Impacts of Urban Land Use Development on Pedestrian-Motor Vehicle Collisions: An Application of the San Francisco Pedestrian Injury Model to Five Neighborhood Plans

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Last updated May 2007 by the San Francisco Department of Public Health, Environmental Health Section. For more information, please visit our website at: http://www.sfdph.org/phes/transportation/TR_pedmodel.htm.

A. Summary

San Francisco's non-fatal pedestrian injury rate is 94 per year per 100,000 people - approximately five times above the Healthy People 2010 national objective of no greater than 19 injuries/year/100,000 people.[1,2] The total quantifiable economic costs of reported vehicle pedestrian collision injuries in San Francisco between 2001 and 2005 can be estimated at over $1 billion.

Growth and development in San Francisco have the potential to affect pedestrian collisions by changing traffic volume; by changing pedestrian volumes; or by changing transportation facilities. Increases in the number of vehicle-pedestrian collisions may be a particular consequence of development that increases the number of pedestrians in areas with high traffic. Reducing safety for pedestrians may be counterproductive to the environmental and social objectives of urban infill development, which include reducing air pollution and increasing physical activity through the promotion of walking.[3] Coordination between land use and transportation systems and effective investments to protect pedestrians from vehicle hazards would benefit human and ecological health.

The San Francisco Department of Public Health has developed an area-level model of pedestrian injury collisions to estimate the impacts of growth and development in five neighborhoods on pedestrian injuries. The model, developed using cross-sectional data for the City and County of San Francisco, relates the number of reported collisions resulting in pedestrian injuries within a census tract to traffic volume, population, and roadway and travel characteristics. Applying anticipated changes in traffic volume and resident population due to development to model parameters provides estimates of changes in collisions resulting in pedestrian injury over a five-year period.

Application of the model to development plans for the Rincon Hill Special Use District and four neighborhoods within the Eastern Neighborhoods Community Planning Area suggests that plans will have significant impacts on pedestrian injury collisions in those areas. These impacts appear mediated by the increase in population in areas with known significant pedestrian safety hazards. The predicted increase in collisions injuring pedestrians suggests that a comprehensive area-wide approach to pedestrian safety should be implemented concomitant with the implementation of development plans.

Table 1. Existing Conditions and Estimated Changes in Five Year Pedestrian Injury Counts Resulting from the Implementation of Approved and Proposed Neighborhood Plans

Census Tract Characteristics

Planning Area (N, Census Tracts)	Existing Conditions						Estimated Changes	
	Traffic Volume[b] (CT sum)	Population (CT sum)	Land Area (Sq. miles, CT sum)	Arterial Streets (%, CT median, min-max)	Without Vehicle Access (%, CT median, min-max)	Commuting via walking or public transit (%, CT median, min-max)	Traffic Volume[b] (% increase, CT)	Population[e] (% increase, CT)
San Francisco (N=176)	*212,238*	*776,733*	*46.7*	*16 (0-48)*	*20 (0-90)*	*23 (5-49)*	*na*	*na*
Rincon Hill Mixed Use District (N=1)	4,422	5,408	0.4	10	28	42	3.9%[c]	150%
Eastern SOMA (N=5)[a]	20,550	19,954	2.1	12 (10-31)	28 (26-75)	30 (13-42)	15%[d]	25%
Mission (N=13)[a]	20,307	60,202	1.9	22 (7-34)	30 (20-61)	29 (18-41)	15%[d]	8%
Show Place Square/Potrero Hill (N=9)[a]	27,771	20,984	2.9	16 (0-25)	22 (9-35)	18 (13-38)	15%[d]	39%
Central Waterfront (N=3)[a]	8,682	6,397	2.1	16 (0-21)	22 (15-26)	16 (11-19)	15%[d]	58%
All Eastern Neighborhoods (N=23)[a]	52,602	91,109	6.4	19 (0-34)	28 (9-75)	28 (11-42)	15%[d]	16%

Pedestrian Injury Collisions

Planning Area (N, Census Tracts)	Existing Conditions		Estimated Changes			
	Reported (CT sum)	Predicted (CT sum)	Predicted (CT sum)	*Lower 95% C.I. (CT sum)*	*Upper 95% C.I. (CT sum)*	Predicted % Change in Pedestrian Injury Collisions [f]
San Francisco (N=176)	*4,039*	*4,050*	*na*	*na*	*na*	*na*
Rincon Hill Mixed Use District (N=1)	55	63	174	*109*	*277*	**176%**
Eastern SOMA (N=5)[a]	412	363	436	*331*	*574*	**20%**
Mission (N=13)[a]	460	508	580	*465*	*727*	**14%**
Show Place Square/Potrero Hill (N=9)[a]	252	239	288	*222*	*375*	**21%**
Central Waterfront (N=3)[a]	53	52	64	*50*	*83*	**24%**
All Eastern Neighborhoods (N=23)[a]	940	942	1,104	*864*	*1,414*	**17%**

CT: Census Tract

a These areas were defined based on the boundaries detailed by SF Planning in the map at the following link: http://www.sfgov.org/site/ planning_index.asp?id=25288, and the census tracts used for the *Eastern Neighborhood Rezoning Socioeconomic Impacts* . See the *Impact Analysis* section of this report for more detail regarding the specific census tracts.

b Census Tract, Aggregate Traffic Volumes. See *Impact Analysis* section of this report for more detail.

c Based on intersection level counts in the transportation analysis for the Rincon Hill Mixed Use District Transportation Study.

d Based on the Air Quality Chapter, Eastern Neighborhoods Pre-draft Environmental Impact Report, San Francisco Planning Department, 2007. This estimate will be revised based on the Transportation Analysis in the Draft EIR.

e Population increases for neighborhoods except Rincon Hill based on increased population and housing units projected in Rezoning Option B, as detailed in the draft Eastern Neighborhoods Rezoning and Community Plans, Environmental Setting and Impacts, San Francisco Planning Department, April 2007.

f Predicted % change in pedestrian injury collisions based on model predictions for existing and future pedestrian injury collisions.

B. Background

The Significance of Pedestrian Injuries as a Public Health Problem

Over the past three decades, the United States has slipped from being a world leader in traffic safety to 13th place as measured by the number of traffic deaths per million vehicles.[4] Motor vehicle traffic accidents are a major cause of morbidity and mortality in the United States,[5] and the greatest cause of disability and death for persons aged 5-27.[6] Nationally, for people aged one to 40, traffic injuries are the single greatest cause of disability and death. Over 42,000 people have died on US roads since 2002. Fatal and non-fatal traffic accident injuries also cause a serious economic burden, with an estimated cost of $24.8 billion in 2004.[7]

In 2005, of the 39,000 people who died in motor vehicle accidents, approximately 12% were pedestrians.[8] Pedestrian collisions have indirect public health and environmental consequences as well. Unsafe streets are a primary barrier to walking behavior. Increasing pedestrian safety helps to prevent obesity and limit the burden of chronic diseases associated with lack of exercise. Pedestrian safety is also necessary to reduce the harmful impacts of vehicle trips on air and noise pollution and energy consumption.[9,10]

Environmental Causes of Pedestrian Injuries

Pedestrian injury research has increasingly recognized the potential impact of environmental, socio-demographic, and transportation network characteristics on pedestrian injury collisions. Research shows that after adjusting for physical environmental determinants, traffic volume is a significant predictor of pedestrian injury collisions,[11,12,13,14] while injury severity is largely determined by vehicle speed.[15,16] The magnitude of effect of vehicle volume on injuries is significant. For example, a study of nine intersections in Boston's Chinatown, researchers calculated an increase in 3-5 injuries per year for each increase in 1000 vehicles.[17]

Studies have also found that area-level pedestrian volumes predict the frequency of pedestrian-vehicle collisions.[18,19] At the same time, there appears to be a protective effect of increasing pedestrian volumes on the risk of collisions for an individual pedestrian.[20]

Vehicle speeds predict both the frequency as well as the severity of pedestrian injuries.[21] Below 20mph the probability of serious injury or fatal injury is generally less than 20%; this proportion rapidly increases with increasing speed and above 35mph, most injuries are fatal or incapacitating.

