and non-EJ TAZs expressed with the ratio can be compared across exposure measures.) Crashes in EJ TAZs occur more frequently on roads with more lanes. This is supported by the fact that, as a whole, the percent of freeways, interstates, and arterials make up a greater percentage of total lane miles in EJ TAZs than they do in non-EJ TAZs.

Table 8
Crashes, Injuries, and Fatalities per 10 Lane Miles, 2010–14

	EJ TAZs	**Non-EJ TAZs**	**MPO Region**	**Ratio of EJ: Non-EJ Crash Rate**
Lane Miles	3,758.33	21,896.39	25,654.71	N/A
Full and Partial Access Miles	3,049.68	19,064.21	22,113.89	N/A
Fatal Crashes				
Auto[1]	0.27	0.13	0.15	2.06
Pedestrian and Bicyclist[2]	0.21	0.06	0.08	3.87
Injury Crashes				
Auto[1]	39.63	16.91	20.24	2.34
Pedestrian and Bicyclist[2]	11.21	1.93	3.21	5.82
PDO Crashes				
Auto[1]	131.31	56.41	67.38	2.33
Pedestrian and Bicyclist[2]	5.48	0.79	1.44	6.89
All Crashes				
Auto[1]	**171.22**	**73.45**	**87.78**	**2.33**
Pedestrian and Bicyclist[2]	**16.90**	**2.78**	**4.72**	**6.09**

[1]Controlled by total lane miles. [2]Controlled by lane miles for roads with full or partial access, on which pedestrians and bicyclists are permitted to travel.
EJ = Environmental justice. MPO = Metropolitan planning organization. N/A = Not applicable or available. PDO = Property damage only. TAZ = Traffic analysis zone. VMT = Vehicle miles traveled.
Sources: 2010 Decennial Census; CTPS.

4 DISCUSSION

The above analyses raise questions about why pedestrian and bicyclist crashes are so much more frequent in EJ TAZs, across three out of four exposure measures, than car crashes. It could be that people living in EJ communities bicycle and walk more than those who live in non-EJ communities, or that they are susceptible to crashes because of unsafe behaviors such as not walking on a sidewalk or texting while bicycling—while these behaviors may exist, it is not evident that they are more prevalent in EJ communities—or because of unsafe roadway infrastructure. Underreporting of crashes may also contribute to these differences. While this memo cannot directly answer these questions, we have tried to clarify the extent to which crash rates are higher in EJ TAZs, find the best ways to quantify crash risk, and identify ways that this information could be useful to the MPO.

1. **Auto crashes are less frequent in EJ TAZs than in non-EJ TAZs.**
   This is the case across all exposure measures except lane miles and roadway miles. There may be fewer drivers in EJ TAZs. The trip productions suggest as much, with 66.0 percent of the auto trips produced in non-EJ TAZs compared to 34.0 percent in EJ TAZs—meanwhile, 36.6 percent of the MPO population live in an EJ TAZ and 64.4 percent live in a non-EJ TAZ.

2. **Conversely, pedestrian and bicyclist crashes are relatively more frequent in EJ TAZs than in non-EJ TAZs.**
   Three out of four exposure measures point to relatively more pedestrian and bicyclist crashes in EJ TAZs. This could be explained partly by the fact that 62.7 percent of non-auto trips originated in an EJ TAZ, compared to 37.3 percent in a non-EJ TAZ. (Many EJ TAZs are in urban locations, which may help explain this discrepancy.) That imbalance is supported by the fact that 68.6 percent of EJ TAZs also exceed the MPO's threshold of 15.8 percent for zero-vehicle households. Put another way, 70.1 percent of all TAZs that exceed the zero-vehicle household threshold are also EJ TAZs. It appears that pedestrians and bicyclists are more likely to be found in EJ TAZs.

3. **Overall, fatalities are more frequent in non-EJ TAZs.**
   The ratio of crash rates between EJ and non-EJ TAZs is lower overall for fatalities compared to other crash severities, meaning that there is a higher risk of fatal crashes in non-EJ TAZs than in EJ TAZs. Conversely, the ratios for injury and PDO crashes are higher, indicating that they are relatively more frequent in EJ TAZs.

