

OAK TO NINTH AVENUE PROJECT

Addendum #1 to the Certified Environmental Impact Report

State Clearinghouse No. 2004062013

Prepared for:
City of Oakland CEDA

June 7, 2006

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CHAPTER I

Introduction

A. Background

On March 15, 2006, the City of Oakland Planning Commission certified an environmental impact report (EIR) for the Oak to Ninth Avenue Project (ER04-0009). Prior to and since the Planning Commission's action, the project sponsor has been asked to consider a number of matters regarding the project and its potential impacts. Also, comments on the Draft EIR that were not received for inclusion in the certified Final EIR document have been received by the City. This Addendum is a comprehensive compendium of the new analysis and responses to address these matters.

B. Purpose of the EIR Addendum

The City has prepared this Addendum to the 2006 certified EIR¹ for the Oak to Ninth Avenue Project (Addendum) to provide additional analysis for 1) an alternative project site plan (eliminating Parcel N development and redistributing 300 dwelling units), and 2) the project's potential effects on the proposed reconfigured 12th and 14th Streets adjacent to Lake Merritt, and 3) to present responses to additional comments received on the EIR, some of which were previously submitted to the Planning Commission.

The information provided in this Addendum does not change the environmental analysis contained in the certified EIR. The scope and analysis presented in this document were prepared consistent with to the requirements of Section 15162 and 15164 of the California Environmental Quality Act (CEQA) discussed below. The City will use this Addendum, together with the 2006 certified EIR, when considering its action on the project.

CEQA Framework for the Addendum

According to CEQA Guidelines Section 15164, an addendum to a previously certified EIR may be prepared if some changes or additions are necessary to the EIR but none of the conditions described

¹ This document generally refers to the certified "EIR" which, pursuant to CEQA, consists of the Draft EIR (DEIR) and the Final EIR (FEIR) / Response to Comments document for the project.

below for preparation of a subsequent EIR have occurred (CEQA Guidelines Section 15162) (*emphasis added*):

- (1) Substantial changes are proposed in the project which will require major revisions of the previous EIR or negative declaration *due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects*;
- (2) Substantial changes occur with respect to the circumstances under which the project is undertaken which will require major revisions of the previous EIR or Negative Declaration *due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects*; or
- (3) New information of substantial importance, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous EIR was certified as complete or the Negative Declaration was adopted, shows any of the following:
 - (A) The project will have one or more significant effects not discussed in the previous EIR or negative declaration;
 - (B) Significant effects previously examined will be substantially more severe than shown in the previous EIR;
 - (C) Mitigation measures or alternatives previously found not to be feasible would in fact be feasible, and would substantially reduce one or more significant effects of the project, but the project proponents decline to adopt the mitigation measure or alternative; or
 - (D) Mitigation measures or alternatives which are considerably different from those analyzed in the previous EIR would substantially reduce one or more significant effects on the environment, but the project proponents decline to adopt the mitigation measure or alternative.

CEQA allows the lead agency or responsible agency to prepare an addendum to a previously certified EIR if only minor technical changes or additions are necessary (but none of the above conditions have occurred). The decision making body shall consider the addendum with the final EIR or adopted negative declaration prior to making a decision on the project.

Based on the analysis conducted and provided herein, this addendum concludes that the alternative project site plan or the potential effects to the proposed reconfigured 12th and 14th Street at Lake Merritt analyzed herein would not constitute a major revision to the certified EIR; that there is no substantial change in circumstances as a result of the potential project change that would cause new or more intense significant impacts; and that there is no new information of substantial importance that identifies new or more intense significant impacts (CEQA Guidelines Section 15162). Thus, preparation of an addendum to the certified EIR is appropriate pursuant to CEQA.

CHAPTER II

“No Parcel N” Development Scenario

A. Description

Parcel N is located on the westernmost edge of the project site directly west of the Jack London Aquatic Center (Aquatic Center) and north of Estuary Park. As described and analyzed in the Draft EIR and in the Final EIR (which analyzed an alternative configuration of Parcel N), the Oak to Ninth Avenue Project would develop 300 dwelling units, approximately 15,000 square feet of ground-floor non-residential use, and approximately 300 onsite parking spaces on Parcel N in its final phase of development (estimated year 2024). This Addendum considers an alternative project scenario in which Parcel N would not be developed and would instead be improved with approximately 2.41 acres of new open space and parking extending north from Estuary Park. The open space portion of Estuary Park (excluding Jack London Aquatic Center facilities) would be increased from 3.5 acres (existing) to approximately 5.9 acres, and would extend north to Embarcadero. Surface parking would line the west of the park. **Figure II-1**, on the following page, illustrates the alternative Oak to Ninth Avenue site configuration with no development on Parcel N. The development previously proposed on Parcel N would be redistributed to other parcels within the site. **Table II-1** below shows the revised development program by parcel.

**TABLE II-1
DEVELOPMENT PROGRAM COMPARISON – DEIR AND “NO PARCEL N” SCENARIO**

Parcel	Acres		Ground Level Non-Residential Area (s.f.)		Total Units		Units/Net Acre		Parking	
	DEIR	No Parcel N	DEIR	No Parcel N	DEIR	No Parcel N	DEIR	No Parcel N	DEIR	No Parcel N
A	2.74	2.38	10,000	10,000	375	407	137	171	375	444
B	1.53	1.53	6,000	6,000	160	175	105	114	160	185
C	1.48	1.48	6,000	6,000	160	175	108	118	160	185
D	1.46	1.46	6,000	6,000	160	175	110	120	160	185
E	1.20	1.20	8,000	8,000	86	131	72	108	86	147
F	1.49	1.75	5,000	5,000	164	165	110	94	164	172
G	2.72	2.72	42,000	45,000	280	300	103	110	514	372
H	2.08	2.08	35,000	36,000	335	375	161	180	435	472
J	1.84	1.84	12,000	15,000	292	339	159	184	392	375
K	2.23	1.69	17,000	10,000	310	322	139	190	310	355
L	1.45	1.45	15,000	15,000	144	146	99	101	144	176
M	2.65	(M1) 1.45 (M2) 1.15	5,000	(M1) 5,000 (M2) 15,000	334	(M1) 265 (M2) 125	126	(M1) 183 (M2) 109	334	(M1) 275 (M2) 157
N	2.41	0	15,000	0	300	0	124	0	300	0
Terminal	-	-	18,000	18,000	-	-	-	-	-	-
TOTAL	25.28	22.19	200,000	200,000	3,100	3,100	120	140*	3,534	3,500

*Average Net Density
Source: Oakland Harbor Partners, 2006



--- BCDC JURISDICTION



ILLUSTRATIVE PLAN

Brooklyn Basin - Oak to 9th Development Plan

Prepared for Oakland Harbor Partners by ROMA Design Group in association with MVE Architects, Moffatt & Nichol and BKF Engineers

MAY 16, 2006

B. Environmental Effects on “No Parcel N” Scenario

The Draft EIR (DEIR) discusses certain topics for which specific effects could be directly attributed to the development of Parcel N. These include General Plan consistency (Estuary Policy Plan); traffic, circulation and parking; and visual quality (views and shadow). This following discussion focuses on the potential changes that could occur for each of the CEQA topics analyzed in the 2006 certified EIR but focuses on these three most affected topics. The discussion concludes that the “No Parcel N” scenario would result in the same or less severe environmental impacts as those identified for the proposed project analyzed in the Draft EIR.

Land Use, Plans, and Policies

The Draft EIR states that the series of parks that would be created by the DEIR project would be generally consistent with those envisioned in the Estuary Plan, except that the existing Estuary Park would be increased by approximately 2.41 acres that would extend north to the Embarcadero, as illustrated in the Estuary Policy Plan (Estuary Plan). The total area of *new* open space would be 23.11 acres compared to 20.7 new acres with the DEIR project. Therefore, the No Parcel N scenario would remain and be further consistent with numerous Estuary Plan objectives and policies that call for the creation of new public open space along the Oak-to-Ninth District waterfront.

Transportation, Circulation, and Parking

Because the dwelling unit and commercial space totals are identical between the No Project scenario and the project analyzed in the Draft EIR, the overall project trip generation would also therefore be identical. Based on the analysis conducted by Fehr & Peers Transportation Consultants for this Addendum (**Appendix A**), the distribution of project-generated traffic would be unaffected by changes to the site plan, therefore the project impacts are expected to be the same at all off-site intersections. Off-site intersections would include all intersections except those directly adjacent to the project site.

The number of driveways proposed along Embarcadero is proposed to remain the same under the No Parcel N scenario. At one of these driveways (Estuary Drive near the former Parcel N), the traffic volume is expected to decrease significantly with the removal of the previous Parcel N dwelling units and commercial space from this driveway.

Throughout the remainder of the project site, the number of trips is expected to increase, however, the increase at any one driveway to the site or individual development parcels is expected to be minimal. The trip increase at each driveway ranges from 5 AM peak hour trips at Embarcadero / 5th Avenue to 40 PM peak hour trips at Embarcadero / 6th Avenue/I-880 off-ramp. The other driveways would also experience minimal increases in traffic volumes. This minimal increase occurs for the following reasons:

1. The change in the site plan results in the redistribution of no more than 10 percent of the uses on site (300 dwelling units and 15,000 square feet of commercial)

2. These dwelling units and the commercial space are distributed across the remaining areas of the project
3. There are six driveways which provide access to the site
4. The project maintains an extensive internal roadway system which allows vehicles from the various parcels to access multiple driveways

Therefore, the redistribution of land uses results in a minimal increase in trips across all driveways.

The impact analysis for the EIR included two of the major intersections adjacent to the project site. These intersections are Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp. As noted in above, there will be a minor increase in the number of vehicles at these intersections. The traffic study documented in the Draft and Final EIR identified impacts and recommended mitigation measures at these two intersections. With the recommended mitigations, mainly a widening of Embarcadero from 5th Avenue along the project frontage, both of these intersections would operate at an acceptable service levels (LOS D or better).

An analysis of intersection operations indicates that the additional trips cause a minimal increase in delay and no change in LOS. The delay change ranges from less than 1 second at the intersection of Embarcadero/5th Avenue in the AM peak hour to a change in delay of 3 seconds at the intersection of Embarcadero/6th Avenue/I-880 off-ramp in the PM peak hour. During all analysis periods, the change in delay is insufficient to cause a change in LOS. Therefore, these two intersections would continue to operate at acceptable levels even with the change in the project site, assuming implementation of the mitigation measures identified in the Draft and Final EIR.

Air Quality and Meteorological Conditions

Since the No Parcel N scenario would have the same traffic and circulation characteristics as the DEIR project, it would generate the same number of vehicle trips and criteria air pollutant emissions. No change would result to the operational air quality impacts identified in the DEIR. Also, although the duration of construction would likely be reduced, specifically adjacent to existing residential uses, construction-related air quality impacts identified in the DEIR would also remain since demolition of the large existing building on Parcel N would still occur.

Hydrology and Water Quality

Since less paved development and more turf area would occur on Parcel N, there would be a slight reduction in the total area of impervious surface onsite. Under the No Parcel N scenario, for all parts of the project site, the project would continue to remove existing uses and onsite handling and storage of hazardous material, improve the onsite storm drain system, and implement measures to treat runoff. As a result, the same or reduced water quality and hydrology impacts during construction and operations would occur, as identified for the DEIR project.

Cultural Resources

The No Parcel N scenario would not affect historic resources since none are located on or near Parcel N. Therefore, the same cultural resources impacts would occur as those identified for the DEIR project.

Geology, Soils, and Seismicity

As with the DEIR project, residential use buildings would still be constructed on the overall project site although not on Parcel N. Therefore the same impacts relative to geology, soils and seismic hazards that would occur with the DEIR project would occur with the No Parcel N scenario.

Noise

Since the No Parcel N scenario would have similar traffic and circulation characteristics and internal street layout as the DEIR project, the same traffic-related noise impacts identified for the DEIR project would occur. Like the DEIR project, a significant, unavoidable impact would result because residential uses would continue to be in a noise environment that exceeds the City's "normally acceptable" standard, although not on Parcel N. Operational noise impacts associated with utility equipment and commercial activities (e.g., loading, etc.) in particular would be reduced since these activities and facilities would no longer occur adjacent to existing residential uses. As with air quality, construction-related noise impacts also would be reduced but would still occur due to demolition activities required for Parcel N.

Hazardous Materials

The No Parcel N scenario would involve construction activities and would therefore still expose the public to hazardous materials during construction. Remediation would still occur, and any operational hazardous materials impacts would be the same, as with the DEIR project.

Biological Resources

The development of Parcel N would not affect any specific biological resources not otherwise identified as being impacted by the overall development project. Therefore, the No Parcel N scenario would not affect biological resources, and the same impacts identified in the DEIR would occur.

Population, Housing and Employment

The No Parcel N scenario would not change the total number of housing units, population, or number or types of jobs proposed by the project. Similarly, the same amount of total ground-floor non-residential use would occur on the project site overall, so there would be no change in employment. Therefore, the No Parcel N scenario would have the same population, housing and employment impacts identified for the DEIR project.

Visual Quality and Shadows

The DEIR project proposed a building that would vary from approximately 65 to 86 feet tall on 2.4 acres fronting the Embarcadero on Parcel N. No structure would be constructed on Parcel N under the No Parcel N scenario, therefore, although no significant impacts to visual quality or shadow were identified in the Draft EIR, the removal of the Parcel N structure would eliminate any new project shadow near adjacent residential uses and would not affect a change in short, medium or long range views across the area of the Oak to Ninth Avenue project site west of Lake Merritt Channel. The visual character of this area would be open space expanding south from the Embarcadero to the Bay Trail along the waterfront.

The height, massing and location of the buildings proposed on the remaining development parcels, east of the Channel, would not be changed from what was analyzed in the Draft EIR. Under the No Parcel N scenario, these buildings would absorb the development originally proposed for Parcel N. Therefore, impacts to visual character, views and shadow would remain less than significant as identified in the Draft EIR (as well as identified for the Reconfigured Parcel N scenario analyzed in the Final EIR). Effects specifically associated with the up to 86-foot tall building originally proposed on Parcel N adjacent to residential uses would be avoided.

Public Services and Recreation

The No Parcel N scenario would result in approximately 2.41 more acres of total open space than analyzed in the DEIR. Since the overall population would remain the same as with the DEIR project, the ratio of park acres per 1,000 residents would be increased from 4.1 to 4.6 (compared to the City standard of "4.0 acres per 1,000 residents"). Also, the No Parcel N scenario would include the same number of dwelling units and types of other land uses as analyzed in the DEIR, therefore it would not change the demand for public services or recreational facilities identified for the DEIR project.

Utilities and Service Systems

Similar to public services impacts above, since the No Project N scenario would not change the total number of dwelling units, estimated population, or land uses on the overall project site, the impacts identified for public utilities and service systems would be the same as those identified in the DEIR for the proposed project.

Summary

The potential environmental effects that would occur under the No Parcel N development scenario would be essentially the same or less severe than those identified for the proposed project analyzed in the Draft EIR. This is primarily due to the overall development program remaining unchanged with the development assumed for Parcel N being distributed throughout the project site. An increase in unpaved area and public open space similar to that envisioned by the General Plan, and the removal of the 65 to 86-foot tall structure proposed near existing residential uses would also result in reduced effects compared to those identified in the Draft EIR.

CHAPTER III

Potential Impacts to Reconfigured 12th and 14th Streets at Lake Merritt

A. Background

Within the foreseeable future, the City of Oakland will be reconfiguring 12th and 14th Streets south of Lake Merritt to create a six-lane boulevard. In response to direction from City staff, additional analysis was conducted to estimate project traffic impacts on the proposed reconfigured 12th and 14th Streets. Based on the analysis prepared by Fehr & Peers Transportation Consultants, dated May 18, 2006, (provided in **Appendix B**), the Oak to Ninth Avenue Project would not impact the operations of the proposed reconfiguration of this roadway system.

B. Potential Traffic Impacts

Level of Service (LOS) Analysis

The transportation impact analysis for Oak to Ninth Avenue Project focused on project impacts at the intersection level. Impacts to the freeways and other major regional roadways throughout Alameda County were also evaluated, based on the requirements of the Alameda County Congestion Management Agency (ACCMA). As documented in the Draft EIR, the analysis concluded that the intersections along both the west side and east side of the 12th/14th Street roadway segment would operate at acceptable service levels.

An additional level of analysis is presented in this addendum and estimates the 2025 level of service (LOS) for this roadway segment using the following information:

- Traffic volumes from adjacent intersections at 1st Avenue/International Boulevard, 1st Avenue/Foothill, and 5th Avenue/East 12th Street; based on the roadway configuration, it is likely that traffic on this roadway segment would pass through these three intersections. Volumes on the segment of 12th/14th Street adjacent to Lake Merritt were estimated by combining the traffic volumes at these intersections.
- The roadway capacity was estimated by applying a per lane capacity of 800 vehicles per hour. This capacity was used for the impact analysis on regional roadways, except

for freeway facilities. Therefore, the directional capacity on the 12th Street/14th Street roadway segment would be 2,400 vehicles per hour, in each direction.

The results of the LOS analysis are provided in **Table III-1**. As indicated in this table, the westbound direction is expected to be deficient during the AM period while the eastbound segment will be deficient during the PM period. In both cases, the addition of project traffic would increase the volumes on the deficient segments by less than 3 percent.

TABLE III-1 LOS RESULTS FOR 12TH/14TH STREET ROADWAY SEGMENT							
Period	Direction	2025 No Project			2025 With Project		
		Volume	V/C	LOS	Volumes	V/C	LOS
AM	Eastbound	894	0.37	A	912	0.38	A
AM	Westbound	2775	1.16	F	2850	1.19	F
PM	Eastbound	3290	1.37	F	3381	1.40	F
PM	Westbound	1262	0.53	A	1326	0.55	A

Source: Fehr & Peers, April 2006

Impact Analysis

The following criterion was applied to determine if the project impacts on these roadway segments are significant:

- The project would cause a roadway segment on the Metropolitan Transportation System to operate at LOS F or would increase the V/C ratio by more than three (3) percent for a roadway segment that would operate at LOS F without the project

While the 12/14th Street roadway segments are not located on the Metropolitan Transportation System, the above criterion does relate to a roadway segment and was applied for this analysis. As indicated in the above table, the V/C ratio increases by 3 percent or less on all segments. The impact is therefore less than significant.

CHAPTER IV

Further Responses to Comments on the Draft EIR

This chapter addresses further comments received on the 2006 certified EIR. Addressed is correspondence received from the California Department of Transportation, the Metropolitan Greater Oakland Democratic Club, Ms. Cynthia Shartzter, and Dr. Rajiv Bhatia. Some of this correspondence was previously submitted to the Planning Commission. Those letters are noted throughout this chapter.

A. Caltrans Letter and Response

The California Department of Transportation (Caltrans) submitted a comment letter dated October 21, 2005, on the Draft EIR. Caltrans' correspondence is presented as Letter D in Chapter VI (Other Responses to Written Comments on the Draft EIR) in the Final EIR, and the City's responses to the comments follow the letter on Final EIR pages VI-11 through VI-16.

Caltrans subsequently submitted a letter dated March 20, 2006 in response to the Final EIR, and that letter is provided on the following pages. The City's responses to the questions and concerns raised follow the letter.

DEPARTMENT OF TRANSPORTATION

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*Flex your power!
Be energy efficient!*

March 20, 2006

ALA880618
ALA-880-30.37
SCH#2004062013

Ms. Margaret Stanzone
City of Oakland
Community Development Agency
250 Frank Ogawa Plaza, Suite 3315
Oakland, CA 94612

Dear Ms. Stanzone:

Oak to 9TH Mixed-Use Project – Final Environmental Impact Report

Thank you for continuing to include the California Department of Transportation (Department) in the review process for the proposed Oak to 9th Mixed-Use project. The following comments are based on the Final Environmental Impact Report referencing the Response to Comments notation. As lead agency, the City of Oakland is responsible for all project mitigation, including any needed improvements to state highways. Any required roadway improvements should be completed prior to issuance of project occupancy permits. An encroachment permit is required for work in the State right-of-way (ROW), and the Department will not issue an encroachment permit until our concerns are adequately addressed. Therefore, we strongly recommend that the lead agency work with the applicant and the Department to resolve project issues prior to submittal of the encroachment permit application. Further comments will be provided during the encroachment permit process.

D-6

Although we agree that off-ramp intersections would impact ramp operations, we disagree that intersection analysis alone is adequate. According to the Caltrans' *"Guide for the Preparation of Traffic Impact Studies"*, the impact to state facilities needs to be addressed. Furthermore, although City staff and EIR consultants recognized "that further operational analysis may be needed to design improvements at intersections containing freeway ramps" in the response to our comment, it is unclear whether the freeway ramps would be included in the analysis. As such, the document should expand discussion to include ramp impacts and mitigation measures.

D-7

Quantifying the change in delay values at intersections with Level of Service F conditions would

provide a clear, analytic basis for comparing with and without project traffic conditions and should be included in the Environmental Impact Report.

D-25

Response to comment states that “Parking was inadvertently shown under the freeway structure on several DEIR figures. These ‘typos’ have been eliminated from the affected figures.” However, the Preliminary Development Plan and Vesting Tentative Tract Map No. 7621 for the Oak to 9th Mixed-Use Project submitted with the Project Referral dated December 20, 2005 shows proposed parking under the Interstate 880 (I-880) freeway structure south of the northbound Embarcadero off-ramp. As stated in the Department’s January 31, 2006 correspondence, the proposed parking facility conflicts with drainage facilities to be constructed as part of the Department’s 5th Avenue Overhead Structure Replacement Project. While it is our understanding that parking under the freeway structure will not be pursued as part of this project, please be sure to correct all documents associated with this project.

D-26

As an affected agency, the Department requests the opportunity to review all engineering studies which address the proposed drainage improvements for the project. As stated in the Department’s previous comments, the project’s drainage design should accommodate drainage runoff from tributary areas east of the development site, which includes the freeway. Those new facilities should be coordinated and compatible with the Department’s highway drainage facilities. The drainage proposal shown in the Preliminary Development Plan does not address the existing connection between the Department’s drainage system and the City’s drainage system opposite 8th Street. As the general drainage pattern is from east to west, there is an obligation on the development to maintain the natural drainage patterns, and to accept and convey storm flows in a manner that does not adversely affect upstream properties.

State’s Requirements

The Department’s policy is to upgrade existing non-standard highway facilities to meet current standards if warranted. If modifications to the state facilities do not provide full standards, a design factsheet not to upgrade the existing non-standard mandatory features shall be provided through the exception process.

All work within the State’s ROW affecting the State’s facilities requires approval and/or coordination with the State.

Should you require further information or have any questions regarding this letter, please call Lisa Carboni of my staff at (510) 622-5491.

Sincerely,

TIMOTHY C. SABLE
District Branch Chief
IGR/CEQA

c: Ms. Terry Roberts, State Clearinghouse

“Caltrans improves mobility across California”

Responses to Caltrans Comments (3/20/06)

D-6 **Table IV-1** below indicates the results of a Level of Service (LOS) Analysis for the various ramp facilities proximate to the project site. As indicated in the Table below, there is one ramp facility which operates at a deficient LOS. This analysis was conducted using Highway Capacity Manual (HCM) methodology for ramp junctions. This methodology uses freeway traffic volumes, lanes, ramp volume, ramp length and other considerations to determine ramp LOS.

This ramp is the I-880 Northbound ramp at 6th Avenue, where traffic would exit from I-880 onto the Embarcadero. These deficient LOS results result mainly from deficient operations on I-880, which was identified as operating at a deficient level in the Draft EIR. This deficient operations was noted as a significant impact in the DEIR, along with other segments of the freeway which were determined to operate at a deficient level. Our experience with using the ramp analysis methodology is that poor freeway operations often influence the results of the ramp analysis.

In a practical sense, these results indicate that the traffic may not be able to reach the ramp due to freeway congestion. All indications are that the ramp will operate at an acceptable level with any delays or congestion occurring on the freeway itself.

This conclusion is bolstered by development of a micro-simulation model in VISSIM which was presented to Caltrans staff in a meeting on March 23, 2006. As this model demonstrated, the queuing on the ramp would not extend back to the freeway, even with the passage of a freight train along the project frontage.

Ramp Junction	AM		PM	
	Density	LOS	Density	LOS
I-880 Northbound/6 th Avenue Off-Ramp	32	D	44	F
I-880 Southbound/10 th Avenue On-Ramp	26	C	24	C
I-880 Southbound/16 th Avenue Off-Ramp	38	E	35	D

Source: Fehr & Peers, 2006

D-7: Fehr & Peers Transportation Consultant's have updated the Draft EIR tables to provide the delay values for the LOS F intersections. In several cases, the LOS F value was assigned based on field observations instead of the technical analysis. In those cases, no delay is reported. There are also several unsignalized intersections where it is not possible

to report delay because the delay can not be calculated, due to the high volumes. In those cases, the “overflow” conditions are reported.

The following should be noted regarding the information provided:

1. While the software employed in this analysis (Synchro) is capable to calculating delay for even the most oversaturated conditions, Fehr & Peers has found these delay calculations to be unreliable at very high levels of delay.
2. In particular, Fehr & Peers found that the addition of a small number of vehicles at an intersection with very high levels of delay will lead to a disproportionate increase in delay. This phenomenon is particularly true at unsignalized intersections, since the analysis includes side street delay only.
3. Fehr & Peers’ assessment of intersection impacts considered both changes in delay and the project’s contribution to growth at study intersections. The addition of this information does not change the identified project impacts and mitigation measures.

TABLE IV.B-2 REV
EXISTING INTERSECTION LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Traffic Control	Existing AM		Existing PM	
			LOS	Delay	LOS	Delay
#1	Atlantic & Webster (Alameda)	Signal	C	28.2	C	30.2
#2	Atlantic & Constitution (Alameda)	Signal	C	27.9	C	27.0
#3	Embarcadero & Broadway	All-Way Stop	A	8.0	A	9.5
#4	Embarcadero & Oak Street	Side Street Stop	B	13.3	C	16.0
#5	5th Street & Broadway	Signal	C	30.2	F	* a
#6	5th Street & Webster Street	Side Street Stop	A	9.4	A	9.3
#7	5th Street & Jackson Street	Signal	B	11.1	B	10.3
#8	5th Street & Madison Street	Signal	A	8.2	B	10.7
#9	5th Street & Oak Street	Signal	B	12.4	B	12.5
#10	6th Street & Broadway	Signal	C	22.2	B	19.8
#11	6th Street & Webster Street	Side Street Stop	A	9.5	A	9.2
#12	6th Street & Jackson Street	Signal	C	* b	C	* b
#13	7th Street & Market Street	Signal	B	12.0	B	12.3
#14	7th Street & Broadway	Signal	B	12.8	B	16.6
#15	7th Street & Webster Street	Signal	A	8.7	B	11.4
#16	7th Street & Jackson Street	Signal	B	11.0	B	11.9
#17	7th Street & Madison Street	Signal	B	12.9	B	14.3
#18	7th Street & Oak Street	Signal	B	12.5	B	14.0
#19	8th Street & Market Street	Signal	A	9.1	B	10.9
#20	8th Street & Broadway	Signal	B	11.4	B	11.8
#21	8th Street & Webster Street	Signal	C	28.1	E	* b
#22	8th Street & Jackson Street	Signal	B	16.5	B	14.2
#23	8th Street & Madison Street	Signal	A	8.9	A	9.4
#24	8th Street & Oak Street	Signal	B	16.6	B	16.0
#25	West Grand Avenue & Market Street	Signal	B	12.9	B	14.7
#26	West Grand Avenue & Broadway	Signal	B	15.5	B	17.4
#27	West Grand Avenue & Harrison Street	Signal	C	31.2	C	29.2
#28	10th Street & Oak Street	Signal	A	9.4	A	9.6
#29	1st Avenue & International Boulevard	Signal	B	16.9	B	13.4
#30	Lakeshore Avenue & Foothill Blvd	Signal	C	25.5	B	12.9
#31	Lakeshore Avenue & East 18th Street	Signal	B	13.5	C	27.5
#32	Lakeshore Avenue & Hanover Ave.	Signal	A	7.0	A	6.1
#33	Lakeshore Avenue & Brooklyn Ave.	Signal	A	7.0	A	5.8

TABLE IV.B-2 REV (continued)

EXISTING INTERSECTION LEVEL OF SERVICE (LOS) AND DELAY (SECONDS/VEHICLE)

#34	Lakeshore Avenue & MacArthur Blvd	Signal	C	23.6	E	66.9
#35	Lakeshore Avenue & Lake Park Ave.	Signal	D	35.2	D	35.5
#36	Embarcadero & 5th Avenue	Side Street Stop	F	54.0	F	401
#37	Embarcadero & I-880 NB Off-Ramp	Side Street Stop	B	12.3	B	14.2
#38	Embarcadero & I-880 SB On-Ramp	All-Way Stop	B	10.3	B	13.5
#39	Embarcadero & I-880 SB Off-Ramp	Side Street Stop	B	12.9	B	11.7
#40	5th Avenue & 7th/8th Streets	Signal	B	13.0	B	13.1
#41	14th Avenue & 7th St./12th St. (SB)	Signal	C	22.4	C	24.6
#42	14th Avenue & East 12th St. (NB)	Signal	B	12.3	B	10.1
#43	East 12th Street & 23rd Avenue	Signal	B	12.9	B	12.3
#44	East 12th Street & 5th Avenue	Signal	B	12.9	B	13.9
#45	International Boulevard & 14th Ave.	Signal	B	11.3	B	12.9
#46	International Boulevard & 23rd Ave.	Signal	B	12.4	B	11.7
#47	International Boulevard & 5th Ave.	Signal	B	13.4	B	12.8
#48	Foothill Boulevard & 5th Avenue	Signal	B	11.2	B	16.1
#49	Foothill Boulevard & 14th Ave. (WB)	Signal	B	19.7	B	17.0
#50	Foothill Boulevard & 14th Ave. (EB)	Signal	C	23.9	C	22.0
#51	Foothill Boulevard & 23rd Avenue	Signal	B	16.8	B	13.2
#52	16th Street & 23rd Avenue	Signal	B	15.8	C	33.7

^a See text on page IV.B-8 about how field observations show substantially worse LOS than calculated LOS under existing conditions.

^b See text below about how field observations show worse LOS than calculated LOS under existing conditions.

Note: The LOS/Delay for Side-Street Stop-Control (SSSC) intersections represent the worst movement or approach; for Signalized and All-Way Stop-Control (AWSC) the LOS/Delay represent overall intersection.

SOURCE: Fehr & Peers Transportation Consultants

TABLE IV.B-5 REV

2010 AM AND PM PEAK HOUR INTERSECTION
LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Traffic Control	AM Peak Hour				PM Peak Hour			
			Baseline		With Project		Baseline		With Project	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#1	Atlantic & Webster (Alameda)	Signal	D	52.7	D	54.3	D	49.0	D	50.0
#2	Atlantic & Constitution (Alameda)	Signal	C	34.6	C	34.8	C	31.3	C	32.0
#3	Embarcadero & Broadway	AWSC	A	8.3	A	8.9	B	10.5	B	12.5
#4	Embarcadero & Oak Street	SSSC	C	22.9	E	42.1	D	25.3	F	109.2
#5	5th Street & Broadway	Signal	D	44.1	D	43.8	F	* a	F	* a
#6	5th Street & Webster Street	SSSC	A	9.8	A	9.8	A	8.6	A	9.8
#7	5th Street & Jackson Street	Signal	B	11.0	B	11.0	B	10.4	B	10.3
#8	5th Street & Madison Street	Signal	A	8.4	A	8.4	B	11.0	B	10.8
#9	5th Street & Oak Street	Signal	B	13.7	B	14.2	C	20.5	C	22.8
#10	6th Street & Broadway	Signal	C	24.2	C	24.8	C	20.7	C	20.4
#11	6th Street & Webster Street	SSSC	A	9.9	A	9.9	A	9.3	A	9.3
#12	6th Street & Jackson Street	Signal	C	* b	C	* b	E	61.0	F	80.5
#13	7th Street & Market Street	Signal	B	12.9	B	12.9	B	14.7	B	14.7
#14	7th Street & Broadway	Signal	B	14.2	B	14.2	B	17.3	B	18.8
#15	7th Street & Webster Street	Signal	B	11.0	B	11.1	B	13.0	B	13.2
#16	7th Street & Jackson Street	Signal	B	12.4	B	11.9	B	14.4	B	15.7
#17	7th Street & Madison Street	Signal	B	12.8	B	12.9	B	15.6	B	15.8
#18	7th Street & Oak Street	Signal	B	12.6	B	12.4	B	16.7	B	16.5
#19	8th Street & Market Street	Signal	A	9.4	A	9.4	B	12.2	B	12.2
#20	8th Street & Broadway	Signal	B	11.7	B	11.8	B	12.2	B	12.5
#21	8th Street & Webster Street	Signal	C	29.0	C	29.3	E	* b	E	* b
#22	8th Street & Jackson Street	Signal	B	17.8	B	18.9	B	14.8	B	15.2
#23	8th Street & Madison Street	Signal	A	9.0	A	9.0	A	9.4	A	9.3
#24	8th Street & Oak Street	Signal	B	16.4	B	16.3	B	15.7	B	15.6
#25	West Grand Ave. & Market Street	Signal	B	13.7	B	13.7	B	18.3	B	18.4
#26	West Grand Ave. & Broadway	Signal	B	19.9	B	19.9	C	19.9	C	27.0
#27	West Grand Ave. & Harrison Street	Signal	D	44.6	D	45.1	D	36.0	D	36.2
#28	10th Street & Oak Street	Signal	A	9.5	A	9.5	A	9.8	A	9.8
#29	1st Ave. & International Blvd	Signal	B	16.7	B	16.9	B	16.1	B	16.2
#30	Lakeshore Ave. & Foothill Blvd	Signal	C	31.7	C	32.9	B	14.7	B	15.1
#31	Lakeshore Ave. & East 18th Street	Signal	B	14.6	B	14.6	C	29.8	C	30.2
#32	Lakeshore Ave. & Hanover Avenue	Signal	A	6.2	A	6.3	A	7.2	A	7.2
#33	Lakeshore Ave. & Brooklyn Ave.	Signal	A	7.1	A	7.1	A	6.1	A	6.1
#34	Lakeshore Ave. & MacArthur Blvd	Signal	C	23.8	C	24.1	F	90.0	F	90.3

TABLE IV.B-5 REV (continued)

2010 AM AND PM PEAK HOUR INTERSECTION
LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Traffic Control	AM Peak Hour				PM Peak Hour			
			Baseline		With Project		Baseline		With Project	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#35	Lakeshore Ave. & Lake Park Ave.	Signal	D	39.7	D	39.8	D	48.4	D	48.5
#36	Embarcadero & 5th Avenue	SSSC	F	108.8	F	Overflow	F	Overflow	F	Overflow
#37	Embarcadero & I-880 Northbound Off-Ramp – 6th Avenue	SSSC	B	12.3	F	95.4	B	14.5	F	1358
#38	Embarcadero & I-880 Southbound On-Ramp – 10th Avenue	AWSC	B	10.3	B	12.1	B	13.7	B	17.3
#39	Embarcadero & I-880 Southbound Off-Ramp – 16th Avenue	SSSC	B	13.5	B	13.7	B	11.9	B	12.8
#40	5th Avenue & 7th/8th Streets	Signal	B	13.5	B	13.8	B	15.0	B	16.1
#41	14th Avenue & 7th/12th St. (SB)	Signal	C	24.0	C	24.3	D	41.0	D	45.3
#42	14th Avenue & East 12th St. (NB)	Signal	B	13.2	B	13.1	B	11.8	B	11.6
#43	East 12th Street & 23rd Avenue	Signal	B	14.3	B	14.8	B	13.7	B	14.4
#44	East 12th Street & 5th Avenue	Signal	B	13.4	B	13.9	B	15.8	B	17.9
#45	International Blvd & 14th Avenue	Signal	B	11.9	B	11.9	B	14.2	B	14.3
#46	International Blvd & 23rd Avenue	Signal	B	13.2	B	13.3	B	13.1	B	13.5
#47	International Blvd & 5th Avenue	Signal	B	13.9	B	14.2	B	14.2	B	14.5
#48	Foothill Blvd & 5th Avenue	Signal	B	11.2	B	11.4	B	18.3	B	19.8
#49	Foothill Blvd & 14th Ave. (WB)	Signal	C	24.2	C	24.3	B	17.6	B	17.8
#50	Foothill Blvd & 14th Ave. (EB)	Signal	C	24.8	C	24.7	C	22.7	C	22.8
#51	Foothill Blvd & 23rd Avenue	Signal	B	18.0	B	17.8	B	13.4	B	13.5
#52	16th Street & 23rd Avenue	Signal	B	16.0	B	15.7	D	50.1	D	52.2

^a See text on page IV.B-8 about how field observations show substantially worse LOS than calculated LOS under existing conditions.

^b See text on page IV.B-10 about how field observations show worse LOS than calculated LOS under existing conditions.

Note: The LOS/Delay for Side-Street Stop-Control (SSSC) intersections represent the worst movement or approach; for Signalized and All-Way Stop-Control (AWSC) the LOS/Delay represent overall intersection. Significant impacts are denoted in **Bold** typeface.

SB = Southbound; NB = Northbound; WB = Westbound; EB = Eastbound

Significant impacts are denoted in **Bold** typeface.

SOURCE: Fehr & Peers Transportation Consultants

TABLE IV.B-6 REV

2010 AM AND PM PEAK HOUR MITIGATED INTERSECTION
LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Mitigation	Project Condition				Mitigated Condition			
			AM Peak		PM Peak		AM Peak		PM Peak	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#4	Embarcadero & Oak Street	Signal	E	42.1	F	109.2	B	13.5	B	15.8
#5	5th Street & Broadway	None feasible	D	43.8	F	* a	D	43.8	F	* a
#12	6th Street & Jackson Street	Optimize Timing	C	* b	F	80.5	C	* b	D	50.0
#36	Embarcadero & 5th Avenue	Signal	F	108.8	F	Overflow	A	9.5	C	21.2
#37	Embarcadero & I-880 Northbound Off-Ramp – 6th Avenue	Signal	F	95.4	F	1358	A	6.9	C	22.3

^a See text on page IV.B-8 about how field observations show substantially worse LOS than calculated LOS under existing conditions.

^b See text on page IV.B-10 about how field observations show worse LOS than calculated LOS under existing conditions.

Significant impacts are denoted in **Bold** typeface.

SOURCE: Fehr & Peers Transportation Consultants

TABLE IV.B-7 REV

2025 AM AND PM PEAK HOUR INTERSECTION
LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Traffic Control	AM Peak Hour				PM Peak Hour			
			Baseline		With Project ^a		Baseline		With Project ^a	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#1	Atlantic & Webster (Alameda)	Signal	E	74.6	F	82.0	E	57.9	E	61.7
#2	Atlantic & Constitution (Alameda)	Signal	D	44.0	D	45.4	D	38.5	D	40.8
#3	Embarcadero & Broadway	AWSC	A	9.4	B	14.5	C	21.3	F	93.7
#4	Embarcadero & Oak Street	SSSC/ Signal	F	63.6	C	20.2	F	57.4	D	39.0
#5	5th Street & Broadway	Signal	E	77.6	E	75.2	F	* b	F	* b
#6	5th Street & Webster Street	SSSC	A	10.0	B	10.1	A	9.5	A	9.7
#7	5th Street & Jackson Street	Signal	B	10.9	B	11.2	B	10.6	B	12.7
#8	5th Street & Madison Street	Signal	A	8.2	A	8.3	B	14.6	B	17.8
#9	5th Street & Oak Street	Signal	C	21.9	D	52.9	E	60.7	F	111.7
#10	6th Street & Broadway	Signal	C	25.3	C	28.8	C	23.1	C	25.6
#11	6th Street & Webster Street	SSSC	B	10.3	B	10.3	A	9.5	A	9.6
#12	6th Street & Jackson Street	Signal	E	77.0	F	130.6	F	134.5	F	148.0
#13	7th Street & Market Street	Signal	B	15.2	B	15.2	C	26.2	C	26.7
#14	7th Street & Broadway	Signal	B	14.9	B	15.5	C	22.3	E	57.6
#15	7th Street & Webster Street	Signal	B	13.2	B	13.7	B	14.8	B	15.7
#16	7th Street & Jackson Street	Signal	B	14.3	B	16.0	C	23.6	D	36.9
#17	7th Street & Madison Street	Signal	B	13.9	B	13.9	B	16.7	B	17.2
#18	7th Street & Oak Street	Signal	B	13.4	B	12.6	E	61.4	E	60.3
#19	8th Street & Market Street	Signal	B	10.3	B	10.4	B	14.2	B	14.2
#20	8th Street & Broadway	Signal	B	12.7	B	13.2	B	13.0	B	14.3
#21	8th Street & Webster Street	Signal	D	38.2	D	45.5	E	* c	E	* c
#22	8th Street & Jackson Street	Signal	C	24.4	D	39.6	B	16.5	C	19.5
#23	8th Street & Madison Street	Signal	A	10.0	A	10.0	A	9.6	A	9.4
#24	8th Street & Oak Street	Signal	B	15.5	B	15.5	B	15.4	B	15.2
#25	West Grand Ave. & Market Street	Signal	B	15.6	B	15.6	E	73.8	E	74.1
#26	West Grand Ave. & Broadway	Signal	E	60.4	E	60.3	E	78.0	E	78.9
#27	West Grand Ave. & Harrison Street	Signal	F	151.4	F	156.0	D	49.3	D	50.6
#28	10th Street & Oak Street	Signal	B	10.4	B	10.4	B	10.4	B	10.4
#29	1st Ave. & International Blvd	Signal	B	16.3	B	16.5	C	22.1	C	22.4
#30	Lakeshore Ave. & Foothill Blvd	Signal	E	58.1	E	64.1	B	18.3	B	19.7
#31	Lakeshore Ave. & East 18th Street	Signal	D	39.9	D	39.3	D	37.5	D	40.2
#32	Lakeshore Ave. & Hanover Avenue	Signal	A	6.2	A	6.2	A	7.4	A	7.4
#33	Lakeshore Ave. & Brooklyn Ave.	Signal	A	7.7	A	7.7	A	6.8	A	6.9
#34	Lakeshore Ave. & MacArthur Blvd	Signal	C	25.5	C	26.2	F	111.1	F	111.4
#35	Lakeshore Ave. & Lake Park Ave.	Signal	D	43.5	D	43.9	E	55.8	E	58.9
#36	Embarcadero & 5th Avenue	SSSC/ Signal	F	Overflow	D	49.2	F	Overflow	F	511
#37	Embarcadero & I-880 Northbound Off-Ramp – 6th Avenue	SSSC/ Signal	B	12.6	B	19.0	B	14.8	F	350
#38	Embarcadero & I-880 Southbound On-Ramp – 10th Avenue	AWSC	B	11.1	D	29.4	B	14.3	E	42.7
#39	Embarcadero & I-880 Southbound Off-Ramp – 16th Avenue	SSSC	B	14.7	C	15.5	B	13.0	C	16.5
#40	5th Avenue & 7th/8th Streets	Signal	B	14.7	B	16.8	D	37.4	F	81.5
#41	14th Avenue & 7th/12th St. (SB)	Signal	C	24.9	C	27.2	E	72.0	F	87.7
#42	14th Avenue & East 12th St. (NB)	Signal	B	16.0	B	16.0	B	12.1	B	12.6
#43	East 12th Street & 23rd Avenue	Signal	B	19.0	C	20.8	B	16.8	B	18.9
#44	East 12th Street & 5th Avenue	Signal	B	16.5	C	28.3	B	19.1	D	40.5
#45	International Blvd & 14th Avenue	Signal	B	12.8	B	13.1	B	16.8	B	17.3
#46	International Blvd & 23rd Avenue	Signal	B	19.0	C	21.0	B	19.0	C	24.2
#47	International Blvd & 5th Avenue	Signal	B	14.6	B	15.0	B	14.9	B	14.9
#48	Foothill Blvd & 5th Avenue	Signal	B	12.1	B	13.2	C	20.2	C	28.2
#49	Foothill Blvd & 14th Ave. (WB)	Signal	D	54.1	E	55.8	C	21.2	C	21.5
#50	Foothill Blvd & 14th Ave. (EB)	Signal	C	27.4	C	27.4	F	101.7	F	108.4
#51	Foothill Blvd & 23rd Avenue	Signal	C	21.5	C	21.3	B	13.1	B	13.7

No.	Intersection	Traffic Control	AM Peak Hour				PM Peak Hour			
			Baseline		With Project ^a		Baseline		With Project ^a	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#52	16th Street & 23rd Avenue	Signal	B	17.3	B	17.6	E	70.7	E	74.2

^a Mitigation measures required for impacts in 2010 are assumed to be in-place under 2025 “with project” conditions

^b See text on page IV.B-8 about how field observations show substantially worse LOS than calculated LOS under existing conditions.

^c See text on page IV.B-10 about how field observations show worse LOS than calculated LOS under existing conditions.

Note: The LOS/Delay for Side-Street Stop-Control (SSSC) intersections represent the worst movement or approach; for Signalized and All-Way Stop-Control (AWSC) the LOS/Delay represent overall intersection. Significant impacts are denoted in **Bold** typeface.

SB = Southbound; NB = Northbound; WB = Westbound; EB = Eastbound

Significant impacts are denoted in **Bold** typeface.

SOURCE: Fehr & Peers Transportation Consultants

TABLE IV.B-8 REV

2025 AM AND PM PEAK HOUR MITIGATED INTERSECTION
LEVEL OF SERVICE (LOS) AND DELAY (seconds/vehicle)

No.	Intersection	Mitigation	Project Condition				Mitigated Condition			
			AM Peak		PM Peak		AM Peak		PM Peak	
			LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
#1	Atlantic & Webster (Alameda)	Add Lanes	F	82.0	E	61.7	E ^a	62.3	D	48.3
#3	Embarcadero & Broadway	Signal	B	14.5	F	93.7	A	7.5	B	10.7
#5	5th Street & Broadway	None feasible	E	75.2	F ^a	104.5	E	75.2	F ^b	>104.5
#9	5th Street & Oak Street	Optimize Timing	D	52.9	F	111.7	D	52.9	E	62.2
#12	6th Street & Jackson Street	None feasible	F	134.5	F	148.0	F	134.5	F	148.0
#27	West Grand Ave. & Harrison St.	Optimize Timing	F	156.0	D	50.6	C	31.4	D	50.6
#30	Lakeshore Ave. & Foothill Blvd	Optimize Timing	E	64.1	B	19.7	E ^a	59.3	B	19.7
#34	Lakeshore Ave. & MacArthur Blvd	None feasible	C	26.2	F	111.4	C	26.2	F	111.4
#35	Lakeshore Ave. & Lake Park Ave.	Optimize Timing	D	43.9	E	58.9	D	43.9	D	47.5
#36	Embarcadero & 5th Avenue	Widen Embarcadero	D	49.2	F	511	C	27.3	C	29.9
#37	Embarcadero & I-880 NB Off-Ramp	Widen Embarcadero	B	19.0	F	350	B	10.1	C	30.8
#38	Embarcadero & I-880 SB On-Ramp	Signal	D	29.4	E	42.7	B	17.6	B	19.0
#40	5th Avenue & 7th/8th Streets	Optimize Timing	B	16.8	F	81.5	D	38.7	D	47.9
#41	14th Avenue & 7th/12th St. (SB)	Optimize Timing	C	27.2	F	87.7	C	27.2	E ^a	63.8
#49	Foothill Blvd & 14th Ave. (WB)	Optimize Timing	E	55.8	C	21.5	C	26.7	B	17.9
#50	Foothill Blvd & 14th Ave. (EB)	Optimize Timing	C	27.4	F	108.4	C	25.1	C	28.7
#52	16th Street & 23rd Avenue	Optimize Timing	B	17.6	E	74.2	B	17.6	C	29.3

^a After implementation of the identified mitigation measure, the increase in average delay from the No Project condition would be less than the four-second threshold of significance established by the City of Oakland, and the project impact would be mitigated to a less-than-significant level, even with an unacceptable LOS.

^b See text on page IV.B-8 about how field observations show substantially worse LOS than calculated LOS under existing conditions.

Significant impacts are denoted in **Bold** typeface.

SOURCE: Fehr & Peers Transportation Consultants

D-25: The comment is noted. The Preliminary Development Plan (PDP) and Vesting Tentative Tract Map have been revised to delete the indication of proposed parking under the I-880 freeway structure south of the northbound Embarcadero off-ramp.

D-26: The project's new stormwater drainage system will be designed to accommodate drainage from the project site. Any existing drainage that flows through the site will continue to be accommodated.

B. Metropolitan Greater Oakland Democratic Club (MGO) Comments and Responses

The following comment letter on the Draft EIR was emailed to but not received by City staff prior to publication of the Final EIR, therefore, the letter was not included in the Final EIR. This omission was brought to the staff's attention after publication of the Final EIR, and the letter was resubmitted and received in March 2006. A copy of the letter was provided to the Planning Commission attached to its March 15, 2006 staff report. The correspondence is copied below, and the City's responses follow the letter.

From: Frank Russo [mailto:fdr@sbcglobal.net]
Sent: Monday, October 24, 2005 9:19 AM
To: 'Mstanzione@oaklandnet.com'
Cc: mgobd@yahoogroups.com
Subject: Letter of the Metropolitan-Greater Oakland Democratic Club on Draft Environmental Impact Statement on Oak to Ninth Development

To: Margaret Stanzione, Project Planner, City of Oakland, CEDA

RE: Draft EIR, Oak to 9th

Dear Ms. Stanzione:

The Metropolitan Greater Oakland Democratic Club (MGO) submits these comments on the draft EIR of the proposed development of Oak to 9th. We have held three club meetings on the subject of this project and heard from the developer and a number of other speakers. We concur with the League of Women Voters on a number of issues and concerns they have raised in a letter to you.

1

First, we have a process question: The Draft EIR was very hard to find online (and requires multiple clicks, with links that are not particularly intuitive). For this reason and those stated by others, we join them in requesting an extension of the comment period.

2

Secondly, MGO supports full compliance with Estuary Policy Plan (EPP). The EPP was developed through a process that included lengthy public discussion, debate and compromise - and that process should be respected. Further, by "full compliance with the Estuary Policy Plan", we mean just that - not 'most of the elements of', or 'in the spirit of', or 'many of the principles of' - but full compliance.

3

Third, the EPP calls for a "specific plan" for this site prior to development; there is a statement in the Draft EIR that "The City and Port of Oakland have not elected to prepare a specific plan for the Oak-to-Ninth District as called for in the Estuary Plan.", with the rationale that the process we are in now is 'essentially equivalent' to a specific plan. We ask that the Planning Commission look at this, and ensure

4

that 'essentially equivalent' doesn't leave out anything, especially the chance for a back and forth public discussion about various alternatives.

Fourth, we have a somewhat technical question regarding the open space in the plan: How do we protect public use/access to public space? By assessing the condo owners to maintain the open space, the private ownership group has more control over the open space, potentially allowing them to place restrictions on public access to "their" space.

5

In addition to the above, MGO is insists that 25% of any housing created as a result of the project, should be affordable to Oaklanders. The requirement of affordable housing is an established principle in Oakland City law and precedents and must be included.

6

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Responses to MGO Comments

- 1 The comment is noted, and the referenced League of Women Voters' letter is Letter N in the Final EIR. The responses to Letter N are presented on page VI-43 of the Final EIR.
- 2 The comment is noted. The Planning Commission considered several public comments requesting that the public review and comment period on the Draft EIR be extended. The Commission closed the public review and comment period on the DEIR on September 28, 2006, however, the Commission's action noted that the City would continue to accept written comments on the Draft EIR through October 24, 2005, as noticed in the Notice of Availability.
- 3 The Draft EIR discusses how the project relates to the Estuary Policy Plan on DEIR pages IV.A-11 through IV.A-17, and under Impact A.2 on pages IV.A-36 and IV.A-37. As concluded there, the project would not conflict with Estuary Plan policies or its overall vision for the Oak to Ninth District. The project would introduce a series of large open spaces along the waterfront that would be a major recreation designation in the city and transform the area from an industrial backwater to a recreational centerpiece and a regional and local asset.

The Draft EIR also discusses how conflict with a specific General Plan policy does not inherently result in a significant impact on the environment within the context of CEQA (DEIR pp. IV.A-6 and IV.A-36). Ultimately, in deciding whether to approve the project, the City will assess whether the project is consistent with the overall policies of the General Plan through its process of balancing competing General Plan goals and objectives.

- 4 The City's decision not to prepare a specific plan for the project is discussed in detail in Master Response A of the Final EIR. City decisionmakers will consider this information, all information provided about the project beyond that in the EIR, as well as the public input process conducted for the environmental and project review, and will then determine the appropriateness of the analysis and public input opportunities for the project and its relevant equivalence to a specific planning process.
- 5 The purpose of the proposed owners' assessment is to ensure the adequate and continued maintenance of the open space areas within the project site. The maintenance agreement mechanism and its purview is not an issue pertinent to the impacts of the project on the physical environment under CEQA. However, the City will ultimately establish the final mechanism and its details through the conditions of approval for the project or a Development Agreement between the City and the project sponsor. Additionally, all public open spaces on the project site would be owned by the City of Oakland and therefore public access would not be restricted. As discussed on Draft EIR page IV.L-18, the City of Oakland would review the adequacy of the public access to public parks, open spaces, and recreational facilities on the project site, as would the Bay Conservation and Development Commission (BCDC) for areas along the shoreline. The City also will

evaluate the extent to which the site arrangement of public and private areas on the site appears to limit public access, physically or perceptually.

- 6 Master Response H in the Final EIR discusses that the project's provision of affordable housing is not a topic pertinent to the physical environmental impacts addressed under CEQA. The project would assist the Oakland Redevelopment Agency (ORA) in meeting its affordable housing requirements under state law, as discussed on Draft EIR pages IV.A-28 and IV.A-29 within the context of the *Central City East Redevelopment Plan* and the *Central City Urban Renewal Plan*. Additional detail is provided on Draft EIR page IV.J-42 within the detailed analysis of *Potential for Indirect Physical Impacts (Development of Affordable Housing)*. Since publication of the EIR (Draft and Final), Development Agreement discussions and negotiations among the City, the ORA, and the project sponsor have been ongoing and address the number (and other characteristics) of affordable housing units to be provided within the Oak to Ninth Avenue Project site and the Redevelopment Plan area.

C. Comments from Cynthia Shartzter, and Responses Previously Submitted to the Planning Commission

After the close of the public review and comment period on the Draft EIR, the City received comments from Cynthia Shartzter dated October 24, 2004. The City prepared and submitted responses to those comments (designated as Letter UU) to the Planning Commission, and that information was incorporated by reference into the Final EIR.

For convenience and documentation, the comment letter and responses are provided on the following pages.

October 24, 2005

Ms. Margaret Stanzione
 Project Planner
 City of Oakland
 Community and Economic Development Department
 250 Frank H. Ogawa Plaza, Suite 3315
 Oakland, CA 94612

Re: Comments on DEIR for Proposed Project 'Oak to 9th'

Dear Ms. Stanzione:

This letter supplements my June 30, 2004 letter on the 'Notice of Preparation of the EIR,' public comments I made at the June 16, 2004 Planning Commission meeting to advocate for the adaptive reuse of the entire Ninth Avenue Terminal-Ninth Avenue Transit Shed, as a member of the historic preservation group in the 'Small Group Interviews' (with Naomi Schiff and Leal Charonnat), and community meetings on March 30, 2004 and April 9, 2005.

UU-1

The Process

Please note that although the public meetings, e.g., 'small group interviews' responded to public request for a participatory process they were not responsive to the public request. The request was for a 'National Charrette Institute-type' process. The key aspect of this participatory process is that it is progressive and iterative. The City of Oakland's small group interview process—a shadow of an authentic process of public participation—is now referred to in the community as 'charrette-lite.'

The way the City/Port's public process makes a mockery of genuine public process is best summarized by the Executive Summary and the summary report (see p. 9 of the Staff Report dated September 28, 2005) which states: "...Meetings attendees understand and respect the need for the project to be economically feasible for the developer..."

UU-2

The one person that articulated this statement identified herself as a potential investor in the project. Therefore I believe that it is an overstatement and inaccurate reflection of 'the public' to include this sweeping generalization. Based on my personal observations, this individual and employees of the Port of Oakland were strategically placed in breakout groups, i.e., if enough individuals representing the interests of the developer fan out in a 'public' meeting the result is a sweeping generalizations that bring to mind Carpentier and Oakland's waterfront history.

With Oakland's historic ties to the waterfront and the challenges it experienced to return the waterfront to public ownership, it would be unfortunate if the Port and its political allies now hand over public property, i.e., Tidelands trust land, into private ownership.

UU-3

Comments on DEIR for
Proposed Project 'Oak to 9th

Page 2

October 24, 2005

Having followed the 'development' process in Oakland or the 'redevelopment' process as was the case of Jack London Square—beginning with 160 14th Street to 16th to Wood Street Train Station—to me the Oak to Ninth Street project reflects another example of how the system is 'gamed' and how the public process is manipulated.