Other roadway characteristics associated with pedestrian injuries include intersection design and street type (e.g. residential, freeway, arterial).[22,23] For example, a national multi-city study found that crosswalks at locations without traffic signals were a significant hazard for pedestrians on high traffic and multi-lane roads.[24]

Sensitive Subpopulations

Socio-demographic characteristics of a place can also increase risk of pedestrian injuries. Age is an established independent risk factor for pedestrian injury. The elderly and children take longer to cross a street, increasing their exposure for injury;[25] children also have less developed cognitive, perceptual, motor and traffic safety skills.[26] Further, collisions involving pedestrians over age 65 versus younger pedestrians are more likely to result in fatal injuries.[27] Lower income children have also been found to have a higher rate of pedestrian injury than higher income children, though the mechanisms contributing to this disparity – including the physical and social environment – are not well understood.[28,29,30]

Impacts of Growth and Development on Pedestrian Collisions

Growth and development in existing urban locations can increase pedestrian collisions in three primary ways: by increasing traffic volume; by increasing pedestrian volumes; or by altering transportation facilities in a way that increase the likelihood of collision. Pedestrian hazards, real or perceived, can be counterproductive to the needs of sustainable transportation goals of reducing noise and air pollution and increasing physical activity if development creates barriers to walking.[31]

Between now and 2030, residential and job growth is expected to increase vehicle trips to, from, and within San Francisco by 12% to 5 million trips per day.[32] Of these, 3.3 million trips will be internal to San Francisco and trips via automobile are expected to grow by almost 10% to over 3 million trips per day. Both the significant projected growth in vehicle trips and the expected growth in population will occur in areas with already high levels of roadway vehicle volume, underscoring the need to protect pedestrians and other active forms of transportation in the context of sustainable urban planning.

Pedestrian Safety Analysis and the California Environmental Quality Act

There are diverse processes that involve transportation planning in San Francisco, including neighborhood plans, zoning, congestion management plans, transportation facilities plans, and pedestrian plans. With regards to impacts on pedestrian collision hazards, the California Environmental Quality Act (CEQA) requires that decision-making agencies produce environmental impact reports (EIRs) for all discretionary public policy decisions with potential significant adverse environmental effects.

Environmental effects that may result in a potential significant adverse human impact due to environmental changes are specifically triggers for an EIR. However, analysis of pedestrian hazards within the typical EIR in California is limited to non-existent. Occasionally, an EIR will recognize the impacts of development on pedestrian—vehicle conflicts or provide a qualitative judgment about a new physical hazards or a proposed countermeasure. Analysis in the EIR usually does not include an assessment of the existing conditions and causes of pedestrian injuries or a quantitative estimate of the effects of the project on pedestrian injuries.

The lack of analysis of pedestrian collisions is not due to a lack of available methods. Existing software tools to evaluate area-level pedestrian injuries potentially applicable to Environmental Impact Assessment (EIA) include the Pedestrian and Bicycle Crash Analysis Tool and Crossroads.[33,34] These tools help identify crash patterns and their causes and then link causes to potential mitigation strategies. Zonal analysis is another method that helps planners identify and target areas with high densities of pedestrian injuries.[35]

Under CEQA, local jurisdictions have the ability and responsibility to develop and use comprehensive and locally relevant indicators and standards and methods for environmental impact assessment. Forecasting the impacts of transportation and land use development projects on pedestrian injuries would complement other available or proposed methods for transportation analysis within EIA. To be useful in the context of EIA, a pedestrian injury forecasting tool would need to be simple to use, based on available or routinely produced inputs, provide meaningful, interpretable, and robust estimates, and be applicable in diverse areas. The existing research discussed below suggests that such forecasting models could be readily developed and applied.

Analytic Models of Pedestrian Collisions

Transportation engineers have developed collision prediction models to understand the causes and consequences of traffic accidents.[36] These models primarily focus on predicting motor vehicle-motor vehicle crashes at the micro-environmental level (e.g., specific intersections or road segments). These models inform targeted traffic safety interventions for "hot spots" with pre-existing high accident rates.[37]

Micro-environmental analytic tools provide only a limited lens on the causes of pedestrian collisions. Pedestrian collisions tend to be dispersed throughout urban areas with the majority not associated with intersection "hot spots".[38, 39] Thus, macro-environmental level accident prediction models are a necessary compliment to inform pro-active area-wide community transportation safety planning, potentially reducing the need for micro-level traffic safety mitigation measures.[40]

At the macro-environmental level, increases in road facility vehicle volume increase the probability of pedestrian-vehicle conflicts.[41] This relationship holds unless there is a concurrent change in pedestrian volume or pedestrian behavior or if new design elements are introduced to reduce pedestrian-vehicle conflicts or hazards (e.g. traffic calming).

A simple way to forecast pedestrian collisions resulting from changes in vehicle volume is to apply changes in vehicle volume to a *road safety function*, which describes the relationship between traffic volume and injury rates or collision counts. The following power function (1.1) is a commonly used, empirically supported parametric form of the road safety function:

$$\%\ \text{Change Pedestrian Collisions} = [(\text{Future AADT}/\text{Baseline AADT})^{\beta} - 1] \times 100 \qquad (\mathbf{1.1})$$

AADT = Average Annual Daily Trips

In the equation, typically $\beta<1$, and empirical evidence suggests that 0.5 is a reasonable parameter.[42] With $\beta=0.5$, the rate of pedestrian collisions would be forecasted to increase proportional to the square root of vehicle volume with the increase in collisions attenuated at higher vehicle volumes. Thus, a 50% increase in traffic volume would translate into an approximately 22% increase in the number of pedestrian collisions, assuming that there is no confounding by other environmental changes. To forecast pedestrian collisions prospectively using the power function model requires two data inputs: the baseline and future vehicle volume on roadways in the area. A fundamental limit of the power function is that it does not take into account pedestrian activity and other variables affected by development.

An alternative approach to predicting change in pedestrian collisions is to develop a context-specific prediction model that takes into account local traffic volume and injury data and additional environmental determinants of pedestrian collisions. Some transportation researchers in the United States and Canada have modeled motor vehicle crashes at an area-level using negative binomial regression methods, aggregate variables and linked datasets.[43,44,45] Positive associations between collisions and traffic volume/VMT, population density, road network, and area-level socio-demographic characteristics have been consistently significant in these macro-level models.

The existing area-level models group pedestrian collisions with all motor vehicle collisions. However, these two outcomes may have different determinants, and macro-level *pedestrian* collision models that separately evaluate this outcome are needed.

C. Pedestrian Injuries in San Francisco and the Eastern Neighborhoods

Pedestrian injuries are a serious public safety problem in San Francisco.[46] Pedestrians accounted for 49% of traffic deaths in San Francisco in 2001. [47,48] In 2005, the MTA estimated there were 699 non-fatal and 14 fatal pedestrian injuries in San Francisco.[49] While overall rates of pedestrian fatalities have declined, the proportion motor vehicle fatalities that are pedestrians is still extremely high compared with the rest of the country. [50] Explanations for the relatively high injury rate in San Francisco include a relatively high pedestrian volume, including a higher proportion of residents walking to destinations, a daily influx of workers, and San Francisco tourists.

Based on 2005 U.S. Census Bureau population estimates[51] and Statewide Integrated Traffic Records System (SWITRS) injury data,[52] San Francisco's non-fatal injury rate is 94 per year per 100,000 people - approximately five times above the Healthy People 2010 national objective of no greater than 19 injuries/year/100,000 people. The fatal injury rate for San Francisco was 1.9 deaths/year/100,000 people, almost twice the national objective. [53]

An analysis based on police records for a five-year period (July 1996 through June 2001), determined a similar lower-bound estimate of 4,791 collisions reported in San Francisco involved pedestrians, or about 2.6 collisions per day. In that analysis, the distribution of injured pedestrians by age and gender were similar to the city population, with 10 percent of injuries among children under age 15 and about 13 percent among adults ages 65 and older.

Among pedestrians involved in reported collisions, almost 3 percent were killed, 10 percent had severe injury, 38 percent had visible injury, and virtually all the rest complained of pain. Only 1.5 percent had no injury. Just over half of the Primary Collision Factors (PCFs) were driver factors, and most of these were driver violations of pedestrian right-of-way, followed by excess driving speed. [54]

As discussed above, zone analysis is an established method for planners to identify and evaluate existing local areas with high densities of pedestrian injuries. [55] The *PedSafe* analysis conducted by the San Francisco Metropolitan Transportation Authority in 2003 used this method to identify neighborhoods and intersections that had a high “injury density” (i.e., a large concentration of pedestrian-injury collisions in a relatively small geographic area). [56] This analysis involved mapping 12,557 reported pedestrian-injury collisions by severity that occurred in the city from January 1990 to May 2001.

In the *PedSafe* analysis, visual inspection of the mapped data identified 20 areas of the city, both street segments and geographic areas (see Figure 1, below), that had high densities of pedestrian-injury collisions. Injuries were highly concentrated in (i) the greater downtown area and (ii) along major arterials in the rest of the City. Researchers then calculated injury density for each of the candidate zones (See Table 2, below). For street segments, the injury density of pedestrian injury collisions per roadway mile was calculated by dividing the percentage of total injuries represented by the segment divided by the percentage of the total street length represented by the segment. For areas, the injury density of pedestrian injury collisions per square mile was calculated by dividing the percentage of total injuries represented by the area divided by the percentage of total surface area of the city represented by the area. In both cases (street segments and areas), the injury density was calculated separately for total injuries and for an injury score, in which severe and fatal injuries each received 3 points and the complaint of pain or visible injury received 1 point.