4. **Combined, the percent of freeways, interstates, and arterials make up a greater percentage of total lane and road miles in EJ TAZs than they do non-EJ TAZs.**
   In the course of this analysis, we found that 27.9 percent of roads in EJ TAZs—and 35.9 percent of lane miles—are freeways, interstates, or arterials. Conversely, local roads make up a higher percentage of non-EJ lane and road miles (66.33 percent and 61.6 percent, respectively) than of EJ lane and road miles (60.6 percent and 53.6 percent, respectively). Arterials—which comprise 23.7 percent of road miles and 27.8 percent of lane miles compared to 18.9 percent and 20.2 percent of non-EJ TAZ road and lane miles—might be particularly problematic for pedestrians and

bicyclists in EJ communities because of arterials' characteristic high speeds. This analysis shed some light on this issue, but it is possible to investigate further—for example, by examining potential safety improvements to alleviate particularly dangerous roads in EJ TAZs.

5 CONCLUSIONS AND FURTHER STUDY

This project looked at 1) the geographic distribution of crashes in the Boston Region MPO, 2) various exposure measures that could be used to develop crash rates for EJ and non-EJ communities, and 3) the benefits and challenges of using each type of exposure measure. As discussed in the previous section, injury and PDO crashes are relatively more frequent in EJ communities, as are pedestrian and bicyclist crashes. Regarding exposure measures, automobile crash rates should be analyzed using vehicle-hours traveled (VHT) or VMT; for bicyclist and pedestrian crash rates, neither VHT nor VMT are available, and so, using trips as a measure is a reasonable alternative.

There are some drawbacks and considerations that could be analyzed further should the outcomes of this project be used going forward. These include:

1. **Identifying EJ populations**
   This analysis was geographic-based, because of its focus on the spatial distribution of crashes across the MPO. As such, it was necessary to divide the region into smaller geographic units—in this case, TAZs. Therefore, identification of EJ and non-EJ populations was based on the percent of the EJ population in each TAZ, regardless of their actual population within TAZs. The MPO is moving away from this method of identifying EJ populations in other analyses, but the nature of this particular analysis requires EJ populations to be identified in this way.

2. **The extent to which roads in EJ communities are used by this population**
   Roadway and lane miles are probably more useful in evaluating effects on residents of TAZs. For VMT, it is not known whether the VMT in an EJ TAZ are actually driven by residents of that TAZ—it is simply all of the miles driven within that TAZ over a five-year period, regardless of where they originate. Conversely, for VHT and trips, these result from trips produced by residents of each TAZ, excluding trips originating in other TAZs. For pedestrian and bicyclist trips, the assumption that these trips are taken by residents of these communities likely would be true; however, this is less probable in Boston and other urban communities where the TAZs are small in area.

3. **Tracking results using base-year results**
   Staff should consider using the results for the base year developed for every LRTP to track crash rates over a five-year period. This would allow staff to get a better idea of the extent to which crashes of various types are more or less frequent in EJ TAZs. These data could be made available from the base year if the CTPS modeling group is notified early in the process of the model runs for the LRTP.

4. **Underreporting of crashes**
   According to previous CTPS analyses of crashes in the MPO region, The City of Boston currently underreports crashes. We do not know if any one type of crash is particularly underreported more than others—for example, pedestrian crashes or crashes in certain neighborhoods. If some crashes are reported more frequently than others, it would affect the results of this analysis.

5. **Further exploration of road characteristics in EJ and non-EJ TAZs**
   Although using the road network is not a traditional source for exposure measures, it does perhaps yield information that is more relevant to the MPO's needs than the other exposure measures examined in this project. Unlike the other exposure measures, lane and road miles relay information about effects of roads on *communities* as opposed to the effects on roadway users. This information could be used in evaluating safety issues for the TIP. In addition, CTPS's road network relates information about the physical characteristics of roads within EJ and non-EJ neighborhoods, which could be associated with crash types and severities.