UU-4

Preserving Oakland's History by reusing its cultural resources

As the last survivor of the City of Oakland's three Municipal Terminals from the 1925 harbor bond, the preservation the Ninth Avenue Terminal—in its entirety—would honor the bond between the Port and City of Oakland and symbolized by the Terminal. The Ninth Avenue Terminal—completed in 1930—has a strong link with the establishment of the first Board of Port Commissioners of the Port of Oakland.

UU-5

A copy of the landmark application for the Ninth Avenue Terminal, prepared for the Oakland Heritage Alliance and Friends of the Ninth Avenue Terminal was an attachment to my June 30, 2004 letter.

Proposed demolition of a building of such landmark distinction, even with retention a token portion, is not justified.

There are multiple examples of successful adaptive reuse projects, e.g., Ferry Building in San Francisco and the Subway Terminal Building in Los Angeles. The 500,000 square foot Subway Terminal Building—opened in 1925—has been converted into 277 live-work units called Metro 417. In San Francisco, the new Asian Art Museum is housed in the adaptively reused SF Library (one of the original Carnegie-funded libraries); architect Guy Aulenti also adaptively reused a Paris train station into a museum, the Musée D'Orsay.

UU-6

In Richmond, Orton Development of Emeryville is leading the way in the Bay area by partnering with the National Park Service and the City of Richmond to adaptively reuse the Ford Assembly Plant. Oakland deserves similarly progressive development for its waterfront. The preservation of the Ninth Avenue Terminal-Ninth Avenue Transit Shed—in its entirety—offers an opportunity to build smart and to help Oakland join the ranks of cities around the world that recognize and reap the strategic and economic benefits of adaptive reuse of historic and cultural resources.

Respectfully submitted,

Cynthia L. Shartzter
cell 510-882-0371

Attachments:

Comments on Notice of Preparation of EIR for Proposed 'Oak to 9th' 30 June 2004

Comments on DEIR for
Proposed Project 'Oak to 9th

Page 3

October 24, 2005

June 30, 2004

Ms. Margaret Stanzione
Project Planner
City of Oakland
Community and Economic Development Department
250 Frank H. Ogawa Plaza, Suite 3315
Oakland, CA 94612

Re: Comments on Notice of Preparation of EIR for Proposed Project 'Oak to 9th

Dear Ms. Stanzione:

This letter supplements public comment I made at the June 16, 2004 Planning Commission meeting to advocate for the adaptive reuse of the entire Ninth Avenue Terminal-Ninth Avenue Transit Shed. A copy of the landmark application for the Ninth Avenue Terminal, prepared for the Oakland Heritage Alliance and Friends of the Ninth Avenue Terminal, is provided (Attachment E).

As the last survivor of the City of Oakland's three Municipal Terminals from the 1925 harbor bond, the preservation the Ninth Avenue Terminal—in its entirety—would honor the bond between the Port of Oakland and the City of Oakland and symbolized by the Terminal. The Ninth Avenue Terminal—completed in 1930—has a strong link with the establishment of the first Board of Port Commissioners of the Port of Oakland. The 1925 harbor bond that funded the construction of the Ninth Avenue Terminal required that the Board of Port Commissioners be formed. The date the first Board of Port Commissioners was sworn in—February 12, 1927—is recognized as the birth date of the Port of Oakland.

UU-7

The Ninth Avenue Terminal-Ninth Avenue Transit Shed was rated 'A' by City Staff—eligible for city landmark status—as well as appearing eligible for National Register status (Attachment A). The City of Oakland's Landmark Preservation Advisory Board (LPAB) unanimously approved Resolution 2004-3 to designate this property as an Oakland Landmark pursuant to Section 17.144 of the Oakland Planning Code (Attachment F). In addition, pursuant to the Historic Preservation Element (HPE) Policy 2.3(d) staff found the Ninth Avenue Terminal to have 'exceptional significance.' (Attachment D). The December 8, 2003 Staff report includes a discussion of the LPAB Policies & Procedures, General Plan—Historic Preservation Element Policy: 2.3 (d), 2.4(c), 3.2, 3.3 and notes that the Landmark Designation process "...will alter this application process [application process for a specific project] only with respect to LPAB Design Review" (Attachment C). The June 2, 2004 Planning Commission consideration of the Ninth Avenue Terminal landmark designation was postponed.

At its meeting of June 14, 2004 review of the Notice of Preparation for the Proposed Project 'Oak to Ninth' the LPAB requested that contrary to the described project

Comments on DEIR for
Proposed Project 'Oak to 9th

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intent to demolish the Ninth Avenue Terminal shed building "...with the exception of a[n unspecified] portion..." serious consideration should be given to the preservation of the Transit Shed in its entirety and its adaptive reuse. In particular, the building's monumentality was recognized as part of its essential character. I write in support of the preservation of the Ninth Avenue Terminal-Ninth Avenue Transit Shed, in its entirety. I echo requests by Oakland residents and social profit organizations such as Oakland Heritage Alliance that due consideration must be given in the EIR for the preservation of a significant portion of the Ninth Avenue Terminal. The Resolution 2004-3 to designate Ninth Avenue Terminal-Ninth Avenue Transit Shed an Oakland Landmark best summarizes the historic significance of this property (Attachment F).

UU-7
(CONT.)

As an intact, original wharf and transit shed still in use the Ninth Avenue Terminal is a fine example of simple, Beaux-arts style applied to an industrial/commercial building. It's amalgamation of water, rail, and land transportation capability in one facility is an early example of an inter-modal transportation complex. The building is 1,004 feet long by 180 feet wide. On the interior the sense of its monumentality is carried out in four acres of enclosed space, soaring to 47 feet in the middle and 27 feet on its sides. There are twenty-one cargo doors along the length of the transit shed on the waterfront, each door 16 feet by 16 feet. Along the length of the transit shed on the land side there are eighteen cargo doors, each 14 feet by 10 feet. At both ends of the building—at the transit shed's main entrance and at its rear, open wharf entrance—there is a cargo door, 24 feet by 18 feet.

Proposed demolition of a building of such landmark distinction, even with retention of an unspecified portion, is not justified. Previously the California Supreme Court has ruled that documentation of the historical features of the building and exhibition of a plaque do not reasonably begin to alleviate the impacts of its destruction because, "a large historical structure, once demolished, normally cannot be adequately replaced by reports and commemorative markers." Luckily times are changing, "According to a report by the Harvard University Graduate School of Design, renovation, reuse and preservation of existing buildings represents more than 40 percent of the design and construction market in the United States, particularly in urban areas." (California Real Estate Journal, March 1, 2004)

There are multiple examples of successful adaptive reuse projects, e.g., Ferry Building in San Francisco and the Subway Terminal Building in Los Angeles. The 500,000 square foot Subway Terminal Building—opened in 1925—has been converted into 277 live-work units called Metro 417. Oakland's City officials could benefit from Los Angeles' lessons to develop an adaptive reuse ordinance. In San Francisco, the new Asian Art Museum is housed in the adaptively reused San Francisco Library (one of the original Carnegie-funded libraries); architect Guy Aulenti also adaptively reused a Paris train station into the Musée D'Orsay.

In an article in the California Real Estate Journal, March 1, 2004, "Adaptive Reuse of Older Buildings Can Turn Community Eyesores into Assets," Y. Gaffen notes that,

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"...the economic benefits of adaptive reuse versus demolition can be enormous. According to the 'Journal of Property Management,' reuse projects are popular 'because they can significantly reduce construction costs for developers, and they present economically viable alternatives to commercial tenants in search of large spaces.' It is estimated that adaptive reuse projects cost an average of 16 percent less than new construction...Today, a number of economic incentives, primarily federal, are available to reuse historic buildings...."

UU-7
(CONT.)

There are sustainable benefits to the adaptive reuse of the Ninth Avenue Terminal-Ninth Avenue Transit Shed and the preservation of its materials. Y. Gaffen notes conservation of raw materials along with sustainable benefits at the neighborhood, city-wide, and regional levels. At the regional level he states, "...the preservation of existing facilities contributes to smart growth by reducing pressure on undeveloped green space and decreasing the need to extend infrastructure into undeveloped areas." California Real Estate Journal, March 1, 2004

The Ninth Avenue Terminal is already built on the Oakland Inner Harbor waterfront. Its adaptive reuse would best serve the neighborhood, city, and region due to its significance both to the maritime history of the City of Oakland and of the Bay Area. The resolution for its landmark designation states that it "is an especially prominent visual element in the neighborhood and along the waterfront, a signature and anchor building, due to the building's distinctive design, focal location on the Oakland-Alameda Estuary, and large scale..."

An example of state of the art construction and engineering during an era when projects were 'built to last;' the wharf may be considered 'overbuilt' given current knowledge of the industry. However, because of its exceptionally high standard of construction and engineering, the Ninth Avenue Terminal-Ninth Avenue Transit Shed has survived intact and is a prime candidate for reuse.

During research I located the Invitation For Bids in the Port of Oakland archives. According to the Invitation For Bids (IFB) for the Ninth Avenue Terminal (issued July 16, 1929 and due August 5, 1929) the construction of the Ninth Avenue Pier was started at the west end of the pier and was built from east to west. The construction specifications for the wharf (called a pier) are described in explicit detail including the materials, standards, inspection, etc. Some excerpts from the specifications that reflect the high quality and standards are provided below:

The structural steel required for the pier was described as:

...medium steel, with a tensile strength of at least 60,000 pounds per square inch, and workmanship thereon shall be subject to all the tests and conform with all the requirements of the standard specifications for structural steel for buildings adopted in 1901 by the American Society for Testing Materials and revised in 1921. (p. 21)

The dock iron required for the pier was described as:

Comments on DEIR for
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All bolt, spike and red iron shall have a tensile strength of at least 45,000 pounds per square inch of section. All wrought iron shall be fibrous in texture and capable of being bent double, cold, over a 2-inch cylinder without breaking the fibre. All forgings shall be perfect in every respect.
(p. 22)

The preservation of the Ninth Avenue Terminal-Ninth Avenue Transit Shed—in its entirety—offers an opportunity to build smart and to help Oakland join the ranks of cities around the world that recognize and reap the strategic and economic benefits of adaptive reuse of historic and cultural resources.

Respectfully submitted,

Cynthia L. Shartzner
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tel 510-763-7173; cell 510-882-0371

UU-7
(CONT.)

Attachments:

- (A) LPAB Evaluation Sheet for Landmark Eligibility
- (B) Port of Oakland November 10, 2003
- (C) LPAB Staff Report December 8, 2003
- (D) Findings of 'Exceptional Significance'
- (E) Landmark and S-7 Preservation Combining Zone Application
- (F) LPAB Resolution 2004-3
- (G) S-7 Preservation Combining Zone Regulations

Responses to Cynthia L. Shartzter Comments

- UU-1 The DEIR indicates on page I-2 that comments responding to the Notice of Preparation (NOP) of the Draft EIR and that involved environmental issues associated with the project site and proposed project are addressed in the DEIR. A summary of comments on the NOP was included in **Appendix B** of the DEIR, and copies of responses to the NOP are available for review at all locations where the DEIR was available for review (as specified on the Notice of Availability issued August 31, 2005). The comment is noted.
- UU-2 The comment addresses the City-sponsored community outreach process conducted by CirclePoint consultants (retained by the City), which involved nine small group meetings and two community-wide meetings and that was conducted separate from the environmental review process for the project. The merits of the community outreach process or comments received during that process do not address physical environmental impacts under CEQA or the adequacy of the analysis in the DEIR. The comment is noted.
- UU-3 The comment opines on a separate property transaction between the Port and the State Lands Commission that is not a part of the project, but that is already authorized by the Legislature to take place on behalf of the State. As such, the issue does not concern the environmental consequences of the project discussed in the DEIR. However, as discussed in Response to Comment GG-18, the Legislature delegated to the State Lands Commission the authority to approve and implement the property transaction of Tidelands Trust lands pursuant to specific conditions of Senate Bill (SB) 1622, the Oak to Ninth Avenue District Exchange Act. Additionally, a public hearing before the Board of Port Commissioners, as required by the Charter of the City of Oakland and SB 1622, would occur before the sale or exchange of Tidelands Trust lands may take place. The City's approval of the project will be conditioned upon subsequent compliance with the provisions of SB 1622.
- UU-4 The comment addresses the merits of the redevelopment process for the project and does not address physical environmental impacts under CEQA or the adequacy of the analysis in the DEIR. The comment is noted.
- UU-5 Impact E.3 regarding the proposed demolition of substantial portions of the Ninth Avenue Terminal would be significant and unavoidable, even after mitigation (DEIR p. IV.E-26). This determination considers the historic relevance of the Ninth Avenue Terminal to the development of the city, as discussed on DEIR pages IV.E-15 through IV.E-17 and within the historic resources evaluation (HRE) prepared by Carey & Co., historic resource consultants for the project. The HRE is included in Appendix G of the DEIR and contains and references much of the information provided in the 2003 landmark application for the Ninth Avenue Terminal structure (prepared by the commenter). As stated above in Response to Comment UU-1, information provided in responses to the NOP was addressed the DEIR.

The comment also suggests that demolition of the Terminal is “not justified.” As stated in Response to Comment K-3, Chapter V (Alternatives) of the DEIR describes and analyzes a range of project alternatives that retain all or part of the Ninth Avenue Terminal: Alternative 3 (Enhanced Open Space/Partial Ninth Avenue Terminal Preservation and Adaptive Reuse) and Sub-Alternative (Full Ninth Avenue Terminal Preservation and Adaptive Reuse). Prior to its action on the project, City decisionmakers will evaluate the project alternatives analyzed in the DEIR. The City will either reject these alternatives and adopt the proposed project, or alternatively, they will elect one of the alternatives analyzed, instead of the project.

- UU-6 The comment outlines examples of possible reuse scenarios for the preserved Terminal. See Master Response B regarding further analysis of reuse alternatives for the Ninth Avenue Terminal. Also, the alternatives described and analyzed in the DEIR include a number of reuse scenarios outlined by the community and comply with CEQA mandates for examining preservation alternatives for the historic resource. The City decisionmakers will consider this information before acting on the project.
- UU-7 Previously submitted comments received in response to the NOP for the Draft EIR are provided as attachment to this comment letter. As previously indicated, comments received in response to the NOP were considered and incorporated in the DEIR as appropriate. Overall, the NOP response from the commenter discusses the historic merits of the Ninth Avenue Terminal, the City of Oakland’s process of considering the landmark application to date, the commenter’s support for preserving a “significant portion” of the Terminal, adequate mitigation, successful adaptive Terminal reuse projects and the economic benefits of reuse versus demolition, and the structural and architectural merits of the structure. As stated above, with regard to factors relevant to the physical environmental impacts of the project under CEQA, the DEIR includes accurate historical and architectural setting information about the Terminal, and an adequate range of preservation alternatives that incorporates a number of reuse scenarios outlined by the community. Also, since publication of the DEIR, the project sponsor has prepared an economic feasibility and constraints report (capital and operational) on retaining all or parts of the Ninth Avenue Terminal (as well as on each of the other project alternatives). The economic feasibility and constraints report will be provided to City decisionmakers separate from this environmental report for its consideration of the project and the alternatives evaluated in the DEIR. The City will determine the adequacy of the report for its purposes, and will consider all information provided in the DEIR and this FEIR prior to acting on the project.

D. Comments and Responses to Issues Raised by Dr. Rajiv Bhatia

After publication of the Final EIR, Dr. Rajiv Bhatia submitted to the City several letters that raised a number of issues, some of which pertain to environmental topics under CEQA. Dr. Bhatia's correspondence raised the following environmental issues (date of letter shown in parentheses):

- 1) Pedestrian safety and injuries (March 3, 2006)
- 2) Inclusion of affordable housing to reduced certain transportation and air quality impacts resulting from the project (March 8, 2006)
- 3) Air quality and noise related health impacts (March 22 and March 23, 2006, and undated list of recommendations)²
- 4) Project consistency with the Oakland General Plan Noise Element (April 12, 2006).

Each letter is included in this section, and the City's responses immediately follow each letter.

² Letters addressed to Councilperson Jane Brunner, dated March 22, 2006, and March 23, 2006, are essentially the same, except for variations in formatting. Both letters are included in this Addendum.



March 3, 2006

Colland Jang
Chair, Oakland Planning Commission
Community Economic Development Agency
City of Oakland
250 Frank Ogawa Plaza, Suite 3315
Oakland CA 84612

**Re: Analysis of Pedestrian Injuries Resulting from the Oak to Ninth Avenue Project;
Oakland FEIR; Case ER 04-0009**

Dear Chairperson Jang:

At the public hearing on the DEIR of the Oak to Ninth Development Proposal, you raised the important issue of pedestrian safety and requested the City to conduct in the EIR an adequate analysis of project related impacts on pedestrian safety impacts. As a member of the public health community, I appreciate your concern about this issue.

Adverse environmental impacts on humans and public health must be addressed under CEQA, including but are not limited to impacts on pedestrian safety, noise, air quality, and hazardous materials.¹ Several stakeholders identified deficiencies in the DEIR analysis of project effects on pedestrian injuries in the neighborhoods surrounding the proposed Oak to Ninth development. Unfortunately, the FEIR analysis of pedestrian safety remains inadequate; furthermore, I believe, many City of Oakland FEIR responses to comments on the DEIR are not based on evidence.

This letter provides additional evidence and original analysis demonstrating that pedestrian injuries will increase significantly directly due to project-related increases in traffic volume in several neighborhoods of Oakland surrounding the project. The evidence and analysis includes the following key points:

- **The definition and use of the term *pedestrian injury rate* in the DEIR and FEIR is neither accurate nor consistent with definitions used by the Federal Government or those used in epidemiologic investigations.**
- **Oakland has a rate of pedestrian injuries several times higher than Federal public health standards. The neighborhoods surrounding the project have a disproportionate share of pedestrian injuries relative to other neighborhoods in Oakland.**
- **Project-related impacts on pedestrian injuries are significant. Quantitative forecasting of changes to Oakland's pedestrian injury rate based on project related changes in traffic flows and a baseline injury rate of 100 injuries/year in the area of influence estimates that the project's traffic alone will contribute about 5.4 additional injuries per year or 268 pedestrian injuries in the years 2025-2075. The cumulative impact of increased traffic in the area by 2025 forecasts 20 additional injuries per year with a total of 1000 growth related additional injuries in the years 2025-2075.**
- **The DEIR and FEIR have not proposed or evaluated the feasibility of sufficient pedestrian safety improvements including circulation changes and street and intersection facility improvements, available to prevent increases in traffic related injuries.**

¹ Section 15065 of the regulations for the California Environmental Quality Act (CEQA) mandates an environmental impact report (EIR) to analyze any "...environmental effects of a project [that] will cause substantial adverse effects on human beings, either directly or indirectly. CEQA guidelines section 15126.2, subdivision (a) requires an EIR to discuss "health and safety problems caused by the physical changes" that the proposed project will precipitate. Bakersfield Citizens for Local Control vs. the City of Bakersfield reaffirmed the necessity of health analysis in an EIR prepared under CEQA. Environmental Justice also demands a full analysis of the health impacts on low-income and minority populations.

Significance of Pedestrian Injuries, National Injury Standards, and Inadequacies in the Oak to Ninth FEIR

A significant error in the FEIR is the inaccurate definition of the term, *rate of injury*. The FEIR inaccurately defines "rate of injury" as "accidents per number of vehicles." Using this definition, the City of Oakland argues that *the project will not affect the rate at which motor vehicle accidents occur because it will not affect the roadways*. This statement is misleading. The number of accidents per vehicle and the number of accidents per mile might reflect the relative safety of vehicle and roadways, respectively, but these measures do not reflect the impacts to human health. With regard to human health impacts, an appropriate measure of adverse impact is the increase in the number of injuries or the increase in the rate of injuries **defined as the number of injuries per unit time**. This definition is the one used by the Federal Department of Health and Human Services in pedestrian injury objectives for the Nation. Holding the number of accidents per vehicle trips constant, the rate of injuries will increase simply because the number of vehicle trips will increase.

The US Department of Health and Human Services (USDHHS) has established National objectives for the **rate of pedestrian injuries**.² Much like National Air Quality Standards, these objectives or standards can serve as thresholds for significance for pedestrian injuries within CEQA analysis. These objectives include:

- 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.

According to Oakland's Pedestrian Master Plan, Oakland residents suffer approximately 85.5 vehicle injuries to pedestrians per 100,000 every year including 3 pedestrian fatalities per 100,000 per year.³ **This rate of injuries is about 4 times the USDHHS standards. The published rate of fatal injuries in Oakland is 3 times the USDHHS standard.** Based on current rates and national standards, any increase in pedestrian injuries should be considered a significant adverse effect.

A significant number of Oakland pedestrian injuries occur in the neighborhoods and streets (e.g., Downtown, Jack London Square, Chinatown, Lakeshore, East Lake, Lower San Antonio, International Blvd) surrounding the proposed project. Based on population and the intensity of pedestrian injuries, this impact analysis estimates a baseline injury rate of at least 100 pedestrian injuries per year in the area affected by the Oak to Ninth Project.⁴ Furthermore, the neighborhoods surrounding this project contain sensitive populations more vulnerable to impacts on pedestrian safety, including children, the elderly, walking-dependent, and the low-income transit-dependent.

Vehicle injuries to 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 5634 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 economic costs of vehicle injuries to pedestrians disaggregated by injury severity are provided in the table below.

Pedestrian Injury Severity	Economic Cost per Injury
Fatal Injury	\$2,709,000
Severe Injury	\$180,000
Visible Injury	\$38,000
Complaint of Pain	\$20,000

Environmental Factors Affecting Pedestrian Injuries

² U.S. Department of Health and Human Services. Healthy People 2010 Objectives.

³ Oakland Pedestrian Master Plan. Page 30.

⁴ The author of this analysis has requested a map of counts of pedestrian injuries from the City of Oakland. A more precise estimate of pedestrian injuries in the area of influence of the Oak to Ninth project is pending this data.

The rate of pedestrian injuries in an area is dependent on several **environmental factors** such as vehicle volume, vehicle type (truck vs. car), vehicle speed, pedestrian volume, roadway width, vehicle speed, pedestrian facilities (sidewalk width, driveway conflicts, buffers), intersection design (crossing distance, signal phasing and timing, corner radii, cross walk treatments, median islands, curb extensions), lighting, and weather.^{5 6 7 8 9}

Vehicle speeds are the most important predictor of the **severity** of pedestrian injuries. 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.¹⁰ With regards to sensitive populations, the elderly and the very young populations are more vulnerable to vehicle injuries while walking because of slower walking speeds or slower reaction times.

Public health and transportation safety research consistently demonstrates that **vehicle volumes** are an **independent environmental predictor of pedestrian injuries**.^{11 12 13 14} In other words, all things being equal, when the number of vehicle trips increases, the number of vehicle injuries to pedestrians will also increase. A national study of pedestrian injuries and crosswalks that included data from Oakland also found that higher average daily traffic and multi-lane roads were significant and independent environmental risk factors for vehicle-pedestrian crashes in multi-variate analysis.¹⁵ One recent study found that traffic volume, traffic speed and lateral separation between pedestrians and traffic explained 85% of the variation in perceived safety and comfort for pedestrians.¹⁶ The City of Oakland Pedestrian Master Plan also highlights the negative effect of high volumes on safety.¹⁷ 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.¹⁸

4
(cont.)

5 La Scala EA, Johnson FW, Gruenewald PJ. Neighborhood Characteristics of Alcohol-related Pedestrian Injuries. *Prevention Science*. 2001; 2:123-134.

6 Taylor M, Lynam D, Barua A. The effects of drivers speed on the frequency of road accidents. Transport Research Laboratory. TRL Report 421 Crowthorne, UK, 2000.

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17 City of Oakland. Pedestrian Master Plan. Page 18.

18 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.

Impact Analysis

Empirical research on traffic safety and vehicle volumes shows that the rate of pedestrian injuries increase consistently as vehicle volume increases but the relative increase in this rate is attenuated as vehicle volumes rise. The attenuation may be caused to reduced pedestrian activity in areas with high traffic. A common parametric form of the injury-vehicle volume relationship is described as follows:

$$\text{Injuries} = \alpha X (\text{Average Annual Daily Trips})^\beta ; \text{ typically where } \beta < 1 \quad 19$$

Several empirically tested pedestrian injury estimation models provide evidence that pedestrian crashes are proportional to the square root of vehicle volume (e.g., $\beta = 0.5$ in the equation above).²⁰ This means the number of pedestrian injuries after the project can be estimated simply as:

$$\text{Total Annual Injuries} = \text{Current Annual Injuries} X (\text{Future AADT} / \text{Baseline AADT})^{1/2}$$

The Draft EIR acknowledges that development of the Oak-to-Ninth Avenue Project, which includes 3100 residential units and 3500 parking spaces, will result in an additional 27,110 daily vehicle trips external to the project. (Table IV.B-4) As described in the detailed intersection level traffic analysis in the DEIR, these trips will increase traffic volume on local streets in the downtown, Chinatown, and Jack London Square, and other neighborhoods.

According to traffic analysis in the DEIR, the increase in vehicle volumes at intersections in the neighborhoods around the project will varies considerably, ranging from about 2% to 127%. The average project-related increase in vehicle volume in the surrounding neighborhoods at the studied intersections is about 11% after project completion. The average cumulative increase in vehicle volume by 2025 at these intersections is 45%.

Assuming the current annual rate of pedestrian injuries in affected neighborhoods is 100 per year, the model described above estimates an increase in 5.4 injuries per year or 268 injuries between 2025 and 2075.²¹ Based on the cumulative increase in average daily trips of 45% in 2025, the impact is 20 injuries per year or 1000 injuries between 2025 and 2075.

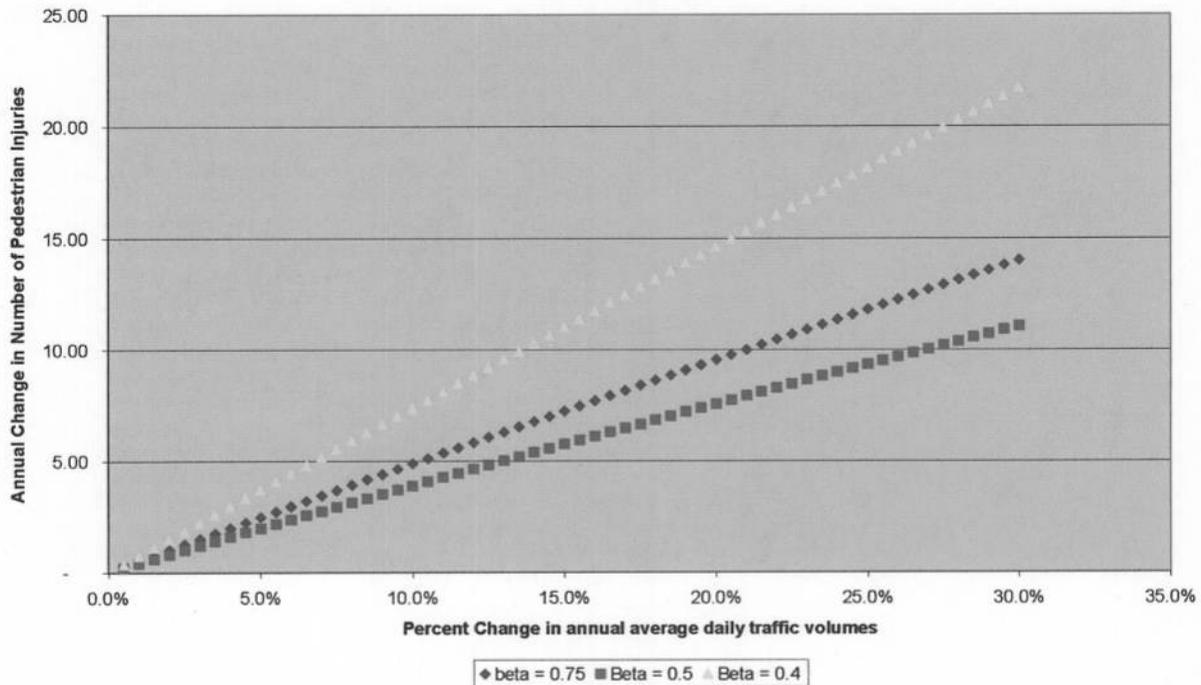
The figure below graphically illustrates the relationship between change in vehicle volume and the change in the number of injuries. The middle line represents a model with Beta set to equal 0.5 in the equation above. The upper and lower lines provide a reasonable upper and lower bound on this volume—injury relationship. A more refined analysis might estimate changes in pedestrian injuries based on vehicle flow on all segments on all roadways; nevertheless, this estimate shows that the Oak to Ninth Project will result in a significant environmental impact on pedestrian injuries in an area where the rate of pedestrian injuries already exceeds the national standard.

19 Lord D, Manar A, Vizioli A. Modeling crash-flow density and crash-flow-V/C ratio relationships for rural and urban freeway segments. *Accident Analysis and Prevention* 2005; 37: 185-199.

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

21 Estimates of pedestrian injuries in the project's area of influence are based on review of available injury data. This estimate will be updated based on the most recent pedestrian injury data when available.

**Change in Injury Counts In Relation to Changes in Traffic Flow
For Downtown, Jack London Square, West Lake, Chinatown, Oakland, California
Estimated Baseline Injury Rate = 100 per year**



Available Pedestrian Safety Mitigations are not Utilized

The DEIR indicates that as mitigations to intersection LOS impacts, the project will only include new signals with pedestrian signal heads at a few intersections (Embarcadero and Oak, Embarcadero and 5th Ave; Embarcadero and I-880 Northbound off-ramp; Embarcadero and Broadway.) A Master Response in the FEIR also includes further analysis of safety impacts around train crossings. However, no mitigations are proposed in other neighborhoods where traffic will increase significantly. The DEIR summarily concludes (without evidence) that these traffic control devices at these few intersections will “safely accommodate the added vehicle and pedestrian traffic and the project would have a less than significant impact.” The following evidence argues against the City of Oakland’s conclusions in the DEIR and FEIR:

- The DEIR does not fully analyze impacts on pedestrian injuries resulting from project-related vehicle trips in the neighborhoods surrounding the project. It is not possible to judge the effectiveness of mitigations if the impact is not fully characterized.
- Pedestrian Safety measures proposed by the project focus on intersections. Many vehicle injuries do not occur at intersections.²²
- The mitigations proposed are for a limited number of intersections. The FEIR does not propose or evaluate environmental mitigations at other intersections in and around the project area that are impacted by significant changes in traffic volume.
- For the mitigations proposed, the FEIR does not provide any evidence to support the efficacy of these traffic signal devices as a means to reduce pedestrian injuries.
- The FEIR does not consider other environmental mitigations impacts on pedestrian safety including curb extinctions, median islands, cross walk treatments, presence of sidewalks, roadway buffers, street lighting, and reduced crossing speeds.
- The FEIR does not consider traffic calming as mitigation. Reviews of international studies demonstrate that on average traffic calming interventions reduce accidents by 15%.²³

²² According to the National Highway Traffic Safety Administration 78% of pedestrian injuries occur at non-injury locations. NHTSA. Traffic Safety Facts. 2002.

- The FEIR inaccurately states that pedestrian safety measures in the Revive Chinatown Plan include only the fully funded short term measures. The FEIR also mischaracterizes sidewalk widening as a pedestrian amenity but *not a safety measure*. Sidewalk widening and one-way to two-way conversions are two of the longer term recommendations proposed in the Revive Chinatown Plan that are also pedestrian safety measures. The study by Landis cited above demonstrates that sidewalk widths are a determinant of pedestrian safety. Sidewalk widening also may require lane reductions which may alter vehicle flows.
- The FEIR suggests that the Pedestrian Master Plan provides a framework for mitigating the adverse impacts of vehicles on pedestrians but the project does not contribute to improvements suggested by the Plan.

Further analysis of pedestrian safety impacts and mitigations should focus on all Oakland streets and intersections with significant increases in traffic volume resulting from the Oak to Ninth Project. The mitigations should consider all appropriate and effective practices in pedestrian safety including but not limited to:

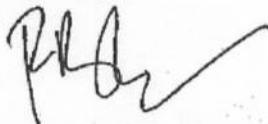
- Traffic Calming including vehicle lane narrowing, raised crosswalks, raised intersections and traffic circles;
- Bulb outs and center median refuge islands;
- Diversion of through traffic around mixed use neighborhoods;
- One-way to two way conversions and lane reductions in mixed use residential areas;
- Speed limit reductions in mixed-use residential areas;
- Grade separated crossings where significant pedestrian pathways cross high volume multi-lane streets;
- Pedestrian warning signs or lights at crossings or cross walks without traffic signal lights
- Sidewalk widening or buffers between sidewalks and vehicle lane buffers.

Summary

Overall, the analysis of pedestrian safety in the DEIR and FEIR includes little substantive evidence or original analysis, just unsupported conclusions. An evidence based analysis shows that project-related impacts on pedestrian safety are significant. The project has provides for no mitigations specific to the needs of pedestrians in the mixed use neighborhoods surrounding the project area. I strongly urge the Developer, the City of Oakland, the Planning Commission, and the Oakland City Council to provide additional pedestrian safety mitigations as described above to prevent the pedestrian injuries expected to result from this project.

Thank you for your consideration of this analysis and the proposed mitigations. I look forward to learning of Oakland Planning Commission actions to prevent pedestrian injuries. Please do not hesitate to call me with questions.

Sincerely,



Rajiv Bhatia, MD, MPH.

CC: Claudia Cappio, Douglas Boxer, Nicole Franklin, Suzie Lee, Michael Lighty, Mark McClure, Anne Mudge, Zac Wald, Jane Brunner, Nancy Nadel, Pat Kernanhan,

23 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.

Responses to March 3, 2006 letter regarding Pedestrian Safety and Injuries

- 1 The discussion summarizes the key points addressed in letter. Responses to the key points are provided below.
- 2 The comment provides an alternative definition for *rate of pedestrian injury* as the “number of injuries per unit of time,” which the comment indicates is used in national objectives for the rate of pedestrian injuries. The comment suggests that certain national standards of injuries per year per population be applied to determine significant adverse pedestrian safety impacts resulting from the Oak to Ninth Project. However, the national standards cited by the comment, do not relate to the impacts of individual projects.

The comment relies on the macro-level assumption that increasing traffic volumes increases the likelihood of pedestrian collisions, a conclusion that fails to consider the several other relevant factors that influence the potential for pedestrian injury, particularly the site specificity - the unique characteristics of a development site. This consideration is discussed further in Response to Comment 5, below, however, it is relevant to this response regarding significance criteria because, as stated in the Fehr & Peers technical memo of June 6, 2006 (**Appendix C**), there is currently no safety consideration comparable to the Highway Capacity Manual that would allow the assessment of whether an intersection is safe and specifically whether project-level changes to an intersection increases the likelihood of pedestrian collisions.³ Also, the City of Oakland does not have a policy, standard, or significance criterion to form the basis of a significance criterion that would accurately determine if additional pedestrian impacts are a significant impact under CEQA. Overall, the necessary site-specific level of analysis of pedestrian safety considerations is limited by the lack of state-of-the-practice tools.

- 3 First, the comment states a minimum, baseline estimate of injuries per year in the area affected by the Oak to Ninth Project. The commenter’s analysis is based on hypothetical numbers of pedestrian collisions rather than actual data regarding pedestrian collisions, particularly in the project area. As presented in the Fehr & Peers memo in **Appendix C**, an assessment of historical reported data for pedestrian collisions at the 50 study intersections analyzed in the Draft EIR suggests that there is not sufficient numbers of pedestrian collisions to allow a reliable statistical analysis of the incidence or rate of collisions - even with a sampling of 50 intersection (many located in the high pedestrian traffic areas of Chinatown and the downtown core, as shown in **Appendix C**, Figure 1) and a total of 98 reported pedestrian-involved collisions. However, based on data provided by the City of Oakland, 20 of the 50 study intersections had no reported pedestrian-related collisions from 1995 to 2004, as shown in **Appendix C**, Figure 2.⁴

³ A new Highway Safety Manual is currently being developed.

⁴ Minor collisions, particular those with no injuries, are unreported in collision reporting systems throughout the US, therefore the data provided here is not all-inclusive, but suitable to provide cross-intersection comparisons.

This finding is typical given that pedestrian-related collisions normally represent only a fraction (generally less than ten percent) of total collisions. An additional 20 of the study intersections reported three or fewer pedestrian collisions a period of nine years (1995 to 2004), which represents one or fewer collision per three-year period. However, at one intersection, Webster and 8th Street, an average of one pedestrian collision per year occurred, which, given the low rates per year previously mentioned for 80 percent of the study intersections, supports the conclusion that there is not sufficient data to allow a reliable statistical analysis specific to the Oak to Ninth Project. Furthermore, the number of pedestrian collisions by year of the 50 study intersections varied significantly, as depicted in **Appendix C**, Figure 3. The highest number occurred in 1995 with 20 collisions at study intersections. In other years, the number of collisions varied between 6 and 12 per year at study intersections. Again, the data is not sufficient to conclude a clear trend of pedestrian collisions increasing or decreasing over the nine-year period.

- 4 As stated in the comment and indicated by Fehr & Peers (**Appendix C**), the number or rate of pedestrian collision at an intersection is a function of several factors. As such, the comment oversimplifies these complex relationships by suggesting that traffic volume growth can be isolated as the factor contributing to increased pedestrian volumes or collisions. Data fail to support a direct correlation between increased numbers of pedestrian collisions and increased traffic volumes at the same intersection. The PMP identifies ten intersections where a majority of pedestrian collisions occur in Oakland. These intersections generally averaged one collision per year over four years, 1996 to 2000, and the recent trend is downward. None of these ten intersections carry a significant amount of project traffic. None of the studies cited by the commenter and other relevant studies identified by Fehr & Peers (and provided in **Appendix C**) identified an instance where an increase in pedestrian collisions was correlated with a historical increase in volume at the same intersection. **Appendix C** includes a list of and synopsis of the findings of most citations provided by the commenter.
- 5 As discussed in the Fehr & Peers memo in **Appendix C**, the macro-level conclusion that increasing traffic volumes increases the likelihood of pedestrian collisions lacks the consideration of site specificity necessary to draw a nexus between the potential impact and proposed improvements or mitigations. This nexus is critical under CEQA. As previously mentioned, it is important to be able to provide site specificity to the question of pedestrian collisions. The traffic impact analysis and mitigation measures in the EIR are site specific, and it is likely that any increase in pedestrian collisions may occur at certain locations or at locations with certain characteristics (e.g., unsignalized intersections or those lacking crosswalks). However, without site specificity it is not possible to draw a nexus between the impact and mitigation measures. Additionally, site specificity allows specific intersections with safety concerns to be identified and collision data monitored over time to determine whether there are engineering solutions to minimize the impact. Furthermore, given the pedestrian collision data limitations discussed in Response to Comment 4, there would no way to determine if a significant

impact would occur under CEQA, as well as whether an adequate mitigation for such an impact exists.

As stated in the Final EIR, the design of the project site, augmented by mitigation measures identified in the Draft EIR, incorporates a circulation system that accommodates traffic streams (vehicle, bicycle, and pedestrian) in a safe, efficient way. As also described in the Draft EIR, consistent with the PMP, traffic control devices (traffic signals with pedestrian signal heads), as well as striped crosswalks and signage would safely accommodate the added vehicular and pedestrian traffic by controlling the flow of the traffic streams through positive guidance. PMP Policy 1.2 recommends traffic signals and their associated features to improve pedestrian safety, and according to Fehr & Peers, the addition of signals with full pedestrian treatments (countdown timers, crosswalks, etc.) could improve pedestrian safety, with documented cases showing reductions in pedestrian collisions of approximately 52 percent.

The Draft EIR's finding of a less-than-significant impact to pedestrian safety is further supported by the project's provision of a continuous public Class I trail and the inclusion of appropriate internal street and sidewalk and crosswalk characteristics (location, width, configuration) consistent with all City regulations and safety standards. The comment identifies several general design or traffic calming measures that purportedly reduced accidents, and while this EIR does not discount the benefits of such measures, the standard improvements proposed by the project, including those identified in the Final EIR related to pedestrian safety at rail crossings, are adequate to find the impact on pedestrian safety (onsite or in nearby areas) less than significant and that no additional measures beyond those identified in the EIR would be required.

Pedestrian safety measures in the Draft EIR focus on intersections in particular since the City summarizes and provides the pedestrian collision data at intersection level. Note that in some cases, these accidents actually occur at the intersections. In other cases, the accident occurs near the intersection but is associated with the intersection for reporting purposes.. Therefore, the information analysis considers and responds to accidents that occur at and near intersections.

The information provided the Final EIR about the Revive Chinatown Plan improvements was provided for information only. Although short- and mid-term pedestrian improvements are mentioned, the plan also includes long-term improvements. Several of these improvements, such as intersection bulb-outs and pedestrian scramble signals, will directly benefit pedestrian travel. There are other proposed improvements which serve as both an amenity as well as a potential pedestrian safety improvement. For example, changing the parking meter design to create additional clear space on the sidewalks. The sidewalk widening measures outlined in the Revive Chinatown Plan are intended primarily as an amenity but could also provide a secondary safety benefit.

Regarding improvements outlined in the PMP, the Draft EIR discusses the project's consistency with the PMP starting on page IV.A-24 of the Draft EIR. Specifically, the

project supports key policies most relevant to the project in that it will improve pedestrian crossings, incorporated pedestrian-focused streetscape elements including sidewalks, recreational paths, street furniture signage, lighting and landscaping, art), and will facilitate safe routes to transit. As mentioned above, the project will adhere to the City's standard regulations and safety standards regarding sidewalks, including sidewalk width.



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March 8th, 2006

Colland Jang
Chair, City of Oakland Planning Commission
Community Economic Development Agency
250 Frank Ogawa Plaza, Suite 3315
Oakland CA 84612

Re: Housing Affordability Can Mitigates Adverse Transportation and Air Quality Impacts of the Oak to Ninth Project; Case ER 04- 0009

Dear Mr. Jang:

This letter provides compelling evidence and analysis demonstrating that modifications in the Oak to Ninth project with regards to housing affordability would mitigate adverse transportation and air quality impacts.

The Draft EIR acknowledges that development of the Oak-to-Ninth Avenue Project, which includes 3100 residential units and 3500 parking spaces, will result in an additional 27,110 daily vehicle trips external to the project. The indirect impacts of these trips on Transportation System Performance, Air Quality, and Pedestrian Safety are significant. The analysis below, using existing regional transportation data and Air Resources Board modeling tools, shows that by modifying project design and increasing the number and type of units below market rate, the project could mitigate a significant portion of these transportation and air quality impacts.

Based on this analysis, the City of Oakland has a legal responsibility to transparently evaluate the environmental impacts of affordability as well as the feasibility of increasing affordability either as a project alternative or as potential air quality and transportation impacts mitigation. The letter makes the following key points:

- **The Oak to Ninth FEIR inappropriately denies a nexus between housing affordability and environmental impacts on transportation and air quality.**
- **The Metropolitan Transportation Agency (MTC) Bay Area Travel Survey (BATS) provides evidence for an unequivocal relationship between household income and personal vehicle trip generation.**
- **Based on MTC data, relative to the project as proposed, 15% affordability requirements would generate 1113 fewer weekday vehicle trips while a project that balances affordability relative to regional household incomes would produce 3426 fewer vehicle trips.**
- **Reducing vehicle trips would mitigate indirect effects of trips including those on traffic congestion and pedestrian safety.**
- **The Urban Emissions Model (URBEMIS) includes a parameter (variable) for housing affordability as an emissions mitigation measure.**

- **The URBEMIS model has the capacity to estimate changes in emissions for different proportions of restricted below market rate housing unit. The Oak to Ninth FEIR did not use this functionality to analyze the effects of varying levels of affordability on air emissions.**
- **Analysis using the URBEMIS model shows that greater housing affordability would reduce indirect air quality impacts of the Oak to Ninth Project.**
- **Increasing affordability would also increase the number of vehicle free households resulting in less need for parking and potentially allowing a greater proportion of the site to serve open space needs.**
- **The feasibility of project alternatives or mitigations with greater affordability must be analyzed by the City of Oakland as part of the FEIR.**
- **The results of negotiation between the developer, the City, and other stakeholders on affordability should be made transparent in the EIR because of their impacts on the significance of traffic, noise, air quality, and pedestrian safety impacts.**

Regulatory Context

Sections 15131 and 15064 of the California Environmental Quality Act require the analysis of significant physical environmental impacts resulting indirectly from project-related social effects or produced through project-related socio-economic mechanisms.^{1 2} Case law has affirmed this requirement.³ An EIR must similarly consider socioeconomic measures that mitigate significant effects of the project⁴.

The FEIR addresses the concern related to housing affordability in Master Response H: Non-CEQA Topics and Considerations. The Section acknowledges the responsibility of the EIR to evaluate social and economic effects if evidence suggests that these effects will produce significant environmental impacts. The Section claims that this analysis has occurred in Section IV.J of the DEIR on Population and Housing.

The City of Oakland's Oak to Ninth FEIR is deficient in not mitigating effects on transportation and air quality through altering project design with regards to housing affordability. Neither the DEIR nor Master Response H acknowledge that housing affordability is directly related to several of the significant and potentially significant environmental effects of the project, including impacts on transportation, pedestrian safety, noise, air quality, and open space adequacy.

It is important to also note that housing affordability is an important policy goal within the City of Oakland's Housing Element of the General Plan.

Master Response H also notes that the City, the Developer, and the Redevelopment Agency are currently negotiating the inclusion of some affordable units in the project. The results of this negotiation should be described in the EIR because, as described below, the percentage of affordable housing will affect the significance of traffic, noise, air quality, and pedestrian safety impacts of the project.

1 California Code of Regulations. §15131

2 California Code of Regulations. §15064

3 Citizen's Association for Sensible Development v. County of Inyo, 172Cal.App.3d 151 (1985)

4 CEQA Guidelines section 15126.4

Housing Affordability—Vehicle Trips Analysis

The mechanism of the relationship between housing affordability and vehicle trips is mediated through relationships among household income, vehicle ownership, and vehicle driving. Abundant evidence in the transportation and planning research literature has documented this relationship. Specific to the Bay Area, the MTC quantified the relationship between household income, travel behavior, and vehicle trips based on results from their Bay Area Travel Survey. The results show the strong relationship between household income and vehicle trip generation. Households in the highest income quartile generate almost 4 more vehicle trips per day (160 percent increase) than those in the lowest quartile.

Quartile of Household Income	Q1	Q2	Q3	Q4
Range of Household Income	<\$30,000	\$30,000-59,999	\$60,000-99,999	\$100,000 +
Weekday Vehicle Driver Trips	2.402	4.102	5.302	6.327

The relationship between household income and vehicle trips suggests that variants of project design with greater affordability would be a mechanism by which the project could generate fewer vehicle trips and consequently fewer environmental impacts indirectly related to vehicle trips. The table below provides an illustration of this relationship based on three scenarios:

- Project as currently proposed with housing affordable only to those making greater than the median income⁵;
- Project meeting minimum redevelopment area requirements for housing affordability with 15% of units affordable to those making less than the median income;
- Project with housing affordability in balance with the regional distribution of household income.

Scenario	Housing Affordable to Each Household Income Quartile				Weekday Trips
	Q1	Q2	Q3	Q4	
Market Rate (Current Project)	0.0%	0.0%	50.0%	50.0%	18025
Min Affordability Requirements	6.0%	9.0%	42.5%	42.5%	16912
Regionally Balanced	16.0%	30.6%	29.5%	23.8%	14599

Based on MTC data, relative to the project as proposed, a modified design with minimum Redevelopment Area affordability requirements would generate 1113 fewer weekday vehicle trips. **A design which balances affordability relative to regional household incomes would produce 3426 fewer vehicle trips.**

The analysis shows that a project with affordability balanced to regional needs would have significantly less adverse environmental impacts of the proposed project. Increasing affordability would also increase the number of vehicle free households resulting in less need for parking and potentially allowing a greater proportion of the site to serve open space needs.

Housing Affordability—Air Quality Analysis

⁵ Median Household income is defined as \$60,000 in order to be consistent with the quartiles of income used in the MTC Bay Area Travel Survey.

The California Air Resources Board (CARB) developed the "Urban Emissions Model" (URBEMIS) to assist local public agencies with estimating air quality impacts from land use projects when preparing a CEQA environmental analysis. The model is situated in a user-friendly computer program that estimates construction, area source, and operational air pollution emissions from a wide variety of land use development projects in California. The model further estimates emission reductions associated with specific mitigation measures including transportation demand reduction measures and affordable housing.

This analysis applied the URBEMIS model to the Oak to Ninth project and found that the emission estimates were mitigated by increasing the proportion of below market rate (BMR) housing (See table below). We used the following land use inputs: (1) 3100 condo/townhouse high rise, (2) 170,000 sq. feet regional retail, (3) 30,000 sq. feet supermarket; (4) 28.4 acres city park. Operational emission sources were set at default with temperature site specific and target year 2025. We varied the proportion of BMR units between 0 and 50%.

OPERATIONAL (VEHICLE) EMISSION ESTIMATES (lbs/day)

	ROG	NOx	CO	SO2	PM10
unmitigated	64.80	46.97	539.25	1.29	194.36
BMR 15%	64.42	46.57	534.53	1.27	192.62
BMR 25%	64.16	46.30	531.37	1.27	191.47
BMR 50%	63.51	45.63	523.49	1.25	188.58

It is important to note that the URBEMIS model provides very conservative estimates of the effect of greater affordability on reduced air emissions, and we believe the above estimates likely underestimate the beneficial effect of affordability. The URBEMIS model assumes a 4% reduction in vehicle trips for each deed-restricted below market rate housing unit.⁶ The 4% reduction parameter is significantly less than the three fold difference in vehicle trip generation between households in the lowest and highest income quartiles in the Bay Area Region based on regional travel survey data. The URBEMIS parameter may reflect differences in the income—vehicle trips relationship between the Bay Area and the rest of the State of California. While this analysis provides sufficient evidence for an effect of affordability on air emissions, we would recommend modifying this parameter using Bay Area specific data in future analyses.

Summary and Recommendations

Numerous comments on the project and the DEIR including those made by Oakland City Council Members, Oakland Planning Commissioners, stakeholder organizations, and Oakland residents have stressed the need for the project to make housing created through the project affordable to average Oakland residents. The many articulate comments related to project affordability reflect the sensible position that ensuring affordability balanced with the needs of local residents is a critical requirement of social, economic, and environmental sustainability. This analysis provides specific evidence that greater affordability has a role in mitigating transportation and air quality impacts.

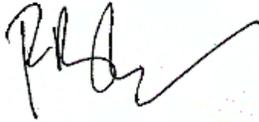
- **The Oak to Ninth FEIR should acknowledge and describe the nexus between housing affordability and environmental impacts on transportation and air quality.**

⁶ Software User's Guide: URBEMIS2002 for Windows with Enhanced Construction Module, Version 8.7, South Coast Air Quality Management District, April 2005.

- **The Oak to Ninth FEIR should analyze the effects of 15%-50% affordability requirements on vehicle trips and air pollution emissions using MTC data and the URBEMIS model.**
- **The Oak to Ninth FEIR should analyze the effects of 15%-50% affordability requirements on open space preservation.**
- **The Oak to Ninth FEIR should transparently analyze the feasibility of project variants with greater affordability, including the substance and results of any financial analysis or negotiations between the developer, the City, and other stakeholders on affordability.**

Thank you in advance for your consideration of this analysis. I look forward to learning of your actions to analyze the effects and feasibility of greater housing affordability in the FEIR. Please do not hesitate to call me with questions about this analysis.

Sincerely,

A handwritten signature in black ink, appearing to read 'Rajiv Bhatia', with a long horizontal flourish extending to the right.

Rajiv Bhatia, MD, MPH

Edmund Seto, PhD

CC: Claudia Cappio, Douglas Boxer, Nicole Franklin, Suzie Lee, Michael Lighty, Mark McClure, Anne Mudge, Zac Wald, Jane Brunner, Nancy Nadel, Pat Kernanhan,

Responses to March 8, 2006 letter regarding Affordable Housing, relative to Transportation and Air Quality Impacts

The following comprehensive response addresses the overall premise of the comment letter.

The comment letter focuses on the claim that there is a correlation between the provision of affordable housing in the project and the resulting reductions in transportation and air quality impacts. Specifically, the comment asserts that, because of this relationship between affordable housing and environmental impacts, the EIR should analyze increased percentages of affordable units in the project in order to reduce or mitigate significant impacts resulting from increased vehicle trips and air emissions, and to explore increased open space area.

The Draft EIR reported that, to assist the Oakland Redevelopment Agency (ORA) meet its legally-required affordable housing obligation, development of the project would require at least 420 low- to moderate-income units in the Central City East Redevelopment Project Area. However, as of publication of the Final EIR, the affordable housing component of the project had not been specifically determined. *Since* publication of the Final EIR, discussions among the City, ORA and the project sponsor have established that the project will provide between 420 and 465 units of affordable housing units within the project site – approximately 14 to 15 percent of the total 3,100 units proposed by the project. To the extent that the provision of these units will result in reduced vehicle trips and related emissions, these benefits would accrue to the Oak to Ninth Project.

There is significant research that links travel behavior to land use changes. As indicated in the comment, some of this research is incorporated into URBEMIS and other tools. While the comment suggests that the EIR analysis should consider increased affordable housing to reduce environmental impacts, there is no CEQA or City requirement that this analysis automatically be incorporated into an EIR analysis, and the Oak to Ninth EIR purposely does not take advantage of such reductions in order to ensure the most conservative (maximum impact) analysis and avoid potentially understating the impacts of the project. This approach is especially appropriate given other factors that could influence the degree that affordable housing correlates with reduced vehicle trips, such as proximity of residences to transit and/or linkages to transit. City's policies that encourage the provision of affordable housing by development projects will guide the City's deliberations on the project, and the information provided in the EIR and this Addendum is adequate to allow decisionmakers to consider both the policy and potential environmental aspects of providing such below-market housing.



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March 22, 2006

Honorable Jane Brunner
One Frank Ogawa Plaza
One City Hall Plaza, 2nd Floor
Oakland, CA 94612

RE: Air Quality and Noise Related Health Effects of the Oak to Ninth Proposal

Dear Councilwoman Brunner:

This letter requests the Oakland City Council's attention to the potential public health impacts of poor air quality and high levels of noise on future residents of the Oak to Ninth Project and residents of surrounding neighborhoods.

Even in the context of our State's housing shortage, housing should be built where it will be healthful. The central issues raised in this letter are the avoidable conflicts between residential uses and noise and vehicle emissions due to the I-880 freeway. Without mitigations, many future residents of the Oak to Ninth Avenue will experience levels of noise unacceptably high for residential uses; furthermore, residents living within 500 feet of a busy freeway might experience higher rates of respiratory illnesses. The project also indirectly increases exposure to roadway particulate matter emissions in neighborhoods surrounding the project. **What is most important is that these health impacts due to air quality and noise have not been adequately or accurately evaluated in the CEQA process and the full range of feasible mitigations has not been considered by the City.** This letter will provide evidence for the following key points.

- **The City has a responsibility to study freeway related air quality and noise health impacts and their feasible mitigations under CEQA;**
- **The project creates potentially significant environmental impacts on air quality by locating a residential use in proximity to Interstate 880**
- **The FEIR for the Oak to Ninth Project fails to fully acknowledge the potential health impacts due to compromised air quality and fails to document that wintertime winds can blow from the freeway over the project;**
- **Oak to Ninth residents are likely to experience some adverse health effects due to freeway related traffic noise;**
- **Project design changes can potentially mitigate and prevent health impacts due to noise and poor air quality.**

A. The City has a responsibility to study freeway related air quality and noise health impacts and their feasible mitigations under CEQA

It is the responsibility of an EIR to analyze environmental effects that may cause either direct or indirect adverse effects on humans.

A lead agency shall find that a project may have a significant effect on the environment and thereby require an EIR to be prepared for the project where any of the following conditions

1

occur: (d) the environmental effects of the project will cause substantial adverse effects on human beings, either directly or indirectly.¹

While the freeway predates the project, CEQA guidelines specifically recognize that bringing people into proximity with a known environmental hazard is itself a potentially significant impact.

The EIR shall also analyze any significant environmental effects the project might cause by bringing development and people into the area affected. For example, an EIR on a subdivision astride an active fault line should identify as a significant effect the seismic hazard to future occupants of the subdivision. The subdivision would have the effect of attracting people to the location and exposing them to the hazards found there.²

B. The project creates potentially significant environmental impacts on air quality by locating a residential use in proximity to Interstate 880

The California Air Resource Board, Air Quality and Land Use Handbook: A Community Health Perspective (2005) recommends not locating sensitive land uses, including residential developments, within 500 feet of a highway with more than 100,000 vehicles per day.³ The average daily traffic on I-880 is in excess of a quarter of a million vehicles with over 18,000 vehicles traveling this highway during the peak hour. These traffic conditions put 1400 future residences located on parcels A, F, G, K, and M at risk for respiratory diseases due to poor air quality.

The CARB guidelines are based on findings from extensive health research, demonstrating that proximity to high traffic density or flow results in reduced lung function and increased asthma hospitalizations, asthma symptoms, bronchitis symptoms, and medical visits. The research literature includes the following specific findings:

- Reduced lung function in children associated with traffic density, especially trucks, within 1,000 feet and the association was strongest within 300 feet⁴
- Increased asthma hospitalizations associated with living within 650 feet of heavy traffic and heavy truck volume.⁵
- Increased asthma symptoms with proximity to roadways with the greatest risk within 300 feet.⁶
- Asthma and bronchitis symptoms in children associated with high traffic in a San Francisco Bay Area community with good overall regional air quality⁷
- Increased medical visits in children living within 550 feet of heavy traffic in San Diego.⁸

¹ CEQA Guidelines. Section 15065.