Pedsafe identified a number of specific neighborhoods or planning areas as having relatively higher densities of pedestrian injuries. For example Western SOMA contained 5.7% of the City’s pedestrian injuries but only 0.93% of the City’s area. Injury density was similarly high for the Eastern portions of SOMA, the Mission District, the Western Addition, Downtown, and the Tenderloin and Civic Center area. In *Pedsafe* analysis, injury density appeared to be associated with pedestrian and traffic volumes. Vehicle speeds did not appear to be strongly related to injury density.

Table 2. *PedSafe* Analysis

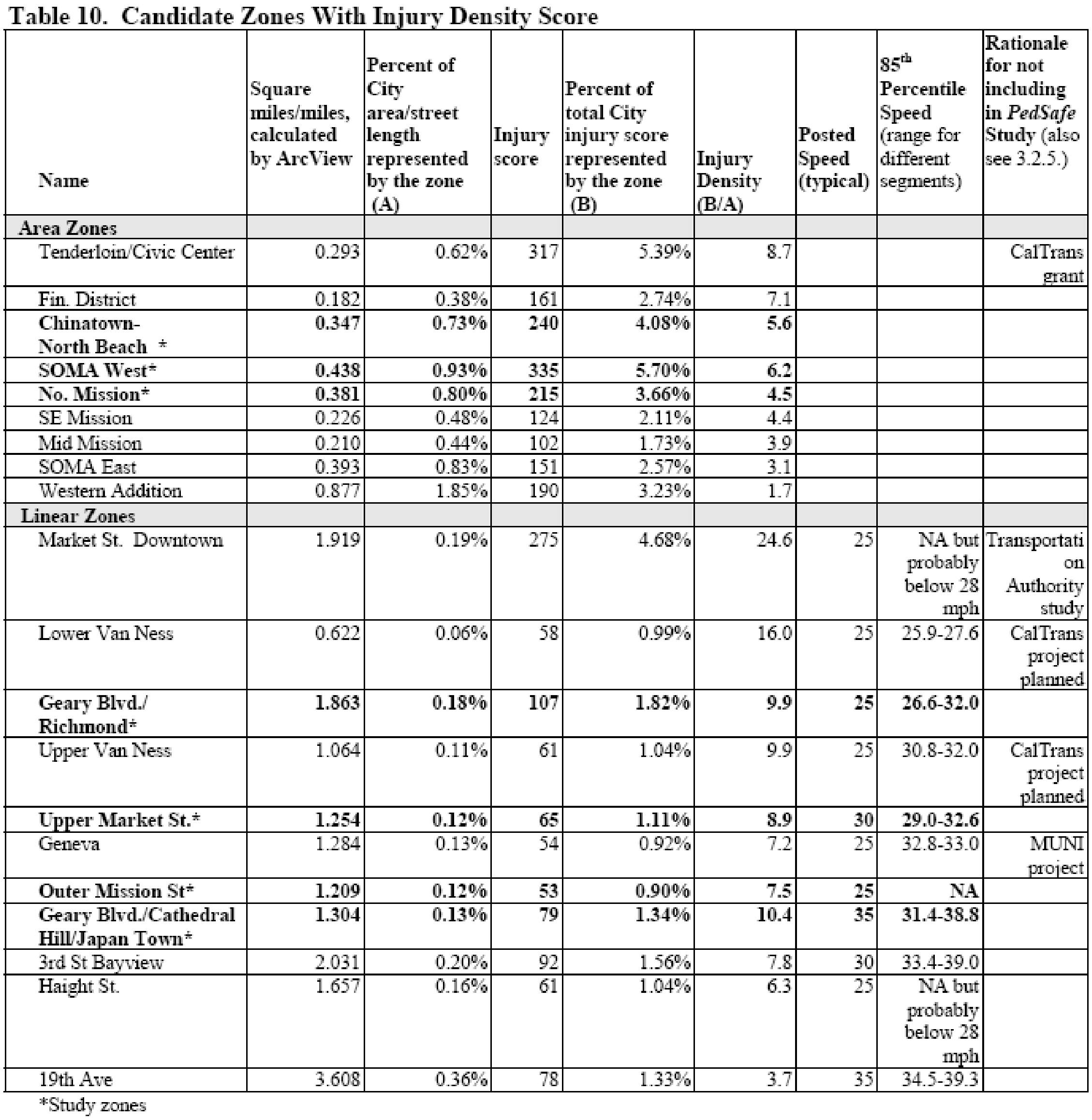
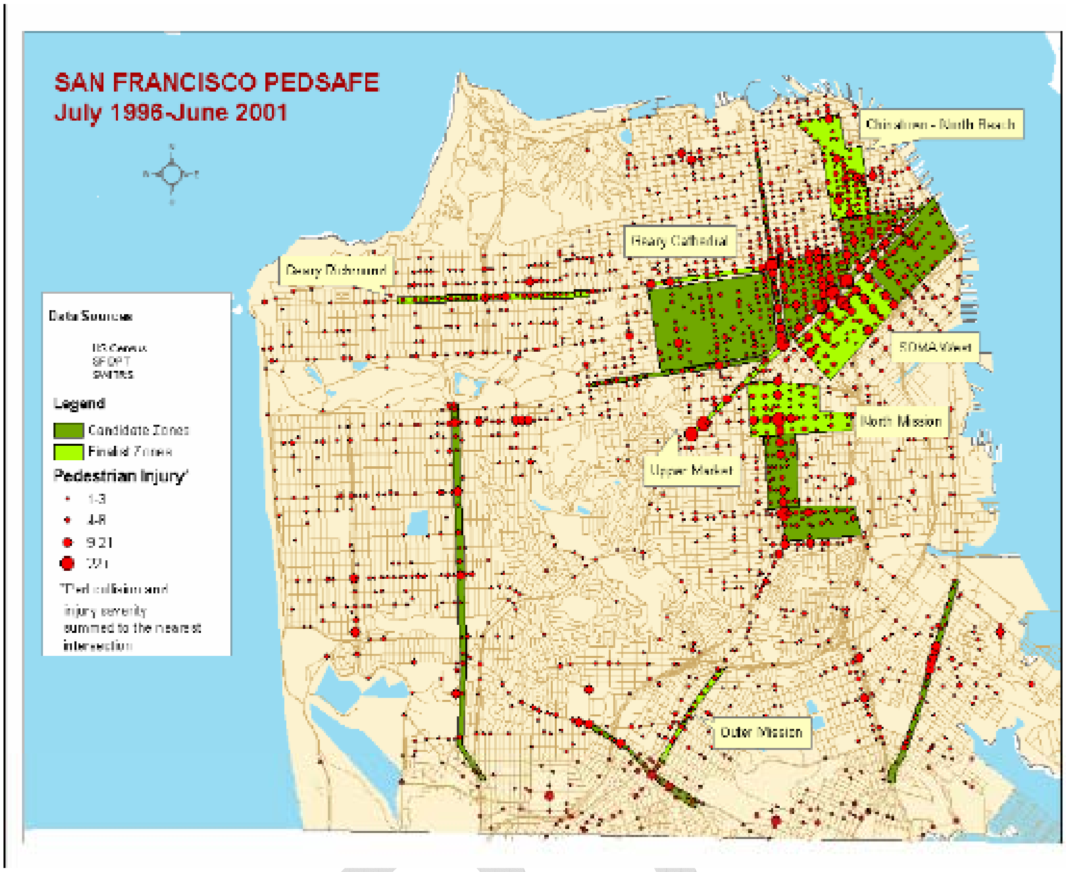


Table 10. Candidate Zones With Injury Density Score

Name	Square miles/miles, calculated by ArcView	Percent of City area/street length represented by the zone (A)	Injury score	Percent of total City injury score represented by the zone (B)	Injury Density (B/A)	Posted Speed (typical)	85^{th} Percentile Speed (range for different segments)	Rationale for not including in *PedSafe* Study (also see 3.2.5.)
Area Zones								
Tenderloin/Civic Center	0.293	0.62%	317	5.39%	8.7			CalTrans grant
Fin. District	0.182	0.38%	161	2.74%	7.1			
Chinatown-North Beach *	**0.347**	**0.73%**	**240**	**4.08%**	**5.6**			
SOMA West*	**0.438**	**0.93%**	**335**	**5.70%**	**6.2**			
No. Mission*	**0.381**	**0.80%**	**215**	**3.66%**	**4.5**			
SE Mission	0.226	0.48%	124	2.11%	4.4			
Mid Mission	0.210	0.44%	102	1.73%	3.9			
SOMA East	0.393	0.83%	151	2.57%	3.1			
Western Addition	0.877	1.85%	190	3.23%	1.7			
Linear Zones								
Market St. Downtown	1.919	0.19%	275	4.68%	24.6	25	NA but probably below 28 mph	Transportation Authority study
Lower Van Ness	0.622	0.06%	58	0.99%	16.0	25	25.9-27.6	CalTrans project planned
Geary Blvd./ Richmond*	**1.863**	**0.18%**	**107**	**1.82%**	**9.9**	**25**	**26.6-32.0**	
Upper Van Ness	1.064	0.11%	61	1.04%	9.9	25	30.8-32.0	CalTrans project planned
Upper Market St.*	**1.254**	**0.12%**	**65**	**1.11%**	**8.9**	**30**	**29.0-32.6**	
Geneva	1.284	0.13%	54	0.92%	7.2	25	32.8-33.0	MUNI project
Outer Mission St*	**1.209**	**0.12%**	**53**	**0.90%**	**7.5**	**25**	**NA**	
Geary Blvd./Cathedral Hill/Japan Town*	**1.304**	**0.13%**	**79**	**1.34%**	**10.4**	**35**	**31.4-38.8**	
3rd St Bayview	2.031	0.20%	92	1.56%	7.8	30	33.4-39.0	
Haight St.	1.657	0.16%	61	1.04%	6.3	25	NA but probably below 28 mph	
19th Ave	3.608	0.36%	78	1.33%	3.7	35	34.5-39.3	