² CEQA Guidelines Section 15126.2 Consideration and Discussion of Significant Environmental Impacts. Subsection (a)

³ California Environmental Protection Agency Air Resources Board Air Quality and Land Use Handbook: A Community Health Perspective May 2005.

⁴ Brunekreef, B. et al. "Air pollution from truck traffic and lung function in children living near motorways." *Epidemiology*. 1997; 8:298-303.

⁵ Lin, S. et al. "Childhood asthma hospitalization and residential exposure to state route traffic." *Environ Res*. 2002;88:73-81.

⁶ Venn. et al. "Living near a main road and the risk of wheezing illness in children." *American Journal of Respiratory and Critical Care Medicine*. 2001; Vol.164, pp. 2177-2180.

⁷ Kim, J. et al. "Traffic-related air pollution and respiratory health: East Bay Children's Respiratory Health Study." *American Journal of Respiratory and Critical Care Medicine* 2004; Vol. 170. pp. 520-526.

⁸ English P., Neutra R., Scalf R. Sullivan M. Waller L. Zhu L. "Examining Associations Between Childhood Asthma and Traffic Flow Using a Geographic Information System." (1999) *Environmental Health Perspectives* 107(9): 761-767.

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(cont.)

C. The FEIR for the Oak to Ninth Project fails to fully acknowledge the potential health impacts due to compromised air quality and fails to document that wintertime winds can blow from the freeway over the project

The Oak to Ninth EIR includes an air quality and health analyses that focuses exclusively on diesel particulate exposure and cancer risk, finding that the project will have less than a significant impact. This air quality and health analysis has three major flaws.

- First, the CARB handbook bases its land use guidelines both on the long term lung cancer risks as well as short term health effects, including reduced lung function⁹, bronchitis, asthma, and cardiovascular mortality.¹⁰ These non-cancer health effects are not related exclusively to diesel exhaust particulates but also to non-diesel particulates from gasoline fueled cars and trucks. In addition, driving and vehicle emissions are expected to increase on I-880.
- Second, the EIR argues that because prevailing winds are westerly, project residents would not experience exposure from freeway vehicle emissions. According to the Bay Area Air Quality Management District, the highest levels of traffic related air pollutants occur during the winter.¹¹ **The EIR fails to disclose that, based on a 20 year analysis of wind at Lake Merritt, wintertime winds often blow from the southeast and northwest and winds are calm over 40% of the year.**¹² Given that the I-880 freeway runs from the northwest to the southeast, one can expect that freeway related vehicle emissions will often be entrained directly over the project resulting in particulate matter and nitrogen dioxide exposures to Oak to Ninth residents.
- Third, the EIR has not evaluated vehicle-related particulate matter effects on residents of Jack London Square, Chinatown, Downtown, Lower San Antonio, and around Lake Merritt. Traffic volume increases of 11% in surrounding neighborhoods will also increase exposure to particulate matter for residents and workers in these areas. Furthermore, westerly winds would blow cold start pollution emissions due to vehicle trips originating at the project to neighborhoods to the east.

2

D. Oak to Ninth residents will potentially experience adverse health effects due to freeway related traffic noise

The residents of parcels A, F, G, K, and M will be exposed to noise levels between 70 and 85 dBA depending upon proximity to the freeway. The EIR clearly documents that the exterior traffic noise will impact the parcels adjacent to I-880 and residential uses on these parcels would be considered normally unacceptable to clearly unacceptable based upon the noise element of the Oakland General Plan. The USEPA estimates that these unmitigated noise levels will result in community reactions ranging from threats of legal action to vigorous protest.¹³ This level of annoyance is directly related to several health effects associated with noise induced stress response, including: elevated blood pressure, circulatory disease, ulcer, colitis, and sleep deprivation. In addition, the traffic noise will prevent normal voice level communication at unprotected exterior locations.¹⁴ The EIR concludes that full mitigation is not possible due to the height of the proposed residential towers. In addition, while code-requirements can reduce indoor

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⁹ Venn. et al. "Living near a main road and the risk of wheezing illness in children." American Journal of Respiratory and Critical Care Medicine. 2001: Vol.164, pp. 2177-2180

¹⁰ Peters, A , et al, "Increased particulate air pollution and the triggering of myocardial infarction." Circulation, 103:2820-2815 (2001)

¹¹ Fairley, David, "Sources of Bay Area Fine Particles: A Chemical Mass Balance Analysis" BAAQMD, April, 2005, draft. <http://www.baaqmd.gov/CARE/documents/050609-fine-particles-7-fairley.pdf>.

¹² Monteverdi, John P., Background Information: "Wind and Rainfall Climatology for the Lake Merritt Area of Oakland", CA: Period 1950-1970, <http://www.mayacamaswx.com/Examples/Report.pdf>

¹³ EPA, Noise Effects Handbook, 1979, p. 8-1, <http://www.nonoise.org/library/handbook/handbook.htm>

¹⁴ *ibid.*, p. 4-4, <http://www.nonoise.org/library/handbook/handbook.htm>

noise levels substantially, residents will be exposed to high noise levels whenever they open their windows or walk outside.

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(cont.)

E. Project design changes can potentially mitigate and prevent health impacts due to noise and poor air quality

We believe a number of potentially feasible design changes might reduce environmental exposures to project residents and residents of surrounding neighborhoods. Our recommended mitigations are as follows:

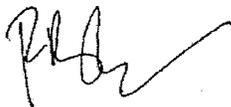
- Provide each residential unit located within 500 feet of the freeway with individual HVAC systems in order to allow adequate ventilation with windows closed
- Locate all air intakes as far as reasonably practicable from areas of poor air quality due to traffic and filter all supplied air that cannot be delivered from a clean source.
- Provide each residence within 500 feet of the freeway with HEPA filtration to remove air pollution particles from air within residences.
- Notify all potential buyers that the property they are occupying has air quality risks and educate them in the proper use of any installed air filtration.
- Design units exposed to high noise levels with interior courtyards and patios that open into acoustically protected and shielded areas.
- Require, as a condition of development, all feasible traffic demand management actions, including shuttle service to BART at frequency of no less than every 15 minutes, a pedestrian and bike pathway connecting development to the BART and surrounding neighborhoods, and greater affordable housing.
- As a comprehensive mitigation, consider modifying the layout of the project in a way that places multilevel parking structures between the residences and the freeway and re-aligns the Embarcadero between the residences and the waterfront; the parking structure could serve as an acoustical barrier, a visual barrier, and distance residents from air emissions.
- Require, as an additional condition of development, prospective monitoring of particulate matter hot spots both on the Oak to Ninth site and in neighborhoods to the east, northeast, and southeast. Develop requirements for additional air quality mitigation measures and / or traffic demand management measures that would be triggered by local particulate matter levels that exceed California standards.

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Overall, we recommend that the Oakland City Council fully analyze the health effects of air quality and noise on current and future area residents and require the developer to plan, engineer, design, and build the new development in such a manner that mitigates air quality and noise exposures.

Thank you in advance for your consideration of these issues and recommendations. If you have any questions please do not hesitate to contact me at ucbhig@gmail.com.

Sincerely,



Rajiv Bhatia, MD, MPH.
UC Berkeley Health Impact Group

CC: Oakland City Council; Claudia Cappio



Rajiv Bhatia, MD, MPH
Assistant Clinical Professor of Medicine
Center for Occupational and Environmental Health
School of Public Health
University of California
Berkeley, CA 94720-7360

March 23, 2005

Honorable Jane Brunner
One Frank Ogawa Plaza
One City Hall Plaza, 2nd Floor
Oakland, CA 94612

RE: Air Impact Assessment of the Oak to Ninth Proposal

Dear Councilwoman Brunner:

This letter requests the Oakland City Council's attention to the public health impacts of poor air quality and high levels of noise on future residents of the Oak to Ninth Project

The central issue raised in this letter is conflict between residential uses and environmental health the I-880 freeway. Even in the context of our current housing shortage, housing should be built where it will be healthful. Oakland's General Plan, many parts of the Oak to Ninth Avenue will have unacceptably high levels of noise for residential uses. The best environmental and public health evidence suggests residents living within 500 feet of a busy freeway will experience higher rates of respiratory illnesses. **What is most important is that health impacts due to air quality and noise have not been adequately studied in the CEQA process and the full range of feasible mitigations has not been considered by the City.** This letter will provide evidence for the following key points.

- The City has a responsibility to study freeway related air quality and noise health impacts and their feasible mitigations under CEQA;
- The project creates potentially significant environmental impacts on air quality by locating a residential use in proximity to Interstate 880
- The FEIR for the Oak to Ninth Project fails to fully acknowledge the potential health impacts due to compromised air quality and fails to document that wintertime winds can blow from the freeway over the project;
- Oak to Ninth residents are likely to experience some adverse health effects due to freeway related traffic noise;
- Project design changes can potentially mitigate and prevent health impacts due to noise and poor air quality.

The City has a responsibility to study freeway related air quality and noise health impacts and their feasible mitigations under CEQA

It is the responsibility of an EIR to analyze environmental effects that may cause either direct or indirect adverse effects on humans.

A lead agency shall find that a project may have a significant effect on the environment and thereby require an EIR to be prepared for the project where any of the following conditions occur: (d) The environmental effects of the project will cause substantial adverse effects on human beings, either directly or indirectly.¹

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While the freeway predates the project, CEQA guidelines specifically recognize that bringing people into proximity with a known environmental hazard is itself a potentially significant impact.

The EIR shall also analyze any significant environmental effects the project might cause by bringing development and people into the area affected. For example, an EIR on a subdivision astride an active fault line should identify as a significant effect the seismic hazard to future occupants of the subdivision. The subdivision would have the effect of attracting people to the location and exposing them to the hazards found there.²

The project creates potentially significant environmental impacts on air quality by locating a residential use in proximity to Interstate 880

The California Air Resource Board, Air Quality and Land Use Handbook: A Community Health Perspective (2005) recommends not locating sensitive land uses, including residential developments, within 500 feet of a highway with more than 100,000 vehicles per day.³ The average daily traffic on I-880 is in excess of a quarter of a million vehicles with over 18,000 vehicles traveling this highway during the peak hour. This high traffic conditions puts the future 1400 residences located on parcels A, F, G, K, and M at risk for respiratory diseases due to poor air quality.

The CARB guidelines are based on findings from extensive health research, demonstrating that proximity to high traffic density or flow results in reduced lung function and increased asthma hospitalizations, asthma symptoms, bronchitis symptoms, and medical visits. The research literature includes the following specific findings:

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The FEIR for the Oak to Ninth Project fails to fully acknowledge the potential health impacts due to compromised air quality and fails to document that wintertime winds can blow from the freeway over the project

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⁸ English P., Neutra R., Scalf R. Sullivan M. Waller L. Zhu L. "Examining Associations Between Childhood Asthma and Traffic Flow Using a Geographic Information System." (1999) *Environmental Health Perspectives* 107(9): 761-767.

The Oak to Ninth EIR uses air quality and health analyses that focus on diesel particulate exposure and cancer risk, finding that the project will have less than a significant impact. This air quality and health analysis has two major flaws.

- First, the CARB handbook bases guidelines both on the long term lung cancer risks as well as short term health effects, including reduced lung function⁹, bronchitis, asthma, and cardiovascular mortality.¹⁰ These non-cancer health effects are not related exclusively to diesel exhaust particulates but also related to non-diesel particulates from gasoline fueled cars and trucks. Driving and vehicle emissions are expected to increase on I-880.
- Second, the EIR argued that prevailing westerly winds would limit exposure from freeway vehicle emissions to project residents. According to the Bay Area Air Quality Management District that the highest levels of these traffic caused air pollutants occurs during the winter.¹¹ The EIR also failed to note that wintertime winds often blows from the southeast and northwest or that winds are calm over 40% of the year.¹² Given that the I-880 freeway runs from the northwest to the southeast, one can expect that freeway related vehicle emissions will often be entrained directly over the project resulting in particulate matter and nitrogen dioxide exposures to Oak to Ninth residents.

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Project design changes can potentially mitigate and prevent health impacts due to noise and poor air quality

We believe a number of potentially feasible design changes might reduce environmental exposures to project residents. These recommended mitigations are as follows:

- ① Provide each residential unit located within 500 feet of the freeway with individual HVAC systems in order to allow adequate ventilation with windows closed

⁹ Venn, et al., "Living near a main road and the risk of wheezing illness in children." American Journal of Respiratory and Critical Care Medicine. 2001: Vol.164, pp. 2177-2180

¹⁰ Peters, A., et al., "Increased particulate air pollution and the triggering of myocardial infarction." Circulation, 103:2820-2815 (2001)

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- Locate all air intakes as far as reasonably practicable from areas of poor air quality due to traffic and filter all supplied air that cannot be delivered from a clean source.
- Provide each residence within 500 feet of the freeway with HEPA filtration to remove air pollution particles from air within residences.
- Notify all potential buyers that the property they are occupying has air quality risks and educate them in the proper use of any installed air filtration.
- ① ▪ Design units exposed to high noise levels with interior courtyards and patios that open into acoustically protected and shielded areas.
- Require, as a condition of development, all feasible traffic demand management actions, including shuttle service to BART at frequency of no less than every 15 minutes, a pedestrian and bike pathway connecting development to the BART and surrounding neighborhoods, and greater affordable housing.
- ② ▪ As a comprehensive mitigation, consider modifying the layout of the project in a way that places multilevel parking structures between the residences and the freeway and re-aligns the embarcadero between the residences and the waterfront; the parking structure could serve as an acoustical barrier, a visual barrier, and distance residents from air emissions.

Overall, we recommend that the Oakland City Council fully analyze the health effects of air quality and noise on project residents and require the developer to plan, engineer, design, and build the new development in such a manner that mitigates air quality and noise exposures.

Thank you in advance for your consideration of these issues and recommendations. If you have any questions please do not hesitate to contact us at ucbhig@gmail.com.

Sincerely,

Rajiv Bhatia
For the UC Berkeley Health Impact Group

CC: Oakland City Council
Claudia Cappio



Rajiv Bhatia, MD, MPH
Center for Occupational and Environmental Health
School of Public Health, University of California
Berkeley, CA 94720-7360

Oak to Ninth Avenue Development: Priority Recommendations for Health Promotion and Illness and Injury Prevention

The UC Berkeley Health Impact Group has analyzed the Oak to Ninth Avenue Development proposal in response to significant public debate on health related land use and design issues. We are recommending that the City Council take the following eight actions to promote and protect the health of Oakland residents.

Recommendation I Oak to Ninth should model ethnic and economic integration by providing housing affordable so that **(1) the distribution of housing costs reflects the current household income distribution of Oakland, (2) at least 25% of housing is affordable to low income and very low income households, and (3) an additional 25% of housing is affordable to households earning the area's median income.**

Human Health Rationale Policies such as zoning and redevelopment can either facilitate or prevent segregation. Residents of low-income economically segregated communities in Oakland and elsewhere now live about six fewer years and experience a much greater burden of chronic disease than those in non-poverty neighborhoods. Research has demonstrated that reductions in life expectancy are caused by many place based factors including air pollution, violence, traffic hazards, poor schools, the absence of parks, and limited economic opportunity and mobility. In contrast, mixed income neighborhoods are assured the health benefits of access to healthier foods, better schools, better public transit, safer neighborhoods, park access and cleaner environments. In addition, based on MTC data and the Air Resources Board URBEMIS, higher levels of affordability will significantly reduce traffic congestion and reduce vehicle air pollution emissions.

Recommendation II Project should maximize accessibility to waterfront natural areas and recreation for Oakland residents by **(1) modifying the project's footprint and bulk to create some unobstructed views of the water and open spaces from the Embarcadero OR by re-aligning the Embarcadero between residential uses and the shoreline park, (2) requiring high quality bicycle and pedestrian trails between the waterfront and neighborhoods and transit stations east of I-880, (3) providing infrastructure and facilities necessary for diverse recreational uses identified through outreach with residents of surrounding neighborhoods, (4) requiring safe, frequent public transportation to the site, and (5) creating a oversight body with citywide membership for Oak to Ninth's waterfront parks.**

Human Health Rationale Contact with and views of natural landscapes reduce stress and depression, reduce violent and anti-social behaviors, and improve the ability to focus, pay attention, work, and learn. Access to open space facilitates physical activity reducing population levels of obesity, diabetes and hypertension.

Recommendation III The project should mitigate increases in the pedestrian injury rate caused by the project in the project area itself and in surrounding neighborhoods through: **(1) crosswalk improvements (e.g. median islands), (2) sidewalk improvements (e.g. bulb-outs), and (3) grade separated bicycle and pedestrian trails and paths between the project, surrounding neighborhoods, and transit stations**

Human Health Rationale Oakland currently has ~85 pedestrian injuries per year per 100,000 people which is about ~4 times the Federal objective. Our pedestrian injury impact analysis shows that the project would contribute to 5 additional injuries per year in the surrounding neighborhoods, and when combined cumulatively with other projects, to an additional 20 injuries per year, generating medical and lost productivity costs of roughly \$3 to 13 million dollars annually.

Recommendation IV The project should mitigate adverse air quality impacts by: **(1) building HVAC systems with air intakes oriented away from particulate sources and (2) requiring all feasible and effective transportation demand management measures, and (3) advising future residents that living in proximity to a freeway can worsen with asthma or other chronic respiratory conditions. The city should require the**

developer to conduct long-term monitoring for particulate matter hot spots both at Oak to Ninth site and at neighborhoods to the east.

Human Health Rationale According to the California Air Resources Board (ARB) the project is likely to result in increased frequency of respiratory symptoms and asthma exacerbations among project residents because of its location adjacent to I-880. Winds blowing from the North and Northwest in the wintertime have the potential of concentrating freeway particulate matter emissions directly over the project area.

Recommendation V The project should protect residents from outdoor environmental noise by (1) orienting buildings to buffer roadway noise in courtyards and open spaces and (2) considering a multi-level parking as an additional acoustical buffer

Human Health Rationale Exposure of 1400 residents to exterior noise levels up to 85 dBA in parcels A, F, G, K, and M will potentially result in mental stress, hypertension, speech disturbance, annoyance, and protest.

Recommendation VI The Oak to Ninth Project should include an on-site public elementary school.

Human Health Rationale Neighborhood schools reduce traffic and air pollution, facilitate physical activity, promote parent involvement in schools and their children's educational success.

Recommendation VII The design and placement of housing units at Oak to Ninth design should support person-to-person contact, social relationships and social capital by (1) creating crossing points and common paths of access and (2) providing common courtyards with benches, plants and fountains.

Human Health Rationale Social capital and community ties can promote an individual's sense of security and satisfaction, reduce stress and blood pressure levels, provide material and emotional support, and facilitate recovery from illness.

Recommendations VIII The City of Oakland should specifically document how the project design has been responsive or not to public concerns and constructive design change recommendations raised in the numerous public meetings and hearings on the Oak to Ninth Project.

Human Health Rationale Government responsiveness and accountability to needs articulated by the public is a critical determinant of population health. Meaningful participation means creating the opportunities for all affected people to understand what is at stake, to speak to their needs and concerns, and to have their needs addressed by people making the decision. A review of transcripts and public meeting summaries reveals that several concerns have been made repeatedly by diverse stakeholders at various stages of this process. Some of the most common statements are related to lack of attention to the existing Estuary Policy Plan, insufficient consideration of the impact upon traffic congestion and access to public transportation, the need for affordable housing for lower-income individuals and families, preservation of open space and the 9th avenue terminal, and lack of meaningful and responsive public engagement.

About The UC Berkeley Health Impact Group The UC Berkeley Health Impact Group, which includes graduate students and faculty within the School of Public Health, has been analyzing the Oak to 9th project as a class project in the winter and spring of 2006. Our aim has been to understand how the project might best contribute to community health assets, whether the project might lead to adverse health impacts, and how can the project be improved in a way that best protects and promotes health? These recommendations take as a given the need for a residential neighborhood at Oak to Ninth Avenue. We also recognize that development of well-designed higher density housing in surrounding neighborhoods such as the San Antonio and Chinatown districts, with existing transit, civic, educational, and urban infrastructure may also be a feasible and potentially superior alternative to meeting regional housing needs. We anticipate a full draft report of our findings will be available for review by the City Council in late April. UCBHIG members are: Edmund Seto PhD, Alberto Ortega, Ray Minjares, Miriam Rotkin-Ellman, Tom Rivard, MS, Heather Kuiper, Megan Gaydos, Rajiv Bhatia, MD, MPH. Please email comments and questions about UCBHIG to ucbhig@gmail.com.

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(cont.)

Responses to March 22 and March 23, 2006 letter regarding Air Quality and Noise Related Health Impacts, and Related Recommendations

- 1 The EIR analysis fully examined the potential air quality and noise impacts of the project, including those associated with potential health related effects, and appropriate mitigation measures are identified where necessary and feasible.

Regarding air quality, as discussed in Response to Comment Q-6 in the Final EIR, the Draft EIR analyzes potential health risks to project residents due to exposure to diesel emissions on I-880, the rail line north of the site, and from boats in the Estuary, south of the site. This is discussed in the Air Quality Section of the Draft EIR, starting on page IV.C-21, under *Toxic Air Contaminants*. The analysis finds that these potential health impacts would be less than significant due to prevailing with conditions, new regulations for diesel emissions, and the level of human exposure necessary for health risk to occur.

The comment specifically relies on the ARB Handbook's recommendation that sensitive land uses (e.g., residential) should not be located within 500 feet of a freeway. As addressed in Final EIR Response to Comment Q-6, and supported by the subsequent analysis prepared by ENVIRON subconsultants in response to these comment letters provided in **Appendix D** to this Addendum, the ARB Handbook states that the recommendations provided therein are advisory and should not be interpreted as defined "buffer zones." Furthermore, ENVIRON clarifies that some of the support used to develop the Handbook's recommendations on freeways makes clear the critical factor of wind direction in determining health risk. The site-specific analysis presented in **Appendix D** uses the actual distance of the nearest residential units on the project site from I-880 (200 feet) and detailed data on prevailing winds at the project site.

As discussed on page 2-2 of **Appendix D**, based on the meteorological data from the Alameda Naval Air Station (NAS), winds have the greatest potential to blow from the freeway towards potential residents 9.1 percent of the time during between 5AM and 9PM, when freeway traffic is likely to be most significant. Therefore, the combination of the low rate of winds blowing from the freeway toward the project residents during the most impactful times of day, and the distance of the residential units from the freeway, project residents would be less impacted by emissions from the freeway than other areas where winds blow with higher frequency from freeways to residential areas, such as the conditions studied for much of the Handbook's recommendations.

Also addressed in the ENVIRON report, data presented in the Handbook indicates that "all elevated levels of particulate matter (both from diesel and gasoline-burning sources) is unlikely to persist at levels greater than background [levels] for more than between 300 feet from the edge of the freeway, therefore, "accounting for the small fraction of winds from I-880 to the proposed residences [proposed 200 feet downwind], the annual average distances that elevated particulate matter would persist above background in this location is likely less than the distance cited in the Handbook." This analysis supports the

findings in the Draft EIR that cancer health risk to project residents would not be significant.

- 2 First, as stated above, the data provided in the Handbook, and the analysis conducted in the Draft EIR, address potential effects from both diesel and gasoline-burning vehicles. Also, project traffic is likely to be gasoline-burning vehicles rather than diesel vehicles. Second, as discussed in the ENVIRON report in **Appendix D** to this Addendum, many of the commenter's assertions regarding wintertime wind conditions at Lake Merritt are inaccurate based on ENVIRON's review of the cited references. In fact, the cited reference as well as subsequent analyses that uses newer data show that the fraction of calm winds throughout the year ranges from 4.7 to 15.7 percent compared to the 40 percent cited by the comment. Also, the reference cited by the commenter shows only a small fraction of winds from directions relevant to the project site (see **Appendix D**, page 2-3). Thus, the EIR fully acknowledges the potential health impacts related to air quality with regard to prevailing winds at the project site year-round. Lastly, given the above discussion in Response to Comment 1, increases in particulate matter from the development that would affect residents in the cited nearby areas would likely be indiscernible from the existing background produced by existing mobile sources.
- 3 The EIR analysis fully examined the potential noise impacts of the project, including those associated with locating residences in proximity to the freeway. Impact G.4 in the Draft EIR acknowledges the potential adverse effects of located project residences in an environment where outdoor noise levels are above what is considered "normally acceptable" - near I-880 - and that the impact would be significant and unavoidable. As presented in the EIR, the main open spaces proposed by the project would be located *at least* 200 feet from I-880, and outdoor sound attenuation can occur for areas located away from I-880, with some sound blockage *potentially* attributable to buildings sited between open spaces and I-880. (See also Response to Comment 2 to the April 12, 2006 letter regarding consistency with the Oakland Noise Element.)

The comment states that "residents will be exposed to high noise levels whenever they open their windows or walk outside." This is an inaccurate and overstated assertion since noise levels perceived at the project site are generated primarily by traffic noise along I-880, which varies throughout the day. The noise levels experienced by residents would depend on the specific location and orientation of the unit relative to I-880, landscaping and adjacent buildings. Also, the main open space areas are proposed along the waterfront and away from the primary noise source of I-880. What is also relevant to the commenter's assertions is that, as indicated in the Draft EIR (Table IV.G-3), the existing noise measurements that were taken along key points on the Embarcadero for the analysis were obtained at heights of 45 to 70 feet in order to evaluate the effect of noise at higher elevations where the project residences would be located.

Regarding indoor noise impacts relative to project residences, Response to Comment RR-11 in the Final EIR acknowledges the potential effects of noise on residents and human

health. Mitigation Measure G.3 identified in the Draft EIR addresses indoor noise exposure and requires the project to adhere to the maximum interior noise levels prescribed by the requirements of Title 24 through the use of sound-rated assemblies (i.e., windows, exterior doors, and walls). Compliance will reduce the impact to less than significant. In addition, standards, regulations and guidelines included in the proposed draft Planned Waterfront Development Zoning District as well as the Preliminary Oak to Ninth Design Guidelines include setback and landscaping requirements intended to reduce potential noise effects to the project. For example, the design guidelines acknowledge noise issues along the Embarcadero and require that the project maintain a minimum setback of 25 feet from the back of sidewalk and generous landscape buffer along the Embarcadero frontage. As discussed in the Draft EIR for Impact G.4 (outdoor noise), while the construction of sound walls along the northern perimeter of the project (Embarcadero) would reduce the outdoor noise level at the site, this is not considered feasible given the height of the walls that would be required, which would effectively block the line of sight of the Embarcadero and I-880 traffic, negatively affect the aesthetics of the area and separate the project from the surrounding neighborhood, thus reducing the publicly-accessible character of the development and access and visibility of the waterfront, new waterfront open spaces, and to both.

4 Based on the information provided in the above responses, the analysis and mitigation measures in the EIR, and the analysis prepared by ENVIRON consultants (provided in **Appendix D** to this Addendum), the potential health impacts related to air quality and noises are presented and mitigated to the extent feasible. Health related air quality impacts resulting from diesel emissions in particular would be less than significant, therefore no mitigation is required. The proposed development and design guidelines for the project, which are incorporated into the Oak to Ninth Preliminary Development Plan (PDP), as well as standard building standards required for the project, include requirements and standards specific to aspects of the project that would effectively reduce indoor and outdoor noise levels perceived by residents and users on the site. The design changes suggested by the commenter are not required or relevant to the potential impacts identified for the project.

5 ENVIRON consultants prepared specific responses to each of the recommendations put forth by the commenter in the undated correspondence to the City. These responses are provided in **Appendix D** to this Addendum and summarized below:

Recommendation 1: The commenter's opinion regarding the preferred distribution of affordable housing should occur on the project site is noted. See Response to the March 8, 2006 letter from Dr. Bhatia.

Recommendation 2: The recommendation is not specific to the project site and the effectiveness of the recommendation is not substantiated with documentation or rationale. As stated in the EIR, the project layout of streets and buildings will increase the opportunity for views to the Estuary where none currently exist. The project proposes a

system of bicycle and pedestrian trails that will connect to future pathways to Lake Merritt as well as access to public transportation (BART, AC Transit). The Transportation Demand Management Plan (TDMP) will expand access to transit and benefit accessibility of the waterfront areas by the public. As discussed in Chapter II of this Addendum, the project proposes a total of 23.11 acres of new open spaces, and the Preliminary Oak to Ninth Design Guidelines include elements aimed at ensuring a diverse network of public open spaces.

Recommendation 3: See Responses to the March 3, 2006 letter from Dr. Bhatia, and Response to Recommendation 2, above, regarding the proposed bicycle and pedestrian trail network.

Recommendation 4: The commenter misstates the ARB Handbook, which does not state that the project is likely to result in increased frequency of respiratory symptoms and asthma exacerbations among Project residents because of its location adjacent to I-880. This is the commenter's interpretation of the Handbook's policy. See Responses to Comments 1 and 2, above. Also, the TDMP includes comprehensive measures aimed at encouraging and facilities alternative modes of transportation to driving automobiles.

Recommendation 5: See Response to Comments 3 and 4, above.

Recommendation 6: The comment provides no documentation or technical support showing that the provision of an elementary school on site would have any positive effects on the impacts claimed by the commenter, or that attendance at a nearby existing school would have negative effects.

Recommendation 7: The comment provides no documentation or technical support showing that the alternative site design or placement of housing units on the project site would have significant positive effects on the health impacts claimed by the commenter. The project will include several parks that will provide opportunities for a variety of passive and active activities. Additionally, the project will incorporate a system of new pedestrian and bicycle paths that will connect to parks and neighborhoods beyond the project site, particularly via the Bay Trail. This system will create natural venues for "person-to-person contact, social relationships, and social capital."

Recommendation 8: The record of the environmental process and the design development process of the project over time has been available to the public throughout the process. The Final EIR includes public comments, responses to those comments, and changes that were made to the project or information provided in the environmental document, either as a result of public input or other reasons. A complete history of the project is documented on the City of Oakland's website and includes all public notices, agendas, staff reports, postings for public outreach by the project sponsor, and other relevant reports and information.



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April 12, 2006

Honorable Pat Kernighan
Oakland City Councilmember, District 2
One City Hall Plaza, 2nd Floor
Oakland, CA 94612

RE: Oak to Ninth Project Inconsistency with the General Plan Noise Element

Dear Councilmember Kernighan:

This letter calls attention to the significant inconsistency between certain Oak to Ninth Avenue Project proposed residential uses and the City of Oakland Noise Element as well as related environmental justice impacts.

Correspondence submitted to the Oakland City Council prior to the informational hearing of March 28th, 2006 provided evidence of the potential public health impacts of poor air quality and high levels of noise on future residents of the Oak to Ninth Project secondary to extremely high motor vehicle volumes on the I-880 freeway. Infill residential development, undertaken in areas with existing public infrastructure and connections to public transit, has clear regional environmental health benefits; however, the prior correspondence pointed out that residential uses on parts of the project are inconsistent with State of California Air Resource Board Guidelines for land use and would result in relatively high exposures to environmental noise for future residents. The correspondence suggested additional analyses of these concerns and provided a list of project and building design changes to mitigate these effects.

I am writing this letter because City of Oakland staff reports and planning documents have not adequately or accurately addressed the issue of violations of the City's Noise Element and related public health and safety effects. I would like to call attention to the following facts and evidence:

- Noise and air quality related health impacts associated with this project are of significance equal to or greater than groundwater and soil contamination.
- Measured long term environmental noise levels on parcels A, G, F, K, and M are very loud, ranging from 75 to 85 dB Ldn. (DEIR IV.G-11)
- The Oakland General Plan Noise Element's Land Use Compatibility Chart proscribes residential uses as "clearly unacceptable" where noise levels are greater than 75 dB Ldn, stating that such "development should not be undertaken".
- The March 15th City Planning Staff Report did not inform the Oakland Planning Commission that project clearly violates the Oakland Noise Element in its description of General Plan consistency (pages 11-23)
- The March 15th Staff report recommended the Commission adopt findings of consistency with the General Plan and findings stating the absence of health and safety problems in order to approve Vesting Tentative Tract Map (page 26).
- As written, Impact G.4 in the CEQA findings document presented to the Planning Commission did not provide an accurate or reasonable description of inconsistency between the Noise Element and the project.

- The March 28th, 2006 informational report to the City Council does not identify the violation of the City's Noise Element or conflicts with California ARB air quality guidelines as key issues.
- Mitigating indoor environmental noise through construction practices is feasible; however, it can typically add 20% to residential construction costs.
- Limited mitigation of environmental noise in outdoor residential is feasible; the existing outdoor noise levels of 75-85 dB means that outdoor conversation at normal speech volumes will not be likely.
- Limited mitigation of project-related adverse air quality impacts is possible, for example, by ensuring building HVAC systems, orienting HVAC air intakes oriented away from particulate sources, and implementing air filtration.
- Members of low income households should be expected to be more sensitive to the health and developmental impacts of high environmental noise levels and high airborne particulate matter levels.
- The City of Oakland Redevelopment Agency is contemplating purchasing project area parcels with the highest levels of noise for the construction of below market rate housing, potentially creating new environmental health and justice impacts.

Increasing housing supply in Oakland and integrating BMR housing and market-rate housing in new projects is certainly good health and social policy; still, the following remain significant and unresolved policy questions for the City of Oakland regarding noise and air quality:

1. **The Noise Element is arguably the most important public health regulation to limit adverse environmental exposure to excessive noise. If the City Council approves residential development where the General Plan Noise Element clearly prohibits such development, does this action set a precedent for future land use decisions in Oakland?**
2. **Will the purchase of the land most compromised by noise and poor air quality for below market rate units result in a disparate environmental health burden for lower income Oakland residents and, if so, would this act be consistent with State Environmental Justice Statutes?**
3. **Does the City have the ability to purchase parcels other than parcels A, G, F, K, and M that are less compromised by environmental noise and air quality for BMR housing?**
4. **Has the City investigated best practices in building design and orientation for limiting noise in outdoor residential areas on parcels A, G, F, K, and M**
5. **Has the City investigated best practices in building design, ventilation and orientation for mitigating adverse air quality secondary to freeway emissions?**
6. **Has the City considered requiring the developer to conduct long-term monitoring for particulate matter hot spots and noise hot spots at Oak to Ninth site?**

Thank you in advance for your consideration of these issues, questions, and suggestions. If possible and appropriate, I would appreciate a written response from City staff. If you have any questions please do not hesitate to contact me at ucbhig@gmail.com.

Sincerely,



Rajiv Bhatia, MD, MPH.
UC Berkeley Health Impact Group

CC: Oakland City Council; Claudia Cappio; David Vanderpriem

2
(cont.)

Responses to April 12, 2006 letter regarding the Project's Consistency with the General Plan Noise Element

- 1 The comment states that the residential uses on parts of the project site are inconsistent with State of California Air Resources Board Guidelines for land use and that the project would violate the City's Noise Element. The comment also states that the City's staff reports and planning documents have not adequately or accurately addressed the issue of the project's violation of the City's Noise Element. The comment notes that the Noise Element "prescribes residential uses" in areas where the noise environment exceeds 75 dB Ldn. Based on this interpretation, the letter poses a number of policy questions and states various conclusions. While the April 12, 2006 letter primarily does not address issues concerning the adequacy of the environmental analysis provided in the Draft EIR, it is addressed in this Addendum.

See Response to Comments 1 and 2 to the March 22 and March 23, 2006 letters from Dr. Bhatia regarding air quality impacts. The commenter's concerns and assumptions about the environmental and potential health impacts related to noise at the project site are provided in the March 22 and March 23, 2006 letters, and responses to those are presented in Responses to Comments 3 and 4 to those letters.

- 2 The comment bullets numerous points, many unsubstantiated or rationalized, related to noise impacts, potential mitigations, the effectiveness of potential mitigations, and a number of City's considerations for the project. Again, a number of considerations about the project and its requirements suggest that noise levels will not occur as asserted by the commenter or presented in the EIR. With respect to the noise issue, the Draft EIR disclosed that certain noise readings taken near and along the Embarcadero would fall into the "clearly unacceptable" category in the Noise Element's "Land Use Compatibility for Community Noise Environment" chart. In fact, this incompatibility was determined to be an unavoidable significant impact of the project (Draft EIR VI- p.G-27, Impact G-4). Thus, the public and the City decision makers were fully informed about the potential incompatibility.

Table IV.G-3 in the Draft EIR lists various existing noise environment measurements. Certain of these measurements show noise levels that would fall into the Noise Element range for "clearly unacceptable" for residential development. As mentioned in Response to Comment 3 to the March 22 and March 23, 2006 letters, of the twelve measurements over 75 Ldn, few reflect ground level conditions. The other measurements were taken above ground level (between 14 and 70 feet) and do not represent conditions that residents would experience while outside of the buildings in these locations. Moreover, these measurements do not represent 24-hour conditions and noise levels will be lower during nighttime and other off-peak hour traffic times. Although the comment implies that these noise conditions will affect entire lots, the readings were taken close to the edge of the Embarcadero (at 45 to 70 feet high at key locations) and do not reflect conditions across the parcels.

As also discussed in previous responses to noise issues, the majority of the open space planned for the site will be in areas shielded from the I-880 noise either because these areas are located along the water's edge or because the distance to the freeway is significant. Gateway Park is located near the Embarcadero along one edge, but most of the park will be far enough away from the road that noise will be attenuated. Additionally, Gateway Park is primarily an entry area and it is expected that most visitors to the park will be passing through to other locations.

In accordance with the proposed Planned Waterfront Development Zoning District, all project buildings will be required to undergo design review. The design review process will examine all aspects of the building and its location on the site. Appropriate siting and landscaping to reduce potential noise impact will be one of the many considerations examined in the design review process. The project's Preliminary Oak to Ninth Design Guidelines call for buildings along the Embarcadero to be set back and screened with landscaping to limit the impact of the roadway and the freeway. Additionally, all of the buildings must comply with state interior noise standards so that residents will be shielded from noise while in their units.

As previously stated, given the combined affect of these characteristics, regulations, guidelines and City review processes required for the project design, the actual noise impacts that would occur are likely to be less than those characterized by the comment or represented in the EIR.

In summary, it is important to note that the Noise Element acknowledges that "because the various elements of the Oakland general plan contain policies that address numerous different goals and some policies might compete with each other. If deciding whether to approve a proposed project, the City's Planning Commission and City Council must balance the various policies and decide whether the project is consistent (that is, in general harmony) with the general plan overall." (Noise Element, p. 2.) Thus, in deciding whether to approve the project the City Council will weigh compatibility with the noise element, based on the facts described above, in relation to other General Plan goals and policies, such as the provision of housing, the provision of open space, environmental remediation of the site, and economic revitalization of this area, among others.

APPENDIX A

Traffic Impacts Resulting from New Site Plan



MEMORANDUM

Date: May 18, 2006

To: Patrick Van Ness, Signature Properties

From: Chris Gray, Fehr & Peers

Subject: Oak to 9th Project Traffic Impacts Resulting from New Site Plan

1031-1998

This memorandum documents our analysis of the newly proposed site plan for the Oak to 9th Development. The major change from the previous site plan is that the dwelling units and commercial space were deleted from the site of Estuary Park (formerly known as Parcel N), with these units redistributed to other areas of the project.

We reviewed the new site plan to determine if these land use changes would result in additional traffic impacts beyond those previously identified in the Draft and Final EIR published previously. Our analysis considered three questions:

1. Does the new site plan contain more overall development than the previous one, which could lead to additional traffic impacts beyond those previously identified at off-site intersections?
2. Does the redistribution of dwelling units and commercial space increase traffic volumes at project driveways, particularly the major access routes into and out of the project at Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp?
3. Does any increase in traffic volumes lead to additional traffic impacts at project driveways, particularly the major access routes into and out of the project at Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp?

QUESTION #1- DOES THE NEW SITE PLAN CONTAIN MORE DEVELOPMENT?

A review of the new site plan indicates that there are 3,100 multi-family dwelling units proposed within the project site. 200,000 square feet of commercial space are proposed to be constructed as well. The old site plan also contained 3,100 multi-family dwelling units and 200,000 square feet of commercial space. Therefore, the dwelling unit and commercial space totals are identical between both uses. The overall project trip generation would also therefore be identical.

Since the trip generation between the two alternatives is identical, and the distribution of project-generated traffic would be unaffected by changes to the site plan, we would expect the project impacts to be the same at all off-site intersections. Off-site intersections would include all intersections except those directly adjacent to the project site. 49 of the 51 study intersections can be classified as off-site. The only study intersections directly adjacent to the project site would be Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp.

QUESTION #2- DOES THE REDISTRIBUTION OF UNITS INCREASE TRAFFIC VOLUMES AT PROJECT DRIVEWAYS

As noted above, the major change in the site plan is the movement of dwelling units and commercial space from the former Parcel N to the remaining areas of the development. The number of driveways proposed along Embarcadero is proposed to remain the same. At one of these driveways (Estuary Drive near the former Parcel N), the traffic volume is expected to decrease significantly with the removal of dwelling units and commercial space from this driveway.

At the remaining six parcels, the number of trips is expected to increase, although the increase at any one driveway is expected to be minimal. The trip increase at each driveway ranges from 5 AM peak hour trips at Embarcadero / 5th Avenue to 40 PM peak hour trips at Embarcadero / 6th Avenue/I-880 off-ramp. The other driveways would also experience minimal increases in traffic volumes. This minimal increase occurs for the following reasons:

1. The change in the site plan results in the redistribution of no more than 10 percent of the uses on site (300 dwelling units and 15,000 square feet of commercial)
2. These dwelling units and the commercial space are distributed across the remaining areas of the project
3. There are six driveways which provide access to the site
4. The project maintains an extensive internal roadway system which allows vehicles from the various parcels to access multiple driveways

Therefore, the redistribution of land uses results in a minimal increase in trips across all driveways.

QUESTION #3- DOES ANY INCREASE IN VOLUMES AT PROJECT DRIVEWAYS RESULT IN ADDITIONAL IMPACTS AT PROJECT DRIVEWAYS

The impact analysis for the EIR included two of the major intersections adjacent to the project site. These intersections are Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp. As noted in the response to Question #2, above, there will be a minor increase in the number of vehicles at these intersections.

The traffic study documented in the Draft and Final EIR identified impacts and recommended mitigation measures at these two intersections. With the recommended mitigations, mainly a widening of Embarcadero from 5th Avenue along the project frontage, both of these intersections would operate at an acceptable service levels (LOS D or better).

An analysis of intersection operations indicates that the additional trips cause a minimal increase in delay and no change in LOS. The delay change ranges from less than 1 second at the intersection of Embarcadero/5th Avenue in the AM peak hour to a change in delay of 3 seconds at the intersection of Embarcadero/6th Avenue/I-880 off-ramp in the PM peak hour. During all analysis periods, the change in delay is insufficient to cause a change in LOS. Therefore, these two intersections would continue to operate at acceptable levels even with the change in the project site, assuming implementation of the mitigation measures identified in the Draft and Final EIR.

SUMMARY

The answers to the three questions posed at the beginning of this memo are as follows:

1. Does the new site plan contain more overall development than the previous one, which could lead to additional traffic impacts beyond those previously identified at off-site intersections?- **No, trip generation and trip distribution the same. No additional off-site impacts.**
2. Does the redistribution of units increase traffic volumes at project driveways, particularly the major access routes into and out of the project at Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp?- **Yes, slight increase in traffic at driveways.**
3. Does any increase in traffic volumes lead to additional traffic impacts at project driveways, particularly the major access routes into and out of the project at Embarcadero/5th Avenue and Embarcadero/6th Avenue/I-880 off-ramp?- **No, minimal increase in volume leads to minimal increase in delay. No additional impacts.**

We hope you find this information to be helpful. If you have any questions or comments about this analysis, please call me at 949.859.3200 or e-mail me at cgray@fehrandpeers.com.

APPENDIX B

Project Traffic Impacts on 12th and 14th Streets



MEMORANDUM

Date: May 18, 2006
To: Patrick Van Ness, Signature Properties
From: Chris Gray, Fehr & Peers
Subject: Oak to 9th Project Traffic Impacts on 12th/14th Street

1031-1998

At your request, we have conducted an additional analysis related project traffic impacts on 12th/14th Street in the City of Oakland adjacent to Lake Merritt. It is our understanding that the City of Oakland will be reconfiguring these roadways to create a six-lane boulevard along the waterfront. Our analysis below estimates whether or not the development of the Oak to 9th site would impact the operations of this reconfigured roadway system along Lake Merritt.

LEVEL OF SERVICE (LOS) ANALYSIS

The transportation impact analysis for Oak to 9th focused on project impacts at the intersection level. We also evaluated impacts to the freeways and other major regional roadways throughout Alameda County, based on the requirements of the Alameda County Congestion Management Agency (ACCMA).

Our previous analysis, as documented in the DEIR, concluded that the intersections along both the west side and east side of this roadway segment would operate at acceptable service levels.

As an additional level of analysis, presented in this memo, we also estimated the 2025 level of service for this roadway segment using the following information:

- Traffic volumes from adjacent intersections at First Avenue/International Boulevard, 1st Avenue/Foothill, and 5th Avenue/East 12th Street. Based on the roadway configuration, it is likely that traffic on this roadway segment would pass through these three intersections. By combining the traffic volumes at these intersections, we can estimate the volumes on the segment of 12th/14th Street adjacent to Lake Merritt
- The roadway capacity can be estimated by applying a per lane capacity of 800 vehicles per hour. This capacity was used for the impact analysis on regional roadways, except for freeway facilities. Therefore, the directional capacity on this roadway segment would be 2,400 vehicles per hour, in each direction

The results of the LOS analysis are provided in Table 1. As indicated in this table, the westbound direction is expected to be deficient during the AM period while the eastbound segment will be deficient during the PM period. In both cases, the addition of project traffic would increase the volumes on the deficient segments by less than 3 percent.

Period	Direction	2025 No Project			2025 With Project		
		Volume	V/C	LOS	Volumes	V/C	LOS
AM	Eastbound	894	0.37	A	912	0.38	A
AM	Westbound	2775	1.16	F	2850	1.19	F
PM	Eastbound	3290	1.37	F	3381	1.40	F
PM	Westbound	1262	0.53	A	1326	0.55	A

Source: Fehr & Peers, April 2006

IMPACT ANALYSIS

To determine if the project impacts on these roadway segments is significant, we applied the following criteria:

- The project would cause a roadway segment on the Metropolitan Transportation System to operate at LOS F or would increase the V/C ratio by more than three (3) percent for a roadway segment that would operate at LOS F without the project

While these roadway segments are not located on the Metropolitan Transportation System, the above criteria does relate to a roadway segment and was applied for this analysis. As indicated in the above table, the V/C ratio increases by 3 percent or less on all segments. The impact is therefore less than significant.

We hope you find this information to be helpful. If you have any questions or comments about this analysis, please call me at 949.859.3200 or e-mail me at cgray@fehrandpeers.com.

APPENDIX C

Fehr & Peers Response to Rajiv Bhatia Letter of March 3, 2006



MEMORANDUM

Date: June 6, 2006

To: Patrick Van Ness, Signature Properties

From: Chris Gray, Fehr & Peers
Matthew Ridgway, Fehr & Peers

Subject: *Response to Rajiv Bhatia's March 3, 2006 Letter Related to Pedestrian Injuries Related to the Oak to 9th Development*

1031-1998

At your request, we have completed a review of a letter prepared by Rajiv Bhatia, MD, related to the proposed Oak to 9th Development. In his letter, Dr. Bhatia asserts that increased traffic from the project would cause a significant number of pedestrian injuries at various locations throughout the City of Oakland. Dr. Bhatia supports his assertion through a review of the City of Oakland's *Pedestrian Master Plan*, various research studies, and a collision prediction model.

Based on our review of this letter, we have identified the following comments:

1. Pedestrian safety is an important consideration but the methodology used in the letter to draw a connection between the Project and the need for pedestrian safety enhancements lacks nexus.
 - a. The macro-level conclusion that increasing traffic volumes increases pedestrian collision likelihood lacks site specificity. Our analysis of traffic impacts and mitigation measures is based on a site specific analysis. It is likely that any increased pedestrian collisions may occur at only a few locations or at locations with certain characteristics, for instance at unsignalized intersections or those lacking crosswalks.
 - b. Without site specificity, it is not possible to draw a nexus between the impact and a proposed improvement/mitigation. This nexus is critical under CEQA to require a project to contribute to a specific mitigation measure.
 - c. Dr. Bhatia's analysis is based on hypothetical numbers of pedestrian collisions rather than actual data regarding pedestrian collisions.
2. Analysis of site-specific pedestrian safety considerations is not supported by state of the practice tools.
 - a. There is no safety-consideration comparable to the Highway Capacity Manual (although a new Highway Safety Manual is under development) that would allow assessment of whether an intersection is safe and whether project-level changes to the subject intersection increases the likelihood of pedestrian collisions.
 - b. The City of Oakland does not have a policy or other guidance to form the basis of significance criteria even if there were a basis for conducting the site-specific

safety analysis. Without a policy, standard, or significance criteria, we can not determine if additional pedestrian impacts are a significant impact under CEQA.

3. There is no precedent, in Oakland or elsewhere, for such an analysis.
 - a. As noted in the studies cited by Dr. Bhatia and other relevant studies identified by Fehr & Peers, there was no instance identified instance where an increase in pedestrian was correlated with a historical increase in volume at the same intersection. Copies of these studies are attached to this document.
 - b. There were no studies which analyzed the impact of a development project's traffic on a pedestrian system.
 - c. The nearest thing would be an analysis of collisions per million vehicles or collisions per million pedestrians for study intersections. A potential basis for determining whether the observed collision rates are problematic would be to compare the rate of collisions per million vehicles with statewide average collision rates for comparable intersections published by Caltrans annually. (There is no basis for determining an appropriate rate of collisions per million pedestrians because the is little or no data on pedestrian volumes).
 - d. Such a comparison would allow us to identify intersections with safety concerns and we could proceed to review actual collision reports for the subject intersection to determine whether there are engineering solutions (for example - if a disproportionate number of collisions were between right-turning vehicles and pedestrians in a particular crosswalk, we could then recommend a No Right Turn on Red sign).
 - e. Even if this process were to be employed, there would be no way to determine if a significant impact occurs under CEQA and if there is adequate mitigation for such an impact.
4. The number of pedestrian collisions at an intersection is a function of the traffic volume, speed, intersection configuration, traffic control, surrounding land uses, location, and number of pedestrians. At any location, it is difficult to isolate the contribution of traffic volume growth to any increases in pedestrian volumes.
5. The City's Pedestrian Master Plan lists 10 intersections where a majority of the pedestrian collisions occur. These intersections generally averaged 1 collision per year or more from 1996 to 2000. None of these 10 intersections carry a significant amount of project traffic.

Fehr & Peers has also obtained data from the City of Oakland regarding historical reported pedestrian collisions at the 50 study intersections that are analyzed in the Oak-to-Ninth EIR. Figure 1 shows the locations of these intersections, many of which are in the downtown core and Chinatown areas, which have high levels of pedestrian traffic. A significant shortcoming of collision reporting systems throughout the US is that minor collisions, particularly those within no injuries are unreported. As a result, the data presented below should not be considered all-inclusive, but is good for cross-intersection comparisons.

1. As shown in Figure 2, nearly half (20) of the 50 study intersections had no reported pedestrian-related collisions from 1995 to 2004. Given that pedestrian-related collisions normally represent only a fraction (generally less than 10 percent) of the total collisions, this is not an unusual finding.

2. At 20 of the remaining 30 intersections, three or fewer pedestrian collisions took place over the nine-year period (1995 to 2004), which represents one or fewer collision per three-year period.
3. At one intersection, Webster/8th, an average of one pedestrian collision per year occurred. The conclusion from this and the prior two bullets is that there are not sufficient numbers of pedestrian collisions to allow a reliable statistical analysis; this despite a sampling of 50 intersections with a total of 98 reported pedestrian-involved collisions. This also highlights the complexities of collision prediction, which is normally based on a statistical analysis of collision trends and factors.
4. The number of pedestrian collisions by year varied significantly. As shown on Figure 3, the highest number of pedestrian collisions occurred in 1995 with 20 collisions. In other years, the number of pedestrian collisions varied between 6 and 12 per year at our study intersections. There was no clear trend of pedestrian collisions increasing or decreasing over the nine-year period.

We hope you find this information helpful. If you have any questions, comments, or require any additional information, please call me at 949.859.3200.

Articles referenced by Dr. Bhatia (letter's endnotes are included in the references below):

7. 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 Epidemiol Community Health*. 2003; 57: 327-333.

The authors reviewed published and unpublished research articles pertaining to transportation interventions to improve health. Traffic calming and nighttime lighting was found to reduce accidents, however it is unclear the type of accidents the authors are referencing in the review.

8. Jacobsen, PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention*. 2003; 9: 205-209.

Jacobsen studied bicycle and pedestrian collision data sets from around the world. He found that a motorist is less likely to collide with a pedestrian or bicyclists the more non-motorized users are present. The research demonstrates that this is the case at all levels of analyses, from intersections to regions.

9. Leden, Lars. Pedestrian risk decrease with pedestrian flow. Study based on data from signalized intersections in Hamilton, Ontario. *Accident Analysis and Prevention*. 2002; 34: 457-464.

The researcher studied pedestrian accidents at 300 signalized intersections in Hamilton, Ontario, Canada between 1983 and 1986. The results show that as the number of pedestrians increase the number of vehicle-pedestrian collisions decrease, pedestrian accidents increase with increases in vehicle flow, and that left-turning vehicles are more of a risk to pedestrians than right-turning vehicles.

11. LaScala EA, Gerber D, Gruenewald PJ. Demographic and Environmental Correlates of Pedestrian Injury Collisions: a spatial analysis. *Accident Analysis and Prevention*. 2000; 32: 651-658.

In this study, the researchers use a spatial analysis to study pedestrian injury collisions from San Francisco, California in 1990. The results found that a variety of environmental factors, including vehicle flow, population density, the local population's age, unemployment, gender, education, and availability of alcohol are all related to pedestrian injury rates.

14. Agran PF, Winn DG, Anderson CL, Tran C, Del Valle CP. The Role of the Physical and Traffic Environment in Child Pedestrian Injuries. *Pediatrics*. 1996; 98: 1096-1103.

This analysis was performed in Orange County, California during the afternoon hours, when more young pedestrians are present on streets. The authors conclude that residential streets with multifamily residences and on-street parking should receive high priority for intervention programs reducing children pedestrian injuries.

15. (Different Source but same author and topic) Zegeer CV, Stewart RJ, Huang HH, Lagerwey PA. Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations. *Transportation Research Record*. 1773: 56-68.

Research in this study includes five years of pedestrian crash statistics at 1,000 marked crosswalks and 1,000 unmarked crosswalks located at sites without traffic signals or stop signs in various United States' cities. Results found that marked crosswalks on two-lane roads presented no difference in pedestrian crash rates than unmarked crosswalks on two-lane roads. On multi-lane roads with 12,000 or more vehicles per day, the research found marked crosswalks increased pedestrian crash rates compared to unmarked crosswalks.

16. Landis, BW, Vattikuti, VR, Ottenberg, RM, McLeod, DS, Guttenplan, M. Modeling the Roadside Walking Environment: A Pedestrian Level of Service. TRB Paper No. 01-0511.

This research develops a Pedestrian Level of Service (LOS) Model for the state of Florida based on 1250 observations of 75 pedestrians in Pensacola, Florida. The Pedestrian LOS focuses on pedestrians' perception of safety and the "primary" factors that affect perception of safety. Factors include: separation between pedestrians and traffic, traffic volume, traffic speed, percentage of truck traffic, and driveway access and frequency.

20. Lee, C, Abdel-Aty M. Comprehensive Analysis of Vehicle-Pedestrian Crashes at Intersections in Florida. Accident Analysis and Prevention 2005: 37: 775-786.

This study focuses on vehicle-pedestrian crashes in Florida between 1999 and 2002. The authors found that demographic factors, road geometries, and traffic and environmental conditions are all related to the frequency of pedestrian crashes. The research found that higher average traffic volumes at intersections increases pedestrian crashes, but the rate of increase is steeper at lower average traffic volumes (in rural areas).

Other articles reviewed:

Houton, RV. The Effects of Advance Stop Lines and Sign Prompts on Pedestrian Safety in a Crosswalk on a Multilane Highway. Journal of Applied Behavior Analysis. 1988: 21: 245-251.

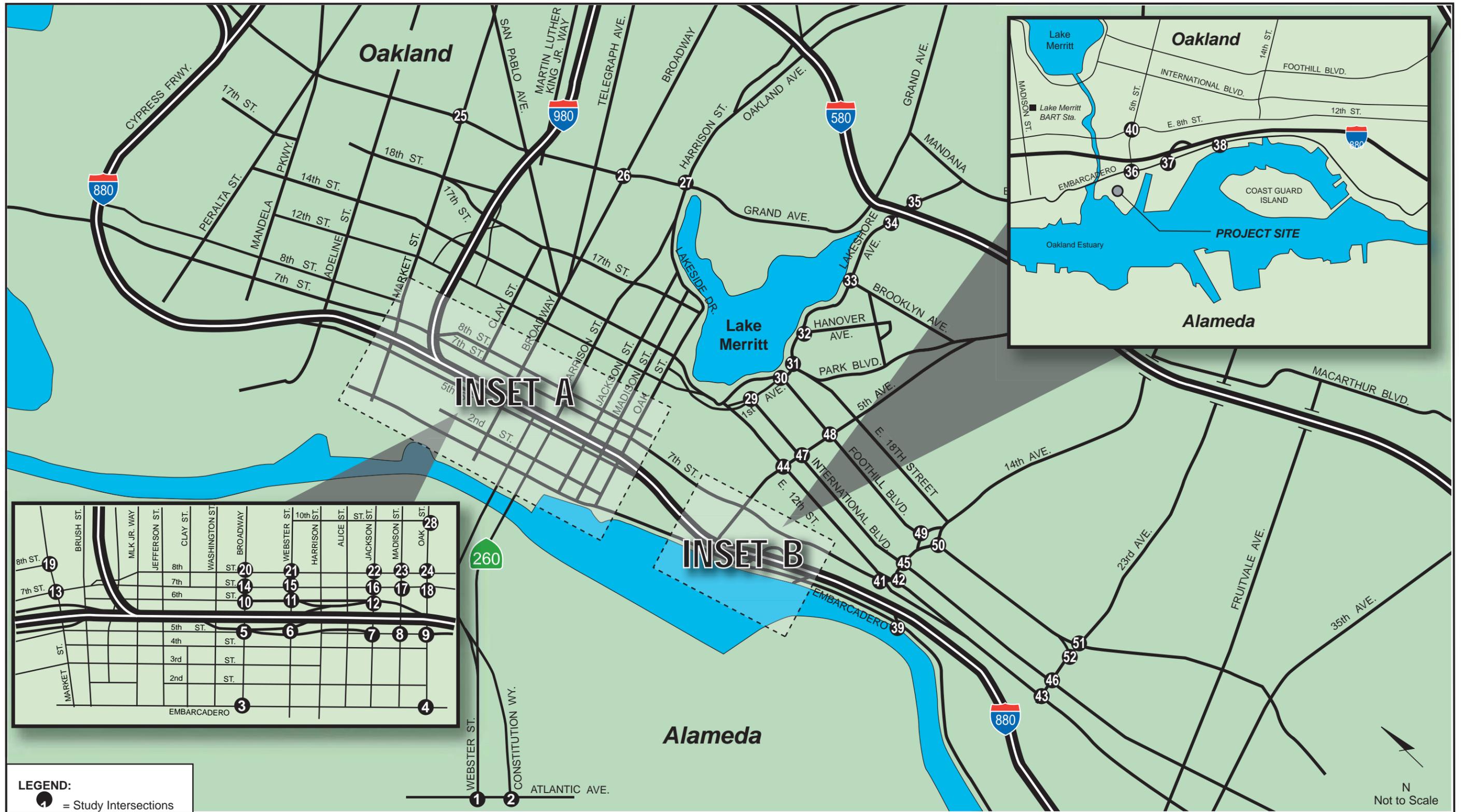
A study in Dartmouth, Nova Scotia, Canada focuses on the use of stop line bars at unsignalized crosswalks. The results found that stop line bars with pedestrian crossing signs reduce vehicle-pedestrian collisions or near vehicle-pedestrian collisions by almost 80 percent.

Lord, Dominique. Analysis of Pedestrian Conflicts with Left-Turning Traffic. Transportation Research Record. 1538: 61-67.

Lord analyzed pedestrian-vehicle conflicts at eight intersections in Hamilton, Ontario, Canada. In the analysis, he found that T-intersections have a greater traffic conflict rate between vehicles and pedestrians than four-legged intersections.

Markowitz, F, Sciortino, S, Fleck, JL, Yee, BM. Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation. ITE Journal. January 2006, 43-48.

Researchers conducted a pedestrian countdown signal "before and after" study in San Francisco where 600 crossings were evaluated before installation and over 900 after installation. The results found that the number of pedestrian injury crashes with vehicles decreased by 52 percent after the installation of the countdown signals.



Brooklyn Basin - Oak to 9th Development Plan

Figure 2- Total Number of Pedestrian Collisions (1995 to 2004)

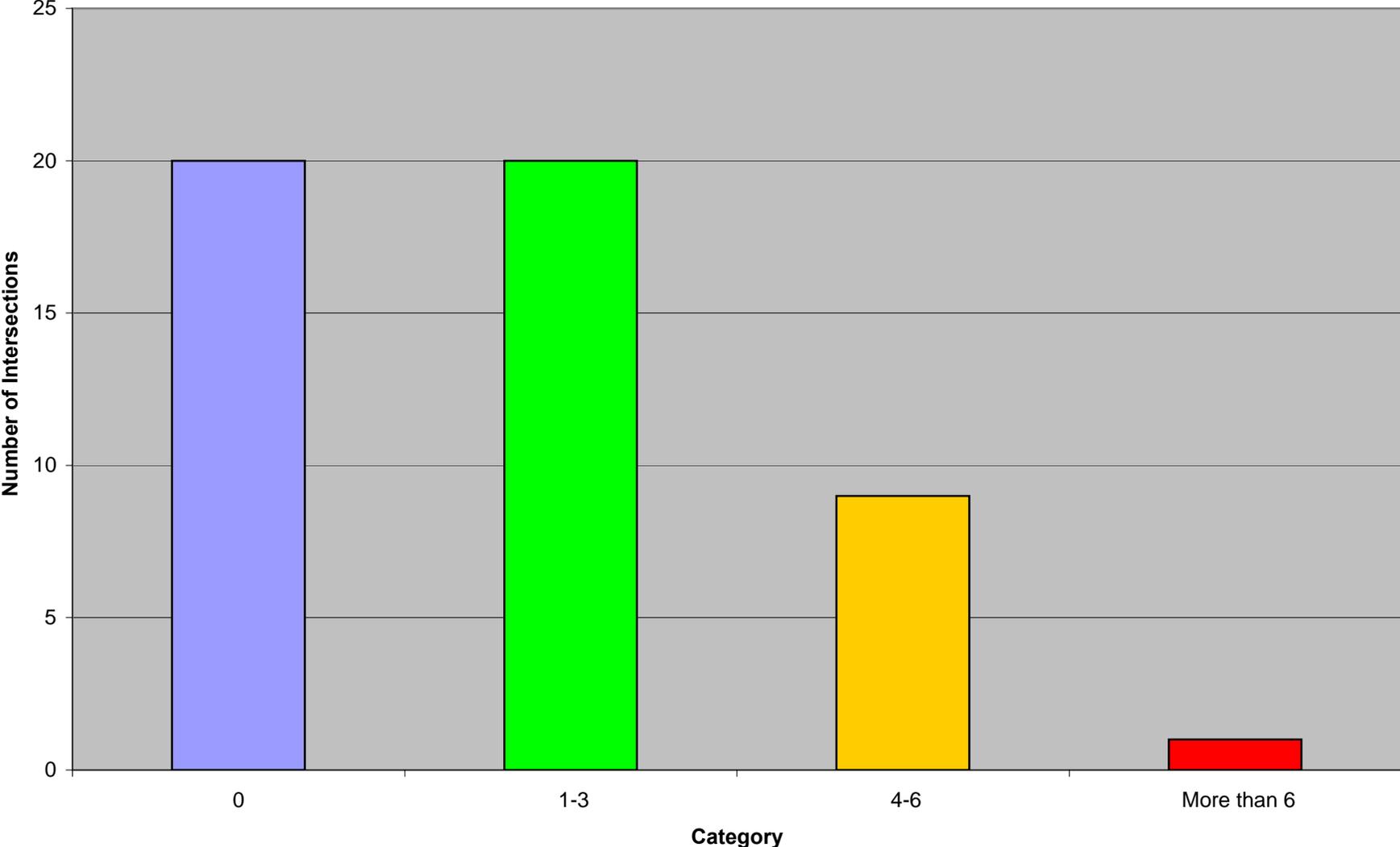
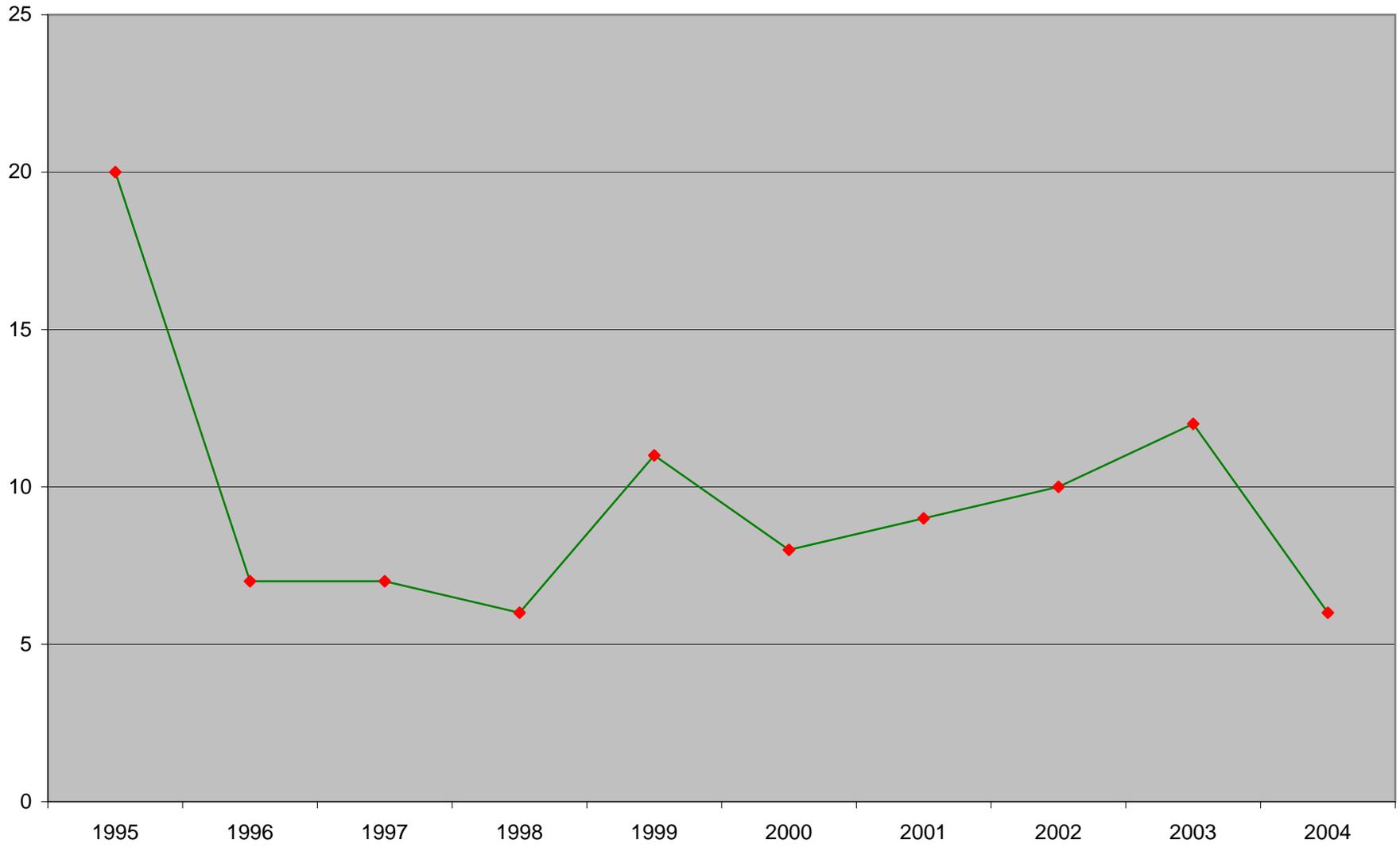


Figure 3- Yearly Pedestrian Collisions (1995 to 2004)



Comprehensive analysis of vehicle–pedestrian crashes at intersections in Florida

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Abstract

This study analyzes vehicle–pedestrian crashes at intersections in Florida over 4 years, 1999–2002. The study identifies the group of drivers and pedestrians, and traffic and environmental characteristics that are correlated with high pedestrian crashes using log-linear models. The study also estimates the likelihood of pedestrian injury severity when pedestrians are involved in crashes using an ordered probit model. To better reflect pedestrian crash risk, a logical measure of exposure is developed using the information on individual walking trips in the household travel survey. Lastly, the impact of average traffic volume on pedestrian crashes is examined. As a result of the analysis, it was found that pedestrian and driver demographic factors, and road geometric, traffic and environment conditions are closely related to the frequency and injury severity of pedestrian crashes. Higher average traffic volume at intersections increases the number of pedestrian crashes; however, the rate of increase is steeper at lower values of average traffic volume. Based on the findings in the analysis, some countermeasures are recommended to improve pedestrian safety.

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Keywords: Pedestrian; Crash frequency; Injury severity; Exposure; Intersection

1. Introduction

As population and traffic volume increase, the conflicts between pedestrians and vehicles on roads are more frequent and consequently, vehicle–pedestrian crashes have become a major concern in improving traffic safety. According to the National Highway Traffic Safety Administration (2004), approximately 4700 pedestrians were killed and 70,000 pedestrians were injured in the United States in the year 2003. Although the number of pedestrian victims has continuously decreased over the last 16 years (1988–2003), actual pedestrian crash risk may not have been reduced considering the fact that the number of pedestrian trips has been reduced as more people own and drive cars. In particular, the current intersection design guidelines mainly focus on the operation and safety of vehicles rather than pedestrian safety (Pietrucha and Opiela, 1993).

For the improvement of pedestrian safety at intersections, understanding the effects of crash-related factors on pedestrian crashes can help develop more effective countermeasures as the types of pedestrian crashes vary with these factors (Stutts et al., 1996). Thus, the past studies on frequency and injury severity of pedestrian crashes have generally focused on the effects of pedestrian and driver characteristics, vehicle characteristics and conditions, and road geometric and traffic characteristics of intersections.

A number of studies identified that there exists strong relationship between demographic factors of pedestrians (particularly age) and crash risk. For example, Zegeer et al. (1993) observed high fatality of older pedestrians in daytime, on weekdays, and in winter. They also found that since older pedestrians reacted slowly with reduced vision and wore dark clothing at nighttime, dark lighting conditions were more hazardous to older pedestrians. Fontaine and Gourlet (1997) found that children and the elderly were the most vulnerable to pedestrian crashes among age groups. Oxley et al. (1997) found that when cars approached closely, older pedestrians crossed more frequently and adopted unsafe road crossing

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strategy (e.g. slow walking speed, delay in reaction). Similarly, Tarawneh (2001) observed that old pedestrians walked slower than younger pedestrians and their level of exposure to vehicle traffic increased. Al-Ghamdi (2002) found that the fatality rate of the old-age pedestrian group (age 60 and over) was the highest whereas the fatality rate of the young-age pedestrian group (age 20–29) was the lowest. These results suggest that old pedestrians are most likely to be involved in a crash and also severely injured when they are involved in a crash.

Some studies claimed that a pedestrian's alcohol use is also an important factor affecting pedestrian crashes. Miles-Doan (1996) suggested that alcohol-impaired pedestrians were more involved in pedestrian crashes and their odds of dying relative to surviving were higher than non-alcohol-impaired pedestrians. Öström and Eriksson (2001) found that intoxicated pedestrians were more severely injured and suffered more head injuries than non-intoxicated pedestrians. Some studies considered the combined effect of pedestrian age, gender and alcohol use on crash risk. For example, Holubowycz (1995) reported that young and middle-age intoxicated males are high-risk pedestrian groups.

Vehicle characteristics and conditions such as vehicle speed, vehicle types, and vehicle movement are also closely associated with pedestrian crashes. For instance, Anderson et al. (1997) observed that when the speed limit was reduced, the number of fatal pedestrian crashes was also reduced. Some researchers compared the injury severity of pedestrian crashes caused by different vehicle types and vehicle movement. Lefler and Gabler (2004) found that the pedestrian fatality rate when struck by light trucks and vans (LTV) was two to three times greater than the fatality rate when struck by passenger cars since LTVs have higher bumpers and more blunt frontal profiles. Preusser et al. (2003) found that turning vehicles often caused pedestrian crashes because drivers failed to yield the right of way to pedestrians at intersections.

A few studies examined the effect of road geometric and traffic characteristics on pedestrian crash risk. Given that median not only blocks vehicle interactions in different directions but also provides safe refuge area for pedestrians, Bowman et al. (1994) demonstrated that different types of median have different effects on pedestrian crashes. LaScala et al. (2000) observed that injuries in pedestrian crashes were greater in the areas with higher population density, average daily traffic, and number of cross-streets per kilometer roadway through a spatial analysis using a geographic information system. On the other hand, Garber and Lienau (1996) reported contradicting results that fatality rate of pedestrian crashes in rural areas with lower population density was higher than the fatality rate in urban areas. Similarly, Zajac and Ivan (2003) found that pedestrian injury severity was higher in village and downtown fringe areas than downtown and low-to-medium density commercial areas.

In spite of significant research efforts in the past studies, there still remain some unanswered questions: (1) do we need to analyze pedestrian crashes at driver's fault and pedestrian

crashes at pedestrian's fault separately since their causal factors may be different? (2) Does higher frequency of pedestrian crashes actually reflect higher crash risk by pedestrians? As daSilva et al. (2003) suggested, due to lack of information on walking patterns by different age groups, most studies on pedestrian crashes could not properly reflect risk by age groups. (3) Are there any other important road geometric and traffic characteristics affecting pedestrian crashes, such as average traffic volume at intersections, that we are unable to identify since they are not readily available in typical crash reports?

Thus, this study has three objectives: (1) to investigate the relationship between frequency/injury severity of pedestrian crashes at intersections and various driver, pedestrian, traffic, and environmental characteristics; (2) to explore exposure of pedestrian walking on the roads for estimating the risk of pedestrian crashes; and (3) to examine the effect of average traffic volume at intersections on the occurrence of pedestrian crashes.

2. Frequency and injury severity of pedestrian crashes

This study analyzed pedestrian crashes that have occurred at intersections in Florida over 4 years (1999–2002) using the crash information compiled in Florida Traffic Crash Records Database (Florida Department of Highway Safety and Motor Vehicles, 2002). Approximately 7000 pedestrian crashes occurred at intersections or are influenced by intersections. The crashes at mid-block crosswalks and unmarked locations are not included in this study. Five percent of these crashes were fatal crashes. The study considered the variables associated with the characteristics of pedestrians, drivers and vehicles that are involved in crashes, and traffic/road geometry and environmental conditions at the time of crashes as shown in Table 1. Continuous variables (e.g. pedestrians' and drivers' age, vehicle speed) were classified into several categories based on the classification used in the past studies and the authors' subjective judgment. The number of lanes was classified into 1, 2, and 3 or more lanes.

This study develops two types of models to analyze frequency and injury severity of pedestrian crashes. In the analysis of crash frequency, log-linear models were used to identify the relationship between crash frequency and the crash-related variables. This analysis identifies which factors, or the combination of factors, mainly contribute to the occurrence of pedestrian crashes. In the analysis of crash injury severity, an ordered probit model was used to identify the factors causing higher injury severity of pedestrians who are involved in crashes. The following two subsections illustrate the methodology and discuss the results of model estimates.

2.1. Frequency analysis

The analysis of crash frequency identifies the group of drivers/pedestrians and various traffic and environmental

Table 1
Description of variables

Type	Variables	Categories
Pedestrian characteristics	Pedestrians' age	Children (~14 year old)
		Very young (15–19 year old)
		Young (20–24 year old)
		Middle 1 (25–44 year old)
		Middle 2 (45–64 year old)
		Old (65–79 year old)
		Very old (80 year old and over)
	Pedestrians' gender	Male
		Female
	Pedestrians' alcohol/drug use	No alcohol/drug use
		Alcohol and/or drug use
Driver characteristics	Drivers' age	Very young (15–19 year old)
		Young (20–24 year old)
		Middle 1 (25–44 year old)
		Middle 2 (45–64 year old)
		Old (65–79 year old)
		Very old (80 year old and over)
	Drivers' gender	Male
		Female
	Drivers' alcohol/drug use	No alcohol/drug use
		Alcohol and/or drug use
Vehicle characteristics	Vehicle type	Passenger car
		Bus, truck, van
	Vehicle speed	Low (0–29 mph)
		Medium (30–39 mph)
		High (40 mph and over)
Traffic/road geometric characteristics	Traffic control	No traffic control
		Traffic signal
		Other traffic control (Stop, yield, etc.)
	Divided/undivided	Divided
		Undivided
	Number of lanes	1 lane
		2 lanes
		3 lanes and over
Environmental characteristics	Lighting	Daylight, dusk, dawn
		Dark
	Weather	Clear
		Adverse
	Location	Urban areas
		Rural areas

conditions that are most involved in pedestrian crashes as causers. The analysis does not estimate risk of each driver and pedestrian group in the form of crash rates. The reason for not being able to consider crash rates is that it is difficult to estimate exposure of some factors and the combination of multiple factors used for modeling. For instance, we cannot accurately measure the proportion of intoxicated drivers/pedestrians in total population of drivers/pedestrians,

or the proportion of middle-age male drivers during dark lighting on a divided 3-lane road at signalized intersections in urban areas. To correctly identify factors affecting frequency of pedestrian crashes, it is more appropriate to classify crashes into different types based on actual causes of crashes. Since both drivers and pedestrians make errors leading to crashes, pedestrian crashes are classified into the following two types: (1) crashes at driver's fault and (2) crashes at pedestrian's fault. The premise of this classification is that crashes at driver's fault are more associated with driver characteristics whereas crashes at pedestrian's fault are more associated with pedestrian characteristics. In this study, if the drivers who were involved in pedestrian crashes were cited for moving violation, the crashes were classified as crashes at driver's fault. Otherwise, the crashes were classified as crashes at pedestrian's fault. The data show that the percentage of crashes at pedestrian's fault is substantially higher (80%) than the percentage of crashes at driver's fault (20%).

The two log-linear models were developed for the two types of crashes. The following describes general structure of a log-linear model and the method of calculating odds multipliers (i.e. likelihood of crash occurrence relative to a reference) based on the model estimates. If the two factors affecting pedestrian crashes (categorical variables x and y) are considered, the functional specification of a second-order log-linear model including main effects and the interaction between the two factors is as follows:

$$\ln(F_{ij}) = \theta + \lambda_{x(i)} + \lambda_{y(j)} + \lambda_{xy(ij)} \quad (1)$$

where F_{ij} is the expected number of pedestrian crashes when $x = i$ and $y = j$, θ a constant, $\lambda_{x(i)}$ the effect of the i th level of a factor x , $\lambda_{y(j)}$ the effect of the j th level of a factor y , and $\lambda_{xy(ij)}$ the interaction between the i th level of a factor x and the j th level of a factor y .

For instance, to estimate the odds of the i th level of a factor x relative to the base level ($i = 1$) of the same factor with respect to interaction with the j th level of a factor y , odds multipliers are calculated using the following equation:

$$\begin{aligned} \ln\left(\frac{F_{ij}}{F_{1j}}\right) &= \ln(F_{ij}) - \ln(F_{1j}) = (\theta + \lambda_{x(i)} + \lambda_{y(j)} + \lambda_{xy(ij)}) \\ &\quad - (\theta + \lambda_{x(1)} + \lambda_{y(j)} + \lambda_{xy(1j)}) \\ \frac{F_{ij}}{F_{1j}} &= \exp(\lambda_{x(i)} + \lambda_{xy(ij)} - \lambda_{x(1)} - \lambda_{xy(1j)}) \\ &= \exp(\lambda_{x(i)} - \lambda_{x(1)}) \exp(\lambda_{xy(ij)} - \lambda_{xy(1j)}) \end{aligned} \quad (2)$$

If only main effects are considered (i.e. a first-order log-linear model), the interaction terms no longer exist and odds multipliers are $\exp(\lambda_{x(i)} - \lambda_{x(1)})$. Tables 2 and 3 show the estimated parameters of the log-linear models for crashes at driver's fault and crashes at pedestrian's fault, respectively. Positive estimates indicate higher number of crashes relative to the base case and negative estimates indicate lower number of crashes relative to the base case. Initially a Poisson distribution of the crash frequency was assumed but did not produce a good fit indicating a possible over-dispersion.

Table 2
Estimated parameters of pedestrian crashes at driver's fault

Parameter	Estimate	S.E.
Constant	-4.3884	0.3206
Drivers' age		
Very young (15–19)	0.7284	0.2192
Young (20–24)	0.9392	0.2140
Middle 1 (25–44)	2.1799	0.1989
Middle 2 (45–64)	1.6940	0.2037
Old (65–79)	0.8974	0.2153
Very old (80~) ^a	0	0
Drivers' sex		
Male	0.7046	0.1075
Female ^a	0	0
Vehicle type		
Passenger car	1.1981	0.1094
Van, truck, bus ^a	0	0
Traffic control		
No traffic control	-0.8357	0.2103
Traffic signal	-0.9764	0.2113
Other traffic control ^a	0	0
Location		
Urban areas	1.0062	0.1575
Rural areas ^a	0	0
Traffic control–location interaction		
No traffic control–urban areas	-0.2687	0.2648
Traffic signal–urban areas	0.7794	0.2524
Other control–urban areas	0	0
No traffic control–rural areas	0	0
Traffic signal–rural areas	0	0
Other control–rural areas	0	0
Drivers' alcohol/drug use		
No alcohol and drug	2.0834	0.2266
Alcohol and/or drug ^a	0	0
Lighting		
Daylight, dawn, dusk	-0.4151	0.3176
Dark ^a	0	0
Alcohol–lighting interaction		
No alcohol–daylight	1.8559	0.338
No alcohol–dark	0	0
Alcohol–daylight	0	0
Alcohol–dark	0	0
Pearson chi-square	486.1	
Degrees of freedom	560	
<i>p</i> -Value	0.989	
Number of observations	1168	

^a Base case to calculate odds multipliers.

Therefore, the final models were calibrated using a negative binomial distribution, which showed a very good fit.

In case of crashes at driver's fault, the results showed that middle-age (25–64) and male drivers are more involved in crashes as causers than other driver groups. When only main effects are considered, it appears that crashes occur more frequently at the intersections with other traffic control (e.g. stop signs, yield signs, etc.) in urban areas when non-intoxicated drivers are driving passenger cars at night. Some results are reasonable from a practical sense as there are more middle-age drivers who drive passenger cars, there are more inter-

Table 3
Estimated parameters for pedestrian crashes at pedestrian's fault

Parameter	Estimate	Standard error
Constant	-1.8557	0.1889
Pedestrians' age		
Children (~14)	1.6779	0.1531
Very young (15–19)	1.0867	0.1613
Young (20–24)	0.7725	0.1666
Middle 1 (25–44)	2.3792	0.1536
Middle 2 (45–64)	1.9239	0.1550
Old (65–79)	0.9925	0.1615
Very Old (80~) ^a	0	0
Pedestrians' sex		
Male	0.6235	0.0723
Female ^a	0	0
Divide		
Divided	-0.4466	0.0753
Undivided ^a	0	0
Number of lanes		
1 lane	-4.1076	0.1804
2 lanes	-0.6803	0.0790
3 lanes and over ^a	0	0
Traffic control		
No traffic control	0.0150	0.1308
Traffic signal	-0.4030	0.1370
Other traffic control ^a	0	0
Location		
Urban areas	0.7523	0.1210
Rural areas ^a	0	0
Location–traffic control interaction		
No traffic control–urban areas	-0.2293	0.1733
Traffic signal–urban areas	0.2700	0.1765
Other control–urban areas	0	0
No Traffic control–rural areas	0	0
Traffic signal–rural areas	0	0
Other control–rural areas	0	0
Pedestrian's alcohol/drug use		
No alcohol and drug	1.0348	0.1054
Alcohol and/or drug ^a	0	0
Lighting		
Daylight, dawn, dusk	-1.1162	0.1404
Dark ^a	0	0
Alcohol–lighting interaction		
No alcohol–daylight	2.2127	0.1649
No alcohol–dark	0	0
Alcohol–daylight	0	0
Alcohol–dark	0	0
Pearson chi-square	1812.5	
Degrees of freedom	1997	
<i>p</i> -Value	0.999	
Number of observations	3340	

^a Base case to calculate odds multipliers.

sections in urban areas, and drivers tend to make more misjudgment at night due to their reduced vision. However, it should be noted that due to over-representation of 25–64-year-old drivers in total population of drivers (approximately 70% according to Highway Statistics 2003 (FHWA, 2004)), the result does not imply that middle-age drivers are the most

dangerous driver group. The result should be interpreted in a way that middle-age drivers are more involved in pedestrian crashes as causers than any other driver groups. On the other hand, given that the proportions of total licensed male drivers (50.26%) and female drivers (49.74%) in Florida are almost equal (FHWA, 2004), the result indicate that male drivers are more likely to cause pedestrian crashes than female drivers and we can speculate that male drivers may be more risk-taking than female drivers. In the case of crashes at pedestrian's fault, the crashes occur more frequently under the similar conditions to crashes at driver's fault, but also at the undivided and wide (i.e. more number of lanes) intersections. The results also seem logical since pedestrians, particularly older pedestrians, have difficulty in walking a longer crosswalk without a median and they are more exposed to approaching vehicles.

However, more investigation is needed to explain some counter-intuitive results of main effects: (1) more crashes occurred at the intersections with traffic control (other than traffic signal) than the intersections without traffic control and

(2) more crashes occurred when drivers are not intoxicated than when drivers are intoxicated. Thus, the interactions of alcohol/drug use–lighting and traffic control–location were considered. To better understand the relative impact of factors on the expected number of crashes, the odds multipliers were calculated using Eq. (2) as shown in Table 4.

From the interaction of alcohol/drug use–lighting, it was observed that the odds multiplier of the expected number of crashes for drivers' alcohol/drug use was higher when drivers were intoxicated than when they were not intoxicated in dark lighting. The same trend was observed for pedestrians' alcohol/drug use. These results suggest that drivers' and pedestrians' alcohol/drug uses lead to more pedestrian crashes at night. Thus, drinking and walking at night is equally problematic as drinking and driving.

From the interaction of traffic control–location, the effects of traffic control on the expected number of pedestrian crashes were found to be different between urban and rural areas. First, for crashes at driver's fault, it was found that the odds multipliers were higher at the intersections with traf-

Table 4
Comparison of odds multipliers between two types of pedestrian crashes

Variables	Crashes at driver's fault		Crashes at pedestrian's fault		
Age					
Very old (80~)	1		1		
Children (~14)	–		5.35		
Very young (15–19)	2.07		2.96		
Young (20–24)	2.56		2.17		
Middle 1 (25–44)	8.85		10.80		
Middle 2 (45–64)	5.44		6.85		
Old (65–79)	2.45		2.70		
Sex					
Female	1		1		
Male	2.02		1.87		
Vehicle type					
Van, truck, bus	1		–		
Passenger car	2.74		–		
Divide					
Undivided	–		1		
Divided	–		0.64		
Number of lanes					
3 lanes and over	–		1		
2 lanes	–		0.51		
1 lane	–		0.02		
	Traffic control	Location			
		Urban areas	Rural areas	Urban areas	Rural areas
Traffic control–location interaction	No traffic control	1	1	1	1
	Traffic signal	2.48	0.39	1.11	0.81
	Other traffic control	3.02	1.06	0.52	0.77
	Lighting	Alcohol use			
		No alcohol	Alcohol	No alcohol	Alcohol
Alcohol use–lighting interaction	Daylight, dawn, dusk	1	1	1	1
	Dark	0.23	1.51	0.33	3.05

fic control than the intersections without traffic control in urban areas whereas the odds multiplier was significantly lower at the intersections with traffic signals than the intersections without traffic signals in rural areas as shown in Table 4. This result suggests that drivers tend to drive more carefully when they approach traffic signals than stop or yield signs in rural areas and pedestrian crashes occur less frequently at rural signalized intersections. Second, for crashes at pedestrian's fault, it was found that the odds multiplier was higher at signalized intersections but lower at the intersections with other control in urban areas whereas the odds multipliers were relatively lower at the intersections with traffic control than the intersections without traffic control in rural areas. The low odds multipliers of both types of pedestrian crashes at signalized intersections in rural areas indicate that the installation of traffic signals in rural areas may provide significant reduction of pedestrian crashes.

The odds multipliers of variables were compared between crashes at driver's fault and crashes at pedestrian's fault to identify the difference in causal factors as shown in Table 4. Middle-age males are more involved in pedestrian crashes as both drivers and pedestrians. In particular, high odds

$$y_i = \begin{cases} 0 & \text{if } y_i^* \leq 0 \quad (\text{no injury}) \\ 1 & \text{if } 0 < y_i^* \leq \mu_1 \quad (\text{possible injury}) \\ 2 & \text{if } \mu_1 < y_i^* \leq \mu_2 \quad (\text{non-incapactating evident injury}) \\ 3 & \text{if } \mu_2 < y_i^* \leq \mu_3 \quad (\text{incapacitating evident injury}) \\ 4 & \text{if } y_i^* > \mu_3 \quad (\text{fatal injury}). \end{cases}$$

multiplier for children (age of younger than 14) in crashes at pedestrian's fault suggests that many pedestrian crashes occurred due to children's carelessness and misjudgment.

In comparison of traffic control–location interaction, the frequencies of crashes were consistently lower at signalized intersections in rural areas for both types of crashes but the different trend was observed in urban areas. The frequency of crashes at driver's fault was higher at the intersections with traffic control than the intersections without traffic control whereas the frequency of crashes at pedestrian's fault was only higher at signalized intersection. The results reflect that pedestrian crashes occur more frequently in urban areas when drivers violate traffic signals or signs while pedestrians observe them. On the other hand, the frequency of crashes at pedestrians' fault only increases at the signalized intersections but decreases at the intersections controlled by traffic signs. This may be because pedestrians tend to be more careful at the intersections controlled by traffic signs than traffic signals.

In comparison of alcohol use–lighting interaction, the impacts of alcohol use on chances of nighttime crashes were higher for crashes at pedestrian's fault than crashes at driver's fault. This result indicates that the intoxicated pedestrians are

more involved in pedestrian crashes as causers than the intoxicated drivers at night.

2.2. Injury severity analysis

The analysis of crash injury severity examines the likelihood of pedestrian injuries and fatalities when pedestrians are involved in crashes. In the crash database, the severity of pedestrians' injury is classified into one of the following five categories: (1) no injury, (2) possible injury, (3) non-incapacitating evident injury, (4) incapacitating injury, and (5) fatal injury.

This study uses an ordered probit model since the model can account for the ordinal nature of injury severity categories. The functional specification of an ordered probit model is as follows:

$$y_i^* = \beta' x_i + \varepsilon_i \quad (3)$$

where y_i^* is the predicted injury by a pedestrian i , β' a row vector of unknown parameters, x_i a vector of explanatory variables, and ε_i the random error term that follows normal distribution. The injury level is classified based on the predicted injury using the following criteria (μ_1 , μ_2 and μ_3 are the thresholds estimated by the model):

Most factors used in the frequency analysis were also used as explanatory variables in this analysis. In addition to these variables, the speed of vehicles and weather at the time of crashes were included as they have close relationship with the impact of collision. Since this analysis focuses on the severity of pedestrians' injury after the crash occurrence, all pedestrian crashes were analyzed regardless of causes (driver's fault or pedestrian's fault). The ordered probit models were estimated using the LIMDEP software (Greene, 1998). The results of the models show that older pedestrians are more likely to sustain higher injury than younger pedestrians as indicated by generally increasing parameter values as pedestrians are older as shown in Table 5. In particular, the likelihood of injury severity was significantly higher for the old and very old pedestrians (age 65 and over) whereas the likelihood of injury severity was lower for the young and very young pedestrians (age 15–24) who are most physically healthy. This result reflects that as people age, their physical strength is weakened and the impact of crashes on their bodies is likely to be more severe. The result also indicates that each pedestrian age group tends to cross intersections at different speeds and consequently the impact of crashes is different. It was also found that female pedestrians had higher injury severity than male pedestrians as indicated by higher parameter value that is marginally significant.

Table 5
Estimated parameters of pedestrian injury severity

Variables	Parameter	t-statistics
Constant	-0.423	-1.324
Dummies for pedestrians' age		
1 = very young (15–19), 0 = otherwise	-0.047	-0.703
1 = young (20–24), 0 = otherwise	-0.050	-0.666
1 = middle 1 (25–44), 0 = otherwise	-0.032	-0.627
1 = middle 2 (45–64), 0 = otherwise	0.172	3.293
1 = old (65–79), 0 = otherwise	0.337	5.356
1 = very old (80 and over), 0 = otherwise	0.488	5.949
Pedestrians' sex (1 = female, 0 = male)	0.064	1.885
Pedestrians' alcohol/drug use (1 = intoxicated pedestrians, 0 = non-intoxicated drivers)	0.217	4.106
Vehicle speed	0.474	19.738
Vehicle type (1 = van, truck, bus, 0 = passenger cars)	0.096	2.648
Weather (1 = adverse conditions, 0 = clear)	0.106	2.639
Lighting (1 = dark, 0 = daylight, dawn, dusk)	0.219	5.778
Traffic control (1 = presence of traffic control, 0 = no traffic control)	-0.113	-2.978
Location (1 = rural areas, 0 = urban areas)	0.122	3.357
Thresholds		
α_1	1.421	36.095
α_2	2.562	60.523
α_3	3.909	69.925
Log likelihood at convergence ^a	-5367.3	
Number of observations	4351	

^a Maximized value of the log-likelihood function.

Alcohol/drug use by pedestrians also increased the severity of pedestrians' injury since alcohol and drug impaired pedestrians' perception and made high impact with vehicles inevitable.

The results also showed that the higher speed of vehicles that collided with pedestrians increased the severity of pedestrians' injury due to higher impact of crashes. High likelihood of injury of pedestrians struck by high-speed vehicles was also found in the past studies (Anderson et al., 1997; Gärder, 2004). Environmental conditions such as adverse weather and dark lighting were also found to contribute to higher pedestrian injury severity. This may be because adverse weather (in particular, heavy rain in Florida) and dark lighting severely reduce both drivers' and pedestrians' sight and in turn their reaction times to avoid crashes increase. Consequently, these conditions increase braking distance of vehicles and lead to higher impact at the time of crashes. Also, vans, buses, and trucks tended to cause higher injury severity than passenger cars due to larger area of impacts on pedestrians as consistent with the findings in the past studies (Al-Ghamdi, 2002; Lefler and Gabler, 2004).

In comparing crashes in different locations, the severity of pedestrian' injury was higher in rural areas than urban areas although the frequency of crashes was lower in rural areas as shown in the previous section. This may be because (1) there are relatively fewer medical facilities in rural areas and

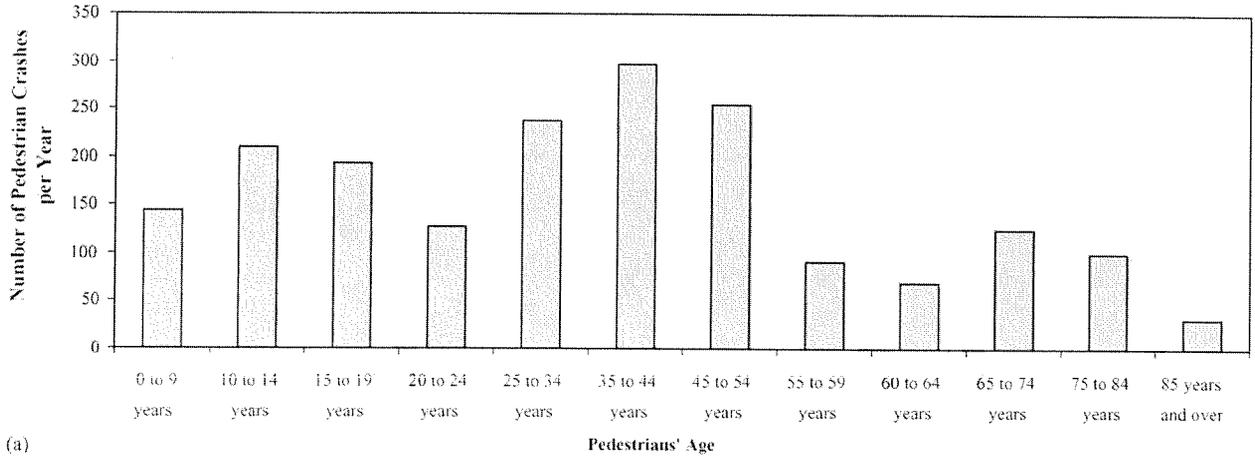
pedestrian victims are less likely to receive timely treatment leading to higher fatality rate; and/or (2) average speed is generally higher in rural areas (average posted speed limits were higher in rural areas than urban areas) and consequently the impact of collision increases. On the other hand, compact building layout in urban areas increases a driver's awareness of pedestrian activity (Zajac and Ivan, 2003) and reduces vehicle speeds resulting in lower impact of collision. For a similar reason, the severity of pedestrians' injury was higher at the intersections without traffic control. In the absence of traffic control, drivers tend to drive faster and increase the impact of crashes when they collide with pedestrians.

In summary, the results of the ordered probit model suggest that pedestrian injury severity caused by crashes is closely related to the following factors (the associated variables in parentheses): (1) pedestrians' physical condition (age and alcohol/drug use), (2) the speed of vehicles (speed at the time of crashes, location of crashes, and the presence of traffic control), (3) drivers' and pedestrians' perception and reaction (weather, lighting), and (4) the area of impacts (vehicle type).

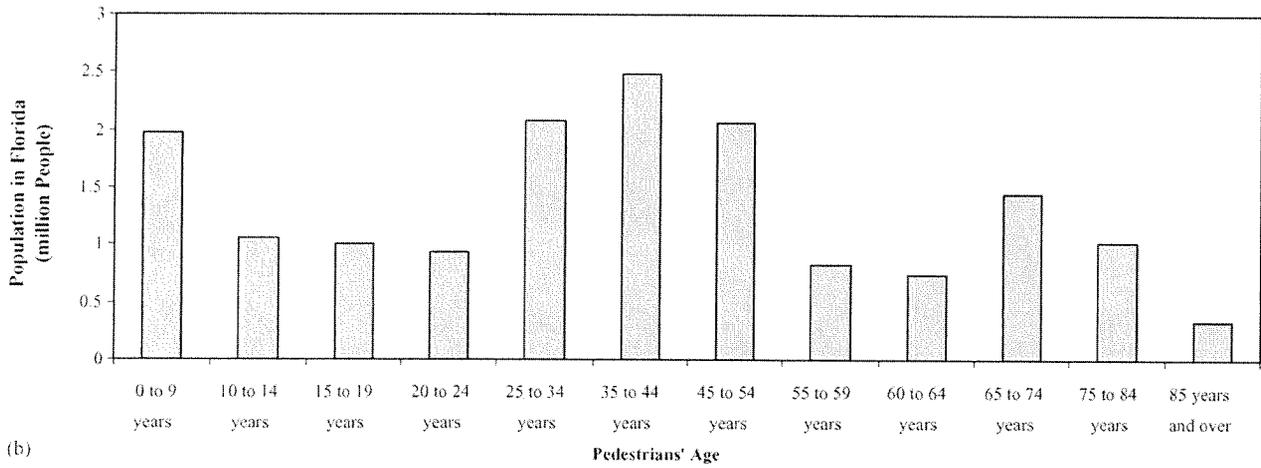
3. Exposure of pedestrian crashes

Despite statistically significant results in the previous sections, it is still uncertain whether the model estimates properly reflect the risk of pedestrian crashes in the absence of exposure measures. In fact, crash risk from a pedestrian's perspective is more influenced by pedestrian volume than vehicle volume (Gärder, 2004). In this regard, population has been often used as exposure to calculate pedestrian crash rate in the form of the number of crashes per capita. Using the classification of ages in Florida in Census 2000 (U.S. Census Bureau, 2004), the number of pedestrian crashes per capita in Florida by age is shown in Fig. 1. The figure shows that in spite of high frequency of pedestrian crashes for middle-age people (age 35–44) (Fig. 1a), the number of crashes per capita is higher for younger people (age 10–19) (Fig. 1c).

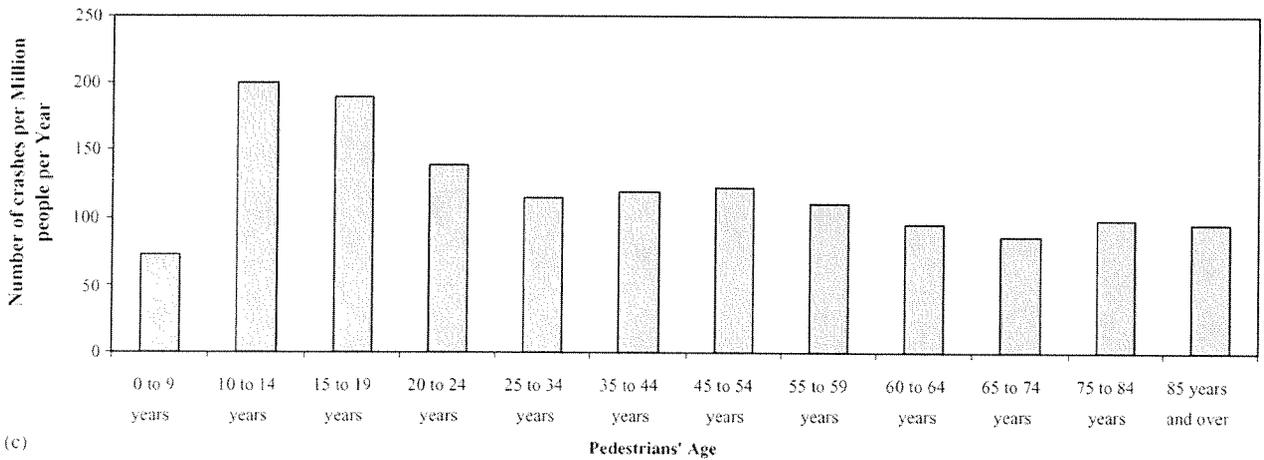
However, the number of crashes per capita only shows what types of people have crashes, but do not show the relationship between crashes and the amount of trips these people make (Ampt, 1995). In fact, we do not know how many pedestrians in the total population of each age group crossed intersections (exposure of risk) and what proportion of the pedestrians was actually involved in crashes. More specifically, the population of age groups does not reflect different walking travel patterns by different age groups. For instance, since older people spend more time on walking and make more frequent walking trips during weekdays than middle-age people, it is expected that their exposure to pedestrian crashes is higher although their population is lower (Fig. 1b). Thus, similar to vehicle-kilometers of travel that are frequently used as exposure to vehicle–vehicle crashes, the frequency and length of walking trips by pedestrians are important in the determination of exposure to vehicle–pedestrian crashes. Clearly, we



(a)



(b)



(c)

Fig. 1. Number of crashes, population and number of crashes per capita by age. (a) Number of pedestrian crashes by age. (b) Population in Florida by age. (c) Number of pedestrian crashes per capita by age.

need to estimate more accurate pedestrian exposure to calculate pedestrian crash rates.

In this regard, Keall's pioneering work (1995) developed better measures of pedestrian exposure to risk of crashes using the New Zealand travel survey data. He used the number of walking trips, the time spent walking on streets, and number of roads crossed by each pedestrian age group as exposure measures. Similarly, Baltes (1998) estimated exposure to pedestrian risk by age in terms of total distance of walk in kilometers using the Nationwide Personal Transportation Survey. However, if exposure by age is estimated, total distance may not reflect actual "duration" of walking trips due to different walk speed by different age groups. For example, the duration of older pedestrians' walking trips is generally longer than that of younger pedestrians' walking trips even for the same trip distance. However, if exposure by gender or by some other traffic and environmental factors is considered, there may be no difference in walking speed among different groups and travel distance can represent exposure.

Similar to the previous works, this study used the travel survey data for U.S. households (U.S. Department of Transportation, 2004) to estimate pedestrian exposure. Since this study analyzes pedestrian crashes in Florida, only responses from the residents in Florida were extracted from the National Household Travel Survey (NHTS) database. The NHTS database contains the total number of daily walking trips, duration (travel time), distance, and purpose of each walking trip by each household member during a 13-month period (April 2001–April 2002). Although trip distance is included in the survey, the study did not use trip distance as an exposure measure because of the difference in walk speed by age group as explained earlier. Also from the authors' point of view, it appears that the distance included in the survey is relatively less accurate than travel time as people tend to remember travel time better than distance in their daily lives.

In this study, pedestrian exposure is defined as the sum of the durations of individual walking trips as follows:

$$EXP_j = \sum_i \sum_j D_{ij} \quad (4)$$

where EXP_j is the exposure of pedestrian j to crash risk and D_{ij} the duration of walking trip i by pedestrian j . Since the travel survey does not show the details of pedestrian movements (e.g. crossing intersections, walking along the intersections, etc.), it is uncertain whether all walking trips occur on the road. However, given that walk is often considered as an alternative mode to automobiles for short-distance work and shopping trips, it is expected that most walking trips do occur on the road. Thus, it is reasonable to assume that the proposed exposure measures represent the frequency of the events that pedestrians are exposed to crash risk on the road.

Since the travel survey was conducted for only sample of households, the number of sample walking trips needed to be expanded to estimate representative walking patterns

of whole population in Florida. For this purpose, specific weights were applied to account for non-response and under-representative person groups in the survey (U.S. Department of Transportation, 2004). The weights were determined based on the national-level distribution of personal characteristics such as age, gender, education, income, etc.

Fig. 2 shows the distributions of the frequency and total duration of walking trips by different pedestrian age groups and pedestrian crash rate defined as the number of crashes divided by total duration of walking trips in hour. It was found that the frequency of walking trips was highest for young pedestrians (age 25–34) (Fig. 2a) whereas the total duration of walking trips was highest for old pedestrians (age 65–74) (Fig. 2b) as shown in solid lines. This clearly reflects that young people are physically more active than old people and they are willing to walk more frequently. However, since old pedestrians walk slower, their duration of walking trip is longer than young pedestrians.

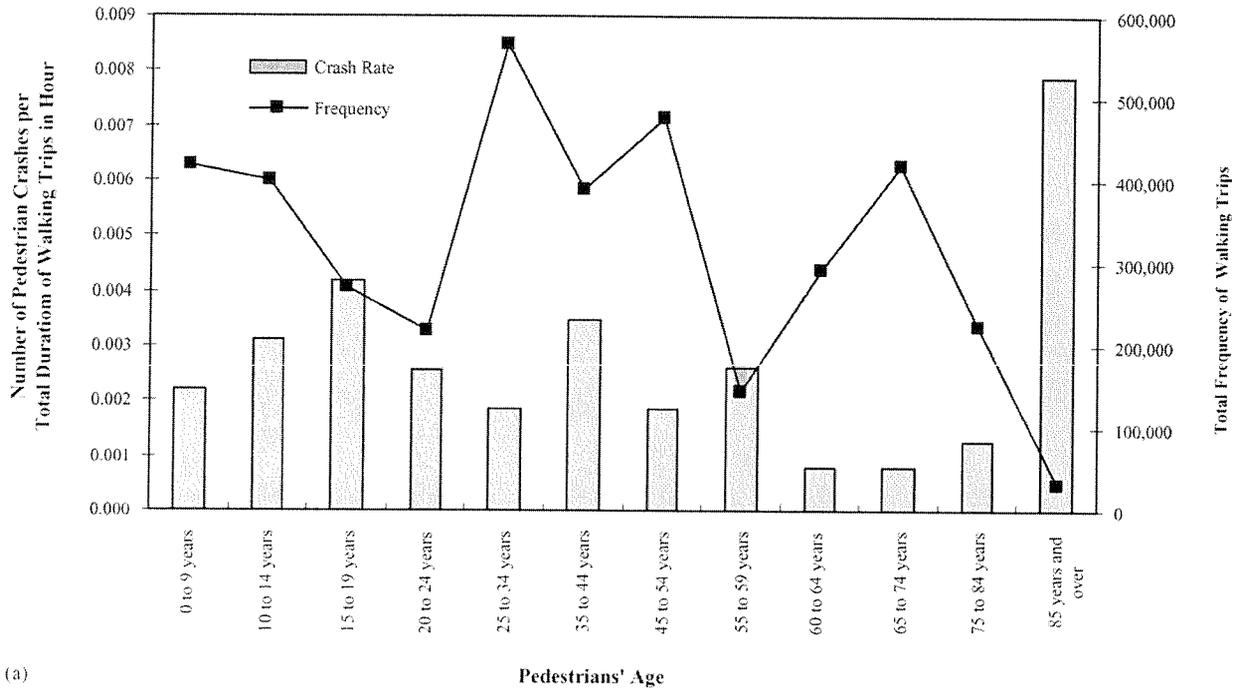
It was also observed that the distribution of the proposed pedestrian crash rate by age was different from the distribution of the number of crashes per capita by age (Fig. 1c). It can be seen that the crash rate was highest for very old pedestrians (age 85 and over) unlike the number of crash per capita that is highest for very young pedestrians (age 10–14). This implies that the number of crashes per capita underestimates high crash risk by very old pedestrians. There were also large differences across crash rates for middle-age pedestrians (age 25–59) whereas the number of crashes per capita was almost the same for the same age group. This suggests that certain middle-age group walks in different patterns and their crash risk is relatively higher.

Although only pedestrians' age was considered in this analysis, the suggested exposure can also be classified by many other factors such as pedestrians' gender, time of walking trips (daytime/nighttime), purpose of walking trips, etc. The findings of this analysis suggest the need of more detailed information on pedestrian travel behavior and understanding its impact on pedestrian exposure to crash risk.

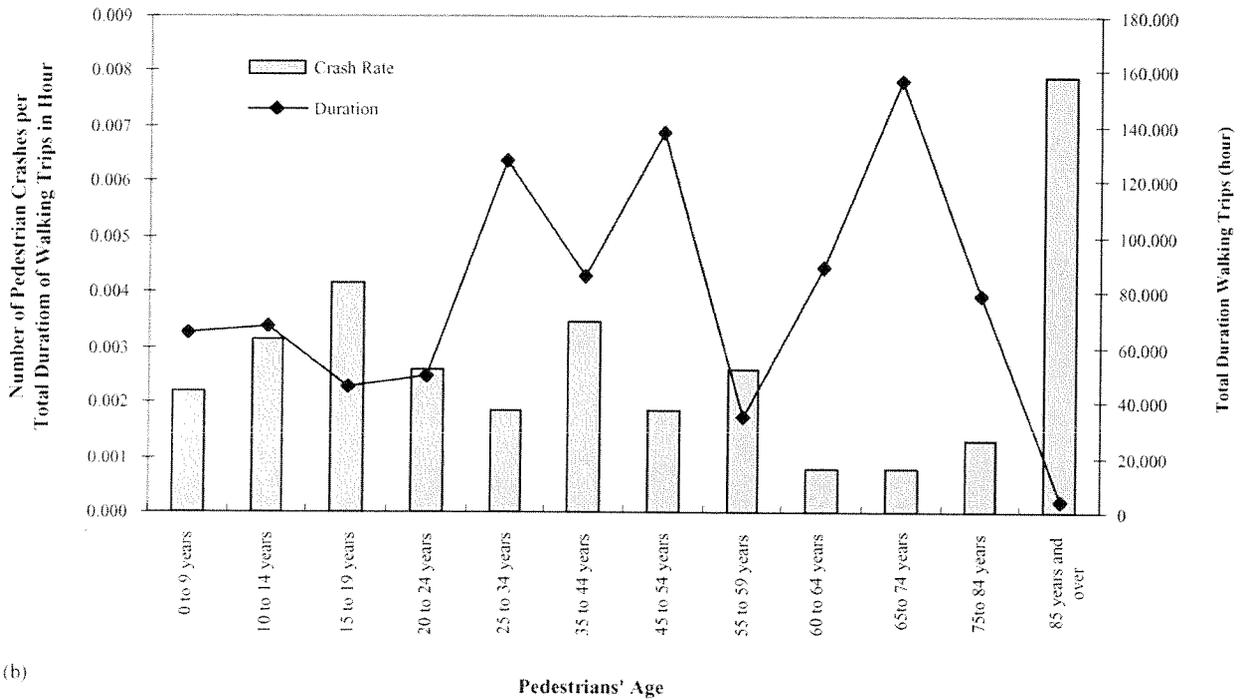
4. Effects of average traffic volume at intersections

It should be noted that all the possible factors affecting pedestrian crashes were not considered in this study, since the factors were limited to only the information included in the crash database. In other words, there may exist more important factors affecting crashes but they could not be captured in the earlier analysis due to lack of data. Thus, this study obtains average traffic volume at intersections that is not typically available in crash reports and investigates its effect on pedestrian crashes. Traffic volume normally reflects the typical traffic condition at each intersection. Traffic volume was measured in the form of average annual daily traffic (AADT) on major roads of the intersections.

In this study, the number of pedestrian crashes and traffic volume at 1563 signalized intersections were ob-



(a)



(b)

Fig. 2. Pedestrian crash rates by age. (a) Comparison between pedestrian crash rates and frequency of walking trips. (b) Comparison between pedestrian crash rates and duration of walking trips.