*Study zones

Figure 1. ***PedSafe*** **Map**



Economic Impacts of Vehicle-Pedestrian Collision Injuries in San Francisco

Vehicle collisions with pedestrians have significant economic costs beyond their physical toll on victims. A recent analysis of California data concludes that in 1999 economic costs resulting from 5,634 fatal and non-fatal vehicle injuries to pedestrians resulted in over $3.9 billion in direct and indirect costs ($692,000 per injury). California Highway Patrol estimates of the economic costs of pedestrian injuries and fatalities in San Francisco from 2001-2005, disaggregated by injury severity, are provided in Table 3.[57] The total quantifiable economic costs of reported vehicle pedestrian collision injuries in San Francisco between 2001 and 2005 can be estimated at over $1 billion.

Table 3. Estimated Economic Costs of Vehicle-Pedestrian Collision Injuries in San Francisco

Pedestrian Injury Severity	Cost per Injury	San Francisco Pedestrian Injuries (2001-2005)	Economic Impact (2001-2005)
Fatal Injury	$ 2,709,000	167	$452,403,000
Severe Injury	$ 180,000	807	$145,260,000
Visible Injury	$ 38,000	5,062	$192,356,000
Complaint of Pain	$ 20,000	11, 599	$231,980,000
Total	***na***	***17,635***	***$1,021,999,000***

D. Impact Analysis

Significance Thresholds for Environmental Impact Analysis

Environmental effects that may result in a potential significant adverse human impact resulting from environmental changes are specifically triggers for an EIR. With regards to pedestrian safety, the City and County of San Francisco determines that a project would have a significant effect on the environment if it would *create potentially hazardous conditions for pedestrians*.

Under CEQA, local jurisdictions have the ability and responsibility to develop local indicators and standards for environmental impact assessment that meet the needs and priorities of their localities. San Francisco does not have a published quantitative threshold with which to evaluate pedestrian safety significance; however, the US Department of Health and Human Services (USDHHS) has established national pubic health objectives for the **rate of injuries in a population**.[58] USDHHS defines the **injury rate** as ***the number of injuries per unit time in a population of a standard size*** (e.g., injuries per year per 100,000 people) and established the following national target for the year 2010:

Unintentional injury prevention

- A rate of non-fatal vehicle injuries to pedestrians no greater than 19 injuries per year per 100,000 people.
- A rate of fatal vehicle injuries to pedestrians no greater than 1 injury per year per 100,000 people.

The rate of pedestrian injuries in San Francisco is currently about 100 per 100,000 or approximately 5 times the national public health objective.

Methodology: The San Francisco Pedestrian Collision Model

Analysis of pedestrian safety impacts in the context of growth and development involves predicting how demographic, traffic, and built environment characteristics affect pedestrian-vehicle conflicts, hazards and injuries. Zonal analysis as discussed above can identify areas with high densities of pedestrian injuries, and along with field evaluation may be able to identify micro-environmental characteristics contributing to pedestrian collisions and mitigating strategies. However, zonal analysis is not a predictive tool to estimate changes in pedestrian injury potentially associated with growth and development; furthermore, the majority of injuries do not occur at intersection “hot spots,” but are dispersed throughout the city.

As discussed above, area-level analysis is required to evaluate the effects of macro-environmental characteristics on pedestrian injuries. Area-level pedestrian injury forecasting models can be readily developed and applied with existing data. Multivariate modeling techniques have allowed traffic safety researchers to estimate the influence of predictor variables on response variables taking into account variation in other environmental characteristics. For example, multiple studies, cited above, used multi-variate modeling techniques to estimate the effect of vehicle volume on injuries independent of other factors.

The San Francisco Department of Public Health developed an area-level cross-sectional model of pedestrian injury collisions in San Francisco, aggregating data at the census tract level. The method for the development of the model is described a separate report.[59] Briefly, researchers geocoded 99% of San Francisco’s pedestrian-involved collisions, reported between 2001-2005 to the Statewide Integrated Traffic Records System (SWITRS),[60] to census tracts and excluded collisions with the extent of damage reported as “Property Damage Only” (i.e., non-injury collisions).[61] Candidate independent variables were identified based on the empirical pedestrian injury research and environmental factors known to be influenced by land use development.

Street segment average daily traffic volume and street length and type data came from a dataset developed by researchers at the San Francisco Department of Public Health and the University of California-Berkeley. This data set includes direct measures of daily traffic counts for approximately 20% of San Francisco’s street segments along with traffic counts imputed based on the average traffic count for the street type within each planning neighborhood. We determined the number of intersections in each census tract using a spatial join with intersection, node, and street CNN data provided by the city of San Francisco.[62] We also obtained census-tract level aggregate variables on vehicle access, commuting behaviors, and demographic characteristics from the U.S. Census 2000 database, Summary Files 1 and 3 and the Census Transportation Planning Package 2000.[63]

We used Negative Binomial regression to model pedestrian injury collisions using continuous, census-tract level aggregate variables.[64,65] Based on previous research findings, the model employed a natural log transformation of the traffic volume and commuting (a proxy for pedestrian volume) variables (1.2). The model form used for our analyses is as follows.

$$E(PI)=\exp(b_0 + b_v(\ln(X_v)) + b_p(\ln(X_p)) + \sum b_i X_i) \quad \textit{equal to} \quad E(PI)=\exp(b_0 + \sum b_i X_i) * X_v^{\,bv} * X_p^{\,bp} \qquad \textbf{(1.2)}$$

$E(PI)$ = predicted pedestrian injury collisions per census tract
b_0 = intercept
b_v = model coefficient for 1-unit change in traffic volume variable
X_v = census tract aggregate traffic volume
b_p = model coefficient for 1-unit change in proportion of residents commuting via walking or public transit
X_p = census tract proportion of residents commuting via walking or public transit
b_i = model coefficient for 1-unit change in predictor variable i
X_i = census tract aggregate data, predictor variable i

The final model included the following six significant variables: log traffic volume, resident population, proportion of occupied housing units without vehicle access, log proportion of population walking or taking public transportation to work, proportion of streets that are arterial (without Muni transit service), and land area. With the exception of land area, all model variables had a positive association with pedestrian injury collisions***.***

Model Parameters: San Francisco Pedestrian Injury Model for Census Tracts (N=176)

Census Tract-Level Variable	Coefficient	SE	p-value
(log) traffic volume (N)	0.687	0.070	<0.001
arterial streets (%)	0.016	0.004	<0.001
land area (N, sq. miles)	-0.340	0.180	0.059
no vehicle access (%)	0.019	0.003	<0.001
(log) walk/public transportation to work (%)	0.398	0.102	<0.001
population (N)	.0000993	0.000	<0.001
constant (intercept)	-4.218	0.536	<0.001

The model explained a significant portion of the variation in census tract pedestrian injury collisions (Pearson R^2 and the R_α^2 values were 74% and 73%, respectively).

Holding all independent variables except vehicle volume constant the model is equivalent to a power function with β=0.687; holding all independent variables except proportion of residents commuting via walking or taking public transit is equivalent to a power function with β=0.398. Therefore, a 15% increase in census tract traffic volume is associated with a 10% increase in pedestrian injury collisions ((1.15^0.687) -1 = 10%). Similarly, a 15% increase in the proportion of people walking or taking public transportation to work (e.g. from 10% to 11.5%) predicts an approximately 6% increase in pedestrian injury collisions ((1.15^0.398) -1 = 6%). Due to the natural log transformation of these predictor variables, these estimated percentage changes are consistent across the range of vehicle volume and commuter variable values.