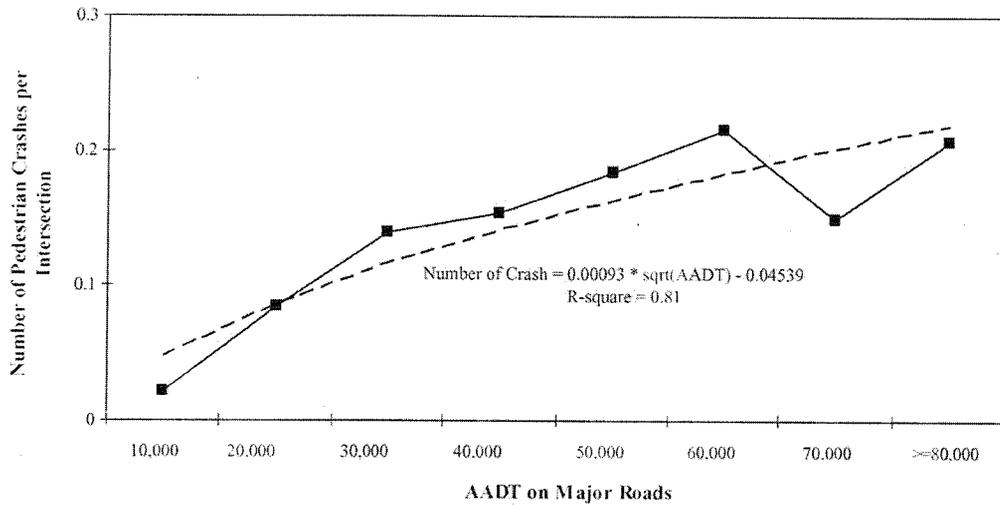


Fig. 3. Relationship between pedestrian crashes and AADT on major roads.

tained from the following six counties in Florida: Brevard, City of Orlando, Dade, Hillsborough, Orange, and Seminole. Among a total of 40,870 crashes in 3 years (1999–2001) that have occurred at these intersections, 219 crashes were pedestrian crashes. The average number of pedestrian crashes per intersection (defined as frequency) was calculated and compared to AADT on major roads.

Fig. 3 shows that the frequency of pedestrian crashes generally increases with AADT. This indicates that pedestrian crashes are more likely to occur at intersections with higher traffic volume that increases the potential conflicts between pedestrians and vehicles. However, it appears that the rate of increase gradually decreases as AADT increases. The figure illustrates that the rate of increase in the average number of pedestrian crashes per intersection increases rapidly up till an AADT value of around 30,000, then the rate of increase is milder for AADT values between 30,000 and 60,000. Above 60,000 there seems to be no apparent trend, suggesting that the rate is almost uniform. This implies that when traffic volume is very high, the traffic condition is likely to be congested (i.e. vehicles are moving slowly) and the likelihood of conflicts with pedestrians will not proportionally increase as in low-volume conditions. The relationship in Fig. 3 can be fit to the following non-linear regression model:

$$\text{number of pedestrian crashes} = 0.00093 \times (\text{AADT})^{0.5} - 0.04539 \quad (R^2 = 0.81). \quad (5)$$

This trend is consistent with the previous British and European models showing a relationship that the number of pedestrian crashes are approximately proportional to the square root of vehicle volume.

5. Conclusions and recommendations

This study analyzed vehicle-pedestrian crashes in Florida from different perspectives. First, the study identified the groups of drivers and pedestrians, and traffic and environmental characteristics that are correlated to pedestrian crashes using a log-linear models. It was found that middle-age male drivers and pedestrians were correlated to more pedestrian crashes than the other age and gender groups, the passenger cars were correlated to more crashes than trucks, vans and buses, and more crashes occurred on undivided roads with more number of lanes than divided roads with less number of lanes. It was also found that intoxicated drivers and pedestrians were correlated to more crashes at nighttime than daytime and the absence of traffic signals were correlated to more crashes than the presence of traffic signals in rural areas. Some differences were observed between crashes at driver's fault and crashes at pedestrian's fault—for example, intoxicated pedestrians were correlated to more crashes than intoxicated drivers at night and drivers were correlated to more crashes than pedestrians at the intersections with traffic control in urban areas.

Second, the study also identified factors affecting injuries and fatalities of pedestrians who are involved in crashes using an ordered probit model. It was found that when pedestrians involved in crashes are old or intoxicated, vehicles collide with pedestrians at high speed, drivers and pedestrians have reduced vision and reaction due to adverse weather and dark lighting, and vehicles involved in crashes are larger than passenger cars in size, injury severity of pedestrians is likely to be higher.

Third, the study developed a logical expression of pedestrian exposure to crash risk using the individual walking trip data collected from the household travel survey.

The proposed exposure (total duration of walking trips) reflects different walking patterns by different age groups of pedestrians. The results of the analysis suggest that the number of pedestrian crashes per total duration of walking trips (in hours) by age captures the high crash risk of very old pedestrians that was underestimated in the number of pedestrian crashes per capita.

Finally, the study investigated the effects of average traffic volume at intersections (that is not readily available in crash reports) on pedestrian crashes. It appears that higher average traffic volume at intersections increases the number of pedestrian crashes per intersection due to increased chances of conflicts between pedestrians and vehicles; however, the rate of increase is steeper at lower AADT values.

Based on these findings, several countermeasures of pedestrian crashes are recommended. For example, more intensive driver education and restrictive traffic regulation (e.g. higher penalty on speed limit violation, drinking and driving, etc.) should be targeted for middle-age male drivers. As the analysis suggested, intoxicated pedestrians were also involved in many nighttime crashes and thus the public should be more aware of the problems with drinking and walking at night. In terms of traffic facilities, more traffic signals should be installed in particularly rural areas to reduce pedestrian crashes. Street lighting also needs to be improved to aid drivers' and pedestrians' reduced vision in adverse weather and dark lighting.

In future work, to investigate the effectiveness of these countermeasures in reducing pedestrian crashes, more refined measures of pedestrian crash risk considering exposure of pedestrian walking should be developed. To accurately estimate exposure with the limited samples of personal trip data, the data should be collected from a number of representative groups of pedestrians based on proportions of age, gender, race, education, etc. in the total population. Also, it is recommended that additional factors such as intersection characteristics be considered to examine their potential effect on pedestrian crashes at intersections.

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THE EFFECTS OF ADVANCE STOP LINES AND SIGN PROMPTS ON PEDESTRIAN SAFETY IN A CROSSWALK ON A MULTILANE HIGHWAY

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The effects of specific signs and stop line bars designed to influence motorists to stop further back from the crosswalk when yielding right of way to pedestrians were evaluated using a reversal design. The introduction of the prompt and stop line reduced motor vehicle-pedestrian conflicts (near collisions) by almost 80%. This finding was replicated in a second experiment the following year on two streets using a multiple baseline design. The use of the advance stop line is now being incorporated by the Provincial Department of Transportation for marking crosswalks on multilane streets.

DESCRIPTORS: pedestrian safety, prompts, safety, transportation safety, conflicts

Each year in the United States, approximately 400,000 pedestrians are struck by vehicles resulting in about 10,000 deaths and many serious injuries (Fruin, 1973; Snyder, 1972). In Canada, pedestrians account for about 15% of traffic deaths (Wolfe & O'Day, 1981). Children are particularly vulnerable to this type of collision (Ross & Seefeldt, 1978). One type of motor vehicle-pedestrian collision, termed a multiple threat, accounts for at least 12,000 pedestrian injuries and 300 deaths in the United States per year (Snyder, 1972). It involves a pedestrian being struck in a crosswalk on a multilane highway by a vehicle after another vehicle has yielded to the pedestrian, thereby blocking the vision of the motorist approaching in the outside lane.

Although actual data on injuries and deaths are essential in traffic safety research, such data must be collected over extended periods. Therefore, in the evaluation of pilot programs more sensitive and immediately available measures are necessary. This is certainly true of the multiple-threat situation. One way to circumvent this problem is to collect data at the location where road users are in conflict.

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Research has demonstrated that conflicts or near collisions correlate very highly with known long-term accident data (Baker, 1972; Older & Spicer, 1976).

Accordingly, the purpose of this experiment was to reduce the occurrence of multiple-threat conflicts in a six-lane crosswalk through the use of prompts designed to encourage motorists to yield right of way at a point further back from the crosswalk, thereby giving motorists approaching in other lanes a better view of the pedestrian in the crosswalk.

EXPERIMENT 1

Method

Subjects and setting. Subjects were motorists and pedestrians using a marked crosswalk on Wyse Road in Dartmouth, Nova Scotia, during daylight hours on weekdays. The crosswalk traversed a six-lane urban street connecting two shopping malls. The speed limit on the street was 50 km per hour. There were no traffic control devices at the crosswalk. The crosswalk lines and advance markings were painted approximately 1 month before the start of the experiment. Advance markings indicating a crosswalk ahead (consisting of an "X") were painted 50 m on each side of the crosswalk. All data were collected before the first snowstorm of the season.

Apparatus. Two signs were constructed to prompt motorists to stop at a specific location for

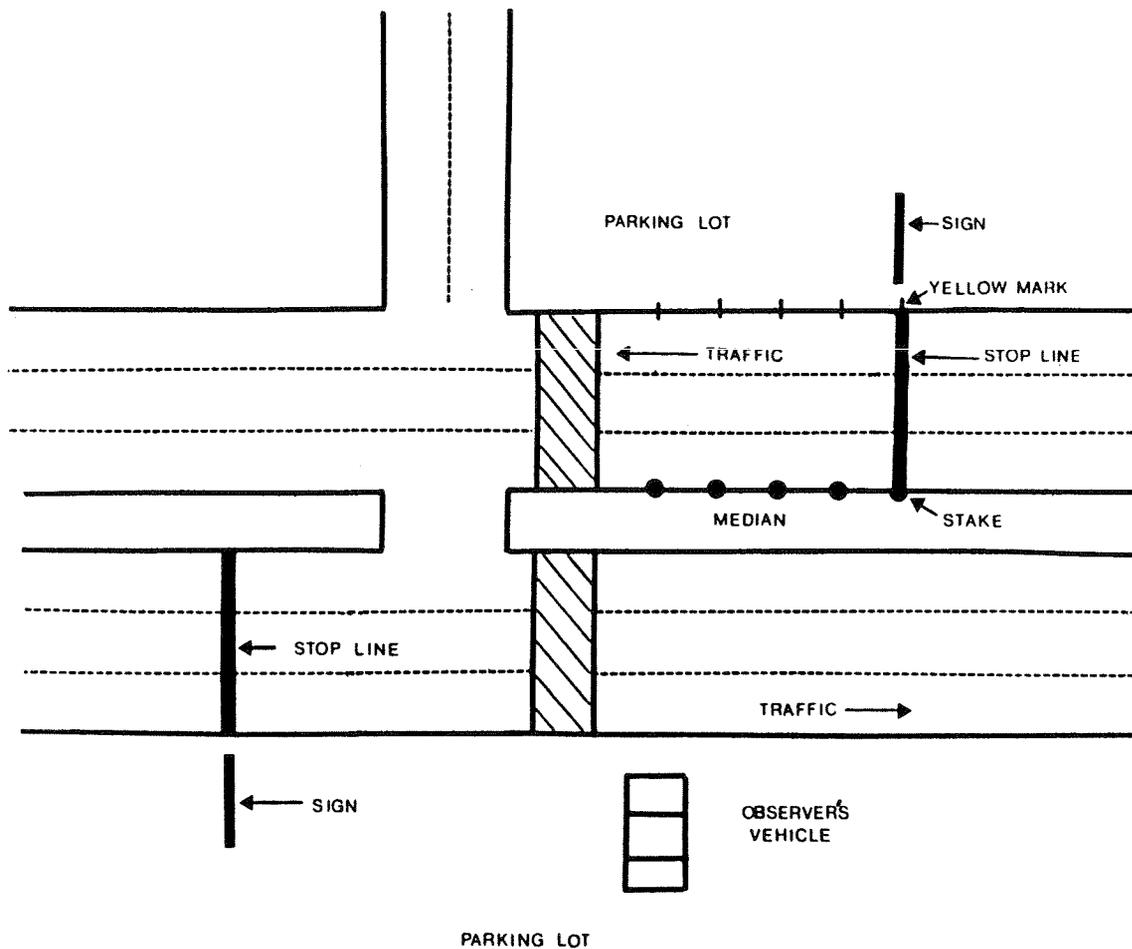


Figure 1. A diagram of the street showing the position of the sign, stop lines, and observer relative to the crosswalk.

pedestrians. These signs read "STOP HERE FOR PEDESTRIANS" and had an arrow pointing down toward the road at an angle of 45° below the horizontal. These signs were constructed from plywood covered with white scotchlite reflective material using 4 in. (10.1 cm) high black lettering. The signs were 1.1 m wide by 0.61 m high and were erected 0.5 m from the side of the highway at a height of 2 m above the street. A 20.3-cm-wide line constructed from two strips of 10.15-cm-wide removable line markings (3M Company) placed side by side was extended across the three lanes beginning at the side of each sign. The purpose of the signs and lines was to prompt motorists to yield further back from the crosswalk to allow overtaking vehicles a better view of pedestrians

crossing the street. The arrangement of the signs and the line is illustrated in Figure 1.

Measures. Two trained observers scored the behavior of motorists and pedestrians each weekday. Data were not collected on days with inclement weather (such as heavy rain) that would reduce pedestrian traffic. Data were collected for the first 30 pedestrians crossing the street beginning at 9:00 a.m. each day. It usually took from 1.5 to 2 hr to score data for 30 pedestrians.

The observers sat in a car parked in a parking lot with a clear view of the crosswalk. When a pedestrian approached a crosswalk and was positioned within approximately 30 cm of the curb facing the crosswalk, the observers scored the behavior of the motorists. Motorist behavior contin-

ued to be scored until the pedestrian had cleared the crosswalk.

Three types of motor vehicle–pedestrian conflicts were scored by the observers. A Type 1 conflict was scored whenever a motorist had to engage in abrupt audible braking, had to change lanes abruptly to avoid striking a pedestrian, or a pedestrian had to jump to avoid being struck by a vehicle. A Type 2 conflict was scored whenever a motorist who failed to yield to a pedestrian passed within less than one lane's distance from the pedestrian but did not qualify as a Type 3 conflict. A Type 3 conflict was scored whenever a vehicle passed in the immediately adjacent lane to the left of a vehicle that had yielded to a pedestrian who was crossing the street.

Motorists were scored as yielding to pedestrian(s) if they stopped before the crosswalk or slowed after passing the advanced markings allowing the pedestrian to cross. They were recorded as not yielding to pedestrians if they proceeded through the crosswalk, provided they had not passed the advance marking (an "X" painted on the road 50 m before the crosswalk) before the pedestrian was positioned within 30 cm of the curb facing the crosswalk. Because the Nova Scotia Motor Vehicle Act requires drivers in all lanes facing pedestrians to yield right of way, motorists traveling in both directions were scored as yielding or not yielding to pedestrians.

Observers also noted the distance motorists stopped behind the crosswalk during three baseline and three intervention conditions. Yellow marks were painted on the curb every 10 ft and stakes were placed in the grass in the median at these intervals opposite the lines to facilitate scoring by the observers. Stopping distance was scored only on the side of the street opposite the observers, because there was less of a problem with parallax on this side of the street. The observers scored whether motorists stopped less than 10 ft from the crosswalk, between 10 to 20 ft, 20 to 30 ft, 30 to 40 ft, 40 to 50 ft, or more than 50 ft from the crosswalk. The percentage of motorists stopping more than 10, 20, 30, 40, or 50 ft from the crosswalk was then calculated by dividing the num-

ber of motorists that stopped more than each of the abovementioned distances by the total number of cars that stopped.

Measures of interobserver agreement were obtained during at least two sessions during each condition by a second independent observer seated in a car parked beside that of the primary observer. An agreement was scored for a conflict if both observers scored a conflict for a particular pedestrian exactly the same way (i.e., Type 1, 2, or 3). An agreement was scored for yielding whenever both observers scored the same vehicle as yielding. An agreement was scored for stopping distance only if both observers recorded the same distance category. Interobserver agreements for conflicts, yielding behaviors, and distance stopped behind the crosswalk were computed by dividing agreements by agreements plus disagreements. Interobserver agreement averaged 100% on the occurrence of conflicts, 93% (range, 89% to 98%) on yielding, and 93% (range, 89% to 98%) on distance stopped.

Experimental design. A reversal design was used. After baseline data were collected, the "STOP HERE FOR PEDESTRIANS" sign plus advance stop line condition was introduced, removed, and reintroduced. Next, this condition was removed and reintroduced for the third time.

Baseline 1. During the baseline condition, the "STOP HERE FOR PEDESTRIANS" signs and stop lines were absent.

Sign plus stop line 1. During this condition the "STOP HERE FOR PEDESTRIANS" signs were each erected 50 ft before the crosswalk. In addition, the advance stop line was laid down across the three lanes adjacent to each sign, even with the sign.

Baseline 2. During this condition the signs and the lines were removed.

Sign plus stop line 2. This condition was carried out in the same manner as the preceding sign plus stop line condition.

Baseline 3. This condition was carried out in the same manner as Baselines 1 and 2.

Sign plus stop line 3. This condition was carried out in the same manner as the preceding sign plus stop line conditions.

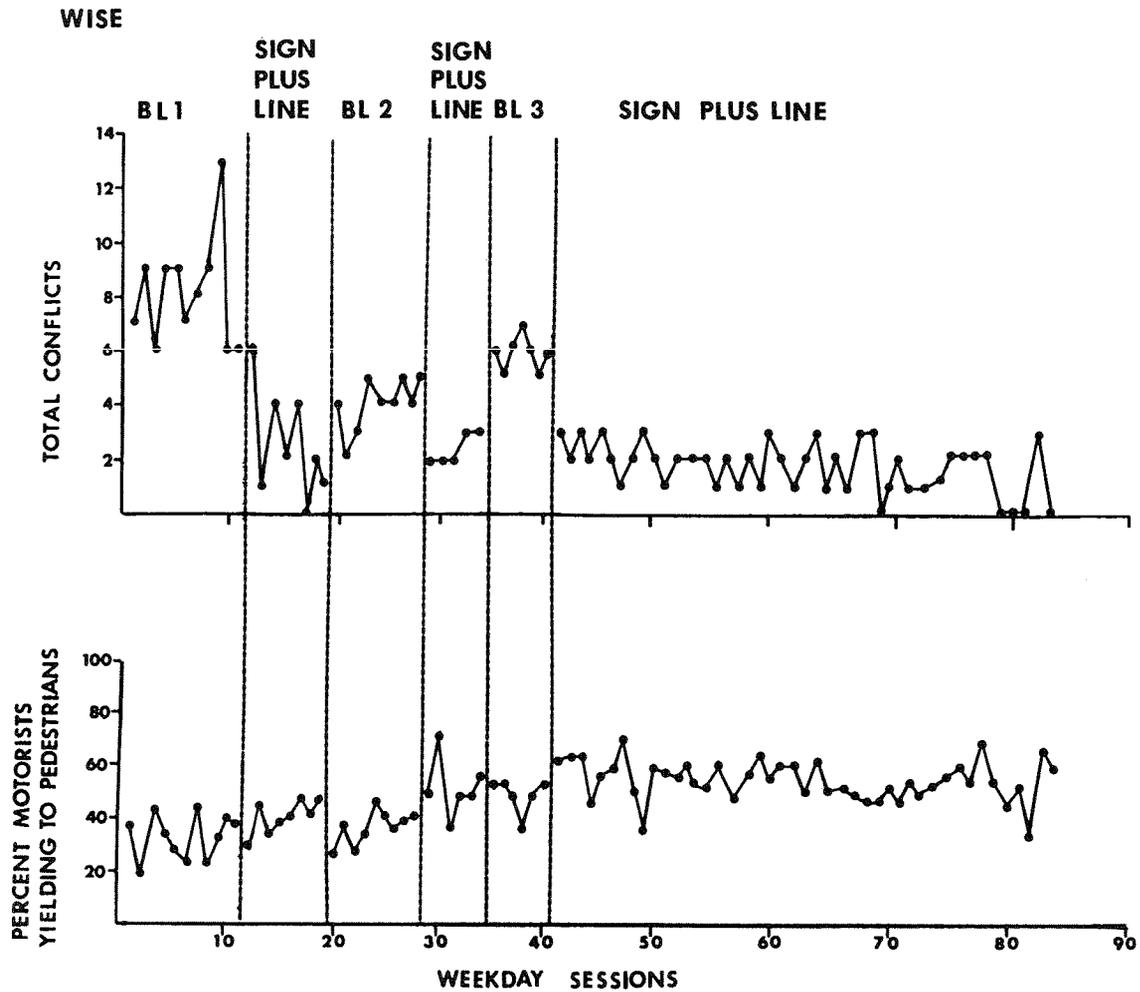


Figure 2. The total number of motor vehicle-pedestrian conflicts and the percentage of motorists yielding right of way to pedestrians during each condition of the experiment.

Results and Discussion

Motorist-pedestrian conflicts. The total number of motorist-pedestrian conflicts recorded during each condition of the experiment is presented in the upper panel of Figure 2. During Baseline 1, the total number of conflicts averaged 8.1 per day. The introduction of the first sign plus stop line condition reduced the number of conflicts to an average of 2.5. This represented a reduction of 69% in the number of conflicts per 30 pedestrian crossings. The removal, reintroduction, second removal, and second reintroduction of the sign plus stop line condition led to 4, 2.5, 5.8, and 1.7 conflicts per

30 crossings, respectively. Original baseline levels did not completely recover during the Baseline 2 and Baseline 3 conditions.

The data for each of the three types of conflicts followed the same trend as the total conflict data. During the Baseline 1 condition, Type 1, 2, and 3 conflicts averaged 0.5, 6.0, and 1.6, respectively, per 30 pedestrian crossings. During the first sign plus stop line condition these frequencies declined to 0.25, 2.0, and 0.25. During the Baseline 2 condition they remained about the same for Type 1 conflicts (0.22) and increased for Type 2 and 3 conflicts to 3.1 and 0.67, respectively. During the

second sign plus stop line condition the percentage of all three conflicts declined to 0.17, 1.83, and 0.5. Type 1 conflicts remained the same during the Baseline 3 condition, whereas the percentage of Type 2 and 3 conflicts increased to 4.33 and 1.33. During the final sign plus stop line condition the number of all three conflicts declined to 0.05, 1.1, and 0.44.

Yielding right of way to pedestrians. The percentage of motorists yielding right of way to pedestrians during each condition of the experiment is presented in the lower panel of Figure 2. Although the introduction of the sign plus stop line conditions was associated with increased yielding, the increases were small.

The data collected on those motorists who did stop behind the line is presented in Figure 3. During the baseline conditions motorists tended to stop close to the crosswalk. The introduction of the sign plus stop line condition resulted in a large increase in the percentage of motorists stopping at least 10 ft from the crosswalk (from 50% to 95%). Although the data indicate that the intervention was effective, the generality of the findings are somewhat limited because the treatment was applied on only one street. The purpose of the second experiment was to extend the generality of these findings through replication.

EXPERIMENT 2

Method

Subjects and setting. This experiment was carried out approximately 1 year after the first experiment and involved two crosswalks. The first was the same one reported in the first experiment and had been in the baseline condition (i.e., no signs or special lines on the road) for 6 months prior to the start of this experiment. A second crosswalk on Portland Street traversed a five-lane street connecting a bus stop with a residential area. Advance markers indicating a crosswalk ahead were painted 50 m on each side of the crosswalk. All data were collected during the spring and summer months after the last snowfall.

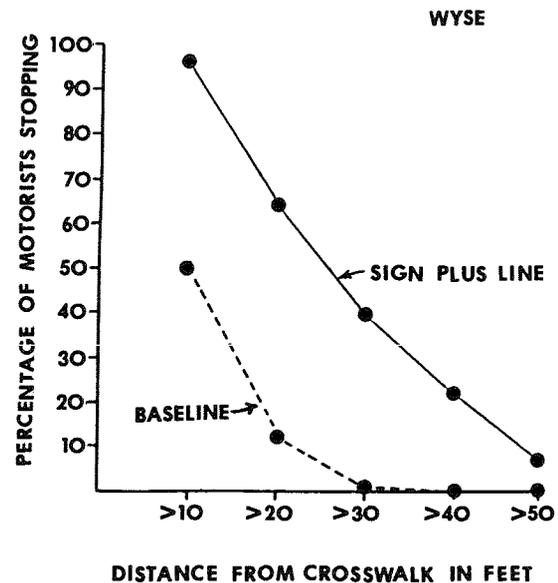


Figure 3. The percentage of motorists stopping more than 10, 20, 30, 40, or 50 ft from the crosswalk during baseline and the sign plus stop line condition of Experiment 1.

Apparatus. The signs and removable line markings used in this experiment were of the same type reported in the previous experiment.

Measures. Data were collected in the same manner as reported in the previous study. Measures of interobserver agreement were obtained three times on each street during each condition of the experiment. Interobserver agreement averaged 99% (range, 95% to 100%) on the occurrence of conflicts, 94% (range, 88% to 100%) on distance stopped, and 95% (range, 91% to 100%) on yielding.

Experimental design. A multiple baseline across settings (crosswalks) design was used in this experiment. The baseline condition as well as the sign plus stop line intervention were carried out in the same manner as reported in the previous experiment.

Results and Discussion

The total number of motorist-pedestrian conflicts recorded on each street during each condition

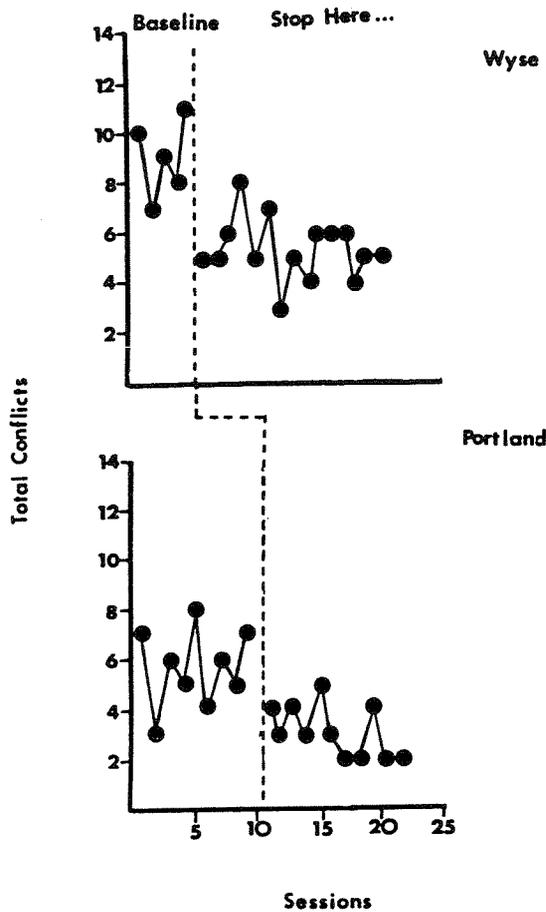


Figure 4. The total number of motor vehicle-pedestrian conflicts on Wyse Road and Portland Street during each condition of the experiment.

is presented in Figure 4. The introduction of the sign plus stop line condition reduced the mean number of conflicts on Wyse Road from a baseline level of 9.0 per session to a posttreatment level of 5.3 per session and reduced the mean number of conflicts on Portland Street from a baseline level of 5.67 per session to a posttreatment level of 3.3 per session. The percentage of motorists yielding right of way to pedestrians increased slightly on Wyse Road from a baseline level of 32% to a treatment level of 39%. On Portland Street the percentage of motorists yielding right of way to pedestrians increased from 20% to 30%.

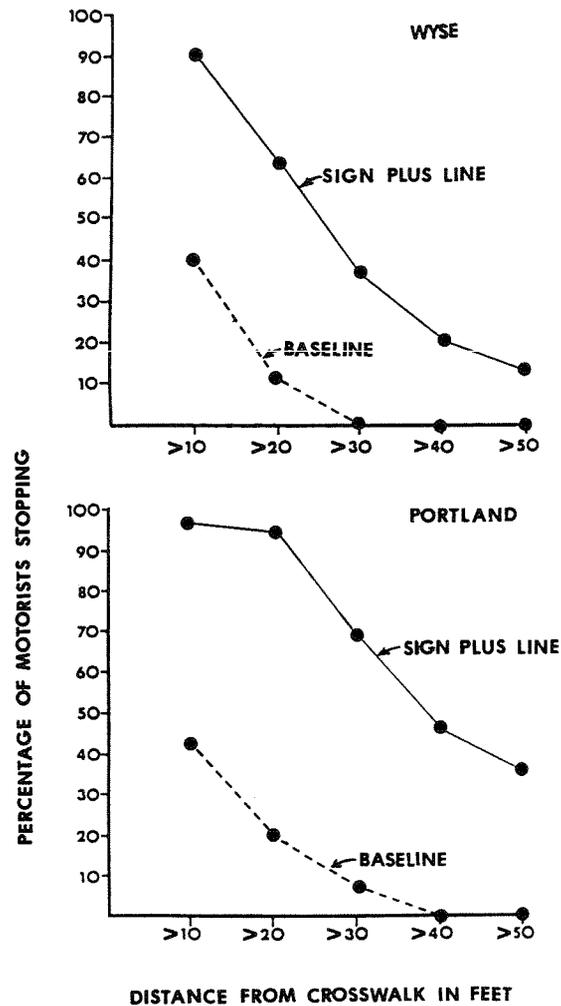


Figure 5. The percentage of motorists stopping more than 10, 20, 30, 40, or 50 ft from the crosswalk during the baseline and sign plus stop line condition on Wyse Road and Portland Street during Experiment 2.

Data collected on motorists stopping behind the line are presented in Figure 5. The introduction of the sign plus stop line condition resulted in a large increase in the percentage of motorists stopping more than 10 ft from the crosswalk on both streets.

GENERAL DISCUSSION

Results of these experiments demonstrate that a simple inexpensive prompting intervention can re-

duce conflicts between motorists and pedestrians. Although the treatment procedure did not produce a large increase in the percentage of motorists yielding to pedestrians, those who did yield tended to do so further back from the crosswalk.

Because crosswalks must be repainted annually, the cost of painting the advance stop lines on all crosswalks traversing multilane roads should be minimal. The cost of a pair of signs for each road in Nova Scotia is approximately \$100. However, once the signs have been in place at a large enough number of sites, it is quite possible that motorists will learn to respond to the presence of the stop lines alone.

This research was carried out with the cooperation of the Nova Scotia Department of Transportation and the Traffic Co-ordinator for the City of Dartmouth. After becoming aware of the results of this research, the Nova Scotia Department of Transportation began incorporating the use of advance stop lines for marking crosswalks on multilane streets. At present the national body regu-

lating highway standards is considering whether to adopt these markings on a nationwide basis.

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ORIGINAL ARTICLE

Safety in numbers: more walkers and bicyclists, safer walking and bicycling

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Objective: To examine the relationship between the numbers of people walking or bicycling and the frequency of collisions between motorists and walkers or bicyclists. The common wisdom holds that the number of collisions varies directly with the amount of walking and bicycling. However, three published analyses of collision rates at specific intersections found a non-linear relationship, such that collision rates declined with increases in the numbers of people walking or bicycling.

Data: This paper uses five additional data sets (three population level and two time series) to compare the amount of walking or bicycling and the injuries incurring in collisions with motor vehicles.

Results: The likelihood that a given person walking or bicycling will be struck by a motorist varies inversely with the amount of walking or bicycling. This pattern is consistent across communities of varying size, from specific intersections to cities and countries, and across time periods.

Discussion: This result is unexpected. Since it is unlikely that the people walking and bicycling become more cautious if their numbers are larger, it indicates that the behavior of motorists controls the likelihood of collisions with people walking and bicycling. It appears that motorists adjust their behavior in the presence of people walking and bicycling. There is an urgent need for further exploration of the human factors controlling motorist behavior in the presence of people walking and bicycling.

Conclusion: A motorist is less likely to collide with a person walking and bicycling if more people walk or bicycle. Policies that increase the numbers of people walking and bicycling appear to be an effective route to improving the safety of people walking and bicycling.

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Motor vehicle collisions are a leading global cause of death and disease burden.^{1,2} Worldwide, more people die in motor vehicle collisions while walking and bicycling than while driving.³

In examining injuries to people walking and bicycling, intuition suggests that injuries increase in locations where, and in time periods when, more people walk and bicycle.³ However, do injuries increase linearly with the amount of walking and bicycling? Is the situation the same as with billiards—will doubling the number of balls on the table double the number of collisions? If so, it implies these collisions are random and “accidental”. If not, then it implies that the numbers of people walking, bicycling, and motoring affects human behavior and hence behavior has an important role in preventing these injuries.

In less motorized countries, non-motorized users account for most of the road users killed in motor vehicle crashes, in contrast to the more motorized countries, where most deaths occur inside motorized four wheelers.³ While information on fatalities is collected in the developing world, reliable information on the amount of walking and bicycling is unavailable, limiting this investigation to industrialized countries.

Across Europe and North America, the amount of walking and bicycling varies tremendously—from 6% of all trips (USA) to 46% (the Netherlands).⁴ Yet the per capita fatal injury rate to people walking and bicycling is more or less the same in the two countries: 1.9/100 000 in the Netherlands and 2.1/100 000 in the USA.⁵ This surprising result shows that the numbers of pedestrians and bicyclists fatally injured does not vary linearly with the numbers of walkers and bicyclists.

Research at specific sites has shown that collisions between a motorist and a person walking or bicycling diminish where more people walk and bicycle. Ekman examined numbers of pedestrians, bicyclists, and motorists, and serious conflicts among them at 95 intersections in Malmö, Sweden. He found

that after adjusting for the number of bicyclists, the number of conflicts/bicyclist was twice as great at locations with few bicyclists compared with locations with more. In fact, the number of conflicts/bicyclist decreased abruptly with more than 50 bicyclists/hour. With pedestrians, Ekman found that although the number of conflicts/pedestrian was largely unaffected by numbers of pedestrians, the conflict rate was still affected by numbers of motorists.⁶

Leden also reported a non-linear relationship in two examinations of intersections. In a before and after study, he examined changes in numbers of bicyclists and collisions between motorists and bicyclists in response to changes in physical configuration at 45 non-signalized intersections between bicycle paths and roadways in Gothenburg, Sweden. The total number of collisions increased with the 0.4 power of the increasing use of the intersections by bicyclists.⁷ He also examined police reported injuries to people walking at approximately 300 signalized intersections in Hamilton, Ontario, Canada. The number of collisions increased with the 0.32 to 0.67 power with increasing numbers of pedestrians.⁸

This paper explores this non-linear phenomenon noted above. Does it occur only at specific intersections, or also at larger scales, such as for a city or country or at different time periods with differing numbers of walkers or bicyclists? Is the relationship consistent and replicable? Is it plausible? Is there a dose-response relationship? And what are the likely causal mechanisms?^{9,10}

METHODS

To explore the relationship between the amount of walking and bicycling and the collisions involving a motorist and a person walking or bicycling, it was necessary to identify locations and time periods with data for both injuries and the amount of walking and bicycling.

In the industrialized world, fatal motor vehicle injuries are recorded well; injury statistics less so.¹¹ Additionally, although

Table 1 Calculated results

Data	Injury measure	Exposure measure	Exponent for growth in injuries	95% Confidence interval
Walking in 68 California cities	Injuries/capita	Portion journey to work trips on foot	0.41	0.27 to 0.54
Bicycling in 68 California cities	Injuries/capita	Portion journey to work trips on bicycle	0.31	0.22 to 0.41
Walking in 47 Danish towns	Injuries/capita	Kilometres walked/capita/day	0.36	-0.10 to 0.82
Bicycling in 47 Danish towns	Injuries/capita	Kilometres bicycled/capita/day	0.44	0.19 to 0.69
Bicycling in 14 European countries	Fatalities/capita	Kilometres bicycled/capita/day	0.58	0.38 to 0.42
Walking in 8 European countries	Fatalities/capita	Trips on foot/capita/day	0.13	-0.71 to 0.98
Bicycling in 8 European countries	Fatalities/capita	Trips on bicycle/capita/day	0.48	0.22 to 0.75
Bicycling in the United Kingdom: 1950-73	Fatalities	Billion kilometres ridden annually	0.41	0.35 to 0.47
1974-83			0.012	-0.25 to 0.28
1984-99			1.5	1.11 to 1.88
Bicycling in the Netherlands, 1980-98	Fatalities	Billion kilometres ridden annually	-1.9	-2.7 to -1.1

motor vehicle use is measured, few jurisdictions collect similar data for the numbers of walkers and bicyclists.¹³ Most available estimates are obtained by surveys. Then again, since much walking and bicycling occurs in short trips that may not be recorded in surveys (for example, children crossing the street), survey data may be inaccurate as well.

Comparisons between jurisdictions are also complex. Laws governing motor vehicle operation, roadway design, techniques for collecting the number of injuries and numbers of people walking and bicycling, and other perhaps significant factors may vary. To minimize these complexities when comparing across jurisdictions, this analysis uses data sets collected by one entity.

This paper uses five data sets (three population level and two time series) to compare the amount of walking or bicycling and the injuries incurring in collisions with motor vehicles.

For each data set, the measure of injuries to people walking or bicycling was compared to measure of walking and bicycling to determine the relationship. Parameters were calculated using least squares analysis for the function shown in equation (1):

$$I = aE^b \quad (1)$$

where I is the injury measure, E is the measure of walking or bicycling, and a and b are the parameters to be computed.

Exponent b indicates the change in the number of injuries in the population in response to changes in walking and bicycling. With b equal to 1, the growth in injuries with increasing exposure would be linear; b less than 1 indicates the growth in injuries would be less than linear; and b less than 0 indicates that increasing the number of walkers or bicyclists would decrease the total number of injures to people walking and bicycling in a given population.

For an individual walking or bicycling, the relevant risk measure is for a unit of walking or bicycling. This risk can be estimated by dividing both sides of equation (1) by the measure of walking and bicycling, E , resulting in equation (2):

$$I/E = aE^{b-1} \quad (2)$$

The graphs show this latter relationship, as it is easier to understand visually.

DATA

In this analysis, three population data sets are employed to examine the relationship between numbers of walkers and bicyclists and the numbers of collisions with motorists across varying sizes of analysis areas, from cities to countries. In addition, two time series data sets are used to examine the effect of fluctuations in walking and bicycling on injuries.

Walking and bicycling in California cities

Cities within one state in the United States allow a relatively consistent comparison. California has one law governing traffic and consistent traffic control devices. However, cities may choose their own roadway design features. In practice, roadway designs vary mostly by era of urbanization.

Injury data were obtained from police collision reports as summarized by the California Highway Patrol for year 2000.¹⁴ Injury incidence rates were calculated using the US census population estimates as adjusted by the State of California's Department of Finance for year 2000.¹⁵ Of the 111 cities in California with a population over 60 000, the 68 cities with per capita injury rates to people walking and bicycling both greater than 30/100 000 were examined.

The US Census Bureau collects journey to work trip data for the year 2000.¹⁶ While such trips constitute only a fraction of all person trips, this analysis assumes that mode of journey to work is in proportion to mode for other person trips and uses it as a proxy for other person trips.

Walking, bicycling, and moped riding in 47 Danish towns

The Danish Bureau of Statistics collected travel behavior for 47 towns with populations greater than 10 000 for years 1993-96.¹⁷ (Søren U Jensen provided the travel and injury data for this analysis.)

Walking and bicycling in European countries

European countries vary as to geography, roadway designs, traffic laws, and societal mores. A European Commission sponsored report compiled bicycling distances for 14 countries and person trips by foot and bicycle for eight countries for 1998.¹⁸ The Organization for Economic Co-operation and Development's International Road Traffic and Accident Database reports traffic fatalities and population numbers for 1998.^{19, 20}

Bicycling in the United Kingdom, 1950-99

The Department of Environment, Transport and the Regions in the United Kingdom measures the distance bicycled with annual surveys, and compiles fatality data, which combined allow a time series analysis.²¹

Bicycling in the Netherlands, 1980-98

The Netherlands *Centraal Bureau voor de Statistiek* measures the distance bicycled with annual surveys and compiles fatality data.²²

RESULTS

Table 1 shows the calculated results. Parameter b indicates the exponential change in the number of injuries in the population in response to changes in walking and bicycling.

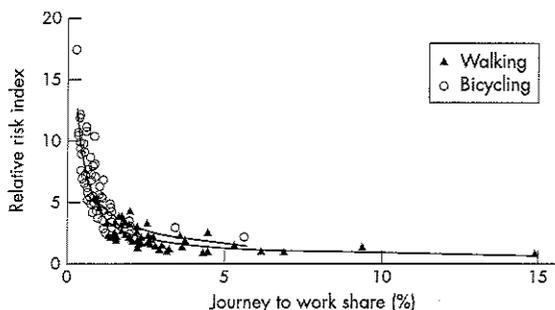


Figure 1 Walking and bicycling in 68 California cities in 2000.

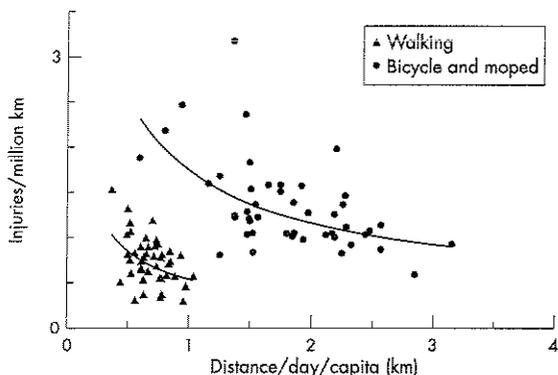


Figure 2 Walking and bicycling in 47 Danish towns in 1993–96.

Walking and bicycling in California cities

Per capita injury rates to pedestrians and bicyclists vary four-fold among the 68 cities, and the portion of journey to work trips made by foot and bicycle varies more than 15-fold and 20-fold (respectively). Dividing the per capita injury numbers by the fraction of work trips on foot or bicycle results in a five-fold and eightfold range of risk for a person walking or bicycling in the 68 cities. Figure 1 shows that the likelihood of an injury is not constant but decreases as walking or bicycling increases.

Walking and bicycle and moped riding in 47 Danish towns

Per capita injury rates to pedestrians and bicyclists varied twofold, and the number trips made by foot and bicycle varied more than fourfold and threefold (respectively). Dividing the per capita injury numbers by the aggregate distance walked or bicycled indicates a fivefold range of risk for a person walking or bicycling for the 47 towns. Figure 2 shows that despite considerable scatter in the results, pedestrians are safer in towns with greater walking and bicyclists are safer in towns with more bicycling.

Walking and bicycling in European countries

In the 14 countries with data, distance bicycled per capita varied 10-fold. Across them, the number of persons killed while bicycling varied fourfold. Dividing the number of bicyclist deaths per capita by the distance bicycled per capita indicates a nearly 20-fold range of risk for a person bicycling a given distance. Figure 3 shows that the number of bicyclist fatalities/distance bicycled decreases with increasing distance bicycled per capita.

In the eight countries with person trip data, the number of bicycle trips per capita varied by more than 10-fold and the number of trips on foot varied threefold. Dividing the per capita fatality rate by the daily foot and bicycle trips per capita

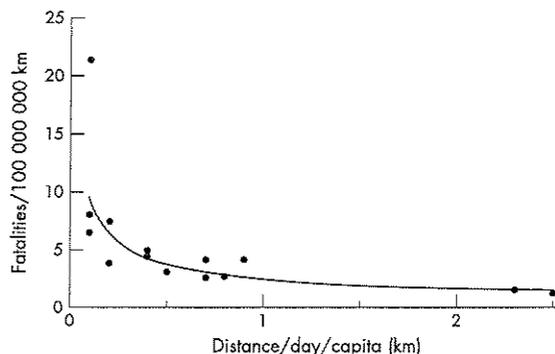


Figure 3 Bicycling in 14 European countries in 1998.

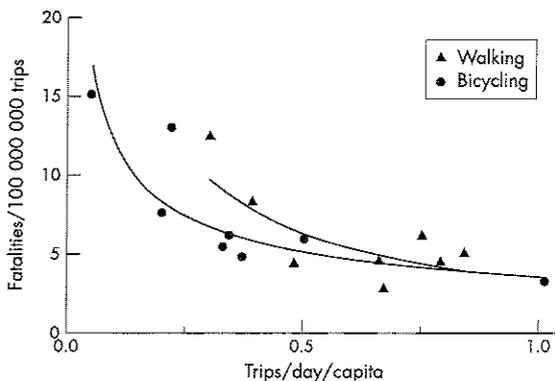


Figure 4 Walking and bicycling in eight European countries in 1998.

data indicates a nearly fivefold range of risk of death for each trip. Figure 4 shows that the risk decreases with increasing trips on foot or on bicycle.

Bicycling in the United Kingdom, 1950–99

In the United Kingdom from 1950 to 1999, distance bicycled varied sixfold and bicyclist fatalities varied fivefold. Dividing the number of bicyclist deaths per capita by distance bicycled indicates a threefold range of risk for a given distance bicycled. Figure 5 shows the complex relationship between the number of bicyclist fatalities and the distance bicycled. Separating the data into three segments using the inflection points for distance ridden allows some understanding. Until 1973, as the United Kingdom motorized, the generally decreasing distance bicycled was accompanied by an increase in bicyclist fatalities/distance bicycled. From 1973 to 1983, the small increase in distance bicycled was accompanied by a large decrease in bicyclist fatalities/distance bicycled. This resurgence in bicycling may be related to the oil embargo and resulting increase in energy costs. In stark contrast, from 1984 to 1999, the decrease in distance bicycled was matched by a decrease in bicyclist fatalities/distance bicycled, indicating an increasing risk of a bicyclist fatality. This change may be related to the seatbelt law in 1983. One review suggested that the increase in seatbelt use transferred some risk to pedestrians and bicyclists as motorists felt safer and drove more aggressively and further.²³ Average motorist speeds in built up areas in the United Kingdom increased from 45 km/h in 1981, before compulsory use of seatbelts, to 53 km/h in 1997.²⁵ Less bicycling is a plausible response to more aggressive and faster motorists.

Bicycling in the Netherlands, 1980–98

In the Netherlands, bicycling distances increased generally from 1980 to 1998. Annual bicyclist fatalities in the same time

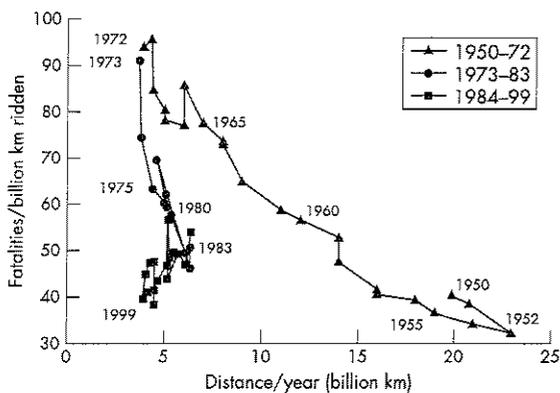


Figure 5 Bicycling in the United Kingdom from 1950-99.

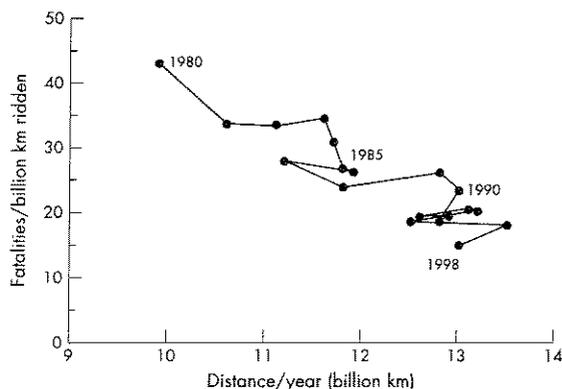


Figure 6 Bicycling in the Netherlands from 1980-98.

period decreased from 426 to 194. Dividing the number of bicyclist deaths per capita by distance bicycled indicates a nearly threefold range in risk for a given distance bicycled. Figure 6 shows that the number of bicyclist fatalities/distance traveled decreased rapidly with increasing distance bicycled.

DISCUSSION

Multiple independent data sets show that the total number of pedestrians or bicyclists struck by motorists varies with the 0.4 power of the amount of walking or bicycling (respectively). This relationship is consistent across geographic areas from specific intersections to cities and countries. Furthermore, Leden found the same relationship in a before and after study of 45 bicycle path intersections with roadways.²⁷ In the industrialized countries examined, this relationship holds across a wide range of walking and bicycling.

Interpreting the time series data is complicated as some changes could result from forces not measured. Improvements in post-trauma medical care complicate comparing years—indeed for the period 1989 to 1995 Roberts *et al* found a 16%/year reduction in fatalities for severely injured children in the United Kingdom.²³ Changes in the distribution of age in the population could also complicate comparisons.²⁸ Furthermore, while the number of fatalities are likely accurately reported, record keeping for the distance bicycled may have changed. Also, the risk of some bicycle fatalities may be unrelated to distance traveled (for example, fewer children playing in residential areas might change the fatality numbers but not distance traveled).

Nonetheless, the British time series data indicate that decreasing bicycle riding leads to increased risk, and increasing risk leads to decreasing bicycle use. In contrast, over the

last two decades, the Netherlands has implemented a range of policies to encourage people to walk and bicycle and make them safer.⁶ These efforts have succeeded in increasing bicycle use and decreasing risk.

The time series data also provide an understanding of cause. The possible explanations are changes in human behavior, roadway design, laws, and social mores. However, insofar as the changes seen in the time series data occurred rapidly and with both increasing and decreasing amounts of bicycling, it is improbable that the roadway design, traffic laws, or social mores, all of which change relatively slowly, could explain the relationship between exposure and injury rates. The more plausible explanation involves changes in behavior associated with changes in the amount of walking and bicycling.

Whose behavior changes, the motorist's or that of the people walking and bicycling? It seems unlikely that people walking or bicycling obey traffic laws more or defer to motorists more in societies or time periods with greater walking and bicycling. Indeed it seems less likely, and hence unable to explain the observed results. Adaptation in motorist behavior seems more plausible and other discussions support that view. Todd reported three studies showing "motorists in the United States and abroad drive more slowly when they see many pedestrians in the street and faster when they see few".²⁷ In addition, motorists in communities or time periods with greater walking and bicycling are themselves more likely to occasionally walk or bicycle and hence may give greater consideration to people walking and bicycling. Accordingly, the most plausible explanation for the improving safety of people walking and bicycling as their numbers increase is behavior modification by motorists when they expect or experience people walking and bicycling.

Given the apparent response of motorists, further study is needed of ways to remind motorists of the presence of people walking and bicycling. Would different roadway design help? Do specific interventions such as marking crosswalks, placing CHILDREN PLAYING signs, and designating bicycle lanes have a community-wide impact? Studies to date on these approaches have tended to examine only the immediate area and ignore community-wide effects. However, it seems reasonable that increasing motorist awareness of people walking and bicycling would provide benefits beyond just the immediate area. Such awareness techniques should be investigated for community wide health benefits.

Another question arises about laws governing the interaction between motorists and vulnerable road users. For example, in the United States, if a motorist strikes a person walking between intersections, the motorist is unlikely to face criminal charges.²⁷ Yet if motorist behavior largely controls the number of collisions, laws should be revised to reflect this finding.

CONCLUSIONS

A motorist is less likely to collide with a person walking and bicycling when there are more people walking or bicycling. Modeling this relationship as a power curve yields the result that at the population level, the number of motorists colliding with people walking or bicycling will increase at roughly 0.4 power of the number of people walking or bicycling. For example, a community doubling its walking can expect a 32% increase in injuries ($2^{0.4} = 1.32$). Taking into account the amount of walking and bicycling, the probability that a motorist will strike an individual person walking or bicycling declines with the roughly -0.6 power of the number of persons walking or bicycling. An individual's risk while walking in a community with twice as much walking will reduce to 66% ($2^{-0.6} = 2^{-0.6} = 0.66$). Accordingly, policies that increase the numbers of people walking and bicycling appear to be an effective route to improving the safety of people walking and bicycling.

Key points

- Where, or when, more people walk or bicycle, the less likely any of them are to be injured by motorists. There is safety in numbers.
- Motorist behavior evidently largely controls the likelihood of collisions with people walking and bicycling.
- Comparison of pedestrian and cyclist collision frequencies between communities and over time periods need to reflect the amount of walking and bicycling.
- Efforts to enhance pedestrian and cyclist safety, including traffic engineering and legal policies, need to be examined for their ability to modify motorist behavior.
- Policies that increase walking and bicycling appear to be an effective route to improving the safety of people walking and bicycling.

ACKNOWLEDGEMENTS

In 1998, the Pasadena, California, City Council asked whether their city was a dangerous place to bicycle, prompting this investigation into the importance of accounting for the amount of walking and bicycling. Anne Seeley of California Department of Health Services asked if the public health goal of more walking and bicycling conflicted with reducing injuries, adding impetus to understanding the role of safety in numbers. Chris Morfas, Søren Jensen, Michael Ronkin, Rick Warring, Malcolm Wardlaw, John Pucher, Lewis Dijkstra, and Petra Staats provided data to help answer these questions. Charles Komanoff, Marie Birnbaum, and three anonymous reviewers provided valuable editorial advice. Virginia Gangsei helped clarify the presentation.

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Demographic and environmental correlates of pedestrian injury collisions: a spatial analysis

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Abstract

Pedestrian injury collisions often occur when and where large numbers of pedestrians travel within complex roadway systems with high traffic flow. The pedestrian injury literature suggests a number of individual and environmental correlates of injury risks, however studies in this area have primarily focused upon demographic differences (e.g. related to age) and a few global characteristics of the roadway system (e.g. aspects of pedestrian traffic). Studies in which the geography of communities has been considered are primarily descriptive, identifying pedestrian injury 'hot spots'. The current study more extensively explores some geographic correlates of pedestrian injury collisions through a spatial analysis of data from the city of San Francisco, CA. A spatial autocorrelation corrected regression model was used to determine factors associated with pedestrian traffic injury in 1990. The study used a geographic information system to map locations of pedestrian injuries, and environmental and demographic characteristics of the city across census tract units. In addition to a number of demographic factors (gender, age, marital status, education, income and unemployment), it was proposed that several environmental features of the city would be related to injury rates (high traffic flow, complex roadway systems, greater population densities and alcohol availability). Results of the study showed that pedestrian injury rates were related to traffic flow, population density, age composition of the local population, unemployment, gender and education. Availability of alcohol through bars was directly related to pedestrian injury collisions in which the pedestrian had been drinking alcohol. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Pedestrian; Injury; Demographics; Alcohol availability; Geostatistics

1. Introduction and literature review

Motor vehicle and traffic collisions remain the leading cause of premature death in the United States. Nationwide, pedestrians are the second largest population group to die in motor vehicle related crashes (motor vehicle occupants are the largest), accounting for about 13% of the death toll (Insurance Institute for Highway Safety, 1997). In 1996, 5412 pedestrians (mostly young children, elderly people and intoxicated people) died; an additional 82 000 were injured (National Highway Traffic Safety Administration, NHTSA, 1997). Within the state of California in 1994, 843 pedestrians were killed, representing the highest absolute number in the nation. When adjusted for population, California ranks eighth in the nation for

pedestrian injury (NHTSA, 1995a). At the local level, San Francisco has one of the highest pedestrian injury rates among all major US cities. According to the National Highway Traffic Safety Administration, 28 out of the 63 persons killed in San Francisco in 1994 traffic collisions, or 44%, were pedestrians. In comparison, statewide, less than 20% of the 4226 persons killed in California traffic collisions were pedestrians (NHTSA, 1995a). Focusing on census year 1990 (the year for which data was collected for the current study), there were 1137 traffic collisions in which a pedestrian was involved in San Francisco, or 10.9% of the 10 419 total collisions that year. In these collisions, there were a total of 35 persons (30 pedestrians) killed and 1227 (1164 pedestrians) injured.

A variety of characteristics of individuals involved and the collision environment appear to be related to pedestrian injuries. Studies of adult pedestrians have found gender and age differences. For example, males

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and older persons appear more likely to be involved in pedestrian crashes. In 1994, 68% of all pedestrian fatalities in the US were male (NHTSA, 1995b) and almost 23% were 65 or older (NHTSA, 1995a). One study found differences in perceptual judgements between younger and older pedestrians (Oxley et al., 1997). The findings suggested that age-related perceptual and cognitive deficits might play a substantial role in crashes involving older pedestrians. Child pedestrian research has found several environmental factors to be associated with pedestrian injury, including traffic flow, traffic speed, the presence of curbside parking and the presence of pedestrian footpaths (Roberts et al., 1995; Stevenson et al., 1995). Other child pedestrian studies have examined geographic variations such as differences in child pedestrian death rates at the state-level (Baker et al., 1991) and identified characteristics of high frequency collision sites using a geographic information system (Braddock et al., 1994). Another recent study of adult pedestrians estimated the effects of reduced travel speeds on pedestrian fatalities (Anderson et al., 1997).

Alcohol consumption by adult pedestrians has been found to play an important role in pedestrian traffic injury. The NHTSA (1997) found that almost one-third (32.3%) of fatally injured pedestrians had blood alcohol concentrations (BAC) at or above the 0.10 g/dl in 1996, the legal limit for drivers in many states. In the same year, the Insurance Institute for Highway Safety (1997) found that of all pedestrians 16 years of age or older who were killed in night-time crashes, 55% had BACs of 0.10% or more. In contrast, the intoxication rate for drivers was 12%, less than half that for the pedestrians. From 1982 to 1992, there were 56 179 drivers involved in 61 129 pedestrian fatalities in which the pedestrian was older than 14 years of age. Only 15.5% of the drivers had BACs in excess of 0.10 g/dl, while 36.9% of the pedestrians had BACs in excess of that value. Although BACs in excess of 0.10 in these drivers has fallen from 20.0% in 1982 to 11.9% in 1992, it has fallen only from 39.4 to 36.2% among pedestrian fatalities during that time (Centers for Disease Control, 1993).

Research from emergency rooms has suggested that many pedestrians who are injured or killed were under some influence of alcohol at the time they were struck; little is known about injuries that do not require admission to emergency rooms. Profiles of injured pedestrians show many, between 19 and 65%, to have been drinking, often heavily (Bastos and Galante, 1986; Brainard et al., 1989; Middaugh, 1989; Vestrup and Reid, 1989). Pedestrians who are under the influence of alcohol also appear to have more severe injuries (Bradbury, 1991; Mittmeyer, 1991) and face higher mortality (Williams et al., 1995) than those who are not under the influence. Case-control studies have shown that intoxication increases the likelihood that a pedestrian is injured. Honkanen et al. (1976) showed that in the US relative

risks of injury increased rapidly with pedestrian BACs in excess of 0.10. These earlier findings have received renewed emphasis in recent studies about the prevalence of alcohol involvement in pedestrian injuries. A study in Australia found that 38% of pedestrian fatalities and 29% of pedestrian emergency room admissions had blood alcohol concentrations at or above 0.10 (Holubowycz, 1995). Another study in Florida found that alcohol use increased by at least fourfold the risk of a pedestrian dying in a traffic collision (Miles-Doan, 1996).

As this review suggests, although the current literature on pedestrian injury includes studies of individual and global environmental characteristics related to injury rates, specific geographic components of pedestrian injury have seldom been introduced; this despite the fact that pedestrian injuries, like all traffic related injuries, have specific geographic correlates (e.g. local traffic flows and locations of pedestrian walk ways, Roberts et al., 1995; Stevenson et al., 1995) and have been shown to geographically cluster (Braddock et al., 1994). Thus, noting the substantial involvement of alcohol in pedestrian injury, it is reasonable to consider the extent to which the geography of retail alcohol availability is related to the geography of pedestrian injuries.

Several geographic studies have suggested that locations of alcohol outlets are associated with alcohol use and alcohol-related crashes (Gruenewald et al., 1993; Van Oers and Garretsen, 1993; Scribner et al., 1994). Gruenewald et al. (1993) suggests that alcohol-related traffic collisions exhibit geographically measurable relationships with the density of and distance from alcohol outlets. Gruenewald et al. (1996) demonstrated that physical availability was related to rates of single vehicle night-time crashes (SVNs) between 20:00 and 04:00 h (a surrogate for alcohol-related crashes). Uniquely, this study used geostatistical modeling techniques to identify a spreading pattern of crashes radiating away from sources of alcohol.

1.1. Spatial analysis

Gruenewald et al. (1996) used geostatistical modeling techniques to study the relationships between the spatial distribution of alcohol outlets and alcohol-related traffic collisions. These statistical techniques allowed the researchers to correct for spatial autocorrelations between rates of crash events due to their relative proximity in space, while at the same time providing a means to explore the relationships between the availability of alcohol in one area and rates of crashes in adjacent areas (i.e. spatial lags). Spatial autocorrelations between adjacent geographic units introduce bias into statistical analyses due to the violation of the assumption of unit independence. Two spatial units

that are physically close together can be expected to exert some effect on each other. Therefore, these units, if taken as separate observations, are not truly independent.

One correction for spatial autocorrelation involves deriving a matrix which shows which geographic units are adjacent to each other (a binary connection matrix, W , an $n \times n$ matrix indicating connections between adjacent spatial units with 0 and 1) and calculating the degree of spatial autocorrelation, ρ , between adjacent units. Generalized least squares estimators are available to provide unbiased tests of regression effects in these spatial contexts (Griffith, 1987). Thus, Levine et al. (1995) used a spatial autoregressive lag model of the form:

$$Y = \rho WY + Xb + \varepsilon \quad (1)$$

to adjust for spatial autocorrelation in traffic collision data, where Y is an $n \times 1$ vector of dependent variables observed across n units, and ρ is the coefficient of the spatial lag term. The scalar multiplication ρ by WY provides an estimate of the weighted effects of the dependent variable measured on adjacent units upon each target unit, X is an $n \times k$ matrix of k exogenous measures, b the $n \times 1$ coefficients for each measure, and ε an $n \times 1$ vector of error terms. Although correcting for one form of spatial autocorrelation, this model is consistent with arguments that collision rates in one location are directly related to those in adjacent areas. If such direct effects are not to be expected, use of this model results in biased estimates of the statistical significance of observed effects. Only in the very rare instance where a collision in one location might set off subsequent collisions in another location, such as a large traffic 'pile-up', would this be the case.

An alternative model used by Gruenewald et al. (1996) makes a somewhat different assumption in which, using similar notation, errors in estimation between geographic units are spatially autocorrelated:

$$Y = Xb + (I - \rho W)^{-1} \varepsilon \quad (2)$$

where I is an $n \times n$ identity matrix. This model suggests that other unmeasured factors related to the clustering of pedestrian injuries (e.g. common patterns of pedestrian traffic between units) cause the rates of pedestrian collisions to exhibit spatial autocorrelation (in the form of spatially correlated measurement error). Should these factors be included in the model, it is expected that the degree of spatial autocorrelation, ρ , would go to 0. In the current study these kinds of factors would cause pedestrian injuries to cluster together and this model is used to correct for any resulting spatial autocorrelation.

As a technical point, the consequence of this argument is that the error variance-covariance matrix used to test statistical effects in the current study is consis-

tent with a model that, quite reasonably, implies the absence of any direct relationship between rates of pedestrian injury collisions across areas. Tests of effects using the error variance-covariance matrix implied by model (1), quite unreasonably, implies the existence of some direct relationship between rates of pedestrian injury collisions across these same areas. It should not surprise the reader that the results of the misapplication of these different statistical models, each consistent with a different set of assumed relationships between measured outcomes, results in biased statistical tests of effects.

1.2. Study goal

The goal of the current study was to elucidate the relationships between observed rates of pedestrian injury traffic collisions and measures of environmental and demographic characteristics of the City and County of San Francisco. It was expected that rates of pedestrian injury would be greatest in those areas of the city that provided greatest access to alcohol via restaurants, bars and retail outlets. It was also expected that this relationship would be strongest among pedestrians who had been drinking. Additional demographic and environmental measures of roadway complexity, traffic flow and population density were included to control for known effects of these variables in geographic studies of traffic related outcomes (Gruenewald et al., 1996).

2. Methods

The study examined rates of pedestrian injuries across 149 census tracts in the city of San Francisco. Over a single annual period, 1990, numbers of motor vehicle collisions in which a pedestrian was injured or killed were aggregated within these geographic units. The traffic injury data were obtained from the California Highway Patrol's Statewide Integrated Traffic Record System (SWITRS) for San Francisco County in 1990. This dataset includes all traffic collisions reported to the California Highway Patrol, and consists of both highway and city street collisions¹. All crashes in which a pedestrian was listed as a party involved in the incident were included. In 1990, there were 1137 such incidents in which 1227 persons were injured. Of these 1137 collisions, 1113 (97.9%) were successfully geocoded. These incidents were used to derive two

¹ Collisions could be reported by the San Francisco Police Department, the Sheriff's Office, or the California Highway Patrol. The design of SWITRS is such that only one reporting agency reports on any collision.

dependent measures: total injuries in pedestrian collisions ($n = 1227$) and injuries in pedestrian collisions in which the pedestrian was determined to have been drinking by police at the scene ($n = 102$, 8.3%). The sample size of the latter measure was constrained by the one year of available data, but did not pose a significant problem in the analysis (see below). The sample size of the latter measure, however, did constrain the selection of geographic units. Smaller units of analysis (e.g. census blocks) would have obviated application of current methods for the assessment of spatial autocorrelation.

Alcohol outlet data for 1990 were obtained from state licensing records provided by California Alcohol Beverage Control. Alcohol outlets were mapped by premise address and categorized by type of license into bars (license types 40, 42, and 48; $n = 505$, 88.7% of which were successfully geocoded), restaurants that serve alcohol (license types 41 and 47; $n = 1986$, 82.9% of which were successfully geocoded), and establishments licensed to sell alcohol that is carried off the premise ('off-premise outlets', license types 20 and 21; $n = 1246$, 89.4% of which were successfully geocoded).

Traffic flow data were obtained from a dataset used by the San Francisco Department of Public Works (DPW) to monitor street use (average daily traffic flow, ADT) and mapped by nearest street intersection ($n = 12\ 710$, 78.6% of which were successfully geocoded). These data were created using computerized traffic count apparatus that counted the number of vehicles traveling through the street in a 24-h period at many intersections throughout the city. These measurements were limited to weekday measurements, and therefore may not reflect weekend traffic patterns and may result in some over-estimation of the b -value relating traffic flow to crash rates. Streets were categorized by DPW according to street type (arterial, residential) and according to whether there was a bus route. ADT values for all city intersections for which there was no direct measurement were then calculated using the average of actual ADT measurements for that street type. There were several weaknesses to the use of this dataset. First, extrapolation from measured traffic flows to approximating 'average' traffic flows for each type of street is problematic, overstating traffic flow for low flow streets and understating traffic flow for high flow streets. Second, intersections at which traffic flows are known are not randomly distributed geographically, leaving some areas of San Francisco unmeasured. Traffic flow measurements are performed as deemed necessary by the Department of Parking and Traffic (DPT), usually because the intersections are considered either high volume or otherwise problematic (e.g. a location at which many motor vehicle collisions occur). The dataset is, nonetheless, viewed to be the best and most complete available, providing representative averages across

some 85 intersections per census tract.

Population data were obtained from the 1990 Census (US Department of Commerce, 1992) for each of the 149 census tracts. Cross-street density was calculated using a Map-Basic subroutine that counts all the street intersections within a census tract (based on America.dbf Digital MapFiles, MapInfo, 1994). The census data files contained numbers of Blacks, Hispanics, Asians, and non-Hispanic whites, in addition to the populations of various age cohorts, number of males, marital status, and education by census tract. These values were converted into proportions using the total population of the census tract as the denominator. In addition, a median income variable was used, which was calculated by the Census Bureau for each census tract. Persons in three age cohorts were also counted (0–15, 16–29 years, and 55 years or older) and proportions were calculated using the total population in the census tract. Ethnic group variables were examined in preliminary analyses, found to be unrelated to rates of pedestrian injury, and so excluded from the final analyses.

The dependent measures were transformed to provide estimates of the densities of pedestrian injuries within the geographic units of the city. Each variable was transformed by dividing the length of the roadway in each census tract (e.g. numbers of pedestrian injury collisions per kilometer of roadway). Since pedestrian collisions occur exclusively on or near streets, traffic flow takes place upon these streets, and community populations use these routes to move from place-to-place within the community, this was assumed to be a natural metric for the examination of rates of these events. The same metric was also applied to the alcohol availability measures and two other environmental variables (i.e. numbers of cross-streets and population). This procedure provided estimates of the numbers of bars, restaurants and off-premise establishments per kilometer of roadway, the number of cross-streets per kilometer of roadway and total population per kilometer of roadway. Thus, it was assumed that for a given aggregate rate of traffic flow, greater availability of alcohol per unit roadway length, greater road network complexity per unit roadway length, and greater population per unit roadway length would be related to greater pedestrian collisions per unit roadway length. The roadway system itself is assumed to be the link between traffic flow, alcohol availability, and exposure to the risks of pedestrian injury collisions. Reasonably, if there are few or no roads in an area, there will be few or no pedestrian injury collisions, regardless of resident population. In rural areas, more wide ranging roadway systems and small populations imply a low pedestrian injury rate per unit roadway length. As suggested by Gruenewald et al. (1996), the use of roadway length as the denominator for these measures reflects the obvious fact that exposure to possible pedestrian injury, access

to alcohol, and the packing of roadways and people within urban areas take place along the roadway system². A final logarithmic transformation of the dependent measures:

$$\ln[1 + (\text{pedestrian injuries})/(\text{roadway length})] \quad (3)$$

provided conditional normal distributions for analysis. This log-normal transform is appropriate for analyses of non-negative positively skewed rates and has been widely applied in geostatistical analyses of such outcome data (e.g. Scribner et al., 1994).

San Francisco County consists of 152 census tracts. Two census tracts are assigned to individual locations (prisons), and were removed from analysis because they had no roads. Another census tract is assigned to San Francisco Bay, which although it has a population, has no roads. During preliminary analyses two census tracts, those representing the Presidio and Golden Gate Park, were found to have extremely high leverage (i.e. observations taken on those units strongly skewed effects estimates from the models, Cooks distances exceeding 1.00, Cook and Weisberg, 1982; see also Gruenewald et al., 1996). The original observations for these areas were smoothed by averaging with observations from all adjacent census tracts. Prior to smoothing, these census tracts exhibited rather extreme characteristics. Each had a high traffic volume but very low population and roadway length (in 1990, the Presidio was a US Naval base with high vehicle traffic volume directly to and from the Golden Gate Bridge; Golden Gate Park is a large park with very low residential population, but very high vehicle and pedestrian traffic). An analysis of the Cook's distances of the residuals from preliminary analyses also revealed one other census tract as a high leverage observation, the Civic Center and performing arts area of the city. Here population densities were very small, but roadway length very large. In the final analyses, including those for the small sample of pedestrian injuries in which the police determined the pedestrian to have been drinking, no significant outliers or highly leveraged cases were detected.

Datasets were managed using Microsoft Excel and SPSS for Windows software packages. Data were aggregated by census tract using MapInfo GIS software. Pedestrian injuries were geocoded to the nearest street intersections, as reported in SWITRS data, and alcohol

outlets were geocoded according to street address. MapInfo was used to calculate variables such as number of cross-streets and length of roadway. It was also used to create a connection matrix indicating the spatial relationships between census tracts, considering as adjacent only those census tracts connected by some portion of the roadway system.

All geostatistical analyses were performed using proprietary Spatial Statistical System software developed at Prevention Research Center (Ponicki and Gruenewald, 1998). The analysis procedure consisted of, first, an examination of the correlation matrix among all variables and, second, a spatial regression analysis relating the dependent to the independent variables. Examination of the correlation matrix for all models revealed little collinearity among the independent measures (Pearson's $r \leq 0.30$). The spatial analysis model is actually a regression model that has been corrected for the error associated with spatial autocorrelation (Eq. (2) above). For each model, an ordinary least squares (OLS) regression analysis was conducted to obtain starting values for a generalized least squares (GLS) procedure that estimated the effects of the independent measures with a simultaneous statistical correction for autocorrelated error (ρ). For both dependent measures (all pedestrian injuries and alcohol-related pedestrian injuries), the performance of each group of variables was first measured (alcohol availability, environment, demographics without age, and age), then the results from the full model reported. The coefficients from the models are interpretable in a similar way as linear regression coefficients; coefficients that are significantly different from zero are said to be linearly associated with the dependent measure.

3. Results

Stepped into the model one at a time, Table 1 presents the performance of each group of variables in predicting pedestrian injuries in the City of San Francisco. Columns one and two present the name of each group of variables and their contribution to the model (Rao's likelihood ratio Chi-Square, ΔG^2). Using the spatial analysis (GLS) procedure discussed above, columns three, four and five, present the effects estimates for the environmental measures of bar, restaurant and off-premise alcohol outlet densities (effects indicated by 'b (bars)', 'b (rest's)', and 'b (off-premise)'). Column 6 presents the estimate from each model of the degree of spatial autocorrelation using the GLS estimator ('GLS ρ '). Column 7 presents a similar diagnostic based upon residuals from the OLS analysis without correction for spatial autocorrelation ('OLS Moran coefficient'). As shown, the spatial autocorrela

² This approach to analyzing pedestrian injury rates is intended to reflect the process by which individuals come to be involved in these events. Thus, the greater packing of people about the roadway system is assumed to increase the exposure of people to traffic related mishaps. The greater availability of alcohol along the roadway system is assumed to increase the numbers of drinking pedestrians and drivers at risk of involvement in pedestrian injury collisions.

tions observed in every analysis were positive and quite substantial. Without correction, this failure of unit independence would have led to considerable Type I errors. That is, many of the observed statistical relationships would have been identified as ‘significantly different from 0’ when, in truth, no such ‘significant’ relationships existed.

With regard to all pedestrian injuries, each class of variable (availability, environment, demographics and age) provides a significantly better fit to these data. This indicates that each group of variables, each taken as a whole, helps predict pedestrian injury rates. In addition, two types of alcohol availability, bars and off-premise outlets, when considered alone, are associated with pedestrian injuries. However, the addition of the environmental variables reduces these apparent effects, and subsequent addition of demographic variables and age further diminishes these associations.

Table 2 shows the coefficients of the full model relating each of the independent measures to the dependent variable, all pedestrian injuries. The table presents the name of each variable group, the specific measure tested, its coefficient, the asymptotic *t*-statistic testing its association to the dependent measure, and the *P*-value for each test. Six variables had significant associations with pedestrian injuries. Population density and the proportion of males both had significantly positive associations; higher population density and a predominance of males within geographic units were associated with higher rates of pedestrian injuries. Persons aged 0–15 and higher education had significantly negative associations; greater proportions of children and better educated populations were associated with lower rates of pedestrian injuries. Average daily traffic flow had a positive association with rates of injury; greater traffic flow was related to greater pedestrian injury rates. Unemployment had a positive association with injury density; greater unemployment was related to greater pedestrian injury rates.

The analysis presented in Table 2 was repeated for the dependent measure: all injuries in pedestrian collisions in which the pedestrian was reported to have been drinking. These collisions included any pedestrian who

had been drinking, regardless of whether the police reported an extent of impairment. This analysis was conducted to uncover specific relationships between alcohol availability and alcohol involvement in pedestrian injury collisions. Table 3 shows a significant relationship between bars per kilometer of roadway and had been drinking pedestrian collisions. This observation supports the expectation that increased outlet densities would be specifically related to increased alcohol-related pedestrian injuries.

4. Discussion

The results of this study demonstrate significant geographically based relationships between specific environmental and demographic characteristics of the City and County of San Francisco and pedestrian injuries. Injuries in pedestrian-involved collisions were most likely to occur in areas of the city with greater population density, with greater proportions of males, with lower proportions of children 0–15 years of age as residents, proportionately greater unemployment, and lower proportions of well educated residents (high school degree or better). In addition, injuries in pedestrian collisions were greater in areas of the city with greatest traffic flow and, in the case of injuries in which alcohol use by the pedestrian was implicated, where densities of bars were greatest. Specifically, the presence of a greater number of bars in a neighborhood was related to a greater rate of ‘had been drinking’ pedestrian injuries, regardless of whether the police reported an extent of obvious impairment.

The results of this study clearly demonstrate that geographically based studies may have significant problems with spatial autocorrelation. In this paper, an OLS regression model was initially used to estimate parameters and test the significance of relationships between variables. Then a Moran coefficient was used to test for the significance of spatial autocorrelated errors in the analyses and found to be significant in each case. The positive Moran coefficients in Table 1 indicate that Type I errors were more likely to result. For this reason, each analysis was again performed using a

Table 1
Geographic analysis results for pedestrian injuries in San Francisco by census tracts (*N* = 149)

Model	ΔG^2	<i>b</i> (bars)	<i>b</i> (rest's)	<i>b</i> (off-premise)	GLS ρ	OLS Moran coefficient
Constant	–	–	–	–	0.763 ^a	0.519 ^a
+ Alcohol availability	41.323 ^a	0.290 ^a	0.062	0.268 ^a	0.578 ^a	0.230 ^a
+ Environment	11.463 ^a	0.197	0.073	0.141	0.416 ^a	0.143 ^a
+ Demographics without age	11.749 ^a	0.133	0.076	0.097	0.448 ^a	0.150 ^a
+ Age	9.752 ^a	0.083	0.977	0.064	0.408 ^a	0.135 ^a

^a *P*-value < 0.05.

Table 2
b Coefficients for full model in analysis of all injuries in pedestrian collisions

Type of variable	Variable	<i>b</i> coefficient	<i>t</i> -statistic	<i>P</i> -value
Alcohol availability	Bars per kilometer roadway	0.083	0.634	0.263
	Restaurants per kilometer roadway	0.077	1.555	0.060
	Off-premise outlets per kilometer roadway	0.064	0.525	0.300
Environment	Cross-streets per kilometer roadway	0.103	1.429	0.077
	Average daily traffic flow × 1000	0.042	1.691	0.045 ^a
	Population per kilometer roadway × 1000	0.826	2.543	0.006 ^a
Demographics: age	Persons age 0–15 (proportion)	–3.935	–2.056	0.020 ^a
	Persons age 16–29 (proportion)	0.931	1.003	0.158
	Persons age 55 and up (proportion)	–0.880	–0.887	0.188
Demographics: other	Persons unemployed (proportion)	2.945	1.643	0.050 ^a
	Never married persons (proportion)	–1.122	–1.141	0.127
	Median income × 10 000	–0.022	–0.317	0.376
	Males (proportion)	2.432	2.208	0.014 ^{a0}
	High school graduate or higher (proportion)	–1.614	–2.262	0.012 ^a

^a $P \leq 0.05$.

regression model that provided a statistical correction for spatial autocorrelation. As shown in Table 1, with this correction, each additional set of explanatory variables improved the fit of the model. The positive Moran coefficient coupled with the systematic improvement in the fit of the model provides strong support for models that go beyond an examination of alcohol availability and injuries alone.

The interpretation of the individual and demographic effects observed in the study, as well as the suggestion of mechanisms by which certain population groups may experience higher rather than lower rates of pedestrian injuries, must proceed with caution. For example, lower education may be associated with work that takes place outside in the community, including a variety of occupations that require physical labor, thus exposing work-

ers to more roadway hazards. Likewise, the positive relationship between unemployment and rates of pedestrian injury may be associated with a greater level of outdoor activity and exposure to traffic risks by individuals who are unemployed. While this kind of reasoning may be appealing, especially in a highly urbanized setting such as San Francisco, it is purely speculative. Support for such arguments must be based upon clearly articulated theory, explicit measurement of the postulated variables and appropriate causal analyses.

The interpretation of the expected environmental effects observed in the study is more intuitively compelling. For example, the positive relationships of population density and traffic flow to pedestrian injury rates suggests that a greater focus on regulating both pedestrian activities and other roadway use in areas of

Table 3
b Coefficients for full model in analysis of all injuries in pedestrian collisions in which pedestrian had been drinking

Type of variable	Variable	<i>b</i> coefficient	<i>t</i> -statistic	<i>P</i> -value
Alcohol availability	Bars per kilometer roadway	0.399	1.910	0.028 ^a
	Restaurants per kilometer roadway	0.001	0.005	0.499
	Off-premise outlets per kilometer roadway	–0.049	–0.242	0.405
Environment	Cross-streets per kilometer roadway	0.151	1.412	0.079
	Average daily traffic flow × 1000	0.002	0.055	0.478
	Population per kilometer roadway × 1000	0.626	1.261	0.104
Demographics: age	Persons age 0–15 (proportion)	–3.822	–1.219	0.112
	Persons age 16–29 (proportion)	–0.106	–0.070	0.472
	Persons age 55 and up (proportion)	–1.000	–0.597	0.276
Demographics: other	Persons unemployed (proportion)	10.954	3.681	<0.001 ^a
	Never married persons (proportion)	–0.103	–0.064	0.475
	Median income × 10 000	–0.131	–1.155	0.124
	Males (proportion)	1.102	0.630	0.189
	High school graduate or higher (proportion)	1.035	0.882	0.189

^a $P \leq 0.05$.

the city where population and traffic flow are greatest may lead to a reduction in injuries. Similarly, the positive relationship of bar densities to pedestrian injury in 'had been drinking' collisions suggests that regulation of the availability of alcohol through neighborhood bars could have beneficial effects for the community at large. While it is feasible that investigating officers may be more likely to check the 'had been drinking box' when a bar is located near the collision site, the association of pedestrian injuries with bars suggests that pedestrians who had been drinking may be struck leaving or while spending time outside and around these establishments. It also suggests that pedestrian intoxication or impairment is a factor in causing these collisions. In both these cases, future research should elucidate in more detail the precise relationships between outlets and pedestrian collisions (e.g. estimating the proximity of one to the other). In any case, the results of the current research suggest that education and environmental prevention efforts intended to reduce rates of pedestrian injury should focus on aspects of traffic flow, neighborhood alcohol availability and raising community awareness about the risks associated with pedestrian alcohol impairment.

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Pedestrian risk decrease with pedestrian flow. A case study based on data from signalized intersections in Hamilton, Ontario

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Abstract

A unique database provided information on pedestrian accidents, intersection geometry and estimates of pedestrian and vehicle flows for the years 1983–1986 for approximately 300 signalized intersections in Hamilton, Ont., Canada. Pedestrian safety at semi-protected schemes, where left-turning vehicles face no opposing traffic but have potential conflicts with pedestrians, were compared with pedestrian safety at normal non-channelized signalized approaches, where right-turning vehicles have potential conflicts with pedestrians. Four different ways of estimating hourly flows for left- and right-turning vehicles were explored. Hourly flows were estimated for periods of 15 min, hours, two periods a day (a.m. and p.m.) and the 'daily' period (7 h). Parameter estimates were somewhat affected by the time period used for flow estimation. However, parameter estimates seem to be affected far more by the traffic pattern (left- or right-turning traffic), even though approaches were selected such that the situation for left- and right-turning turning traffic was similar (no opposing traffic, no advanced green or other separate phases and no channelization). Left-turning vehicles caused higher risks for pedestrians than right-turning vehicles. At low vehicular flows right turns and semi-protected left turns seemed to be equally safe for pedestrians. When risks for pedestrians were calculated as the expected number of reported pedestrian accidents per pedestrian, risk decreased with increasing pedestrian flows and increased with increasing vehicle flow. As risk decreases with increasing pedestrian flows, promoting walking will have a positive effect on pedestrian risk at signalized intersections. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Model; Safety; Pedestrian

1. Background and purpose

The scope of this study was twofold: (a) to explore how safety for pedestrians at conflict with left- and right-turning vehicles is influenced by pedestrian and vehicle flows and (b) to explore how the models are influenced by the choice of different time period for estimating pedestrians and vehicle flows.

The same data base was also used to analyze how typical schemes for accommodating left-turning vehicles influence safety for pedestrians (Quaye et al., 1993).

2. The data

The data gathering part of the project was started by Almuina (1989). His work focused on pedestrian accidents and left-turning vehicles at signalized intersections. As part of his work he prepared an Accident Database and an Intersection Geometry Database for the approximately 300 signalized intersections in the Regional Municipality of Hamilton–Wentworth (Region) in south central Ontario. The majority of the intersections are located in the city of Hamilton in a typical North American grid network with many one-way streets.

To enhance the chances of success of finding a 'pure' relation between pedestrian accidents and pedestrian and vehicle flows, a set of signalized approaches similar in most respects except for traffic flows and accident history were selected. For accidents involving *right-*

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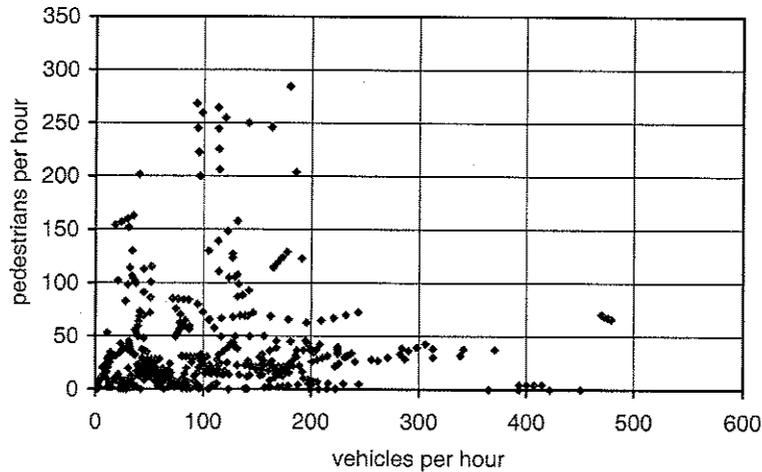


Fig. 1. Pair of flow estimates for the daily model for pedestrians and conflicting left-turning vehicles.

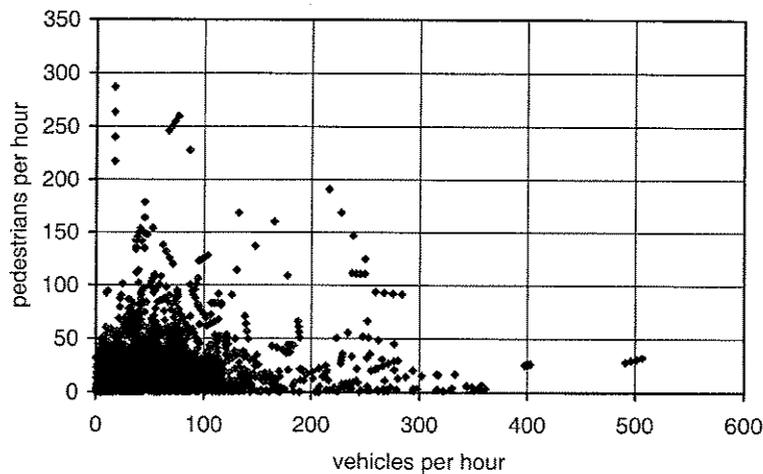


Fig. 2. Pair of flow estimates for the daily model for pedestrians and conflicting right-turning vehicles.

turning vehicles, data were collected for approaches which were not channelized, i.e. where there was no extra island to exclude right-turning traffic from signal control and allow them to yield to pedestrians. Altogether 749 approaches met the criteria for right-turning traffic.

For accidents involving *left-turning* vehicles, the criteria for selecting approaches were: no opposing traffic (so-called *semi-protected scheme*) and no advanced green or other separate phase for left-turning traffic.

Lack of opposing traffic in the approach could be due either to the missing leg in a three-way intersection, or to one-way traffic in the opposite approach leading away from the approach. Altogether 126 approaches met the criteria for left-turning traffic.

The decision as to which approaches fulfilled the criteria was based on information provided in the intersection geometry database and in the microfiches of the

intersection layouts. Information about advanced green or other separate phases for left-turning traffic was obtained by interviewing the engineer in charge of the city of Hamilton (Hart Solomon).

The city of Hamilton provided stream counts of vehicles and pedestrians for 15-min periods for 1983–1986. Typically there was one or two counts per year at each intersection. Counts were conducted from 7 to 10 a.m. and from 2 to 6 p.m. Monday–Friday and reported in 15-min periods. From these counts hourly flows were estimated for each 15-min period for all Mondays–Fridays during the study period (Quaye et al., 1993). These estimates were used as a basis for calculating average hourly flows for 15-min, hourly, a.m./p.m. and daily periods of 7 h. Fig. 1 shows pairs of estimates for the daily model of pedestrian flows and conflicting left-turning vehicles (on the cross-walk). Fig. 2 shows pairs of estimates of pedestrian flows and conflicting right-turning vehicles.

As the available accident data were for 1977–1986, flow estimates had to be extrapolated for the years 1977–1982 to correspond to the accident data. However, as these extrapolated estimates did not appear reliable, only the analysis of data from 1983 to 1986 is described here. To correspond to the available traffic count information, accidents should occur between 7 and 10 a.m. and between 2 and 6 p.m. Monday–Friday, and involve left-turning or right-turning vehicles and a pedestrian. Thus 63 accidents from 1977 to 1982 and 66 accidents from 1983 to 1986 remained for the analysis. As noted above, the analysis was restricted to data from 1983 to 1986, leaving a total of 66 accidents, 27 of them between left-turning vehicles and pedestrians and 39 between right-turning vehicles and pedestrians.

3. Method

For models with left-turning vehicles, accidents between pedestrians on the conflicting cross-walk and left-turning vehicles were related to corresponding vehicle and pedestrian flows. For models with right-turning vehicles, accidents between pedestrians on the conflicting cross-walk and right-turning vehicles were also related to corresponding vehicle and pedestrian flows.

1. Average daily flow for each year, *daily model*;
2. Average hourly flows during a.m. and p.m. periods for each year, i.e. 7–10 a.m. and 2–6 p.m. for 1983, 1984 etc., *a.m./p.m. model*;
3. Average hourly flows for each hour and year, i.e. 7–8, 1983, 8–9, 1983, etc., *hourly model* and
4. Average hourly flows for each 15-min period and year, i.e. 7–7:15, 1983, 7:15–7:30, 1983, etc., *15-min model*.

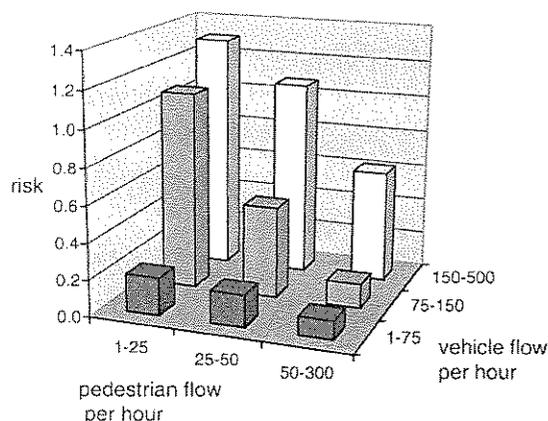


Fig. 3. Pedestrian risks estimated as police-reported accidents per hundred thousand pedestrians for various pedestrian and vehicle flows.

Estimates of average hourly flows were used for a minimum period of 15 min. Flow fluctuates between and within each cycle of a traffic signal system. Flows are systematically higher at the start of the green period. However, the time of the accident related to the start of the green period was not known, therefore it was not possible to study how this influences the safety of a pedestrian.

On the basis of exploratory analysis, one can suggest functional forms for expressions that fit the observations. Experience gained from previous work (Hauer et al., 1989) suggested that it could be reasonable to use the following form of the model:

$$x_i = b_0 F_1^{b_1} F_2^{b_2} + e_i = \hat{E}\{m\} + e_i \quad (1)$$

where for each case i , x_i is the observed number of accidents per unit of time; $\hat{E}\{m\}$ is the estimated number of accidents per unit of time for an 'average' intersection with flow F_1 and F_2 ; F_1 is the vehicle flow per hour (right-turning or left-turning); F_2 is the pedestrian flow per hour and e_i is the 'error' variable, the residual.

To reduce the effect of random variation the exploratory data analysis was done combining (adding) data for left- and right-turning traffic and calculating pedestrian risks as police reported accidents per hundred thousand pedestrians for various pedestrian and vehicle flows. Fig. 3 suggests that risks are high for pedestrian flows below 25 pedestrians per hour, unless vehicle flows are below 75 vehicles per hour.

The usual approach to the analysis is by multiple regression. To estimate parameters the functions in Eq. (1) were transformed with logarithmic values. The model, expressed in traditional form, can then be written:

$$y_i = \ln x_i = b_0 + b_1 \ln F_1 + b_2 \ln F_2 + e_i = m_i + e_i \quad (2)$$

Coefficients were estimated using the Generalized Linear Interactive Modeling (GLIM) software package (Aitkin et al., 1986) with which it is possible to choose an appropriate error distribution. In order to make the right choice it is necessary to understand the conceptual framework, which is discussed below.

Let the safety of a specific intersection be denoted m_i . Imagine a population of intersections that all have the *same traffic flows*. In this imaginary population, the m_i s would still vary from intersection to intersection because, although flows are identical, they involve different drivers in different cities, and so forth. Thus one can speak of the expected value or mean of the m s ($E\{m\}$) in this imaginary population of intersections with *identical* traffic flows. This mean of the m s is what describes the safety of a representative or an 'average' intersection for this imaginary population of intersections with a specific traffic flow. Similarly, one can speak of the variance of the m s.

A model was fitted to accident data, $E\{m\}$ as a function of traffic flow. This describes the m for some 'average' or representative intersection and how it varies with traffic flow. However, the data used for estimation were not for average intersections. Each accident count was for one specific intersection from the imaginary population of intersections with the same flows. It follows that the accident count must be considered as a Poisson random variable originating from a site with $E\{m_i\}$ as its expected value and that this m , in turn, is one of a distribution of m s characterized by $E\{m\}$ and $\text{Var}\{m\}$.

Thus, the distribution of accident counts around the $E\{m\}$ is one family of 'compound Poisson distributions.' In the special case where the distribution of m s in these imaginary populations can be described by a gamma probability density function, the distribution of accident counts around the $E\{m\}$ must be taken as a negative binomial, or in other words the error distribution e_i is a negative binomial (e.g. Leden, 1993).

The variance of accident counts s^2 is given by $\text{Var}\{m\} + E\{m\}$ or

$$\text{Vâr}\{m\} = s^2 - x \quad (3)$$

Note that the relationships are not affected by transformation to a logarithmic scale according to Eq. (2). In principle, these relationships can be used to estimate $\text{Var}\{m\}$ for different subsets of the data with almost the same value of $\hat{E}\{m\}$. ($\text{Vâr}\{y_i\}$ can be estimated as $\Sigma e_i^2/n$.) As there was not enough data for this, results from work already done were used (Hauer et al. (1991)). Hauer and Persaud (1987) found that there is often a relationship between $E\{m\}$ and $\text{Var}\{m\}$ and that it can usually be adequately represented by:

$$\text{Var}\{m\} = (E\{m\})^2/k \quad (4)$$

where k is the first parameter of the negative binomial distribution.

This means that the same relationship is valid for subsets of data as for data for the whole Gamma distribution. From Eq. (4) we get for the whole distribution:

$$\text{Var}\{m\} = k/\lambda^2 = k^2/(\lambda^2 k) = (E\{m\})^2/k$$

Hauer et al. (1991) confirmed the validity of this empirical finding for many groups of their database using Eq. (3).

Two methods can be used to estimate k : the method of moments and the maximum likelihood method. The latter was used. However, some examples calculated by both methods indicate that the two methods give similar results.

Maycock and Maher (1988) and Maher (1989) suggest the method of moments to estimate k . As in Eq. (2), e_i is the residual ($y_i - m_i$), then

$$E\{e^2\} = m_i + m_i^2/k$$

and an estimate of k is given by:

$$k = \Sigma \hat{m}_i^2 / \Sigma (e^2 - \hat{m}_i) \quad (5)$$

Hauer et al. (1991) describe the maximum likelihood method of estimating k . The iterative process of estimating $\text{Vâr}\{m\}$ begins by estimating provisional model parameters on the assumption that $\text{Vâr}\{m\} = 0$ or from some other starting guess. Once we had provisional parameter estimates, a value of k that maximizes the likelihood (L) of the data was estimated as follows: As shown above, the accident counts can be assumed to be distributed as a negative binomial; the parameter a for the negative binomial model can be expressed as a function of k and $E\{m_i\}$ using $E\{m_i\} = b/a$ and $\text{Var}\{m_i\} = b/a^2 = (E\{m_i\})^2/k$. Thus the probability of an accident count x_i for case number i can be written:

$$p(x_i) = [a/(a+1)]^k [k(k+1)\dots(k+x_i-1)/x_i!] \times [(a+1)^{x_i}] =$$

$$[k/E\{m_i\}]^k [k(k+1)\dots(k+x_i-1)]$$

$$\times / [x_i! (k/E\{m_i\} + 1)^{x_i + k}]$$

The likelihood function L describes the probability of having the actual outcome of accident counts $x_1, \dots, x_n, \dots, x_n$. If events are independent this probability can be calculated as $\Pi p(x_i)$. To facilitate calculation, $\ln L$ is calculated instead of L , thus:

$$\ln L = \ln \Pi p(x_i)$$

$$= k[\Sigma \ln(k/E\{m_i\})]$$

$$+ \Sigma [\ln(k) + \ln(k+1) + \dots + \ln(k+x_i-1)]$$

$$- \Sigma (x_i + k) \ln(1 + k/E\{m_i\}) + \text{constant}^1 \quad (6)$$

Since estimates for $E\{m_i\}$ were provided, it was easy to find the value of k which maximizes $\ln L$ (and L) by calculating $\ln L$ for different values of k . This value of k was then used to calculate $\text{Vâr}\{m\}$ from Eq. (4). The provisional error structure was revised, and model parameters were estimated anew. The process converges in two or three iterations.

As the number of accidents was small, the estimates of k were very uncertain, and in some cases it was not even possible to calculate an estimate of k which maximizes the likelihood. However, the estimates of the model parameters were not very sensitive to changes in k .

Four different ways of estimating hourly pedestrian and conflicting vehicle flows on each cross-walk were explored.

¹ Not dependent on k .

Table 1
Parameters for estimating expected number of police-reported accidents per day between left-turning vehicles and pedestrians

Flow period	\hat{b}_0	\hat{b}_1	\hat{b}_2	\hat{k}
1. Day	2.62×10^{-7}	1.19	0.331	2.2
2. a.m./p.m.	$2 \times 4.85 \times 10^{-8}$	1.37	0.346	*
3. Hour	$7 \times 1.82 \times 10^{-8}$	1.32	0.338	0.4
4. 15 min	$28 \times 3.61 \times 10^{-9}$	1.35	0.368	*

* Insufficient data to estimate k .

Table 2
Parameters for estimating expected number of police-reported accidents per day between right-turning vehicles and pedestrians

Flow period	\hat{b}_0	\hat{b}_1	\hat{b}_2	\hat{k}
1. Day	4.19×10^{-7}	0.864	0.475	*
3. a.m./p.m.	$2 \times 1.19 \times 10^{-7}$	0.919	0.570	*
4. Hour	$7 \times 4.08 \times 10^{-8}$	0.913	0.514	*
5. 15 min	$28 \times 2.43 \times 10^{-8}$	0.864	0.321	*

* Insufficient data to estimate k .

4. Results

In all the models estimated, the traffic flows were expressed as vehicles or pedestrians per hour. The dependent variable in each model was based on the number of police-reported accidents occurring in the corresponding time periods² (e.g. for the daily model the number of police-reported accidents per day during study hours 7–10 a.m. and 2–6 p.m. was used, etc.). The parameter estimates obtained after fitting the eight models using Eq. (7) and the Generalized Linear Interactive Modeling (GLIM) software package are given in Tables 1 and 2.

$$\hat{E}\{m\} = b_0 F_1^{b_1} F_2^{b_2} \quad (7)$$

where m is the expected number of accidents per unit of time at a certain intersection with an hourly right- or left-turning vehicular flow F_1 and hourly pedestrian flow F_2 , $\hat{E}\{m\}$ is the estimated number of accidents per unit of time at a certain intersection and b_0 , b_1 and b_2 are parameters to be estimated.

In Fig. 4, the expected number of police-reported pedestrian accidents per day is estimated for a pedestrian flow F_2 of 50 pedestrians per hour for various vehicle flows. Due to the small number of accidents the standard deviation, estimated by the formula $E\{m\}/k^{1/2}$, is relatively great. However it is likely that the expected number of pedestrian accidents per day ($E\{m\}$) is higher for left-turning than for right-turning vehicles (for the specified pedestrian flow).

² Each flow estimate corresponds to 5×52 periods (one for each weekday of a year).

It should be noted that the estimate from the daily model pertains to information aggregated over two a.m. or p.m. periods, 7 h of the day (specifically: 7–10 a.m. and 2–6 p.m.), or 28 15-min periods. Ideally, one would expect that multiplying the 15-min estimate of $E\{m\}$ by 28, the hourly estimate by seven or the a.m./p.m. estimate by two should yield the daily estimate.

In Figs. 4–7, the curves labeled 1 give the estimates of $E\{m\}$ based on the daily model, for various values of left- or right-turning vehicular flow F_1 , while curves 2, 3 and 4 are daily estimates obtained from the a.m./p.m., hourly and 15-min models, respectively, for the same traffic flow combinations.

If risks for pedestrians are calculated as the expected number of reported pedestrian accidents per pedestrian, i.e. Eq. (7) is divided by $7F_2$ (daily pedestrian flow³), the risks decrease with increasing pedestrian flow. Fig. 5 shows estimates for $F_1 = 50$ vehicles per hour and Fig. 6 for 500 vehicles per hour. For small vehicle flows ($F_1 = 50$ vehicles per hour), risk differences vanish between left- and right-turning models.

If risks for pedestrians are calculated as the expected number of reported pedestrian accidents per pedestrian, the risks increase with increasing vehicle flow, as seen in Fig. 7.

It is evident from Figs. 4–7 that estimates from the four different models give similar results. Quayle et al. (1993) conclude in their study concerning the effect of semi-protected (where left-turning vehicles face no opposing traffic but conflict with pedestrians) versus permissive schemes (where left-turning vehicles have to find suitable gaps in the opposing traffic) on the safety of pedestrians that it is not statistically incorrect to use any of the three models: 15-min, hourly or daily model, to explore the safety of an intersection over a time period other than that used in its estimation.

5. Summary and discussion

A unique database provided pedestrian accidents and estimates of pedestrian and vehicle flows for the years 1983–1986 for approximately 300 signalized intersections in Hamilton, Ont., Canada. Pedestrian safety at semi-protected schemes, where left-turning vehicles face no opposing traffic but have potential conflicts with pedestrians, were compared with pedestrian safety at normal non-channelized signalized approaches, where right-turning vehicles have potential conflicts with pedestrians.

Four different ways of estimating hourly flows for left- and right-turning vehicles by fitting daily, a.m./

³ Seven study hours per day.

p.m., hourly and 15-min models to the data were explored. Parameter estimates were affected by the time period used for flow estimation. However, parameter estimates seem to be affected much more by the traffic pattern (left- or right-turning traffic), even though approaches were selected such that the situation for left- and right-turning traffic was similar (no opposing traffic, no advanced green or other separate phases and no channelization). At low vehicular flows, right turns and semi-protected left turns tend to be equally safe for

pedestrians, but right turns are safer for pedestrians than semi-protected left turns (where left turning vehicles have to find suitable gaps in the opposing traffic) at high vehicular flows.

If risks for pedestrians are calculated as the expected number of reported pedestrian accidents per pedestrian, the risk decreases with increasing pedestrian flows. One explanation could be increased driver alertness with increasing pedestrian flow. As the risk decreases with increasing pedestrian flows, promoting walking will

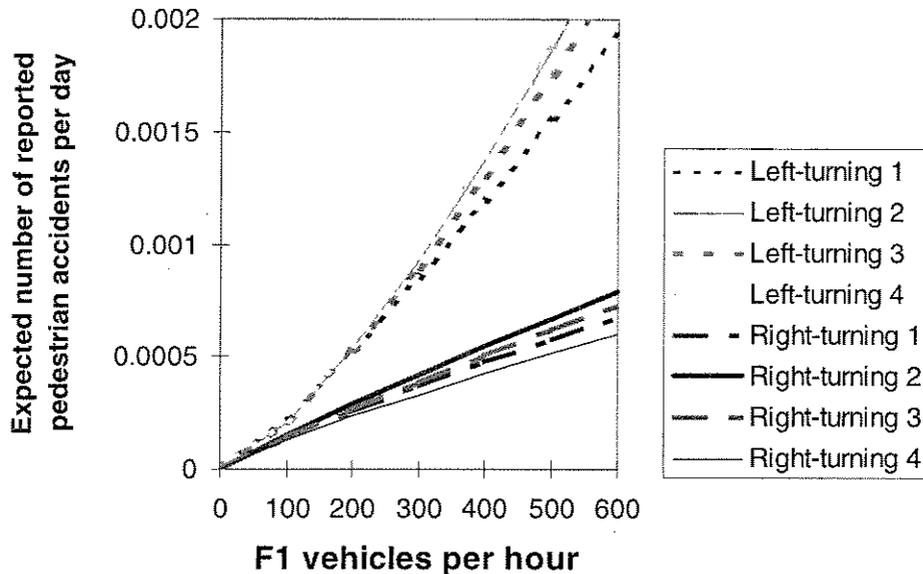


Fig. 4. Estimates of $E\{m\}$ for $F_2 = 50$ pedestrians per hour from the daily (1), a.m./p.m. (2), hourly (3) and 15-min (4) models for left- and right-turning vehicles.

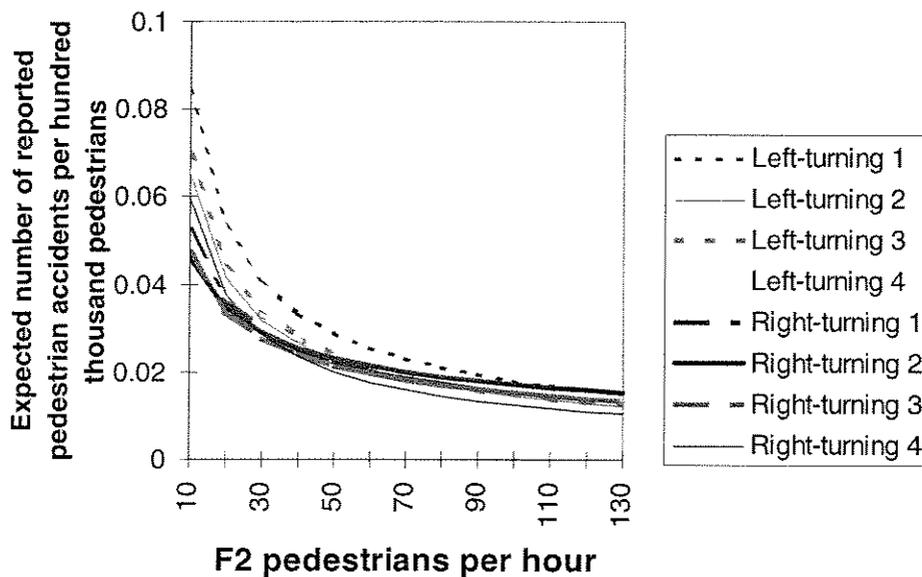


Fig. 5. Estimates of expected number of reported pedestrian accidents per day for $F_1 = 50$ vehicles per hour from daily (1), a.m./p.m. (2), hourly (3) and 15-min (4) models for left- and right-turning vehicles.

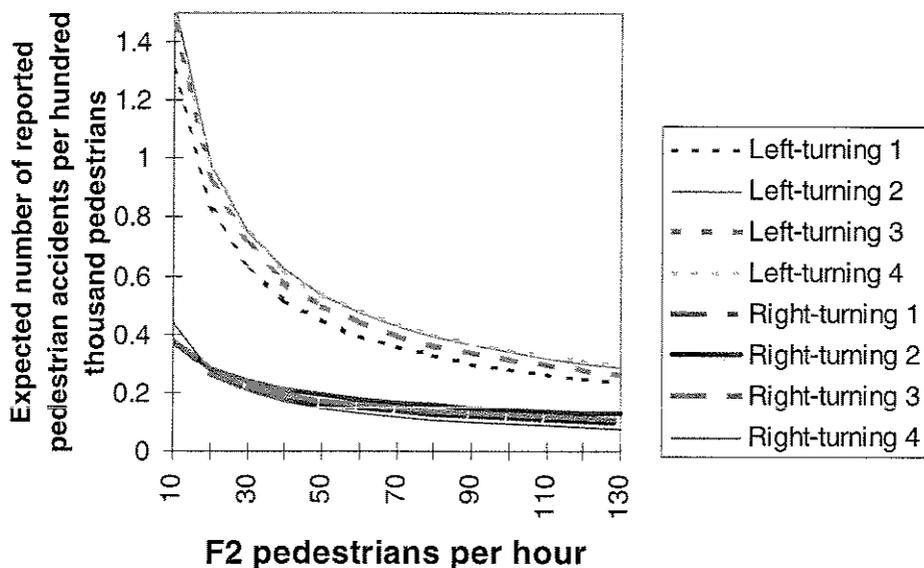


Fig. 6. Estimates of expected number of reported pedestrian accidents per pedestrian for $F_1 = 500$ vehicles per hour from the daily (1), a.m./p.m. (2), hourly (3) and 15-min (4) models for left- and right-turning vehicles.

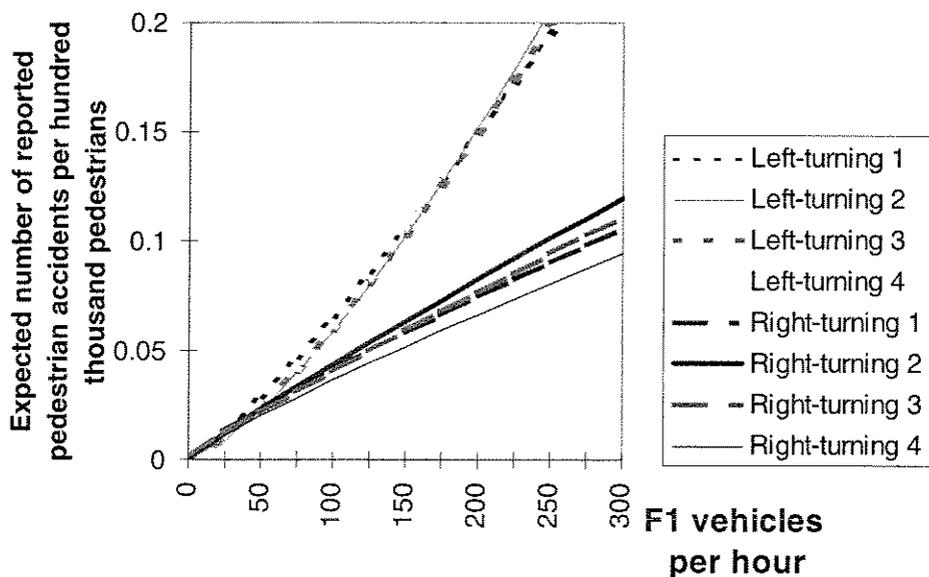


Fig. 7. Estimates of expected number of reported pedestrian accidents per pedestrian for $F_2 = 50$ pedestrians per hour from the daily (1), a.m./p.m. (2), hourly (3) and 15-min (4) models for left- and right-turning vehicles.

have a positive effect on pedestrian risk at signalized intersections. However, an increased pedestrian flow might lead to more pedestrian accidents if promotion is not accompanied by appropriate safety measures, such as speed-reducing devices and increased surveillance of red light running and walking.

Ekman (1996) found for 95 non-signalized intersections in Malmö and Lund in Sweden that the rate of pedestrian conflicts per pedestrian was not influenced by pedestrian flow. According to Ekman this could be interpreted as follows: "The individual pedestrian does

not seem to benefit from the presence of other pedestrians. Another interpretation is that the vehicle drivers do expect pedestrians (at least if the pedestrian flow exceeds 30 pedestrians per hour)." Ekman found that the rate of bicycle conflicts per bicyclist decreases with increasing bicycle flow and concluded that the level of bicycle flow is much more important for bicycle risk than the level of car exposure.

Ekman also found (for the 95 non-signalized intersections) that if risks for pedestrians are calculated as the expected number of reported pedestrian accidents or

conflicts per pedestrian, the risk increases with increased vehicle flow, i.e. the results are similar to those in Fig. 7.

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The Role of the Physical and Traffic Environment in Child Pedestrian Injuries

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ABSTRACT. *Objective.* To identify environmental risk factors on residential streets for pediatric pedestrian injuries.

Method. The sample consisted of 39 Latino children 0 to 14 years of age injured as pedestrians on a street in the same block as their home and 62 randomly selected neighborhood control subjects matched to the case by city, age or year of birth, ethnicity, and gender. The cases were identified from a population-based hospital and coroner's office surveillance system established in north-central Orange County, CA. Neighborhood assessments were performed from 3:45 PM to 5 PM, a fairly active time for young pedestrians. The cases were compared with the controls using conditional logistic regressions; in this study design, the odds ratios were interpreted as estimates of the incidence rate ratios.

Results. Children living in a multifamily residence had an incidence of injury greater than that of children living in single-family residence on a single lot (odds ratio [OR] 3.1, 95% confidence interval [CI] 1.3–7.6). The ORs in the highest category were several times those in the lowest category for both parked vehicles (OR 9.6, 95% CI 2.6–36) and total number of pedestrians observed (OR 4.7, 95% CI 1.4–16). Vehicle parking, total pedestrians, vehicular traffic volume, and speed were examined in a multivariate model. The association of vehicles parked on the street with pedestrian injury risk remained significant. Unlike the crude results, progressively greater vehicular speed was associated with a marked increase in risk. Progressively higher vehicular traffic volume was associated with a progressively lower adjusted OR.

Conclusion. The results of this analysis would indicate that residential streets with a high proportion of multifamily residences, over 50% of the curb occupied with parked vehicles, and a large number of pedestrians observed in unenclosed areas should receive high priority for intervention programs to reduce pediatric pedestrian injuries. The analysis suggests that on these streets, measures to reduce the amount of street parking (thus increasing visibility) and reductions in vehicular speed should be considered to decrease pedestrian injuries.