The remaining independent variable model coefficients estimate the change in the log count of pedestrian injury collisions. In terms of the proportion of arterial streets, a five-unit increase in the proportion of street length in a census tract to an arterial (non-muni) street is associated with an approximately 8% change in pedestrian injury collisions (exp(0.016*5) = 8%). Similarly, a 5-unit increase in the proportion of housing units without vehicle access is associated with an approximately 10% increase in pedestrian injury collisions (exp(0.019*5) = 10%), while an increase in resident population of 500 people would result in an approximately (exp(500* .0000993) = 5.1% increase in pedestrian injury collisions.

Neighborhood Plans Analyzed

The analysis focuses on five neighborhood plans, the Rincon Hill Special Use District and four adjacent planning areas in the Eastern Neighborhoods Rezoning Plan. The Rincon Hill Plan approved by the San Francisco Board of Supervisors in 2006 provides a blueprint for a new residential neighborhood (The Rincon Hill Mixed Use District) south of the Financial District. Residential development will include 3,675 units of new housing along with retail shops and neighborhood services. Details about the Rincon Hill Plan can be obtained at the San Francisco Planning Department website at http://www.sfgov.org/site/planning_index.asp.

The Eastern Neighborhoods Community Planning Process began in January 2002 to respond to conflicts between competing land uses in the Mission, SoMa, Showplace Square/Potrero, and Bayview/Hunters Point. The initial goal was to develop new zoning controls for the industrially-zoned land in these neighborhoods. However, since it became clear that any rezoning option would transform formerly industrial lands into new residential uses, the department initiated place-making that suggests new or modified area plans that address urban design, open space, transportation, housing and community facilities. The EIR is now underway and is expected to be completed in October 2007. Details about these plans can be obtained at the San Francisco Planning Department website at http://www.sfgov.org/site/planning_index.asp.

Model Application

Forecasting planning-related pedestrian injuries associated with these plans using the San Francisco Pedestrian Injury Model involves estimating changes in the Pedestrian Injury Model parameters associated with each plan and then applying those changes to the Model to forecast the change in pedestrian injuries.

Census tracts included in the analysis for the respective planning areas are as follows, based on the boundaries detailed by the San Francisco Planning Department. [66] [67]

Plan Area (n, census tracts)	Census Tract Numbers
Rincon Hill (n=1)	179.01
Eastern SOMA (n=5)	176.01, 178, 179.01, 180, 607
Mission (n=13)	177, 201, 202, 207, 208, 209, 210, 228.01, 228.02, 228.03, 229.01, 229.02, 229.03
Show Place Square/Potrero Hill (n=9)	177, 180, 226, 227.01, 227.02, 227.03, 228.02, 229.03, 607
Central Waterfront (n=3):	226, 227.03, 609

For this application, we assumed conditions related to land area, proportion of streets that are arterial, proportion of housing units with vehicle access, and proportion of residents commuting via walking or public transit would remain the same.

For the analysis of the Rincon Hill Plan, we estimated that the 3,675 new residential units in the plan would add 8,085 new residents (estimated at 2.2 residents/unit, San Francisco's average household size). For project-related traffic volume, we used the estimated *cumulative* increase of 36.4% in Weekday PM Peak traffic volume from 2000-2020 from the Rincon Hill Mixed Use District Transportation Study, based on 17 studied area intersections.[68] We also assumed that the traffic volume changes on roadways not studied in traffic analysis are approximately ½ of the average of volume change of studied intersections in the census tract.

For the analyses of Eastern Neighborhood plans, we used the estimated change in resident population as projected in Rezoning Option B and detailed in the April 2007 draft *Eastern Neighborhoods Rezoning and Community Plans, Environmental Setting and Impacts, Population, Housing, Business Activity, and Employment* analysis from the San Francisco Planning Department.[69] The number of new residents added to each census tract was calculated based on the proportion of land area that the census tract contributed to the neighborhood area, based on the aforementioned boundaries. As noted above, some census tracts had land area included in more than one neighborhood. The estimated population included in the analyses for those census tracts is an aggregate of the estimated increase in population for all neighborhoods included in the Eastern Neighborhoods Rezoning (see Table 1, Existing Conditions and Estimated Changes). We estimated a 15% increase in planning area traffic volumes based on communication with the Planning Department.

Based on our census tract level analysis, San Francisco's Eastern Neighborhoods account for approximately 12% of the city's residential population, but almost one-quarter of the city's pedestrian injury collisions occur in their boundaries (Table 1). Relative to the city, the area has among the highest daily vehicle volumes. Compared with the city median, more residents of the Eastern Neighborhoods census tracts are working outside the home and walk or take public transit to work, or do not have access to a vehicle.

The plans, by design, are expected to produce both a modest increase in local area traffic volume and an more substantial increase in the resident population (and therefore pedestrian activity). (Table 1) Not surprisingly, the model predicts, based on expected changes area traffic volume and residential, that the implementation of approved or proposed neighborhood plans will result in increases in 5-year pedestrian injury collision totals – ranging from approximately 14% in the Mission to 176% in Rincon Hill. Overall, the model predicts total collisions will increase by approximately 17% in the Eastern Neighborhoods – over 30 additional people hit by a motor vehicle while walking on those San Francisco streets each year.

We can use the predicted percent increase in pedestrian injury collision frequency to predict future area and city-wide population *rates* of pedestrian injury collisions (Table 4). Under current conditions, all neighborhoods affected by neighborhood plans currently have high annual population-based rates of pedestrian injury collisions (ranging from 166/100,000 in the Central Waterfront area to 413/100,000 in the Eastern SoMa neighborhood – compared to a much lower city-wide rate of 104/100,000). Based on the model forecasts, Eastern SoMa, Showplace Square/Potrero Hill, and the Central Waterfront would anticipate decrease population-based rates. Rincon Hill, the Mission, as well as the Eastern Neighborhoods, collectively, would expect increased area rates. At a citywide level, the model results predict that implementation of the plans results in a modest increase in the overall pedestrian injury collision rate in San Francisco. The difference in the effects on area and city population rates results from the high current rates of pedestrian injury collisions in the areas proposed for development and the non-linear effects of population increases.

These applications of the model did not account for planned or proposed changes in traffic facilities or the implementation of pedestrian safety countermeasures. Current plans for the area do not include significant approved changes to traffic circulation. Pedestrian friendly design elements are anticipated but specific features are not yet determined. Future, proposed or planned transportation facility changes may mitigate estimated impacts.

Table 4. Existing and predicted future pedestrian injury collision rates by planning area and San Francisco city-wide impact

	Area-level Pedestrian Injury Collision Rates		**San Francisco City-Wide Pedestrian Injury Collision Rate**
Planning Area	**Existing (Reported, Actual) [b]**	**Future (Predicted) [c]**	**Future (Predicted) CITY-WIDE [d,e] with Planning Area Change**
San Francisco	***104***	***na***	***na***
Rincon Hill Mixed Use District	203	225	105
Eastern SOMA[a]	413	396	105
Mission[a]	153	162	105
Show Place Square/Potrero Hill[a]	240	209	104
Central Waterfront[a]	166	130	104
All Eastern Neighborhoods[a]	206	209	106

a These areas were defined based on the boundaries detailed by SF Planning in the map at the following link: http://www.sfgov.org/site/planning_index.asp?id=25288. See the *Impact Analysis* section of this report for further details regarding the specific census tracts.

b Annual rate per 100,000 residents, based on 2001-2005 SWITRS pedestrian injury collision data and 2000 U.S. Census population data.

c Future (predicted) rates based on existing (actual) pedestrian injury collisions as well as population increases and predicted percent change in pedestrian injury collisions as detailed in Table 1.

d Population increases for neighborhoods except Rincon Hill based on increased population and housing units projected in Rezoning Option B, as detailed in the draft Eastern Neighborhoods Rezoning and Community Plans, Environmental Setting and Impacts, San Francisco Planning Department, April 2007.

e Predicted rate based on estimated population increases and estimated % increase in number of collisions as detailed in Table 1.

Evaluation of Significance

Based on the analysis and significance criteria described above, this analysis would judge the impacts of neighborhood plans on pedestrian hazards to be significant for the following reasons:

1. The rate of pedestrian injuries in San Francisco is already 5 times the USDHHS standards.
2. New proposed residential development will occur in areas with existing high numbers of pedestrian injury collisions.
3. Application of the San Francisco Pedestrian Injury Forecasting model estimates an increase in pedestrian injury collisions (Table 1, Table 4).
4. Cumulatively, based on this applied analysis, plans will increase the overall pedestrian injury rate in San Francisco (see Table 4).

E. Caveats on Interpreting Model Results

General Caveats on the use of Predictive Models

The application of all empirically or experimentally derived analytic models to real world predictions assumes the condition of *ceteris paribus*, or "all other things being equal." Predictions, or equivalently statements about cause and effect, are qualified by this assumption in order to acknowledge that a model may not account for unmeasured but influential variables and, furthermore, that relationships among variables may change over time. Similarly, the San Francisco Pedestrian Injury Forecasting model cannot fully account for the complex dynamics between physical and social environments that are likely to affect the frequency of pedestrian-vehicle collisions. For example, the growth in the population in areas with traffic hazards might lead to new political demands for action to improve transportation facilities or to re-route thru traffic in order to mitigate injury risks. Similarly, development of new residential uses may lead indirectly, because of conflicts, to a displacement of businesses to non-residential areas elsewhere in the city or region thus reducing both traffic and related pedestrian activity. In our case, the purpose of such an analytic model is not to anticipate the future precisely, but to alert decision makers about important evidence-based relationships in order to prevent impacts through timely action.

Inferences apply to Area Level Collision Frequencies not Individual Collisions

The San Francisco Pedestrian Injury Model describes the relationship among environmental and aggregate variables and the number of pedestrian injury collisions in census tracts. In applying and interpreting our area-level pedestrian injury collision model, we make inferences only at the area level; no causal inferences are made at the level of the individual.

Accounting for non-linear effects of pedestrian volume and vehicle volume

In general, the effect of increasing pedestrian and vehicle volume on pedestrian-vehicle collision frequency is not linear. For example, pedestrian collision frequencies are roughly proportional to the square root of vehicle volume, indicating that the rate of collisions per pedestrian declines with greater volumes of pedestrians.[70] As discussed above, one plausible explanation is that higher volumes of pedestrians may result in more attention and caution by drivers leading to a reduction in the individual risks. In our model, we use a logarithmic transformation of both the vehicle volume and proportion of residents walking or taking public transit to work variables to account for such non-linear effects, as done by previous researchers.

The Use of Collision Frequencies versus Population-based Collision Rates

The San Francisco Pedestrian Injury Model predicts the frequency (count) of pedestrian-vehicle collisions in each census tract based on changes in population size and other “exposure” variables including traffic volume, land area, proportion of residents that walk or take public transit to work, proportion of streets that are arterial, and proportion of residents that do not own a vehicle. We chose the count measure as the model’s dependent variable because it is a clear and interpretable measure of an adverse health outcome. Collision counts are appropriate measures for rare health outcomes in environmental and spatial epidemiology, and the frequencies of collisions in census tracts provides insight into the distribution and burden of injury.

The San Francisco Pedestrian Injury model intentionally does not predict the population rate of pedestrian-vehicle collisions directly as the population variable is an independent exposure variable in the model. Using population as denominators in constructing the dependent variable in the model would be inconsistent with the goal of understanding the relationship between the future population and vehicle-pedestrian collision frequency.

Collision frequencies can easily be translated into population-based rates if needed and also into economic impacts (e.g., Tables 3 and 4). Our analytic findings also include effects on neighborhood and city population-based rates, in the interest of comparison with current conditions, other studies and USDHHS Healthy People 2010 objectives. It is noteworthy, however, that the resident population not necessarily a complete representation of the “population at risk,” limiting its utility and raising questions regarding the appropriateness and interpretability of using an area’s resident population as a denominator.

Adjusting Estimated Pedestrian-Vehicle Collision Frequencies for Exposure

Traffic engineers sometimes divide collision frequencies by a measure of accident exposure either to normalize the frequency for the intensity of use or to compare the relative hazards of different equipment, facilities, or conditions (e.g. accidents per vehicle mile).[71] In the pedestrian safety discipline, collision densities created using exposure measures of are helpful in identifying "hot spots" or prioritizing areas for safety interventions, for example, in zone analysis. Potential measures of exposure include area, street length, vehicle volume, and pedestrian volume.[72] Most exposure variables used for calculating relative densities except pedestrian volume are readily measurable or available.[73]

The primary purpose of our analytic model is not to compare or rank existing areas with regards to hazards; rather, our aim is to predict the effect of land use plans on future collision frequencies based on changes in exposures. It would thus be inappropriate to normalize predicted collision frequencies based on measures of exposure used in the model to predict future collision frequencies.

Normalizing collision frequency on pedestrian volumes is also inconsistent with the public health prevention goals. Dividing the estimated future frequency of collisions predicted by development-related changes in exposure by the exposure variables would mask the increase in the overall burden of pedestrian collisions. In the same way, calculating vehicle collision "rates" by dividing collisions by vehicle miles traveled similarly masks the growing health burden of vehicle collisions caused by increasing driving. Using proportions in this way may create and perpetuate a bias that there is a "normal" or "natural" rate of traffic accidents and potentially reduce the motivation for action on safety countermeasures.

F. Opportunities to Mitigate Pedestrian Hazards in Land Use Planning

The main aim of this application of the San Francisco Pedestrian Injury Model is to inform the need for pedestrian safety mitigations in the course of land use planning. Given the significance of the impacts of planned land use development on pedestrian collisions, development planning in the five analyzed neighborhoods requires comprehensive pedestrian hazard reduction plans. A comprehensive hazard reduction plan should address area-level factors such as the overall level of traffic volumes and micro-environmental factors based on further analysis of pedestrian safety hazards and mitigations on specific streets and intersections. Particular attention should be given to high injury intersections and street segments and to routes traveled by vulnerable populations (i.e., children, elderly, disabled). Any mitigation to reduce pedestrian injuries should not come at the expense of limiting, or discouraging pedestrian access and activity since there are multiple health benefits to walking.

It is not within the scope of this analysis to identify the feasible and appropriate area-level and micro-level strategies for these plans. It is also not within the scope of this analysis to judge the adequacy of any group of mitigations with regards to their cumulative effectiveness. The 2003 *Pedsafe* Study, however, did involve an evaluation of micro-level countermeasures, focused on intersections; however, a comprehensive pedestrian safety plan will require additional study. Specific interventions for reducing pedestrian injuries and their environmental causes along with available data on their effectiveness are listed below.

A comprehensive program might include the following four categories of mitigations:
- **Transportation-Land Use System Coordination**
- **Traffic Demand Reduction**
- **Implementation of a traffic calming program to reduce vehicle speeds to less than 20mph in mixed-use residential areas.**
- **Micro-environmental Engineering Countermeasures.**

Transportation Land Use System Coordination Reducing the volume of traffic on streets designed for residential or mixed-use residential use could significantly decrease the expected number of pedestrian collisions. Much of the traffic in the planning areas is through traffic moving between the regional freeways and the downtown and periphery of San Francisco. Most streets in the SOMA are specifically designated as arterials for though traffic in the San Francisco General Plan. Planning circulation changes that would re-route through traffic around proposed new residential and mixed-use residential areas would reduce the hazard of pedestrian collisions in a measurable way. Similarly SOMA contains San Francisco's primary freight routes. Re-routing heavy duty truck and freight routes away from residential and mixed use residential areas could have a similar traffic safety benefit. The citywide Better Streets planning effort may provide guidance for such circulation changes; however, that process is in progress and it is unclear how it will be implemented in coordination with the proposed neighborhood plans.

Traffic Demand Reduction Strategies Transportation Demand Management refers to diverse strategies to reduce trips taken using a personal motor vehicle. TDM strategies can include a no-cost shuttle services between a workplace and a regional transit stop, transportation facilities for walking and bicycling, a subsidy or tax incentive for mass transit use, fees or tolls for driving and parking, preferred parking for bicycles, car pool drivers or shared car services, preferred car pool parking. A combination of the best practices in Transportation Demand Management (TDM) implemented both for new and existing land uses could provide an effective and feasible means of reducing area traffic and related pedestrian collision impacts and would also address environmental impacts on noise and air quality.

It is important to note that increasing density, as occurs through the Eastern Neighborhoods Plans, is itself a TMD strategy.[74] The Metropolitan Transportation Agency, the Bay Area Air Quality District, the South Coast Association of Governments are resources for the identification and evaluation of TDM measures. Vehicle emissions programs such as URBEMIS also allow a planner to estimate the effectiveness of a package of TDM measures on trip generation.

Specific effective TDM measures that would be appropriate to implement in the course of the proposed plans in the downtown, SoMa, and Mission would include:

1. Requiring area employers to provide employees universal transit passes.
2. Implementing an area-level congestion pricing system for personal vehicle travel in the downtown district.
3. Requiring new use commercial uses include ample bicycle paring and clothes changing facilities for bicyclists.
4. Provide secure bicycle storage protected from the weather at BART stations.[75]
5. Designs and implementing class II bicycle lanes identified in the SF Bicycle Master Plan in the course of development.
6. Providing adequately sized on site child care with new commercial and residential uses
7. Increasing the frequency of public transit services.
8. Charging employees for parking fees at minimum to exceed the unsubsidized cost of transit fares.
9. Limit the number of structured parking spaces for residential uses below a ratio of 1 spaces for 2 units.
10. Requiring the sale of all structured residential parking at the market rate separate from the sale of residential units. [76]
11. Implementing an area wide residential parking permit program.
12. Prohibiting structured employee parking for commercial uses other than such to serve the business needs. [77]
13. Provide free structured parking for car share.
14. Require transit shuttles to operate at least every 30 minutes in off peak and every 15 minutes during peak travel times with hours to match BART schedules.[78]
15. Providing employee subsidies for mass transit.
16. Implementing van pools or shared shuttle services for large commercial uses.
17. Ensure adequate retail diversity accompanies all new residential enclaves.