Pediatrics 1996;98:1096–1103; *pedestrian injury, childhood, environment, risk factors, case-control study.*

Pedestrian injuries are a leading cause of traumatic death for children younger than 10 years old in the United States. Pedestrian injuries, which are more severe and have a higher case-fatality rate than other types of motor vehicle-related injuries, resulted in 1102 deaths to children in 1990.^{1–3} Police reports have been used to produce a national estimate of approximately 51 000 nonfatal injuries annually.¹ However, this may be an underestimate, due to underreporting by police of those events that occur in nontraffic locations, eg, driveways and on private property.^{4,5} Although marked decreases in motor vehicle-related injuries and deaths have been realized in the last decade, the identification of risk factors and the development of effective measures for reduction of pedestrian injuries remain an area requiring further investigation.

Certain populations have been found to be at high risk for pedestrian injury. Pedestrian injury death rates for non-white children are 1.5 times the rates for white children.¹ In New Mexico, Native American children had a death rate 2.5 times that of other ethnic/racial groups.⁶ Several studies using police data have found the highest rates of pedestrian injury to be in low-income minority residential areas.^{7,8} In southern California, a population-based surveillance study of hospitalized and fatally injured children found the rate of pedestrian injury for Latino children to be 2.05 times that of non-Hispanic white children when controlled by census block group.⁹

Most of the pedestrian motor vehicle collisions involving children occur on residential streets at midblock locations.^{10–13} Rivara and Barber⁷ found that more than half of the pedestrian injuries were not at intersections. A large proportion of these injuries occur within a short distance of the child's residence, frequently when the child darts into the street during play.^{12–18}

Several environmental factors have been identified as risk factors for pediatric pedestrian injuries in a number of studies, using different methodologies, eg, police reports, surveillance systems, and controlled studies of cases as well as sites. Vehicle volume and number of parked vehicles on the streets are associated with an increase in the risk of pedestrian events.^{12,14,19} Mueller et al¹⁴ found an increased risk of pedestrian injury with higher posted speeds.

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However, Roberts et al¹² found that the middle range of vehicle speed (40–49 km/h) had the highest risk, probably because of less exposure of children to streets with high speeds, ie, less crossing.¹² In the same report, a steady increase in odds ratio was associated with increasing traffic volume. Mueller et al¹⁴ reported an increased risk with more than two travel lanes on the road. Both the number of parked vehicles and the proportion of the curb with parked vehicles have consistently been found to be risk factors for pedestrian injury and are frequently cited as factors in descriptions of child pedestrian injury.^{12,15,19}

Population density of children (children/acre), household crowding, housing density, and multi-family dwellings have also been identified as risk factors for pediatric pedestrian injuries.^{7,8,14,17} Absence of play areas for children has been identified as a risk factor; but, absence of a fence around the home was not associated with increased risk of pedestrian injury.¹⁴

The purpose of this study was to identify environmental risk factors on residential neighborhood streets for pediatric pedestrian injuries, using a case-control study of Latino children in southern California. The focus of this study was the street environment in front of children's homes, a common location for childhood pedestrian injuries. The sidewalk, parkway, and street in front of children's homes can serve as an extension of a family's living space and the child's play area. Characteristics of this environment that are associated with childhood pedestrian injuries may be useful both to identify streets for intervention and to suggest environmental modifications that may reduce the risk of childhood pedestrian injuries.

METHODS

Cases were identified from a population-based hospital and coroner's office surveillance system established in north-central Orange County, CA to identify children younger than 15 years old who sustained injuries resulting in hospitalization or death. The study area consisted of seven contiguous cities (Santa Ana, Anaheim, Fountain Valley, Garden Grove, Orange, Villa Park, and Tustin), and one census designed place (Tustin Foothills). Adjacent unincorporated areas with mail service from post offices in the seven cities were included.

Pedestrian cases were defined as children 0 to 14 years old, hospitalized as a result of an injury caused by conflict with a motor vehicle from July 1, 1991 through June 30, 1993. Children using a pedestrian conveyance (such as roller skates or a skateboard) or a tricycle (but not a bicycle) were included. A parent or guardian of the injured child was contacted and informed consent was sought for assessments of the injury location and the injured child's neighborhood. In addition, an interview, approximately 1 hour in length, was conducted with the parent or guardian in the hospital or patient's home. (The interview data were not used in this analysis).

Because the pedestrian injury rate for Latino children was over twice that of non-Latino white children (controlled by census block group), the case-control study of pedestrian injuries was designed to only include Latino children.⁴ Latino children were defined as children with one or two parents who identified themselves as Hispanic or Latino.

One control was obtained for each Latino case. A second control was obtained if an appropriate child could be identified within 1 month of the injury event. Controls were required to have one or two Latino parents, and were matched to the case by city, year of age or year of birth, and gender. From the city where the

case resided, a census tract was randomly selected using a list of census tracts weighted by the number of Latino residents. City blocks were randomly selected and a starting residence was randomly selected for each block. A bilingual field worker began at the designated residence on the first block and proceeded clockwise around the block until a control of the correct age or birth year and gender was obtained. The field worker returned to residences where there was no answer, or no responsible adult present. If necessary, additional blocks were canvassed. If no control was found after 95 residences were canvassed, another census tract was selected. If an appropriate control was found, informed consent was sought for an assessment of the neighborhood and an interview, which was conducted with the parent or guardian.

For this analysis, Latino children were selected if they were injured as pedestrians in the street in the same block as their homes. Data on environmental factors were compared with data obtained on the neighborhood environments of matched control subjects. Seven non-Latino children injured as pedestrians detected in the surveillance study met the selection criteria for the sample for this study, but could not be included in the analysis because no appropriate controls were obtained. However, they were not significantly different from the Latino cases for any of the variables examined in this analysis.

Environmental Assessment

For both pedestrian cases and controls, neighborhood environmental assessments were conducted Monday through Thursday between 3:45 and 5:00 PM. These days and hours were chosen to represent overall conditions in the neighborhood, and to provide safe, daylight conditions for the field workers. Environmental assessments were conducted a median of 6 days after the injury (97% within 30 days) for the case, and a median of 19 days after the case's injury (73% within 30 days) for controls.

During a pilot study, four field workers were trained to conduct neighborhood assessments and the methods were standardized. To improve the estimation of age, the field workers asked children their ages during the pilot study.

The field workers worked in teams of two during the data collection. The neighborhood environmental assessment characterized the child's residence, including play areas; land use; proximity to roadways and physical attributes of those roadways; vehicle volume, speed and parking; and the number of pedestrians present and their ages and movements. Multiple family residence was defined as any residence with more than one housing unit on one lot, including apartments, condominiums, duplexes, and two houses on a single lot. A play area was defined as any grassy or open area, including a courtyard.

Pedestrian and vehicular traffic, and parked vehicles were assessed on the street of the residence within 250 feet of the residence, unless the street ended in a shorter distance. Distances were measured with a 12-inch circumference measuring wheel (Measure Master 12, Rolotape Corporation, Spokane, WA). Counts of vehicular traffic, pedestrians present, specific types of pedestrians, and pedestrian behavior were made over a 15-minute period. All pedestrians that were easily visible and not within enclosed areas were counted, whether or not they entered the street. The age of pedestrians was estimated from their appearance.

Pedestrian counts and counts of parked vehicles made over distances of less than 500 feet were multiplied by the ratio of 500 to the observation distance in feet. Although all pedestrian and vehicular traffic counts and speed measurements were made between 3:45 and 5:00 PM, several variables had significant trends with time. These measurements were adjusted to remove the effect of time. The results of nonlinear regression using an exponential function of starting time were used to correct these measurements to 3:45 PM, the modal starting time for the measurements. Counts were rounded to the nearest unit after correction.

Pedestrian counts are presented in three ranges ≤ 14 persons per 15 minutes, 15 to 29 persons per 15 minutes, and ≥ 30 persons per 15 minutes, which correspond to < 1 , 1 to 1.9, and 2 or more persons per minute. The 15-minute counts were not converted to hourly rates because they included many individuals who were visible for an extended period of time, so that hourly counts of pedestrians could not be accurately projected from 15-minute counts.

Counts of vehicular traffic were converted to counts per hour.

Vehicular traffic is presented as <50 vehicles per hour, 50 to 99 vehicles per hour, 100 to 249 vehicles per hour, and ≥ 250 vehicles per hour. The first three categories combined correspond to Roberts¹² smallest category. These categories represent smaller traffic volumes than the categories used by others^{12,13} because this study was limited to those events occurring in front of the child's home, which included very few streets with large traffic volumes.

The number of vehicles parked on the street was presented as 0 to 11 vehicles per 500 feet, 12 to 17 vehicles per 500 feet, and ≥ 18 vehicles per 500 feet. These categories correspond approximately to 0% to 49%, 50% to 74%, and 75% to 100% of the available curb occupied by parked vehicles.

Vehicle travel times over a fixed distance were used to calculate speed. A distance of 200 feet was used if possible. If the vehicle stream stopped within 200 feet of the residence, vehicles were timed from the point where the vehicles stopped to a point in front of the residence. If there were multiple vehicle paths, vehicles were timed over the common vehicle path. If the common vehicle path was less than 50 feet, vehicles were timed over the most frequent vehicle path. If there was no vehicle path of at least 50 feet without a stop, vehicles were not timed in that direction. Six lead or lone vehicles in each direction were timed with a stop watch, unless that number could not be obtained by 6 pm. Vehicle speed was calculated from the measured distance and time. The mean speed for each direction was weighted by the traffic in that direction to obtain a final estimate of speed.

Vehicle speed is presented in three ranges: <25 miles per hour, 25 to 29.9 miles per hour, and ≥ 30 miles per hour. These are the same ranges used by Mueller and colleagues¹⁴ and are very similar to the metric system ranges used by Roberts et al.¹² If there was no vehicle path of at least 50 feet in either direction, it was assumed that the vehicles were moving slowly, and the vehicle speed was assigned to <25 miles per hour.

Width of roadway was categorized as two lanes <38 feet, two lanes ≥ 38 feet, and three or more lanes. Currently, new local residential streets must be 36 feet wide, and new residential collector streets, which also carry traffic from adjacent residential areas, must be 40 feet wide. These two widths were the widths most frequently observed in our assessments. Thus, two lane streets were divided into those less than 38 feet in width and those 38 feet or wider. Streets with three or more lanes comprised a third category.

To determine how well neighborhood environmental measurements represented the conditions at the time and location of injury, they were compared with measurements made at the location of the injury on the same day of the week and the same time as the injury, 1 week after the injury. These comparisons were restricted to injuries that occurred on the street, rather than a driveway, alley, or parking lot. Pearson correlation coefficients were calculated. These coefficients reflect any differences between the street in front of the home and the injury location, as well as difference in traffic conditions between weekday afternoons and the day of week and time of the injury.

Analysis

The effects of the various environmental factors on the risk of pedestrian injury were estimated using conditional logistic regression in the Egret interactive modeling package (Statistics and Epidemiology Research Corporation, Seattle, WA). Because incident cases were used and the controls were identified contemporaneously, the odds ratios may be interpreted as estimates of the incidence rate ratios.²⁰

Odds ratios and confidence intervals were calculated comparing each range of each continuous variable to the lowest range. *P* values for each variable were obtained by comparing the deviance score for the statistical model that includes that variable to the deviance score without that variable.

RESULTS

A total of 112 Latino children were injured as pedestrians; 5 were fatally injured. Neighborhood environmental assessments were obtained for 104 (97%) of the 107 nonfatally injured children. Seventy-four of these injuries occurred on the street, and 30 occurred in a driveway, alley, or parking lot.

Neighborhood environmental measurements were compared with measurements made at the scene of the injury for the 74 children who were injured in a street (Table 1). Only for injuries occurring in the same block (and on the same street) as the child's home were the two sets of measurements significantly correlated. For injuries occurring at a greater distance, the correlation coefficients were neither significant nor consistently positive. Thirteen of 14 injuries reported as occurring in the next block from home occurred on a different street from the residence, which may explain the low correlation coefficients for this group of injuries.

The analysis was restricted to the 39 pedestrian injuries occurring in the same block as the child's home because only these measurements were closely related to the injury site measurements. The environmental assessments for the homes of these children were compared with environmental assessments obtained in front of the homes of 62 matched control subjects.

The characteristics of the cases are shown in Table 2. Twenty-two (56%) of the children were 1 to 4 years old and 14 (41%) were 5 to 9 years old. The only child in the age category of 10 to 14 was 10 years old. Twenty-eight (72%) of the children were boys. Twenty-six (66%) of the injuries occurred from 3:00 to 8:59 PM, and 19 (49%) occurred on a Friday or Saturday. All of the injuries occurred midblock.

Residence and play area variables are shown in Table 3. Children living in a multiple family residence had an incidence of injury more than three times that of children living in single family residence on a single lot. (Forty [78%] of the multifamily residences were apartments with three or more units.) The lack of a play area, the lack of an enclosed play area, and the lack of a closed barrier between the front door and the street were not associated with the risk of child pedestrian injury. However, almost all the residences had some type of play area, including courtyards.

The primary land use was very similar to the residence of the child. Ninety-six percent of cases and controls in single family homes on a single lot and 71% of cases and controls in multiple family residences lived in neighborhoods where their type of residence was the primary land use. Two cases and one control lived in neighborhoods that were not primarily residential.

TABLE 1. Correlation Coefficients Between Neighborhood Environmental Measurements and Measurements at the Scene of the Injury, by Distance From Home, for Those Cases Occurring on the Street

	Same Block as Home	Next Block	<1/2 Mile to 1 Mile	1 Mile or More
n	39	14	10	11
Width of roadway	1.00*	-0.35	-0.08	-0.42
Vehicular traffic	0.85*	-0.25	-0.28	-0.18
Vehicular speed	0.74*	-0.10	0.20	0.00
Parked vehicles	0.59*	0.04	-0.05	-0.04
Total pedestrians observed	0.78*	0.19	0.30	-0.09

* *P* < 0.01.

TABLE 2. Characteristics of Latino Children Injured as Pedestrians in the Street in the Same Block as Their Home (n = 39)

Variable	Value	No. of Cases	%
Age	<1 y	0	0
	1-4 y	22	56
	5-9 y	16	41
	10-14 y	1	3
Gender	Male	28	72
	Female	11	28
Time of injury	6-8:59 AM	1	3
	9-11:59 AM	6	15
	noon-2:59 PM	5	13
	3-5:59 PM	13	33
	6-8:59 PM	13	33
	9-11:59 PM	1	3
Day of wk	Sunday	3	8
	Monday	4	10
	Tuesday	1	3
	Wednesday	7	18
	Thursday	5	13
	Friday	8	21
	Saturday	11	28
Total		39	100

The odds ratios for variables describing the street and vehicular and pedestrian traffic are shown in Table 4. The odds ratios was greater for wide two lane streets than for narrow two lane streets or streets with three or more lanes. Neither vehicular traffic volume nor speed was significantly associated with childhood pedestrian injuries. (The speed limit was more than 25 miles per hour for only 12 (12%) of 101 case and control environmental assessments). The rate of pedestrian injury increased with greater numbers of parked vehicles and with each category of the total number of pedestrians observed. For both parked vehicles and total number of pedestrians observed, the odds ratio in the highest category was several times that in the lowest category.

Table 5 shows the odds ratios associated with counts of pedestrians by four age categories. These pedestrians included all persons outside and easily visible from the street, and were not restricted to persons entering or crossing the street. The numbers of pedestrians age 15 or older were larger than the numbers in the other age-categories, and the counts of these pedestrians were grouped into larger ranges. For each age category, a larger number of pedestrians was associated with a higher odds ratio. This association was significant for counts of pedestrians age 9 to 14 and pedestrians age 15 or older.

The association of specific observed pedestrian behaviors on the risk of childhood pedestrian injury are shown in Table 6. Streets where pedestrians were observed crossing at intersections or crosswalks were at lower risk. However, observed midblock crossings and the presence of vendors were not found to be associated with childhood pedestrian injury risk. The number of pedestrians entering or leaving a vehicle parked on the street was associated with an increased risk of child pedestrian injury. However, this association was no longer significant when adjusted by the number of vehicles parked on the street and total number of pedestrians observed (not shown).

Four variables that are directly related to the movements of pedestrians and vehicles were examined in a multivariate model. Two of these variables, vehicles parked on the street and total pedestrians, were significantly associated with childhood pedestrian injury in our data and two variables, vehicular traffic and vehicular speed, have been associated with childhood pedestrian injury in other reports. Multiple family residence and width of roadway were significantly related to childhood pedestrian injury in our data, but were not included because they were closely related to other variables in the multivariate analysis. (Multifamily residence is significantly related to vehicles parked on the street and to total pedestrians observed; width of roadway is significantly related to vehicular traffic and vehicles parked on the streets).

As shown in Table 7, the association of vehicles parked on the street with pedestrian injury risk remained significant, and the adjusted odds ratios were similar to the crude odds ratios shown in Table 4. Unlike the crude results, progressively greater vehicular speed was associated with a marked increase in risk. Progressively greater vehicular traffic volume was associated with a progressively lower adjusted odds ratio. Although the adjusted odds ratios for total pedestrians observed are only slightly lower than the crude odds ratios shown in Table 4, the variable is not significant in the multivariate model.

DISCUSSION

Frequently, children, especially young children, are struck by motor vehicles while walking or playing in or near the street where they live.^{12-16,18} This study was designed to identify environmental risk factors for pediatric pedestrian injuries in residential neighborhoods. This report differs from previous case-control studies of child pedestrian injuries and injury sites in that the study was limited to those cases occurring on the street in front of the child's residence; and, measures of neighborhood levels of pedestrian volume and pedestrian behaviors were included.^{12,14} In contrast to previous studies, a majority of the injured children were younger, 1 to 4 years old.^{12,14,18,19}

Environmental Risk Factors for Pediatric Pedestrian Injury

Roadway Factors

The number of parked vehicles on the street was the strongest risk factor for pedestrian injury occurring on residential streets. This finding is consistent with previous research that found that larger numbers of parked vehicles are associated with a higher rate of childhood pedestrian injury.^{12,14} It is widely recognized that parked vehicles obscure the vision of both drivers and pedestrians, which contributes to the frequently cited "dart-out" or "sudden appearance pedestrian injury."^{10,15}

Higher vehicular speeds, in the univariate analysis, were not associated with child pedestrian injury indicating that residential streets that had vehicles traveling at higher speeds were not at

TABLE 3. Number (%) of Cases and of Controls, Crude Odds Ratio, 95% Confidence Intervals, and *P* Values for Variables Describing the Residence and Play Area

Variable	No. (%) of Cases	No. (%) of Controls	Crude Odds Ratio	95% Confidence Interval	<i>P</i>
Multiple family residence	26 (67)	25 (40)	3.1	1.3-7.6	.009
No play area	3 (8)	2 (3)	2.6	0.4-16	.29
No enclosed play area	11 (28)	20 (32)	0.8	0.3-2.1	.71
No closed barrier between front door and street	30 (79)*	42 (68)	1.5	0.6-3.9	.42

* This variable was missing for one case.

TABLE 4. No. (%) of Cases and of Controls, Crude Odds Ratio, 95% Confidence Intervals (CI), and *P* Values for Variables Describing the Street, Vehicles, and Pedestrians

Variable	Range	No. (%) of Cases	No. (%) of Controls	Crude Odds Ratio	95% CI	<i>P</i>
Width of roadway	2 lanes, <38 ft	20 (51)	38 (61)	1.0		.02
	2 lanes, ≥38 ft	18 (46)	14 (23)	2.5	0.9-6.7	
	3 or more lanes	1 (3)	10 (16)	0.2	0.03-2.0	
Vehicular traffic	<50 vehicles/h	9 (23)	17 (27)	1.0		.07
	50-99 vehicles/h	15 (39)	15 (24)	2.1	0.7-5.8	
	100-249 vehicles/h	12 (31)	13 (21)	1.9	0.6-5.9	
	≥250 vehicles/h	3 (8)	17 (27)	0.4	0.1-1.8	
Vehicular speed	<25 miles/h	15 (39)	30 (48)	1.0		.18
	25-29.9 miles/h	18 (46)	17 (27)	2.2	0.81-5.7	
	≥30 miles/h	6 (15)	15 (24)	0.9	0.3-2.9	
Vehicles parked on the street	0-11 vehicles/500 ft	7 (18)	39 (63)	1.0		<.001
	12-17 vehicles/500 ft	14 (36)	12 (19)	8.6	2.1-35	
	≥18 vehicles/500 ft	18 (46)	11 (18)	9.6	2.6-36	
Total pedestrians observed	≤14 persons/15 min	5 (13)	19 (31)	1.0		.02
	15-29 persons/15 min	12 (31)	24 (39)	1.6	0.4-6.0	
	≥30 persons/15 min	22 (56)	19 (31)	4.7	1.4-16	

TABLE 5. No. (%) of Cases and of Controls, Crude Odds Ratio, 95% Confidence Intervals (CI), and *P* Values for Pedestrian Counts

Variable	Range	No. (%) of Observations Case Neighborhoods	No. (%) of Observations Control Neighborhoods	Crude Odds Ratio	95% CI	<i>P</i>
Pedestrians age 0-4 y*	0	11 (29)	27 (44)	1.0		.42
	1-2	14 (37)	21 (34)	1.5	0.6-4.1	
	≥3	13 (34)	14 (23)	2.0	0.7-5.7	
Pedestrians age 5-8 y	0	5 (13)	15 (24)	1.0		.21
	1-2	11 (28)	20 (32)	1.7	0.5-6.1	
	≥3	23 (59)	27 (44)	2.8	0.8-9.6	
Pedestrians age 9-14 y	0	1 (3)	15 (24)	1.0		.01
	1-2	15 (39)	18 (29)	9.1	1.1-74	
	≥3	23 (59)	29 (47)	10.1	1.2-82	
Pedestrians age ≥15 y	0-9	6 (15)	15 (24)	1.0		.008
	10-19	10 (26)	28 (45)	0.9	0.3-2.7	
	≥20	23 (59)	19 (31)	3.8	1.1-12	

* This variable was missing for one case.

increased risk in the absence of other environmental risk factors. However, speed became a significant risk factor when controlling for vehicular volume, number of parked vehicles, and number of pedestrians. Roberts and colleagues¹² found an increased risk with the middle category of vehicular speed, which corresponds quite closely with the middle category of speed used here. The crude odds ratios reported here were similar to theirs, but the confidence intervals reported here were broader. However, in our multivariate model, the odds ratio increased steeply with increasing speed on these residential streets. In contrast to Roberts, our study included only those cases that occurred on residential streets where speeds tend to be lower than on busier streets.

Increased traffic volume was not associated with a greater risk of child pedestrian injury, and in the multivariate analysis there was a lower odds ratios with increasing traffic volume. However, previous studies found that vehicular traffic volume has been associated with an increased rate of child pedestrian injury indicating that more traffic does create more opportunities for a child pedestrian to be injured.^{12,14} Thus, the lack of a positive association in our study with vehicular volume suggests that parents and caregivers may respond appropriately to increased traffic in front of their homes. Young children may be better supervised under conditions of heavier traffic. The effect of traffic volume on the risk of injury to older children crossing major streets may be quite different.

TABLE 6. No. (%) of Cases and of Controls, Crude Odds Ratio, 95% Confidence Intervals (CI), and *P* Values for Pedestrian Behaviors

Variable	Range	No. (%) of Observations Case Neighborhoods	No. (%) of Observations Control Neighborhoods	Crude Odds Ratio	95% CI	<i>P</i>
Crossing at intersections or crosswalks	0	28 (72)	29 (47)	1.0		.04
	1-4	4 (10)	11 (18)	0.4	0.1-1.5	
	≥5	7 (18)	22 (36)	0.3	0.08-0.9	
Crossing midblock or walking in street	0	3 (8)	9 (15)	1.0		.13
	1-4	7 (18)	20 (32)	1.1	0.2-4.8	
	≥5	29 (74)	33 (53)	2.5	0.6-10	
Entering or leaving a vehicle parked in street	0	3 (8)	13 (21)	1.0		.02
	1-4	10 (26)	26 (42)	2.1	0.4-11	
	≥5	26 (67)	23 (37)	5.0	1.0-26	
Vendors	Absent	24 (62)	44 (71)	1.0		.25
	Present	15 (39)	18 (29)	1.8	0.7-4.9	

TABLE 7. Adjusted Odds Ratios, 95% Confidence Interval (CI), and *P* Values for Selected Variables

Variable	Range	Adjusted Odds Ratio	95% CI	<i>P</i>
Vehicular traffic	<50 vehicles/h	1.0		.03
	50-99 vehicles/h	0.7	0.2-3.1	
	100-249 vehicles/h	0.5	0.08-3.0	
	≥250 vehicles/h	0.02	0.0007-0.6	
Vehicular speed	<25 miles/h	1.0		.02
	25-29 miles/h	3.9	0.9-17	
	≥30 miles/h	.39	2.0-752	
Vehicles parked on the street	0-11 vehicles/500 ft	1.0		.002
	12-17 vehicles/500 ft	12	1.6-98	
	≥18 vehicles/500 ft	15	2.1-105	
Total pedestrians observed	≤14 persons/15 min	1.0		.11
	15-29 persons/15 min	0.9	0.1-6.5	
	≥30 persons/15 min	4.6	0.6-37	

Housing/Play Areas

Similar to Mueller,¹⁴ we found that living in multiple family housing was associated with an increase of more than three times in the risk of child pedestrian injury. For more than three fourths of the children, the child's type of housing reflected the norms for the neighborhood for land usage. Multiple family housing was not included in the multivariate model because it is so closely related to total pedestrians observed, and the data were not sufficient to distinguish the separate effects of these two closely related variables.

Almost all of the case and control homes had some sort of play area, and the lack of a play area was not significantly associated with a higher risk. In a previous report the lack of a play area was a risk factor for pedestrian injury.¹⁴ A minimum size or other characteristics of an appropriate play area were not defined. Thus, some play areas in this study may not have been appropriate to the needs of the children who used them.

Pedestrian Volume and Behaviors

Previous reports have not examined the effect of the total number of pedestrians present. This study found that the number of observed pedestrians of all ages was associated with increased risk for child pedestrian injury. This result is not simply an effect of exposure to traffic, because the number of pedestrians age 15 and older was associated with a higher risk of pedestrian injury to children 0 to 14 years old.

This association could not be explained by errors in estimating age, because almost all the injured children were 1 to 9 years old, and would not be confused with pedestrians 15 years and older. The association may be due to the confusion and distraction of child pedestrians and their supervisors in busy environments.

Streets that had older pedestrians crossing at intersections or crosswalks were at lower risk for injury to child pedestrians. This would suggest that modeling of safe pedestrian behavior by adults and older children may actually be protective.²¹ However, streets that had pedestrians crossing at midblock were not found to be at increased risk for child pedestrian injuries. In this community, vendors of produce, meat, and ethnic foods, as well as ice cream trucks and pushcarts, are commonplace, but no risk was associated with their presence.

Implications for Prevention of Childhood Pedestrian Injuries

Results from the crude odds ratios are useful to identify residential streets with a high risk of childhood pedestrian injury. Streets with multiple family residences, with 12 or more parked vehicles parked on the street in 500 feet (or more than 50% of the available curb occupied by parked vehicles), or with 30 or more pedestrians observed in unenclosed areas in 15 minutes should receive high priority for pediatric pedestrian intervention programs.

The multivariate model provides insight into potential environmental changes that should reduce pedestrian injuries on the high risk streets. The large adjusted odds ratios for vehicles parked on the street suggest that decreasing such parking may prevent childhood pedestrian injuries. However, traffic engineering experts suggest that removing such parking provides a wider area for vehicle travel and may increase vehicle speeds.²² Thus, changes in on street parking should be accompanied by traffic calming measures to reduce vehicle speed.²³

Controlling speed on high-risk residential streets is important in controlling pedestrian injuries, both because of the association between speed and child pedestrian injury in the multivariate model and the well-known association between vehicle speed and the severity of pedestrian injuries.¹¹ However, speed alone did not identify neighborhoods at high risk for injury.

The results of this study indicate that educational programs in the high-risk areas should also be considered. Parents and caregivers must be alerted to the fact that children are at risk even when the volume of traffic is light: children were at lower risk with higher traffic volume indicating that parents may accurately perceive traffic as hazardous but are less cautious with their children on a quieter street.²⁴ Because the risk was also lower on streets where more pedestrians crossed at intersections and crosswalks, modeling proper pedestrian behavior on the part of adults and older children should be addressed.

Limitations

This study was restricted to child pedestrians injured in the same block as their homes. We believe that this restriction was useful to clarify the relationship between variables in the neighborhood street environment and injury. The same variables may have a different effect in pedestrian environments that are not primarily residential.

These results are based on observations made at a standard time on a weekday afternoon, which may differ from conditions at the moment the injury occurred. We selected our observations to represent overall conditions in the neighborhood, rather than conditions at the time of injury. The neighborhood environmental measurements and measurements made at the scene of the injury were, however, significantly correlated.

The use of standardized observations, rather than questionnaires, minimizes misclassification of the pedestrian environment.²⁵ Observers were not blinded to the case-control status of the neighborhoods observed. However, the variables were based on physical measurements or discrete categories to minimize observer bias.

Another limitation of this study is that multiple family housing may increase the risk of pedestrian injury by mechanisms that are unrelated to the total pedestrians observed. For example, multiple family housing often has less open space between buildings than single family housing, and individual families have less control over this space.

This study was carried out in a population of Latinos in the southwestern United States. It included a larger proportion of children 0 to 4 years old than other reports of child pedestrian injuries.^{12,14,18,19} Some of the environmental risk factors studied may vary with age. Thus, these results may not apply to other ethnic or racial groups or in populations in which more older children are injured.

CONCLUSIONS

Environmental risk factors for pediatric pedestrian injuries in this southern California study are similar to those found in other areas of the country and in other populations. The number of parked vehicles on the streets, which was the strongest risk factor, and multifamily dwellings were both associated with childhood pedestrian injury. This study also found the number of pedestrians observed, particularly older children and adults, was strongly associated with the risk of pedestrian injury to young children on residential streets near their homes. These risk factors can be used to identify streets to be targeted for childhood pedestrian injury prevention programs. Once the high risk streets are identified, the multivariate model would suggest implementation of measures to reduce the amount of street parking (thus increasing visibility) and reductions in vehicular speed to decrease pedestrian injuries. By targeting high risk areas, a multidisciplinary yet focused approach involving individual and community education, as well as environmental changes, can be developed to prevent childhood pedestrian injuries.

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WHICH COUNTS MORE: ABILITY OR CLASS?

There is plenty of evidence about social mobility in Britain. The best is the National Child Development Survey, which has analyzed all the children born in a single week in 1958 at various points in their lives. In "Two Nations? The Inheritance of Poverty and Affluence," the Institute for Fiscal Studies, an independent research group, analyzed this data. It found that by 1991, 34% of those in the highest income quintile had fathers who were also in the top income group; 11%, however, had fathers in the poorest quintile. In a society with full equality of opportunity, and ability distributed equally across the population, 20% of the richest quintile would have had fathers from the richest quintile, and 20% from the poorest. This suggests that opportunity is dispersed in Britain, but not fully equalized.

But what if ability is not in fact distributed equally amongst the population? This question is explored, using the same data as the Institute for Fiscal Studies, in "Unequal but Fair?", a pamphlet by Peters Saunders, a sociologist at Sussex University, published last month by the Institute of Economic Affairs. He concludes that ability is greater at the top of the class/income pile than at the bottom, and that individual ability plays a crucial part in deciding where an individual will end up. Ability alone is well over twice as important as their class origins, three times more powerful than the degree of interest their parents showed in their schooling, and five times more powerful than their parents' level of education or the aspirations which their parents harbored for them while they were growing up.

The Economist. August 10, 1996.

Noted by J.F.L.

Analysis of Pedestrian Conflicts with Left-Turning Traffic

DOMINIQUE LORD

The interaction between pedestrians and left-turning vehicles at signalized intersections are examined using the traffic conflict technique. Paramount was a comparison of the safety of left turns at two types intersections: T-intersections and X-intersections (cross-intersections). Previous research has indicated that T-intersections are more dangerous to pedestrians. In preparation for the comparison several traffic conflict definitions and their applications to pedestrians were evaluated. Use of a laptop computer for data collection was tested. Eight sites taken from intersections in Hamilton, Ontario, Canada, were selected. A conflict recording methodology was developed for T-intersections and X-intersections that consisted of recording data at various times along the paths of pedestrians and left-turning vehicles, and recording traffic conflicts. Two computer programs were written for the data collection process: one for vehicles and one for pedestrians. Several statistical tests to relate traffic conflicts and the expected number of accidents were performed. These tests indicate that a positive correlation between traffic conflicts and expected number of accidents exists; they also suggest that T-intersections have a higher traffic conflict rate than X-intersections.

The primary objectives of the described study are (a) to examine the interaction of left-turning vehicles and pedestrians at two types of signalized intersections using traffic conflicts; (b) to compare several traffic conflict techniques; and (c) to test the use of a laptop computer to record the traffic conflicts.

Four sections describe the study. The first section reviews the literature on pedestrian accidents and traffic conflicts, concentrating on accidents between left-turning vehicles and pedestrians, various traffic conflict definitions, and the validity of the traffic conflict technique. The second section describes the methodology developed to record traffic conflicts according to the different definitions and the data collection process. Results of the study are presented in the third section, which also examines the conclusions of Quaye et al. (1) and the relationship between conflicts and the expected number of accidents. The fourth section concludes with a discussion of the questions the study sought to answer.

LITERATURE REVIEW

A driver making a left turn at an intersection often has to keep track of several traffic elements simultaneously, including opposing traffic flow, traffic lights, and pedestrians crossing. According to various studies left-turning traffic generally constitutes about 20 percent of the approach traffic in urban areas; however, the proportion of accidents involving pedestrians and left-turning vehicles at intersections is slightly higher (20 to 30 percent of all pedestrian accidents in intersections), as shown in Table 1.

One-way intersections reduce the complexity of turning left by removing the opposing traffic flow, thus allowing drivers to concentrate on the pedestrians in the crosswalk and the traffic lights. Two studies, one each conducted by Habib (2) and Fruin (3), have examined pedestrian accidents at signalized intersections on a one-way grid system (Manhattan, New York). They discovered that vehicle left turns were approximately four times more dangerous to pedestrians than through movements.

In a more recent study, Almuina (4) examined accidents involving left-turning vehicles and pedestrians at signalized intersections in Hamilton, Ontario, Canada, between 1983 and 1986. He found that about 32 percent of the pedestrian accidents involved left-turning vehicles. Almuina further analyzed pedestrian accidents by dividing intersections into three types: one-way-one-way, one-way-two-way, and two-way-two-way. He demonstrated that, with the exception of pedestrian accidents with straight-through vehicles, accidents involving left-turning vehicles had the highest proportion of accidents for all intersection types.

Previous research has indicated that the most important factors in increasing the likelihood of pedestrian accidents are pedestrian and vehicle flows (5,6). Accordingly, numerous relationships between accident frequencies and traffic flows have been examined over the years. The most recent studies, such as Hauer et al. (7), assess the safety of intersections by using the product of vehicular traffic flows raised to a power. They suggest that other circumstances such as highway-rail grade crossings and accidents on two-lane highways support the "product-of-flows-to-power" relationship. Studies by Zegeer et al. (8), Hauer and Persaud (9), and Mengert (10) have reached similar conclusions.

Quaye et al. (1) specifically examined the safety of pedestrians by using the product of pedestrian and vehicular flows raised to a power. Their research relied on accident and flow counts during 15-min periods from Monday to Friday for the years 1983 to 1986 in Hamilton. The multivariate accident prediction model was given as follows:

$$\hat{E}\{m\} = b_0 \times F_1^{b_1} \times F_2^{b_2} \quad (1)$$

where

- F_1, F_2 = vehicle and pedestrian flows, respectively;
- b_0, b_1, b_2 = parameters to be estimated;
- m = entity (signalized intersection);
- $E\{m\}$ = mean of such m 's for different intersections with flows F_1 and F_2 ; and
- $\hat{}\{m\}$ = estimate of $E\{m\}$.

Because the safety of pedestrians at an intersection is influenced by its geometry, Quaye et al. separated fixed-cycle signalized intersections as well as the models into two categories.

TABLE 1 Pedestrian Accidents and Left-Turning Traffic (4)

Study:	Fruin	Habib	Zegeer et al.	Robertson & Carter	Israel	Almuina
Proportion of left-turning accidents	31%	25%	22%	17%	13%	32%
Number of signalized intersections	32	45	1297	62*	520	306

* Only 54 intersections were signalized

Left-Turns at T-Intersections (Category 1)

Approaches with left-turning vehicles that face no opposing vehicle traffic were selected for Category 1. The purpose of this category is that left-turning vehicles, when turning, face no opposing vehicle traffic. As a result the left-turning maneuver is not complicated by conflicting vehicles. Three-legged intersections or one-way streets on the opposing approach are examples of such intersections. The model and expected number of accidents per day are given for this category by Equation 2:

$$\hat{E}\{m\}_T = (2.61 \times 10^{-7}) \times F_1^{1.19} \times F_2^{0.331} \quad (2)$$

Left-Turns at X-Intersections (Category 2)

All approaches with left-turning vehicles that face opposing vehicle traffic were selected for Category 2. At X-intersections (cross-intersections) left-turning vehicles must yield to conflicting vehicles coming from the opposite approach during the entire or part of the green phase. The model and expected number of accidents per day are given by Equation 3:

$$\hat{E}\{m\}_X = (7.34 \times 10^{-7}) \times F_1^{0.410} \times F_2^{0.867} \quad (3)$$

Quaye et al. evaluated the relative safety of pedestrians crossing at T- and X-intersections. For the same vehicle and pedestrian flows on a hypothetical intersection, X-intersections were generally found to be safer than T-intersections for a vehicle flow above 100 vehicles per hour.

TRAFFIC CONFLICTS

Accident data are often used to analyze the safety of intersections. However, evaluations of safety based only on accidents have many drawbacks. For example, reliable estimates of safety require a large number of accidents. Furthermore, not all accidents are reportable, and the ones that are reportable are not always reported. Pedestrian collisions that result in injuries would most likely be reported.

Such drawbacks have led to the development of a surrogate safety measure known as traffic conflicts. In general, a traffic conflict is an event in which two road users (pedestrians, vehicles, and bicycles) would have collided had their paths, speeds, or both remained unchanged on an element of a transportation system (intersection, road section, ramp, and so forth). In the described study a total of four traffic conflict definitions were employed to analyze the safety of pedestrians at signalized intersections. The first one is known as

the U.S. traffic conflict technique. This technique originates from a study conducted by Perkins and Harris (11) that consisted of examining evasive actions or sudden braking. Glauz and Migletz (12) further developed the U.S. definition by stating that the action of the first user is atypical in that it is not an action that every road user would perform under the same circumstances, although it need not necessarily be an infrequent or extreme action. The second definition is called classification by severity (CS). This definition classifies conflicts according to the severity of the evasive actions such as in the German (13) and French (14) definitions. The conflicts are judged subjectively by the recorder according to a predetermined severity scale. For example, the German severity scale (13) classifies traffic conflicts into three categories: light, moderate, and serious. The third definition, called the post-encroachment time (PET) is the only one not based on evasive maneuvers. Cooper (15) defined PET as the time difference between the moment an offending vehicle passes out of the area of potential collision and the moment of arrival at the potential collision by the conflicting vehicle possessing the right of way. The fourth definition is called time-to-collision (TTC). The Swedish traffic conflict technique (16) is one of the techniques that is based on this definition. TTC uses the speed and the distance between the two road users at the time of evasive action. A TTC is then computed by dividing the distance by the speed. According to Hyden (16), conflicts under this definition could be considered dangerous by two means: a fixed TTC below 1.5 sec or a speed-dependent TTC.

Several studies have examined correlations between accidents and conflicts and, in many cases, results have been diverse and contradictory (17). This is partly due to the difference in conflict definitions, location, road user behavior, and so on. The lack of consensus on the relationship between accidents and conflicts has surprisingly fostered only few complementary analyses of pedestrian-vehicle conflicts. From these, some included only conflicting situations with through vehicles (18,12), whereas others described the interaction of pedestrians and left-turning vehicles (19–21). In general, the studies of the correlation between conflicts and accidents arrive at divergent conclusions or are often inconclusive because of data problems.

METHODOLOGY AND DATA COLLECTION

The study population included all fixed-cycle intersections drawn from the Hamilton data base. The approaches of each intersection were examined to determine whether left-turning vehicles had their maneuvers obstructed by oncoming vehicles. Accordingly, all approaches or sites were divided into two categories: left-turns at T-intersections and left-turns at X-intersections. Then the expected number of accidents involving left-turning vehicles and pedestrians was computed for each site according to the category. Equations 2 and 3, developed by Quaye et al., were employed to calculate the expected number of accidents. A sample of eight sites were selected, four from each category. Each approach categorized as an X-intersection was matched with an approach categorized as a T-intersection according to level of exposure. The matched sets were separated into four groups:

- Group 1: high vehicle and low pedestrian flows,
- Group 2: high vehicle and moderate pedestrian flows,
- Group 3: low vehicle and low pedestrian flows, and
- Group 4: moderate vehicle and high pedestrian flows.

Table 2 shows the expected number of accidents for each of the eight sites.

The relative safety of sites included in the T-intersection and X-intersection categories can be calculated using Equation 4 (1):

$$R = 0.075 \times \frac{F_1^{1.046}}{F_2^{0.415}} \quad (4)$$

Relative safety is defined as the number of times a site in the X-intersection category is safer than a site in the T-intersection category with the same level of exposure; the *R*-value represents the relative risk. Therefore, for any combination of pedestrian and vehicular flows a relative risk can be computed. Equation 4 leads to the series of curves shown in Figure 1. This figure shows the four groups according to the respective pedestrian and vehicular flows, as well as the curves for five relative risks. It should be noted that Group 2 is located between the curves *R* = 4 and *R* = 3, whereas Group 3 is located close to the curve *R* = 0.5. In other words, a site in the X-intersection category for Group 2 is expected to be three to four times safer than a site in the T-intersection category. On the other hand, a site in the X-intersection category for Group 3 is expected to be more or less twice as dangerous as a site in the T-intersection category.

A site survey of all selected intersections was undertaken to verify that each intersection shared similar characteristics, such as the correct pedestrian and vehicular flows in the same group and the intersection geometry, and that each intersection had pedestrian traffic lights (Walk and Don't Walk) and painted crossing delineation.

Every method of conflict identification primarily seeks to identify what happens when pedestrians and vehicles approach each other in space and time. In the described study the primary observational task was to record the time at different points along the path of a left-turning vehicle and along the path of a walking pedestrian. The path of the vehicles and pedestrians was not fixed, but was observed on site. The observational procedure was divided into two recording strategies depending on the geometry of the intersection. The first recording strategy was for T-intersections, and the second was for X-intersections. A conflict area was identified according to the PET conflict definition, to simplify the work with the analysis. The conflict area boundaries consisted of the painted lines of the crosswalk and the path of the left-turning vehicle (i.e., width of a vehicle). An example of the second recording strategy is presented in Figure 2. The location of the conflict area was not fixed and was dependent on the path of the left-turning vehicle. In short, for each evasive maneuver or sudden braking the approximate location and the time of the event would be recorded.

To carry out the data collection with the methodology described above two computer programs were written, for the pedestrian and left-turning movements, respectively. Both programs are based on

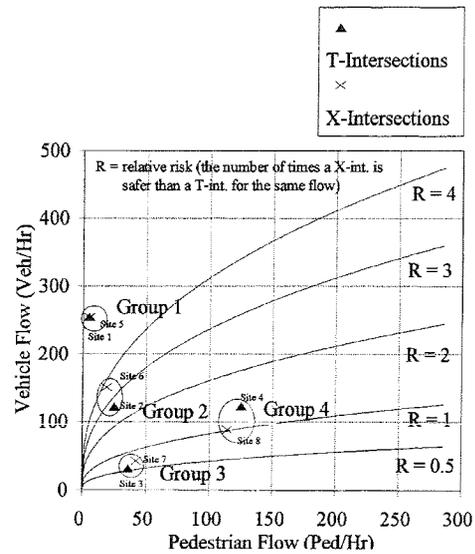


FIGURE 1 Relative safety of pedestrians and selected sites.

a program developed by Jones (22,23). The computer programs allowed for the automatic recording of traffic phases without connection to the intersection controller, as well as the recording of the various times along the path of a pedestrian and a vehicle and the recording of traffic conflicts.

The equipment used to gather data included two laptop computers, a measuring tape, a string, chalk, spray paint, a pen, and a notebook. Paint marks were placed inside the intersection to help indicate the time when each road-user passed certain points. Each site was recorded for two days, from 2:00 pm to 6:00 pm. A trained assistant collaborated with the researcher during the data collection process. The laptop computers were used to record the events. Because the computers' internal clocks ran at different speeds the laptops were synchronized at the beginning of the recording so that the data from each could be time-adjusted for further analysis.

Data collection included all elements needed for four different conflict study methods: U.S., TTC, CS, and PET. The TTC definition was divided into two components according to type of TTC employed. The first TTC definition (TTC1) is characterized by the use of a fixed TTC, whereas the second (TTC2) is characterized by use of a speed-dependent TTC. A conflict was recorded at the instant when a vehicle had to brake or perform an evasive maneuver (pedestrian evasive actions were also included) because of pedestrian activity on the crosswalk. Each conflict was recorded as a U.S. conflict (because that definition is the least restrictive) and was then analyzed to examine whether it also fell under another conflict definition. A PET conflict was added to the count for each instance of a vehicle entering the conflict area less than 3 sec after a pedestrian.

RESULTS AND ANALYSIS

Table 3 reveals that the number of conflicts for sites in the X-intersection category is about half that of sites in the T-intersection category according to the U.S. and the TTC1 definitions. Low speeds at the instant of the evasive action account for the lack of conflicts falling under TTC2. Indeed, the speed of left-turning vehicles seldom surpassed 30 km/hr. Likewise, no conflicts were

TABLE 2 Selected Sites by Category

T-intersection category		X-intersection category	
Site #	$E\{m\} \times 10^{-4}$ accidents/day	Site #	$E\{m\} \times 10^{-4}$ accidents/day
Group 1	Site 1 26.2	Site 5	1.6
Group 2	Site 2 23.0	Site 6	4.5
Group 3	Site 3 4.4	Site 7	5.2
Group 4	Site 4 32.7	Site 8	16.4

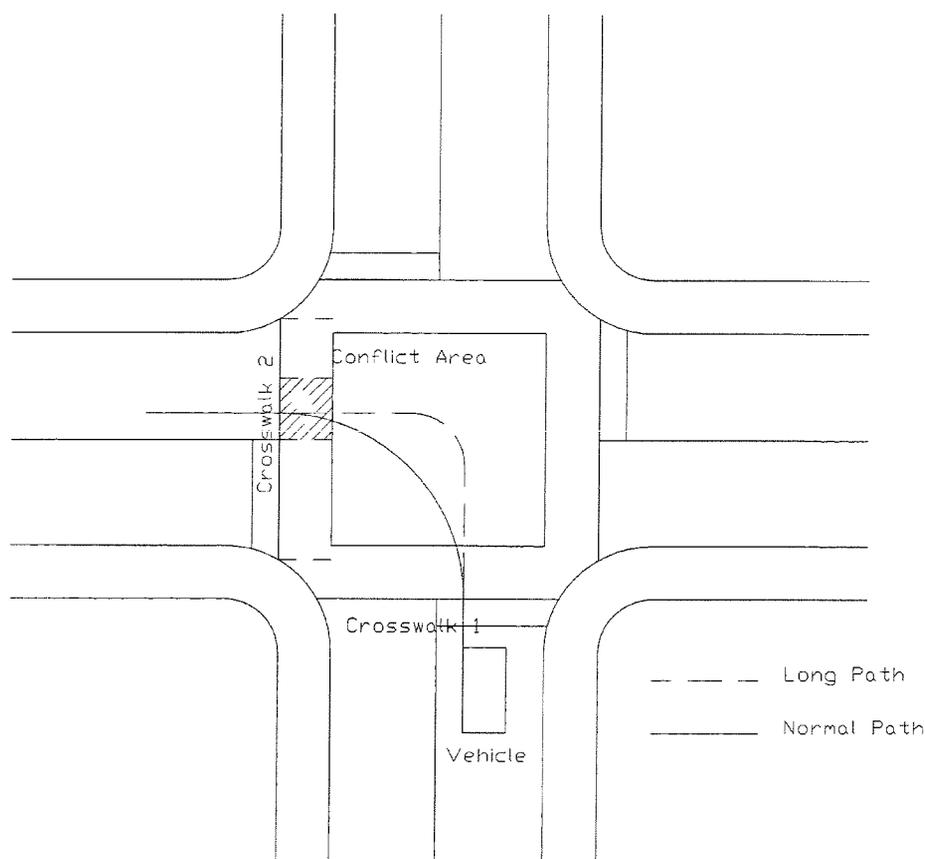


FIGURE 2 Recording strategy for X-intersections.

TABLE 3 Conflict Counts (2 Days) by Definition

T-intersection Category	U.S.	TTC1 ¹	TTC2 ²	SI ⁴	Mo ⁵	Sr ⁶	PET ⁷
Site 1 (Group 1)	6*	n/a	n/a	n/a	n/a	n/a	9 (n/a)
Site 2 (Group 2)	8	5	0	5	2	0	22 (3)
Site 3 (Group 3)	0	0	0	0	0	0	21 (0)
Site 4 (Group 4)	12	5	0	11	1	0	18 (2)
Total	26	n/a	n/a	n/a	n/a	n/a	70 (n/a)
X-intersection Category							
Site 5 (Group 1)	0	0	0	0	0	0	1 (0)
Site 6 (Group 2)	1*	n/a	n/a	n/a	n/a	n/a	2 (n/a)
Site 7 (Group 3)	6	3	0	1	4	0	12 (2)
Site 8 (Group 4)	6	3	0	4	1	0	18 (1)
Total	13	n/a	n/a	n/a	n/a	n/a	33 (n/a)

¹ First Time-to-Collision definition - TTC fixed (1.50 sec.)

² Second Time-to-Collision definition - TTC speed dependent

³ Classification by Severity definition

⁴ Slight

⁵ Moderate

⁶ Serious

⁷ Post Encroachment Time definition (The number in parentheses indicates the number of conflicts entering both this definition and the U.S. definition.)

* Decided subjectively by the author

categorized as serious according to the CS definition, as none of the vehicles left skid marks or made its tires squeal. Conflicts could not be recorded accurately enough for further analysis of Sites 1 and 6. Therefore, only conflicts categorized in the U.S. definition are used for further analysis, because that definition encompasses all conflicts categorized in the other definitions and also includes all eight sites. The number in parentheses in the PET column in Table 3 indicates the number of conflicts that can be categorized under both this definition and the U.S. definition.

To determine at what time during the green phase (for vehicle traffic) conflicts occurred, the phase was divided into segments and is represented graphically in Figures 3 and 4. These figures also show the times at which pedestrians left the curb. For the T-intersection category close to 71 percent of conflicts happened below 60 percent of the green phase, and about 21 percent of the conflicts occurred during the last 10 percent of the green phase. On the other hand, close to 85 percent of the conflicts for the X-intersection category occurred during the second half of the green phase. The time-of-departure histograms in Figure 3 show that a higher proportion of pedestrians in the T-intersection category start crossing at the end of the red phase (0 percent column). This figure underscores the conclusion that the earlier a pedestrian starts crossing at an approach categorized as a T-intersection, the greater chance there is of a conflict. In contrast, there is a greater risk of conflict for a pedestrian crossing at a site categorized as an X-intersection if that person waits to cross.

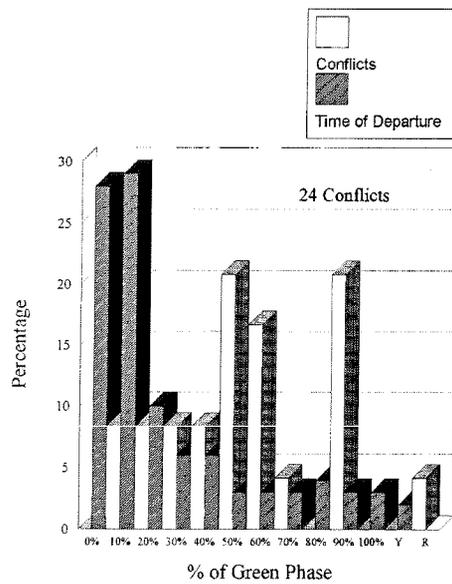


FIGURE 3 Time of departure from the curb and time of conflicts during the green phase for the T-intersection category.

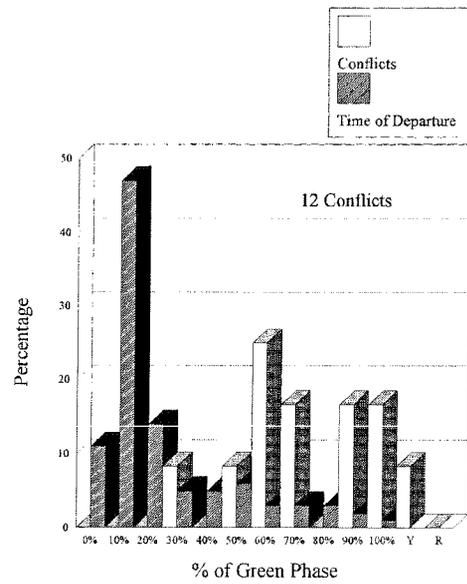


FIGURE 4 Time of departure from the curb and time of conflicts during the green phase for the X-intersection category.

The relative safety of sites in the two intersection categories was examined in conflict counts as presented in Table 4. As has been mentioned, the site in the X-intersection category for Group 2 was found to be between three to four times safer than its matched site, whereas for Group 3 the T-intersection was expected to be about twice as safe. Table 4 reveals that, for Group 2 the X-intersection site has an *R*-value varying from 5 to 8, depending on the definition. TTC1 was the closest to the theoretical values of $R = 4$ or $R = 3$. On the other hand, for Group 3 no result could be demonstrated because in all cases $R = 0$. However, the site in the X-intersection category used for Group 3 was more dangerous than the site in the T-intersection category because it had a higher conflict count, which is confirmed by the theoretical value below unity ($R = 0.5$).

One purpose of the study was to examine whether those intersections predicted to be dangerous in the models developed by Quaye et al. are indeed dangerous. The sites are ranked from the most dangerous to the least dangerous according to the accident prediction models and the U.S. traffic conflicts alone as shown in (Table 5). The approaches in italics represent the sites in Category 2. It can be inferred from this table that the rankings of the sites for the expected number of accidents and the conflict counts are almost identical. The use of conflicts appears to support the accident prediction models.

In a verification of the findings shown in Table 5 two tests were used to correlate traffic conflict counts to the predicted number of accidents. The results of the two tests are presented in Table 6. The first test computed a weighted linear regression coefficient between traffic counts and the expected number of accidents. No regression coefficient was computed for the PET definition because the points were too scattered. The second test used was the Spearman rank correlation test, which determines the rank correlation between two sets of data.

Table 6 shows that two of the three traffic conflict definitions produced a strong positive correlation between conflicts and the

expected number of accidents using the weighted linear regression analysis; the U.S. definition had the highest correlation coefficient with a value of 0.59. The PET definition had no correlation and was discarded from further study. The two remaining definitions were tested for significance because only eight or six sites, depending on the definition, were used in the analysis. Use of the F-test reflected the low number of conflict counts. The two definitions were found to be statistically significant and highly correlated for the Spearman ranking test. A correlation between conflict counts and the expected number of accidents may be inferred from this. Finally, the validation study also supports the accident prediction models.

The relationship of exposure (accident-risk), as measured by the cross product of traffic flow, and the number of conflicts was tested. Exposure was obtained by taking the square root of the product of the traffic flow of pedestrians and vehicles as shown in Table 7. Again, the approaches in italics represent the ones in Category 2.

The ranking for accident risk nearly coincides with the expected number of accidents; once more, the T-intersection approaches

TABLE 4 Comparison of the Relative Safety of Sites in the T- and X-Intersection Categories

		Approach	U.S.	TTC1
Group 2 (<i>R</i> = 4)	X-int	Site 6	1	1*
	T-int	Site 2	8	5
		<i>R</i> =	8	5
Group 3 (<i>R</i> = 0.5)	X-int	Site 7	5	3
	T-int	Site 3	0	0
		<i>R</i> =	0	0

* assume it enters this definition

TABLE 5 Ranked Sites by Conflicts

Rank	Predicted Accidents		Conflicts	
	$E\{m\} \times 10^{-4}$	Approach [†]	Count	Approach [†]
1	32.7	Site 4 (Gr 4)	12	Site 4 (Gr 4)
2	26.2	Site 1 (Gr 1)	8	Site 2 (Gr 2)
3	23.0	Site 2 (Gr 2)	6	Site 1 (Gr 1)
4	16.4	Site 8 (Gr 4)	6	Site 8 (Gr 4)
5	5.2	Site 7 (Gr 3)	5	Site 7 (Gr 3)
6	4.5	Site 6 (Gr 2)	1	Site 6 (Gr 2)
7	4.4	Site 3 (Gr 3)	0	Site 3 (Gr 3)
8	1.6	Site 5 (Gr 1)	0	Site 5 (Gr 1)

[†] The sites in italic represent the ones in the X-intersection category

appear to be more dangerous than the X-intersection ones, with the exception of Site 3. The accident risk data also corroborates the data presented in Table 5. Overall, the two tests and the accident risk method appear to correlate well with the models developed by Quaye et al.