Traffic Calming for Residential Areas Traffic calming, or using physical interventions to lower traffic speeds, is a demonstrated, efficacious intervention for street segments and areas. For example, a synthesis of International studies demonstrates that on average traffic calming interventions in residential area reduce accident rates by 15%.[79]

Intersection Pedestrian Safety Countermeasures Transportation safety professionals have identified and evaluated a number of pedestrian safety countermeasures to prevent pedestrian injuries. In general, countermeasures focus on intersections and pedestrian crossings. Countdown pedestrian signal heads, corner bulb outs, and center median refuge islands appear to be highly effective at reducing pedestrian collisions at road crossings and would be appropriate for most high-volume (>5000) multi-lane intersections. Widening sidewalks or provide buffers between sidewalks and vehicle lanes on high volume roadways may also be an appropriate interventions for street segments.

In 2003, the *Pedsafe* study employed the judgment of San Francisco public agency officials and other transportation professionals in to identify specific engineering countermeasures as appropriate effective and feasible for high pedestrian injury density zones in San Francisco's SoMa and Mission neighborhoods. Some efforts are underway to plan or implement traffic safety interventions in the project area. Specific Countermeasures identified through *Pedsafe* are listed below.

Pedestrian Safety Countermeasures Prioritized in the San Francisco PedSafe Study

Countermeasure	**Indication and Evidence of Effectiveness**
Advance limit lines and red curb program	Use to prevent driver failure to yield to pedestrians in the crosswalk. Improves in drivers stopping outside or four feet before the crosswalk in one study
Curb bulbs	Extends the sidewalk into a crosswalk area, making pedestrians more visible and less likely to be cut off by turning vehicles; gives pedestrians a shorter crossing distance; provides additional sidewalk space for queuing, street furniture, and ADA curb ramps.
Impactable YIELD signs	Used at uncontrolled crosswalks as noticeable than roadside signs; minor traffic-calming effect. Increase drivers yielding to pedestrians by six to 15 percent in one study.
Vehicle left turn phase	Reduces driver failing to yield on left turns.
Audible signals	Improves the compliance of sighted pedestrians
Flashing Pedestrian Beacons	Improves recognition of pedestrians and crosswalks intersections where the main street is uncontrolled,
Pedestrian countdown signals	Reduces percentage of pedestrians still in the crosswalk when the signal turns red. pedestrians who finished crossing an intersection on a red light dropped from 14% to 9%, a statistically significant decrease in one study in San Francisco
Radar speed display sign	Inhibits vehicle, typically near schools.
Roadway lighting improvements	Improves pedestrian visibility at night. Two reports described positive impact on pedestrian safety from lighting improvements including reduction in pedestrian-related collisions when light levels were increased at high-risk locations for nighttime-related pedestrian collision.

In 2005, the National Cooperative Highway Research Program's published a State of the Knowledge Report on crash reduction factors for traffic engineering.[80] The report summarized the best evidence on the effectiveness of diverse traffic safety interventions. For example, according to the report and based on studies of 8 intersections, roundabouts reduced injuries by 70% on single lane urban roadways that had had stop signs. While the report reviews the effectiveness of interventions on motor vehicle accidents overall, it includes a number of studies specifically focused on effects on pedestrian injuries.

FHWA Crash Reduction Factors Associated with Transportation Facility Interventions

Transportation Facility Intervention	**Level of Predictive Certainty**	**AMF (all collision types)**	**AMF (pedestrian Collisions)**
Intersection Treatments			
Install a roundabout	High	0.12-0.95	0.70

Add exclusive left-turn lane	High	0.42-0.81	
Add exclusive right-turn lane	High	0.83-0.96	
Install a traffic signal	High	0.33-1.5	
Remove a traffic signal	High	0.69-0.82	
Modify signal change interval	Medium-High	0.63-1.12	0.63
Convert to all-way stop control	Medium-High	0.28-0.87	0.61
Convert stop-control to yield-control	Medium-High	2.37	
Install red-light cameras	Medium-High	0.84-1.24	
Roadway Segment Treatments			
Narrow lane widths to add lanes	Medium-High	1.03-1.11	
Add passing lanes (two-lane roads)	Medium-High	0.65-0.75	
Add two-way left-turn lane (TWLTL)	Medium-High		
Increase lane width	Medium-High		
Change shoulder width and/or type	Medium-High	See formula	
Flatten horizontal curve	Medium-High	See formula	
Improve curve super elevation	Medium-High	See formula	
Add shoulder rumble strips	Medium-High	0.82-0.87	
Add centerline rumble strips	Medium-High	0.75-0.86	
Install/upgrade guardrail	Medium-High	0.53-0.56	
Install raised medians at crosswalks	Medium-High	N.A.	Marked Crosswalks= 0.54
		N.A.	Unmarked crosswalks = 0.61

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References

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1 http://quickfacts.census.gov/qfd/states/06/06075.html

2 http://www.ci.sf.ca.us/site/uploadedfiles/dpt/Collision_report_2005.pdf

3 Ewing R. Fatal and Non-fatal Injuries. In: Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. 2006. Available at: http://www.activeliving.org/files/LEED_ND_report.pdf.

4 Evans, L. A New Traffic Safety Vision for the United States. AJPH Sept 2003, Vol 93, No. 9 (1384-1386).

5 Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual Causes of Death in the United States, 2000. JAMA 2004;291(10):1238-45.

6 http://www.safecarguide.com/exp/statistics/statistics.htm

7 http://www.chp.ca.gov/switrs/pdf/2004-sec7.pdf

8 National Highway Traffic Safety Administration. Fatality Analysis Reporting System. Available at: http://www-fars.nhtsa.dot.gov/. Accessed September, 2006.

9 Leyden KM. Social Capital and the Built Environment: The Importance of Walkable Neighborhoods. Am J Public Health 2003;93(9):1546-1551.

10 Lavizzo-Mourney R, McGinnis JM. Making the Case for Active Living Communities. Am J Public Health 2003;93(9):1386-1388.

11 Roberts I, Norton R, Jackson R, Dunn R, Hassall I. Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: a case-control study. BMJ 1995;310(6972):91-4.

12 Lee C, Abdel-Aty M. Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida. 2005;37:775-786.

13 Brugge D, Lai Z, Hill C, Rand W. Traffic injury data, policy, and public health: lessons from Boston Chinatown. J Urban Health 2002;79(1):87-103.

14 LaScala E, Gerber D, Gruenwald PJ. Demographic and environmental correlates of pedestrian injury collisions: a spatial analysis. 2000;32:651-658.

15 National Highway Traffic Safety Administration. Literature Review on Vehicle Travel Speeds and Pedestrian Injuries. Washington DC: USDOT, 1999.

16 Ewing R. Fatal and Non-fatal Injuries. In: Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. 2006. Available at: http://www.activeliving.org/files/LEED_ND_report.pdf.

17 Brugge D, Lai Z Hill C, Rand W. Traffic injury data, policy, and public health: lessons from Boston Chinatown. Journal of Urban Health 2002; 79: 87-103.

18 Agran PF, Winn DG, Anderson CL, Tran C, Del Valle CP. The role of physical and traffic environment in child pedestrian injuries. Pediatrics 1996;98(6 pt 1):1096-103.

19 Geyer J, Raford N, Ragland D, Pham T. The Continuing Debate about Safety in Numbers—Data from Oakland, CA. UC Berkeley Traffic Safety Center 2005; UCB-TSC-RR-TRB3. Available at: http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1029&context=its/tsc

20 Jacobsen PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Inj Prev 2003;9:205-9.

21 National Highway Traffic Safety Administration. Literature Review on Vehicle Travel Speeds and Pedestrian Injuries. Washington DC: USDOT, 1999.

22 Eisenberg D, Warner KE. Effects of snowfalls on motor vehicle collisions, injuries, and fatalities. Am J Public Health 2005;95(1):120-4.

23 Ewing R. Fatal and Non-fatal Injuries. In: Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. 2006. Available at: http://www.activeliving.org/files/LEED_ND_report.pdf.

24 Zegeer CV, Steward RJ, Huang HH, Lagerwey PA. Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines. Federal Highway Administration, 2002.

25 Demetriades D, Murray J, Martin M, Velmahos G, Salim A, Alo K, Rhee P. Pedestrians injured by automobiles: relationship of age to injury type and severity. J Am Coll Surg 2004;199(3):382-7.

26 Johnson E, Geyer J, Rai N, Ragland DR. Low Income Childhood Pedestrian Injury: Understanding the Disparate Risk. U.C. Berkeley Traffic Safety Center 2004. Paper UCB-TSC-RR-2004-20. Available online at: http://repositories.cdlib.org/its/tsc/UCB-TSC-RR-2004-20.

27 Sciortino S, Chiapello E. Environmental, Behavioral, and Demographic Factors that Affect the Severity of Pedestrian Injuries. 2005. Available at http://www.dph.sf.ca.us/traffic_safety/traffic-related_injury_data.htm. Accessed September, 2006.

28 Laflamme L, Diderichsen F. Social differences in traffic injury risks in childhood and youth—a literature review and a research agenda. Inj Prev 2000;6(4):293-8.

29 Johnson E, Geyer JA, Rai N, Ragland DR. Low Income Childhood Pedestrian Injury: Understanding the Disparate Risk. Institute of Transportation Studies, UC Berkeley Traffic Safety Center. 2004, available at: http://repositories.cdlib.org/its/tsc/UCB-TSC-RR-2004-20

30 LaScala EA, Gruenewald PJ, Johnson FW. An Ecological Study of the Locations of Schools and Child Pedestrian Injury Collisions. Accid Anal Prev 2004;36(4):569-76.

31 Ewing R. Fatal and Non-fatal Injuries. In: Understanding the Relationship Between Public Health and the Built Environment: A Report Prepared for the LEED-ND Core Committee. 2006. Available at: http://www.activeliving.org/files/LEED_ND_report.pdf.

32 SF Metro Transport Plan, 2004

33 Pedestrian and Bicycle Crash Analysis Tool. Accessed online at: http://www.walkinginfo.org/pc/pbcat.cfm

34 Crossroads Software, Inc. Accessed online at: http://www.crossroadssoftware.com/

35 Zone Guide for Pedestrian Safety. NHTSA, 1998.

36 Statistical Methods and Crash Prediction Modeling. Transportation Research Record: Journal of the Transportation Research Board 2006; 1950.

37 Add citations including San Francisco DPH studies, UC Berkeley Traffic Safety Center: http://repositories.cdlib.org/cgi/query.cgi?op_1=eq&field_2=publication_date&op_2=gt&value_2=2001&advanced=1&connector_3=and&field_3=ancestor.link&op_3=eq&value_3=http%3A//repositories.cdlib.org/its/tsc&hidden_3=1&sortby=publication_date=descending

38 FHWA-RD-03-042

39 Morency P, Cloutier MS: From targeted "black spots" to area-wide pedestrian safety. Inj Prev 2006;12:360-4.

40 Lovegrove, Gordon Richard; Sayed, Tarek. Macrolevel Collision Prediction Models for Evaluating Neighborhood Traffic Safety. Canadian Journal of Civil Engineering. 2006 33(5):609-621.

41 Insert citations

42 Lee C, Abdel-Aty M. Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida. Accident Analysis and Prevention 2005; 37: 775-786.

43 Hadayeghi, A; Shalaby, A S; Persaud, B N. MACROLEVEL ACCIDENT PREDICTION MODELS FOR EVALUATING SAFETY OF URBAN TRANSPORTATION SYSTEMS. Transportation Research Record. 2003 No. 1840:87-95.

44 Ladron de Guevara, F; Washington, S P; Oh, J. FORECASTING CRASHES AT THE PLANNING LEVEL: SIMULTANEOUS NEGATIVE BINOMIAL CRASH MODEL APPLIED IN TUCSON, ARIZONA. Transportation Research Record. 2004 No. 1897:191-199.

45 Lovegrove, Gordon Richard; Sayed, Tarek. Macrolevel Collision Prediction Models for Evaluating Neighborhood Traffic Safety. Canadian Journal of Civil Engineering. 2006 33(5):609-621.

46 National Highway Traffic Safety Administration. Traffic Safety Facts 2004. Available at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2004/809913.pdf Accessed September, 2006.

47 McLoughlin E, Zacher, A, Skaj P, Radetsky M, Sciortino S, Klassen C. Profile Injury in San Francisco 2004. Available at http://www.surgery.ucsf.edu/sfic/profile05.pdf. Accessed September, 2006.

48 National Highway Traffic Safety Administration. Fatality Analysis Reporting System. Available at: http://www-fars.nhtsa.dot.gov/. Accessed September, 2006.

49 San Francisco 2005 Collision Report. City and County of San Francisco Municipal Transportation Agency Department of Parking and Traffic Engineering Division. July 19, 2006.

50 San Francisco 2005 Collision Report. City and County of San Francisco Municipal Transportation Agency Department of Parking and Traffic Engineering Division. July 19, 2006.

51 http://quickfacts.census.gov/qfd/states/06/06075.html

52 http://www.ci.sf.ca.us/site/uploadedfiles/dpt/Collision_report_2005.pdf

53 U. S. Department of Health and Human Services. Healthy People 2010 Objectives.

54 PedSafe San Francisco: San Francisco Metropolitan Transportation Authority, 2003

55 Zone Guide for Pedestrian Safety. NHTSA, 1998.

56 Ragland, DR. Markowitz, F. MacLeod, KE "An Intensive Pedestrian Safety Engineering Study Using Computerized Crash Analysis" (May 1, 2003). U.C. Berkeley Traffic Safety Center. Paper UCB-TSC-RR-2003-12

57 San Francisco 2005 Collision Report. City and County of San Francisco Municipal Transportation Agency Department of Parking and Traffic Engineering Division. July 19, 2006.

58 U.S. Department of Health and Human Services. Healthy People 2010 Objectives.

59 Wier M, Bhatia R, Weintraub J. Predicting Pedestrian Injury Collisions in San Francisco, California: An Area-level Model. San Francisco: San Francisco Department of Public Health, 2007.

60 Geolytics, Inc. Neighborhood Change Database (NCDB) 1970- 2000. Geolytics, Inc. 2004.

61 update once receive SWITRS data

62 San Francisco Department of Telecommunications and Information Services GIS Server. San Francisco Department of Parking and Traffic, San Francisco Street Basemap 2006.

63 http://www.mtc.ca.gov/maps_and_data/datamart/census/ctpp2000/

64 Hadayeghi, A; Shalaby, A S; Persaud, B N. MACROLEVEL ACCIDENT PREDICTION MODELS FOR EVALUATING SAFETY OF URBAN TRANSPORTATION SYSTEMS. Transportation Research Record. 2003 No. 1840:87-95.

65 Ladron de Guevara, F; Washington, S P; Oh, J. FORECASTING CRASHES AT THE PLANNING LEVEL: SIMULTANEOUS NEGATIVE BINOMIAL CRASH MODEL APPLIED IN TUCSON, ARIZONA. Transportation Research Record. 2004 No. 1897:191-199.

66 San Francisco Planning Department. Eastern Neighborhoods Community Planning. Available at: http://www.sfgov.org/site/planning_index.asp?id=25288. Accessed on: April 17, 2007.

67 Hausrath Economics Group. San Francisco's Eastern Neighborhood Rezoning Socioeconomic Impacts: Draft Report to Planning Department, Cuty and County of San Francisco. May 12, 2006.

68 Wilbur Smith Associates. Rincon Hill Mixed Use District Transportation Study: Case Number 2000.1081!. December 2003.

69 Eastern Neighborhoods Rezoning and Community Plans, Environmental Setting and Impacts, Population, Housing, Business Activity, and Employment, San Francisco Planning Department, draft April 23, 2007 page IV.D-54.

70 Jacobsen PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Inj Prev. 2003 Sep;9(3):205-9.

71 Hauer E. On exposure and accident rate. Traffic engineering and control 1995; 36:.

72 Pulugurha SS, krishnakumar VK, Nambisan SS. New methods to identify and rank high pedestrian crash zone: An illustration. Accident Analysis and Prevention 2007; 39: 800-811.

73 Recently, researchers have developed statistical models to estimate pedestrian volume – based on actual pedestrian counts as well as land use, transportation, and other demographic factors of an area, and have used modeled pedestrian volumes in calculating pedestrian injury densities.

74 Holzclaw, John, How Compact Neighborhoods Affect Modal Choice- Two Examples. Available at: www.sierraclub.org/sprawl/articles/modal.asp, 2002

75 Ibid.

76 Shoup, Donald, 1999

77 Air Resources Board, California Environmental Protection Agency, Parking Cash-Out Incentive: Eight Case Studies, June 1998

78 Lund, Hollie: Cervero, Robert; and Willson, Richard, Travel Characteristics of Transit-Oriented Development in California. Final Report, January, 2004

79 Morrison DS, Petticrew M, Thomson H. What are the most effective ways of improving population health through transport interventions? Evidence from systematic reviews. Journal of Epidemiology and Community Health 2003:57:327-333.

80 Source: CRASH REDUCTION FACTORS FOR TRAFFIC ENGINEERINGAND INTELLIGENT TRANSPORTATION SYSTEM (ITS) IMPROVEMENTS: STATE-OF-KNOWLEDGE REPORT Research Results Digest 299 National Cooperative Highway Research Program; 2005. (Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_299.pdf)