DISCUSSION AND CONCLUSION

The study involved (a) an examination of the interaction of left-turning vehicles and pedestrians at signalized intersections using traffic conflicts, (b) an exploration of the validity of the traffic conflict technique, and (c) the use of a laptop computer for data collection.

Findings concur with the accident prediction models developed by Quaye et al. The two tests used in the analysis ranked the approaches similarly to their models. The sites in the T-intersection category were determined to be more dangerous than the sites in the X-intersection for traffic flows over 100 vehicles per hour. One explanation for the lower rate of conflicts in Category 2 might be that the majority of pedestrians starts crossing at the beginning of the green phase, and that while the first left-turning vehicle is waiting to find a gap long enough to turn the majority of the pedestrians has had sufficient time to cross. As a result the number of conflicts for the approaches in the X-intersection category could also be a function of the number of the vehicles coming from the opposite approach. As can be seen in Figure 3, about 30 percent of pedestrians in the T-intersection category start crossing before the green light appears; it is possible that the first few drivers making left turns

TABLE 6 Traffic Conflict Definitions and Validation Study

	U.S.	TTC1	PET
Linear Regression (r^2)	0.59	0.44	--
Spearman ranking (r_s)	0.93	0.90	0.23
F-test	20.38	15.60	--
$F(v_1, v_2)$ ($p=0.05$)	5.14	6.94	--
Significant	yes	yes	--

TABLE 7 Ranked Sites by Accident Risk

Rank	Predicted Accidents		Accident-Risk	
	$E\{m\} \times 10^{-4}$	Approach [†]	Conflicts/($V_1 \times V_2$) ^{1/4}	Approach [†]
1	32.7	Site 4 (Gr 4)	0.0239	Site 1 (Gr 1)
2	26.2	Site 1 (Gr 1)	0.0204	Site 4 (Gr 4)
3	23.0	Site 2 (Gr 2)	0.0200	Site 2 (Gr 2)
4	16.4	Site 8 (Gr 4)	0.0167	Site 7 (Gr 3)
5	5.2	Site 7 (Gr 3)	0.0103	Site 8 (Gr 4)
6	4.5	Site 6 (Gr 2)	0.0038	Site 6 (Gr 2)
7	4.4	Site 3 (Gr 3)	0.0000	Site 3 (Gr 3)
8	1.6	Site 5 (Gr 1)	0.0000	Site 5 (Gr 1)

[†] The sites in italic represent the ones in the X-intersection category

might not expect a pedestrian to be so soon in his or her pathway. Over one-half of the conflicts in this category occurred during the first half of the green phase.

Several conflict definitions were examined. Because other studies have already discussed this subject extensive critical analyses of the definitions were not made; instead their applicability to pedestrian conflicts was assessed. It can be concluded from the analysis that categorization of a conflict at the instant of the evasive maneuver appears to be the most appropriate method. Not all traffic conflicts were classified as dangerous; no conflicts were classified under TTC2 or CS. Either of the two remaining conflict definitions can be used to evaluate the safety of pedestrians at intersections; the U.S. definition has the highest correlation and Spearman coefficients. The U.S. definition may be a good candidate, because it does not require extensive data collection (such as the use of a camera, for example). However, according to Brown (24) support of the TTC definition appears to be gaining more general acceptance in the research community.

A laptop computer proved to be sufficiently accurate for recording all other information, such as the times of travel along both the path of a pedestrian and a vehicle. One positive aspect of the use of the computer was the huge amount of information that could be entered directly and analyzed on a spreadsheet. The programs could be used in the following ways: individually to measure pedestrian counts; to examine when pedestrians start their crossing actions; and to estimate the walking speeds of pedestrians. They may also be used for similar information on left-turning vehicles.

The use of a laptop computer to record traffic conflicts proved to be laborious and difficult. Because traffic conflicts are usually sudden or unpredictable events it was not possible to record conflicts accurately in many cases. A wrong key would often be pressed due to the suddenness of the event, thus disrupting recording. On many occasions it was necessary to predict a potential conflict by looking at the paths of the pedestrian and the vehicle. Sometimes a conflict would occur with a second vehicle following the first; because the first vehicle was being recorded the second could not be. As a result the exact location of the conflict and the vehicle speed had to be estimated from notes taken on site.

The study was the first to attempt correlating traffic conflict rates with the expected number of accidents; all previous studies relied on accident counts alone. One major problem was the rarity of pedestrian accidents, a total of three pedestrian accidents with left-turning

vehicles for the eight approaches observed occurred between 1983 and 1986. As a result validation would be inconclusive. Finally, even though a high correlation existed between the number of conflicts and the expected number of accidents, further studies using the expected number of accidents in other circumstances and with more conflict counts should be attempted.

Recommendations for further research include the analysis of traffic conflicts between vehicles and a validation study with the expected number of accidents. Moreover, a validation study with the technique developed by Hauer and Gärder (25) could be attempted. A laptop computer could still be used to record the events, but it should be combined with a video camera. Finally, a higher number of intersections for the analysis of the traffic conflicts is suggested.

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Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation

SAN FRANCISCO, CA, USA'S PILOT PEDESTRIAN COUNTDOWN SIGNALS WERE ASSOCIATED WITH A DECREASE IN PEDESTRIAN INJURIES AND FEWER PEDESTRIANS FINISHING CROSSING ON RED. THIS FEATURE DISCUSSES THE IMPACTS OF THE POPULAR DEVICES ON COLLISIONS, PEDESTRIAN BEHAVIOR AND ATTITUDES, MOTORIST BEHAVIOR AND SIGNAL MAINTENANCE NEEDS.

BY FRANK MARKOWITZ, STANLEY SCIORTINO, PH.D., JACK LUCERO FLECK, P.E. AND BOND M. YEE, P.E.

INTRODUCTION

At a street corner in San Francisco, CA, USA, one senior citizen said to another, "I'm a '15.' What are you?" They were discussing how long it takes them to cross the street, no longer a mystery with pedestrian countdown signals installed at about 700 of San Francisco's 1,100 signalized intersections.

More than a conversation piece, however, San Francisco's countdown signals have been associated with a 52-percent reduction in pedestrian injury collisions at pilot locations. Figure 1 shows the numeric display. Pedestrian countdown signals attempt to improve safety by displaying the time left to cross. The San Francisco Department of Parking and Traffic equipped 14 intersections in a pilot program beginning in March 2001.

Pedestrian noncompliance with signs and signals is a significant factor in pedestrian injury collisions nationally and in San Francisco, partly reflecting the frequent misunderstanding of conventional pedestrian signals. Countdown signals attempt to improve this situation by providing information on how much time is left to cross safely.

These devices have been used nationwide with generally favorable results.¹ Evaluations in Minneapolis-St. Paul, MN, USA and Montgomery County, MD, USA, each assessed five pilot locations. The Minnesota study found a reduction in pedestrians finishing crossing after conflicting traffic received the green indication and 79 percent of interviewees preferring the countdown to the conventional signal. The Montgomery County study found a reduction in pedestrian/vehicle conflicts.

In San Jose, CA, the percentage of pedestrians finishing crossing on red also was lower with countdown signals, although the study authors noted that

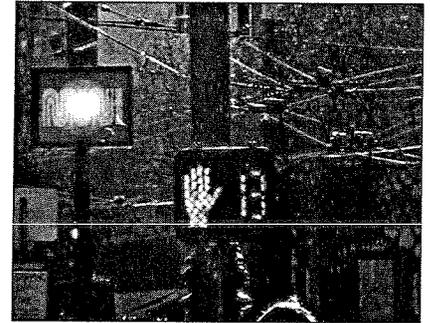


Figure 1. Pedestrian countdown signal.

pedestrians more often interpreted the countdown signal as allowing the start of crossing during the pedestrian clearance interval. This early experience led to the adoption of countdown signals in 2002 as a standard device in the *Manual on Uniform Traffic Control Devices (MUTCD) Millennium Edition, Revision 2*.

Beginning in March 2001, San Francisco equipped 14 intersections in one of the early pilot testing programs in California. The period covered was sufficient that any "novelty" impacts ("the Hawthorne effect") were minimized.

(The Hawthorne effect refers to the phenomenon identified by researchers at the Western Electric Hawthorne plant, who found that virtually any reasonable change in the workplace environment had a positive impact on productivity, which they hypothesized was due to improved morale attributable to the attention paid to workers by researchers, rather than the changes themselves.)²

The pilot intersections were selected based on a range of factors, including pedestrian injury collision record; pedestrian volumes; crossing distance; public complaints about perceived safety; and diversity of physical and social environments. Although a press conference was held with San Francisco's mayor to introduce the new signals and the California State Automobile Association developed a flyer, the basic meaning of the countdown was intuitive to virtually all pedestrians.

Because the countdown starts (per MUTCD) at the beginning of the flashing red hand (the pedestrian clearance interval)—when pedestrians are not to start crossing—the flyer suggested that the countdown should not be used to determine when to start crossing. As discussed later, for many pedestrians who walk faster than the average rate, however, starting at the beginning of the countdown actually is quite safe.

Provided with the opportunity to replace conventional pedestrian signals with light-emitting diode (LED) signals and encouraged by the preliminary results described in this feature, San Francisco decided to convert virtually all pedestrian signals citywide to the countdown version. San Francisco has installed countdown signals at about 700 intersections and intends to install them at all 1,100 signalized intersections in the city.

STUDY PURPOSE AND OBJECTIVES

The first stage of the evaluation (the preliminary evaluation) assessed behavioral impacts and attitudes toward the new devices. The second stage included crash analysis and maintenance history. The evaluation attempted to answer the following questions:

- Do countdown signals reduce pedestrian injuries?
- How do they change pedestrian behavior, especially when pedestrians start and finish crossing?
- How do countdown signals change driver behavior, especially red-light running?
- Do pedestrians like countdown signals and, if so, why?
- Do countdown signals imply to pedestrians that it is acceptable to leave on the flashing red hand?
- Are there any serious maintenance or installation problems?
- How effective is starting the countdown on the flashing red hand, as directed by MUTCD?

DATA COLLECTION AND ANALYSIS METHODS

Crash Analysis

The San Francisco Department of Public Health geo-coded and mapped date-collected data for every pedestrian

injury event that occurred within 50 feet (15.2 meters) before and after the installation of countdown signals at the nine pilot intersections that were equipped first (March to May 2001). There has been insufficient time since the citywide installation to allow for an evaluation of the citywide impacts, but such an evaluation is planned for the near future.

The 21-month “after” treatment period began on April 2, 2001 and ended on December 31, 2002. The “before” treatment period included an equivalent amount of time (July 2, 1999 to April 1, 2001) before the pilot installation was completed.

Changes in injury counts over time may be due to overall changes in pedestrian or motor vehicle travel frequency or behavior throughout San Francisco. Also, because intersections chosen for special improvement typically are selected at least partly because they have high numbers of collisions, statistically, they would be likely to improve even if nothing were done. This is termed “regression to the mean.”

To determine if there was a temporal effect, two other types of intersections were included in the analysis. The authors mapped a list of intersections that were scheduled or considered for countdown signals (that had traffic signals and, in most cases, conventional pedestrian signals) and that had at least one injury during the observation period; these were “Planned CD” intersections. The remaining intersections that had at least one injury in the observation period were “No Signals Planned” intersections. For a statistical test of the differences in injury trends, a Poisson model with the SAS statistical package was used.³

Because the pilot countdown locations were selected based partly on higher-than-average pedestrian injuries, the pilot countdown intersections were compared to a sub-group of signalized intersections that had a minimum of two pedestrian injury crashes in the 21-month pre-installation period. The mean number of pedestrian injury crashes in the pilot group was 3.00; the mean number in the comparison sub-group was 2.74. They were closely matched.

Pedestrian and Driver Behavior

Two sets of behavioral assessments were performed. The first involved observations of pedestrians shortly before and after the devices were installed in 2001 for:

- Signal phase when a pedestrian started and finished crossing;
- Whether a pedestrian ran or aborted crossing; and
- Whether there was a pedestrian-vehicle conflict (near miss).

In addition, a sample of vehicles was observed for:

- Signal phase when a vehicle entered intersection;
- Signal phase when a vehicle cleared intersection; and
- Whether there was a pedestrian-vehicle conflict (near miss).

This initial evaluation included observations of nearly 600 pedestrian crossings before installation and over 900 post installation.

In some cases, yellow intervals were extended and/or all-red phases were added when the countdowns were installed. Positive impacts may be due partly to this signal timing change rather than the countdown devices themselves, although the changes were made gradually to the planned countdown signals control group as well. It is not possible to separate the two effects.

The second set of pedestrian/vehicle observations was carried out in spring-summer 2003 at eight intersections. A total of 1,342 pedestrians were observed for this post-installation phase. Differences in proportions before installation versus post installation were assessed with a Z-test.

Pedestrian Attitudes and Knowledge

During the pre-installation and first post-installation phases, pedestrians at each study intersection were approached and questioned briefly about their attitudes and knowledge. Questions covered:

- Whether respondents noticed the countdowns;
- How helpful respondents found the countdowns;
- How the countdowns compared to conventional pedestrian signals;

- Whether respondents thought they were crossing differently due to the countdowns; and
- Whether respondents knew that to start crossing on the flashing red hand (flashing DON'T WALK) is a violation of the vehicle code.

Installation and Maintenance Experience

The Department of Parking and Traffic's Signal Shop maintains records of maintenance calls. These were available for assessing the reliability of countdown signals.

STUDY RESULTS

Crash Analysis

The number of pedestrian injury crashes declined by 52 percent after the introduction of the countdown signals (see Table 1 and Figure 2), a statistically significant reduction (confidence interval = 24.8 percent, 93.3 percent, p-value <= 0.03). There was a slight decline for the primary comparison intersection types during the time periods in question. These comparison intersection declines were not statistically significant, although the number of intersections and the injury counts were large.

The reduction in injury crashes in a higher injury non-countdown comparison sub-group was almost as great as the decline in the countdown treatment group, and the difference was not statistically significant. This suggests that regression to the mean may have played a major role in the decline.

However, the countdown injury decline was consistently greater than the non-countdown decline, in several different comparisons matching countdown and non-countdown intersections with similar pre-installation injury levels. Therefore, although the 52-percent reduction in collisions overstates the impact of the countdown, a real reduction did occur.

Pedestrian Behavior

The most important findings of the preliminary behavioral observations (as illustrated in Figure 3) were as follows:

- The percentage of pedestrians still in the crosswalk when the signal turned red showed a statistically sig-

Table 1. Pedestrian injury events before and after countdown signals were installed.

Treatment group	Number of intersections	Number of injury events	Percentage of injuries after/before
Group A: Countdown signals installed			
After	9	13	48.1 ^a
Before		27	
Group B: Planned countdown intersections			
After	629	740	97.0
Before		764	
Group C: No signals planned			
After	628	423	90.0
Before		469	
Group D: Countdown signals installed with 2+ crashes pre-installation			
After	7	11	42.3 ^{a,b}
Before		26	
Group E: Planned countdown signals with 2+ crashes for the same period			
After	185	282	55.6 ^{a,b}
Before		507	

* Note:
^a = Sample group crash reduction statistically significant, p-value < .05
^b = Difference between groups D and E not statistically significant
 Before = prior period (July 2, 1999 to April 1, 2001)
 After = treatment period (April 2, 2001 to December 31, 2002)

Pilot countdown locations versus control locations

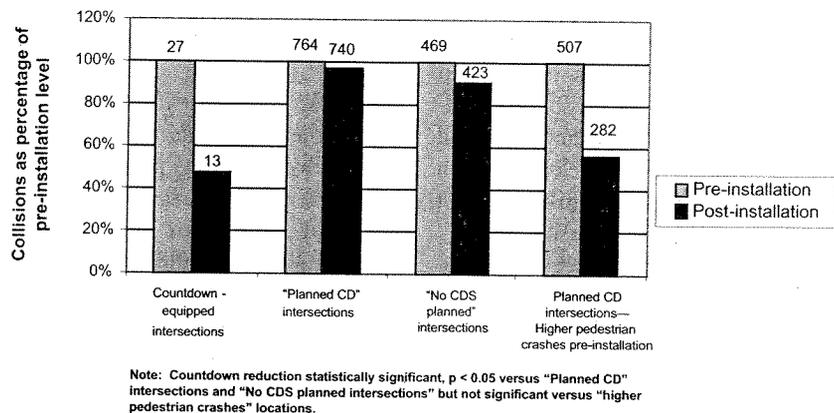


Figure 2. Pedestrian injury collision impacts of countdown signals.

nificant decrease after the installation of countdown signals.

- The percentage of pedestrians leaving during the flashing red hand or solid red hand increased slightly (but not to a statistically significant degree).
- The percentage of pedestrians running or aborting their crossings showed a statistically significant decrease.
- The percentage of observed vehicle/pedestrian conflicts decreased (but

not to a statistically significant degree).

Pedestrians who finished crossing on red dropped from 14 to 9 percent at eight intersections that were observed (during one pre-installation data collection period and two post-installation sets). This decrease is statistically significant (probability less than 1 percent of a difference due to random sample variation, pre-installation N = 591, post-installation

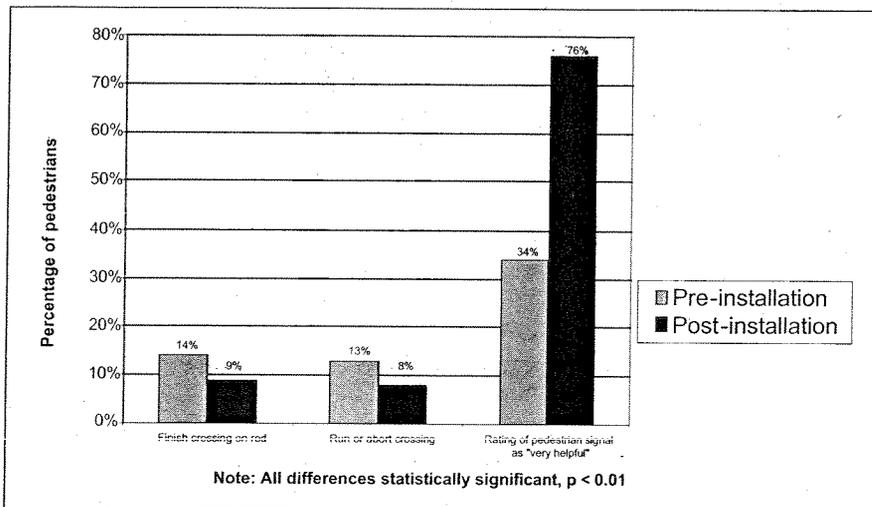


Figure 3. Pedestrian behavior impacts of countdown signals.

tion $N = 916$, on a two-tailed Z-test of the difference of proportions).

This result was due mostly to walkers hurrying across (more often finishing on the yellow) rather than being more compliant with pedestrian signals. The proportion of pedestrians starting crossing on the flashing or solid red hand (DON'T WALK) increased by 1 percentage point—not significant, although the impacts varied widely by location.

The proportion of pedestrians who ran or aborted their crossing dropped from 13 to 8 percent, a statistically significant result ($p < 0.01$). There was a small change in observed vehicle/pedestrian conflicts, dropping from 6 to 4 percent of pedestrians (not statistically significant).

In the second (2003) set of observations, the proportion finishing crossing on red also was 9 percent (down from 14 percent in the pre-installation observations, significant, $p < 0.01$). The proportion observed running or aborting their crossing dropped even further (from 13 to 4 percent, $p < 0.01$). Vehicle/pedestrian conflicts dropped below 1 percent (from the 6 percent initially observed, $p < 0.01$).

Driver Behavior

There was a small decrease in the reported incidence of red-light running (drivers entering the intersection on red), from 2 percent on pre-installation to 1 percent during both post-installation periods (not statistically significant).

A more rigorous study of driver

behavior and human factors in Monterey, CA, found that unsafe driver behavior was not a problem, although concerns had been raised that drivers will use the countdown to decide whether to speed up on a "stale" green.⁴ However, observers generally agree that most drivers seem to use the information to make sure they do not run the red light; some drivers may speed up. At many locations during peak periods, congestion makes speeding difficult or impossible.

Pedestrian Attitudes and Knowledge

In the 2001 data collection effort, interviewees finding pedestrian signals "very helpful" increased substantially with the countdown signals—only 34 percent with conventional signals but 76 percent with countdown signals. About 92 percent of post-installation interviewees explicitly said the countdown signals were "more helpful" than conventional pedestrian signals, primarily because they showed the time remaining to cross.

This is consistent with recent Federal Highway Administration (FHWA) research, which showed that a pedestrian sample strongly preferred countdown signals to actual and theoretical versions of pedestrian signals, and that the countdown version was "most easily understood."⁵

Only 6 percent said the conventional pedestrian signals were more helpful. In these few cases, the apparent reason was the clarity of the walking person/red hand symbol. In the pilot program, the

countdown symbols used only the outline of the red hand/walking man, but current San Francisco specifications call for a solid density of LED pixels.

Few (17 percent) understood that it is a violation of the vehicle code to start crossing during the countdown (flashing red hand). This compares to 40 percent in the pre-installation study. This suggests that pedestrians are using the countdown signals to decide when to start to cross, which is not the official purpose in San Francisco. A substantial proportion of pedestrians do not strictly follow the "letter of the law" (the Uniform Vehicle Code/MUTCD sections on pedestrian signal compliance).

MUTCD calls for pedestrian clearance to be based on a walking speed of 4.0 feet per second or slower. In San Francisco, 77 percent of pedestrians walk faster than this rate; therefore, a large share know they can "beat the countdown" if they start walking early enough in the pedestrian clearance phase. The MUTCD prohibition on starting to cross during the flashing red hand (the pedestrian clearance) is called into question when pedestrians can judge for themselves whether they can cross safely before conflicting traffic starts.

The authors recommend that the wording "pedestrians shall not" begin crossing should be changed to "pedestrians should not" begin crossing. Pedestrians are capable of judging time and distance, as demonstrated when they cross at uncontrolled crossings with heavy traffic volumes, determining whether a gap in traffic is adequate.

Installation and Maintenance Experience

The devices manufactured by GEL-core™ (Valley View, OH, USA) and Dialight™ (Farmingdale, NJ, USA) had a generally positive record. The manager of the Department of Parking and Traffic's Signal Shop believed that the reliability of the countdown signals had been close to that of conventional (incandescent) pedestrian signals.

STUDY CONCLUSIONS AND RECOMMENDATIONS

Although additional long-term studies would be useful, the initial results

from San Francisco's pilot locations provide a number of useful conclusions:

- Countdown signals appeared to reduce pedestrian injuries. Although the test group's reduction by roughly half likely was affected by regression to the mean, because the countdown reductions were consistently greater than those experienced at higher injury non-countdown locations, an improvement in safety is clearly indicated by the study. Although the trial involves a limited number of intersections, the trial period was long enough to reduce the novelty factor.
- The countdowns reduced the proportion of pedestrians finishing crossing on the red. There has not been a significant increase in the number of pedestrians starting to cross during the pedestrian clearance phase.
- The countdowns did not result in an increase in drivers running red lights.
- The devices are viewed very favorably by pedestrians for providing additional information. They are better understood than conventional pedestrian signals.
- The devices appear to imply to a substantial proportion of pedestrians that it is proper to start crossing on the flashing red hand (flashing DON'T WALK). However, the disadvantages of this effect are less important than the advantages listed above.
- The countdown signals are relatively easy to install for signal electricians. The maintenance record from two different manufacturers has been positive.
- Starting the countdown on the pedestrian clearance does not appear to reduce effectiveness substantially or trigger public complaints. Although there initially was concern among pedestrian advocates and some Department of Parking and Traffic staff that the shorter countdown would lead to complaints about allegedly insufficient time to cross and lack of usefulness, that has not been the case.
- The LED signals save energy compared to the incandescent version they replaced. The countdown uses

roughly 9–10 watts and the hand/walking man uses 6–9 watts, versus about 67 watts for conventional incandescent pedestrian signals. The energy savings are a key component of San Francisco's conversion to countdown signals—the cost of installing the new countdowns was financed entirely through a loan with the state of California to be repaid out of reduced energy costs.

NEXT STEPS

Although the results are encouraging, additional analysis will be carried out when citywide results over an extended period are available. Also, within the next several years, national tests will be conducted with pedestrian countdown signals that add “animated eyes.” The shifting eyes during the WALK phase remind pedestrians to check both ways. This would be funded by FHWA as part of an evaluation of several innovative technologies.

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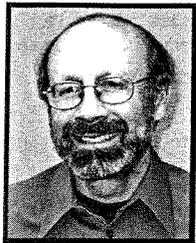
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ITE Coordinating Council Summary Report — Key Projects Completed in 2005

Council	Committee Title	Type	Committee Chair
Management & Operations/Intelligent Transportation Systems Council	Management and operations mega-issue	Informational report	Pat Noyes, 303-440-8171; pat@patnoyes.com
	Traffic signal self-assessment	Other	Les Jacobson, 206-382-5290; jacobsonl@pbworld.com
Parking Council	Rescission of Guidelines for Parking Design	Other	Randy McCourt, 503-243-3500; rsm@dkssassociates.com
Pedestrian and Bicycle Council	<i>Site Design Review Guidelines for Promotion of Alternative Transportation Modes: Canadian Guide to Promoting Sustainable Transportation Through Site Design</i>	Informational report	Eugene Chartier, 905-985-7346 ext. 10; gchartier@township.scugog.on.ca
	Segway investigations	ITE Journal article	Luis Porrello; lporrello@hntb.com
Traffic Engineering Council	<i>Update of Guidelines for Prohibition of Turns on Red</i>	Recommended practice	Bill Savage, 517-339-3933; msusavage@aol.com
	Benefits of retiming traffic signals	Brochure	Srinivas Sunkari, 979-845-7472; s-sunkari@tamu.edu
	<i>Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices (Revision)</i>	Recommended practice	Thomas Lancaster, 503-248-0313; tom@lancasterengineering.com
Transportation Consultants Council	2005 Young Professionals Scholarship Program	Other	Paul Eng-Wong, 212-695-5858; peng-wong@eng-wongtaub.com
Transportation Education Council	Knowledge expectation survey	Survey	Gary B. Thomas, 979-458-3263; g-thomas@tamu.edu
	ASCE Policy 465	ITE Journal article	Martin Lipinski, 901-678-3279; mlipinski@memphis.edu

PUBLIC HEALTH POLICY AND PRACTICE

What are the most effective ways of improving population health through transport interventions? Evidence from systematic reviews

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Study objective: To review systematic review literature that describes the effectiveness of transport interventions in improving population health.

Methods: Systematic review methodology was used to evaluate published and unpublished systematic reviews in any language that described the measured health effects of any mode of transport intervention.

Main results: 28 systematic reviews were identified. The highest quality reviews indicate that the most effective transport interventions to improve health are health promotion campaigns (to prevent childhood injuries, to increase bicycle and motorcycle helmet use, and to promote children's car seat and seatbelt use), traffic calming, and specific legislation against drink driving. Driver improvement and education courses are associated with increases in crash involvement and violations.

Conclusions: Systematic reviews are able to provide evidence about effective ways of improving health through transport related interventions and also identify well intentioned but harmful interventions. Valuable additional information may exist in primary studies and systematic reviews have a role in evaluating and synthesising their findings.

Transport has the potential to affect health in a number of ways.^{1,2} Health may be promoted by enabling access to work and social activities, including exercise, or it may be damaged through accidents, air and noise pollution, and other social and environmental impacts. Observational and experimental evidence is available to describe some of these mechanisms, for example, the effects of physical activity on obesity,³ type 2 diabetes mellitus,⁴ hypertension,⁵ cardiovascular disease,⁶ osteoporosis,⁷ mental health, and some cancers.⁸ But whether any transport policy or programme will actually cause changes in exercise related health depends upon a chain of events occurring and just because some links in the postulated chain can be demonstrated, it does not mean that the whole chain is proved.⁹ At a population level the relation between transport and health is complex and sometimes counterintuitive. For example, an increase in traffic volume in the United Kingdom has been accompanied by a fall in serious and fatal road traffic accidents.¹⁰ Compulsory cycling helmet legislation in Victoria, Australia, was followed by a fall in the severity and frequency of head injuries,¹¹ which may have been partly a result of a 36% reduction in cycling and its health benefits by children and teenagers.¹² In an attempt to reduce inequalities through transport policies in urban programmes, it is worth noting that highly efficacious clinical interventions may be implemented in ways that worsen inequalities.¹³ Thus, the health effects of transport interventions need to be evaluated in field trials so that these complex impacts can be assessed.

The aim of our review was to identify high quality evidence on the effects of transport policies and programmes on health. We restricted our search to literature describing population based interventions and their measured health impacts for the reasons given above. We did not restrict our search to specific diseases or potential risk factors. We sought evidence from systematic reviews for several reasons: the first is that few practitioners, and even fewer policymakers and planners, have the time, skills and other resources to review all the available evidence. Reading a systematic review

is a more reasonable proposition and there is a growing recognition that syntheses of research results rather than results of single studies are needed.¹⁴ Systematic reviews may play an important part in identifying effective social and policy interventions, as illustrated by international initiatives such as the Cochrane Collaboration (<http://www.cochrane.org/default.html>) and the Campbell Collaboration^{15,16} and in the UK, the ESRC funded Evidence-based Policy and Practice Initiative (<http://www.evidencebasedpolicy.com/>). The quality of evidence presented by rigorous systematic reviews is usually of a high standard because reviewers use methods that minimise selection, inclusion, and measurement biases.¹⁷ And lastly,

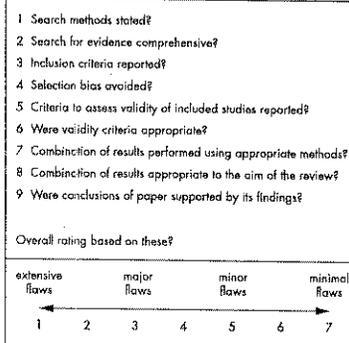


Figure 1 Criteria for evaluating overviews. Oxman and Guyatt.¹⁸

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Table 1 Main findings of systematic reviews on health promotion interventions to improve health through transport

Modes of intervention	Quality indices	Main results
Primary care based counselling to prevent childhood injury	4 ¹⁸	Injury prevention counselling as part of routine health supervision increased car seat and seat belt use, decreased motor vehicle occupant injuries and decreased hospital visits for traffic injuries.
Promotion of childhood rear car seats	6 ¹⁹	School based and public/parent education to use bicycle helmets reduced hospital inpatient rates for bicycle injuries by up to 8.2% more than control groups. Reductions in hospital admissions as a result of general injury prevention approaches showed 20% decrease in 1 study, but NS effects in other programmes. The evidence is weak that either educational campaigns or legislation to encourage front and rear seat belt use and placing children in rear seats are effective in changing behaviour. At some ages, there was a decrease in placing children in rear seats or in using rear seat belts. A number of included studies did not show statistically significant effects of the intervention.
Health promotion and community based approaches to reduce unintentional injury	5 ^{20,21}	[6-15 years old]: Road environment modifications reduced accidents by 7-32%; package of engineering measures reduced accidental injuries by 23%; road safety education can reduce casualties from children emerging from behind a vehicle by 20%; cycle helmets associated with 48% and 70% reduction in hospital admissions and death, plus 23% and 28% reduction in non head injuries over 2 year study period; child restraints and seatbelts reduced injury severity.
Driver improvement and education programmes	7 ^{22,23}	[15-25 years old]: Bicycle and motorcycle helmets reduced head and other injuries and motorcycle helmet legislation was followed by a 30% reduction in fatalities, its repeal by an increase of 25-40% [the effect of reductions in cycling and motorcycling rates in the population is unclear]; raising the minimum drinking age above 18 is associated with decrease in young driver and passenger fatalities. No proven effect of: training in reducing motorcycle injury; enhanced driver education courses; school based programmes; rehabilitation for drink drivers, and education on the effects of constitutive injury. Programmes that unintentionally enable adolescents to drive at a younger age than they would otherwise may have a negative effect.
Road safety campaigns	3 ²⁴	24/59 included programmes resulted in statistically significant reductions in violations [4-21%] but 3/59 resulted in significant increase in violations of 9, 14 and 40%. Crash reductions of 6-32% in 10/59 included programmes but 2/59 resulted in crash increases of 20, 30 and 46%. No proven effect of individual vs group interventions, direct vs indirect approaches or targeting certain types of violation.
Safety belt incentives	7 ²⁵	RCTs show increase in crash involvement and violations as a result of high school aged driver education courses. Ecological studies show both increases and decreases in crash involvement after driving education programmes and increases in licensure rates in 16-17 year olds. Average campaign effect for all campaigns is 7.6% improvement. Persuasive rather than educative approaches are more effective. Legislation alone is not effective but requires enforcement plus publicity. Four qualitative research, 60% positive or rational appeal, theoretical model basis vs none and specific behaviour request, increase the effectiveness of campaigns. Prevalence of baseline knowledge is inversely related to potential for impact of campaign. All road safety campaigns show 7.0% reduction in accidents over and above the background temporal reduction in accident rates. Financial rewards are most effective, followed by enforcement + legislation combinations and in cities rather than rural settings. Campaigns that use tangible incentives (such as money, prizes and vouchers) tend to substantial shorter term increases in safety belt use [mean effect 12.0% increase above baseline] but have more modest longer term effects [mean effect 9.6% increase above baseline]. Campaigns were most effective in elementary schools, where incentives were given immediately rather than delayed, and where the initial baseline use of seatbelts was low. Educational campaigns: 1 found 5% increase in children in rear seats (p<0.05); 1 pilot programme found 30% increase in child restraint use in rear seats (p<0.05) in elementary schools, but other settings and placing children in rear seat were NS. Legislation requiring restraints when children were in front car seats had effects on the use of rear seats: 1 study found 19% increase; 1 study found 9% increase in <1 year olds, 2% in 1-4 year olds and decrease of 4% in 5-9 year olds but NS effects in 10-14 year olds; 2 studies found NS effects. Child restraint use in rear seat: 3 studies found increases of 11-16% (p<0.05); 1 study found decrease in restraint use of 10% in 1-4 year olds and 3% in 5-9 year olds but increase in <1 year olds (all p<0.05). Community and clinical programmes to increase <5 year olds' car seat and seatbelt use have moderate but only short term effects. 3 RCTs showed 36% increase in car seat or seatbelt use. RCTs of pre-education and rehabilitation to reduce alcohol consumption and injury related sequelae showed improvements in motor vehicle crash risks (RR 0.76-0.90) and injuries (RR 0.47 and 0.58) but probation and rehabilitation together may increase risk of injury (RR 1.06 NS). Programmes to rear drink drivers show non alcohol related crashes were worse as a result of the intervention [mean 11% increase] but a small decrease in alcohol related crashes occurred [mean 7% reduction]. More severe licence sanctions reduced crash rates by 1-7%, but lighter sanctions increased crash rates by 7%.
Remediation of drinking and driving offenders	7 ²⁶	

RR, risk ratio; RCT, randomised controlled trial; NS, not significant at p<0.05 level

systematic reviews indicate the principal areas in which evidence exists and may indicate gaps in knowledge.

METHODS

Inclusion criteria

We included all published and unpublished reports in all languages describing systematic reviews or meta-analyses of the effects of any mode of transport or transport policy on health. Health effects included social, psychological, and physical effects that could be measured on humans.

Exclusion criteria

We excluded non-systematic literature reviews, descriptions of environmental or physical effects that did not include human responses to them, behavioural interventions without objectively measured outcomes, predicted but not empirical health impacts, and reviews that described the effects of intermediate mechanisms by which transport affects health—such as exercise, walking or cycling—without evaluating the effectiveness of policies or programmes to bring about these changes.

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Table 2 Main findings of systematic reviews on engineering interventions to improve health through transport

Modes of intervention	Quality indices	Main results
Ignition interlock devices	4*	Ignition interlock devices were used for convicted drink driving offenders. Re-arrest and recoviction were reduced in intervention versus control groups (RR 0.36-0.85) in a variety of study designs, including on RCT.
Studded tyres	3 [†]	Studded tyres may increase or decrease accident rates, depending on road conditions. It included studies found changes in accident rates significant at 95% level on snow (18-72% reduction), on bare roads (increase of 151% to decrease of 62%), and on all road surfaces (16-57% reduction). Studies with higher quality (large size, surface condition of road specified, type of tyre specified, confounding variables accounted for) showed small, NS effect sizes (2-5% accident reduction). 3 studies on the effects of laws prohibiting the use of studded tyres found increases in accident rates of 1-10% (p<0.05).
Traffic calming schemes	6*	Traffic calming devices increases to discourage nonlocal traffic from using residential streets and reducing the speed of the remaining traffic. Area wide traffic calming reduces the number of accidents by a mean of 15% in the whole area affected by the measures (main roads and local roads combined). The effects are relatively constant in different countries and in different years.
Daytime running lights	4 [†]	Daytime running lights are associated with a reduction in multi-perry accident rates of 14-18% (p<0.05 in prospective controlled studies and in uncontrolled prospective designs, NS in RCT). All types of accident (front/side impact, rear-end collision, pedestrian, not specified) reduced by 14% (12-16%). There is no clear dose-response relation between proportion of cars using DRLs and accident rates. The effects of DRLs are greater with increasing latitude (for example, 9% reduction in accidents in rural v 60% reduction in Finland).
Speed limit reductions	4*	Speed limit reductions may be effective on their own in reducing accidents but additional measures may be needed. Speed limit zones in built up areas reduce personal injuries but have no clear effect on material damage. Controlled studies show smaller reductions in personal injuries (10%, 0-26%) than uncontrolled studies (43%, 42-45%). Speed limit zones in quieter peripheral roads are effective in reducing both personal injuries (21%, 9-31%) and material damage (48%, 9-26%). A change to differential speed limits (lower in more built up areas, faster in peripheral roads) is associated with an increase in accidents in the peripheral areas (17%, 0-37%). For 30 km/h zones, accidents are reduced by 3.5% per km/h speed is reduced, independent of study design. Speed reduction by road humps shows non significant reductions in personal injuries in controlled studies (17% reduction, 95% CI 6.7% reduction to 19% increase). Controlled studies show non-significant increases in accidents in areas surrounding road humps. Accidents are reduced by 4.5% per km/h speed is reduced, independent of study design. Raised crossroads are associated with non-significant increases in personal and material accidents. Bumble stripes approaching crossroads are associated with significant decreases in personal (33% 25-40%) and material (25%, 5-45%) accidents.

RR, risk ratio; RCT, randomised controlled trial; NS, not significant at p<0.05 level.

Search methods

We searched the following electronic databases plus the world wide web using www.google.com, Ovid Medline (1966-1/2001), EMBASE (1980-1/2001), CINAHL (1982-1/2001), DARE (1/2001), ERIC (1966-1/2001), Cochrane Database of Systematic Reviews (2000, Issue 4) and PsycINFO (formerly PSYCLIT) (1971-1/2001) using the search terms: meta-analysis, metaanalysis, systematic AND review, evaluation synthesis or research synthesis, limited to human subjects, where 4 denotes all suffixes. Keywords were transport, car, cars, bus, automobile(s), traffic or vehicle, TRANSPORT—which comprises the three databases BRIS, HTR and TRANSDOC—was electronically searched from its first entries in the 1960s to February 2001 for all meta-analyses and systematic reviews without any additional restrictions on the initial search because all entries should be relevant to transport. Bibliographies of selected papers were searched and experts in the field were asked to identify other relevant reviews.

Evaluation of included reviews

Two reviewers independently screened abstracts then scored papers using Oxman and Guyatt's index for quality assessment of reviews,¹⁷ using the nine criteria given in figure 1. A quality index, based on these criteria, could range from 1 (major flaws) to 7 (minimal flaws).

We have presented brief summaries of the most important findings of each review in the Results.

RESULTS

Although 3183 reports were identified in the first electronic search and all abstracts read to select those that met inclusion criteria, a total of 127 candidate papers and reports were selected. All were obtained and considered for suitability.

Twenty papers were agreed to meet the inclusion criteria. A further eight eligible reviews were identified through contact with experts and bibliographies giving a total of 28 systematic reviews and meta-analyses. All reviews that appeared in the same special edition of the *American Journal of Preventive Medicine* were considered with an introductory paper¹⁸ that described the common methodology of all their searches.

We classified reviews into four categories of intervention: health promotion, engineering, environmental, and legislative. Where reviews covered more than one type of intervention, the dominant area determined its classification in our summary. A brief summary of the results of each review is given in tables 1-4. Only six reviews, all of which described health promotion interventions, had minimal flaws.

Health promotion interventions

Systematic reviews with minimal flaws identified beneficial effects of primary care based counselling to prevent childhood injury and efforts to increase bicycle and motorcycle helmets,^{19, 20} and raising the minimum drinking age above 18 years.²¹ Programmes to increase car seat and seatbelt use by children are effective but their benefits seem to be comparatively shortlived.²² There are mixed effects of drink driving remediation, with some interventions, such as the combination of rehabilitation and probation, being associated with a potential increase in the risk of injury.²³ Driver improvement and education courses are associated with an increase in crash involvement and violations.²⁴

Reviews with more methodological flaws, in addition to providing further information on topics already covered by better quality reviews, described beneficial effects of road safety and education campaigns.^{25-31, 33}

Table 3 Main findings of systematic reviews on environmental interventions to improve health through transport

Modes of intervention	Quality indices	Main results
Public lighting	4 ^{††}	Night time accidents were reduced by 15-35% as a result of public lighting interventions. The effect size was greater where more accidents occurred at night as compared with during the day. Fatal accidents reduced by 65% (range 52-74%) and property damage reduced by 17% (range 13-21%). The effects were also dependent upon the decade of study (reported in the 1980s), the country of study (largest effect in Israel, smallest effect in Denmark), rural areas benefited more than urban environments, and pedestrians benefited more than other street users.
Guardrails and crash cushions	4*	Installing median barriers increases the total number of accidents by about 30% (p<0.05). Severity of accidents is reduced. New median barriers reduce the probability of fatal accidents by 72% (range 14-46%), upon the total number of accidents, but apparently have no effect on the probability of injury accidents (2%, -7-4% change). Guardrails reduce both the number of accidents (by 27%, range 18-35%) and their severity. Crash cushions reduce both number (84%, range 74-93%) and severity of accidents although studies are few and of doubtful validity.
Modifiable risk factors for child pedestrian injuries	3 ^{††}	Child risk factors, in order of effect size, are age, behaviour, race, and sex. Social and cultural risk factors increasing likelihood of child pedestrian injuries are: parents (RR 5.7), crossing (RR 1.3 to 3.4), mother's working status and history of hospitalisation (RR 2, 2.5), illness in the family (RR 2.3), and mother's education. Physical environment risk factors are, at descending order, volume of traffic, speed limit, predominant type of dwelling, absence of play area, location of road, proportion of curb side parking, street main vehicle speed, shared driveway, type of road, time of day, weather, and lighting.

RR, risk ratio.

Engineering improvements

Five reviews were identified although four³⁴⁻³⁷ had major methodological flaws (table 2). Flvik's review of traffic calming schemes³⁴ had a Quality Index of 6. It found that traffic calming schemes had a mean effect of reducing accidents by 15% and that similar effect sizes were found in different decades and in different countries.

There is some evidence from less methodologically rigorous reviews for the effects of ignition interlock devices, studded tyres, daytime running lights, and measures to reduce vehicle speeds. Ignition interlock devices, which require drivers to record a legal breath alcohol level before the car engine can be started, were associated with reductions in re-conviction and re-arrest rates for driving while intoxicated of at least a third.³⁸ Studded tyres had mixed effects, on some road surfaces increasing accident rates and in others reducing them.³⁹ Laws to enforce the use of studded tyres were associated with statistically significant increases in accident rates of 2%-10%, the use of sidelights or dipped headlights during the day (daytime running lights) was associated with reductions in accidents involving more than one vehicle of about 14%, but this effect was much greater in more northerly countries.⁴⁰ Speed limit zones are effective in reducing personal accidents and material damage.⁴¹ Creating raised road surfaces at crossroads may increase accidents, while noisy road surfaces (rumble strips) before crossroads are associated with reductions in accidents. Road humps and differential speed limits may reduce accidents locally but increase them in surrounding areas.

Environmental interventions

Three reviews considered environmental interventions (table 3) and all had more than minor methodological flaws.

Flvik's review³⁴ found that public lighting reduced night time accidents in all cases but depended on the baseline risk and the proportion of night time accidents.³⁴ Guard rails and crash cushions were found to increase numbers of accidents but decrease their severity.³⁴ One review,⁴² with a Quality Index of 3, aimed to describe the effects of modifiable risk factors on child pedestrian injuries. Age, behaviour, race, and sex were considered to be among the strongest risk factors although it is not clear how any but behaviour might be modified.

Legislative interventions

Six reviews considered the effectiveness of legislation on accidents, injuries, and drinking and driving (table 4). A review

that had a quality score of 6 found that laws for a maximum legal blood alcohol concentration of 0.02% reduced night time injuries and fatal crashes.⁴³ The introduction of random breath alcohol testing is associated with a reduction in alcohol related hospital admissions, deaths, injuries, night time crashes, and charges for drink driving by around a fifth.⁴⁴ A review of laws against drink driving in the absence of any other offence (administrative per se⁴⁵) had minor flaws and found inconclusive results although no harmful effects. Other studies had more methodological flaws and their results should be interpreted with caution. Legislation to deter drinking and driving was effective in most cases although several studies on mandatory jail sentences showed increases in crashes after legislation.⁴⁶ Lighter sanctions against drink drivers increased subsequent crash rates by 2%⁴⁷ (see table 1). Fox⁴⁸ found that graduated driver licensing (where there is progressive freedom after passing the driving test to drive unaccompanied and at night) and night time curfews were associated with variable reductions in deaths and accidents. These were confounded to some extent by reductions in the rate of licensure among teenagers. Laws to enforce car seat belt use by adults increased belt use and reduced serious and fatal injuries.⁴⁹

DISCUSSION

Evidence is available in well conducted systematic reviews both to support a range of transport related interventions that will benefit health and to indicate interventions that are intended to improve health but are in fact harmful and should not be implemented. Beneficial interventions include health promotion campaigns to prevent childhood injuries, efforts to increase bicycle and motorcycle helmet use, children's car seat and seatbelt promotion, traffic calming, and specific legislation against drink driving. Driver improvement and education courses may increase accidents by encouraging greater numbers of inexperienced drivers on to the roads. We agree with comments made in a review⁵⁰ published during the preparation of this paper that they cannot be recommended. Evidence for other health effects of transport interventions has also been identified in systematic reviews that have more methodological flaws. Ignition interlock devices, daytime running lights, public lighting, graduated driver licensing, and laws to enforce seatbelt use may all be effective in improving health. The evidence is equivocal on the benefits and harms of

Table 4 Main findings of systematic reviews on legislative interventions to improve health through transport

Modes of intervention	Quality indices	Main results
Drinking and driving legislation, including 4 th administrative per se, random screening and lowering the legal blood alcohol limit	4 th 6 th	A systematic review on drink driving control showed that licence suspension, legal and administrative per se laws, selective and regular enforcement patrols and sobriety checkpoints were most effective, with typical effect sizes of around 10% reduction in a variety of outcomes. Several studies on mandatory jail sentences showed increases in crashes following implementation.
	6 th	Laws requiring a reduction to maximum 0.02% blood alcohol concentration associated with reduction in night time injuries of 17% [NS], 12% reduction in injuries in men, 24% in women, 17% reduction in total crashes among younger drivers (p<0.001), 1% in older drivers; 22% net reduction in fatal crashes.
	5 th	Project with interrupted time series (3 study): 4% reduction in serious injuries using time series, 6% reduction using pre-post + both; 145 interrupted time series (1 study): 11% or 32% reduction in "bad-been drinking" crashes depending on model chosen.
	5 th	Evaluation of licence suspension or revocation through administrative determination showed no clear effect in 1/5, in 3/2, reduction in intervention v controls. OR 0.65 (0.54 to 0.80) up to but not after 36 months; in 1/3, intervention v controls in first year - drunk driving offences OR 0.78 (0.70 to 0.79), traffic crashes OR 0.65 (0.63 to 0.67) and alcohol related crashes OR 0.73 (0.70 to 0.77).
Graduated driver licensing among young drivers	4 th	Random breath testing reduced hospital admissions by 20%, reduced deaths and injuries by 17-35%, reduced nighttime crash rates by 10-28% and reduced fatal crashes by 17-25%. Graduated driver licensing was associated with a reduction in hospital admissions of up to 23% and a reduction in deaths of 5-5% in 15-19 year olds; however, there was a simultaneous reduction in 15-19 year olds who drove and a 5% decrease in the teenage population in New Zealand.
Car safety belt laws (only for adults)	3 rd	A governmental licensing programme for 16-17 year olds showed a 5% decrease in daytime crashes; no effect of night time driving restriction; and a 10% decrease in traffic violation convictions. Carlaw laws in under-18s (1/4) found no apparent effect; (3/4) found decrease in fatality by 23-28%.
	3 rd	Prevalence of seat belt use increased by 1.08-1.3 times after laws introduced. Primary enforcement compared with no laws found 1.5-4.1 times more prevalent seat belt use (16 studies); one outlier of 15.4 times more use of seatbelts; RR fatal injury 0.69 to 0.97 (20 studies) but 1.12 (NS) in 1 study; serious non-fatal injury RR 0.20 to 0.89 (11 studies). Secondary enforcement compared to no laws found a prevalence of seatbelt use 2.1-2.6 times higher in the former group (6 studies); RR fatal injury 0.62 to 1.03 (7 studies); but no significant when over 1.02; serious non-fatal injury RR 0.75 to 0.85 (14 studies). Any law compared with no law, 4 studies found that relative risk of fatal injury was 0.91 to 0.95 in the former.

RR, risk ratio; OR, odds ratio; RCT, randomised controlled trial; NS, not significant at p<0.05 level

guard rails, crash cushions, and interventions to reduce vehicle speeds. Some modes of drink driving remediation, including mandatory jail sentences and laws to enforce studded tyres, are associated with harmful effects on health. Further research, beginning with more rigorously conducted systematic reviews, is needed to determine whether these findings are valid.

The scope of this review

All 28 systematic reviews and meta-analyses on transport and health that we identified were concerned with injury prevention and all but four were concerned with preventing motorcar injuries. We did not use accident prevention as a primary search term because published and ongoing reviews exist in this area.²²⁻²⁴ We found no evidence to suggest that any intervention will bring about a shift in the use of different modes of transport and as a result improve health in the broader ways suggested in the Introduction. Such evidence may exist in primary studies that have not been synthesised in systematic reviews. For those who support public policies to promote walking, cycling, and public transport, experimental evidence may be superfluous and the intrinsic value of reducing our dependence on the car may be self evident. But this review has identified several counterintuitive effects of apparently beneficial transport programmes. We therefore believe that evidence of outcomes should guide transport interventions that are intended to benefit health and that good intentions are not enough.

Information from qualitative and quantitative research that describes important relations between transport use and broader determinants of health, for example exercise²⁵ or sev-

erance of communities by roads²⁶ may be helpful both in designing more effective new interventions and in understanding how the social and environmental context of an intervention may influence its effectiveness. It was not our aim to review the entire body of literature on how transport affects health, however, but to identify where population based interventions have been shown to impact upon health. Because of the loss of information in summarising reviews, we would recommend that anyone considering using their findings obtains the original papers.

Quality of included reviews

Oxman and Guyatt's quality scores²⁷ for each study indicate that only six reviews achieved a score of 7, indicating minimal flaws. Six studies had a score of 3 or less, indicating major flaws. Failure to demonstrate that selection bias had been avoided and inappropriate assessment of validity were the commonest methodological problems overall. Oxman and Guyatt scores mark down failure to report review methods, even if they have been carried out. It is therefore important for systematic reviews to make their methodology explicit. Improvements in database search engines are also needed so that, for example, controlled trials can be more readily identified.²⁸

One implication of these results is that systematic reviews and meta-analyses have a useful contribution to evidence based policymaking for transport. As evidence of the health effects of other interventions continues to accrue, regularly updated systematic reviews will be required. Some of this work may fall within the remit of the newly established Campbell Collaboration (<http://www.campbellcollaboration.org>).

Key points

- It may be possible to improve health by changing the way that people use different forms of transport.
- Evidence to support the actual effects of changing transport policies, plans, and programmes is often poorly described.
- Systematic reviews can provide accessible summaries of evidence on the effects of transport on health, using comprehensive search methods and explicit criteria for evaluating the quality of included primary studies.
- We found that health can be improved through health promotion campaigns, traffic calming schemes, and some leg-islation. But some interventions, such as driver improvement and education courses, may be harmful to health.
- The population health would be improved by implementing transport policies based on high quality research evidence and by withdrawing those where there is good evidence that any benefits are outweighed by harms.

Systematic reviews do not, however, obviate the need for high quality primary studies as important sources of evidence to improve health through transport choices.

Conclusions

Systematic reviews are able to provide evidence about effective ways of improving health through transport related interventions. The best evidence indicates that health promotion campaigns to prevent childhood injuries, increase bicycle and motorcycle helmet use, and children's car seat and seatbelt use, plus traffic calming, and specific legislation against drink driving are all beneficial, while driver improvement and education courses may be harmful. A systematic review of primary studies that embraces a wider range of possible health effects of transport—including social and environmental effects—is required and work on this is underway by the authors. This should determine if evidence is available to support claims for a spectrum of health effects, whether this evidence is of acceptable quality, and if not, where new primary studies should be directed. In the meantime, we suggest that policymakers, planners and health professionals put the available evidence into practice and monitor its benefits on health.

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Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations

Analysis of Pedestrian Crashes in 30 Cities

Charles V. Zegeer, J. Richard Stewart, Herman Huang, and Peter Lagerwey

Pedestrians are legitimate users of the transportation system and they should, therefore, be able to use the system safely. Pedestrian needs in crossing streets should be identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark crosswalks is only one consideration in meeting that objective. This study involved an analysis of 5 years of pedestrian crashes at 1,000 marked crosswalks and 1,000 matched unmarked comparison sites. None of the sites in this study had a traffic signal or stop sign on the approaches. Detailed data were collected on traffic volume, pedestrian exposure, number of lanes, type of median, speed limit, and other site variables. Poisson and negative binomial regressive models were used. Study results revealed that on two-lane roads the presence of a marked crosswalk alone at an uncontrolled location was associated with no difference in pedestrian crash rate, compared with an unmarked crosswalk. Further, on multilane roads with traffic volumes above about 12,000 vehicles per day, having a marked crosswalk was associated with a higher pedestrian crash rate (after controlling for other site factors) compared with an unmarked crosswalk. Raised medians provided significantly lower pedestrian crash rates on multilane roads, compared with roads without a raised median. Older pedestrians had crashes that were high relative to their crossing exposure. More substantial improvements were recommended to provide for safer pedestrian crossings, including adding traffic signals (with pedestrian signals) when warranted, providing raised medians, and implementing speed-reducing measures.

Pedestrians are legitimate users of the transportation system and they should, therefore, be able to use this system safely and without unreasonable delay. Pedestrians have a right to cross roads safely; planners and engineers, therefore, have a professional responsibility to plan, design, and install safe crossing facilities. Pedestrians should be included as "design users" for all streets.

As a starting point, roads should be designed with the premise that there will be pedestrians, that they are going to be able to cross the street, and that they will be able to do it safely. The design question is, How can this task be best accomplished?

Providing marked crosswalks has traditionally been one measure used in an attempt to facilitate crossings. They are commonly used at uncontrolled locations and sometimes at midblock locations. However, there have been conflicting studies and much controversy

about the safety effects of marked crosswalks. This study evaluated marked crosswalks at uncontrolled locations and offers guidelines for their use.

HOW TO USE THIS STUDY

Marked crosswalks are one tool to ensure pedestrians can safely cross the street. When marked crosswalks at uncontrolled locations are being considered, the question should not be simply, Should I provide a marked crosswalk or not? Instead, the question should be, Is this an appropriate tool for getting pedestrians across the street? Regardless of whether marked crosswalks are used, there remains the fundamental obligation to ensure that pedestrians can safely cross the street.

In most cases marked crosswalks are best used in combination with other treatments (e.g., curb extensions, raised crossing islands, traffic signals, roadway narrowing, enhanced overhead lighting, traffic-calming measures, etc.). Marked crosswalks should be thought of as one option in a progression of design treatments. If one treatment does not adequately accomplish the task, then move on to the next one.

Failure of one particular treatment is not a license to give up and do nothing. In all cases the final design must accomplish the goal of getting pedestrians across the road safely.

What Is the Legal Definition of a Crosswalk?

The 1992 Uniform Vehicle Code (Section 1-112) defines a crosswalk as follows (1):

- (a) That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs, or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the existing sidewalk at right angles to the centerline.
- (b) Any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.

Thus, legal crosswalks exist at all public intersections where there is a sidewalk on at least one side of the street. The only way a crosswalk can exist at a midblock location is if it is marked. Fur-

ther, according to the *Manual on Uniform Traffic Control Devices* (MUTCD) (Section 3B-18), a crosswalk may be marked with paint, thermoplastic materials, and plastic tape, among other materials (2).

Specifically, crosswalks serve as the pedestrian right-of-way across a street. The level of connectivity between pedestrian facilities is directly related to the placement and consistency of street crossings.

Why Are Marked Crosswalks Controversial?

There has been considerable controversy in the United States regarding whether providing marked crosswalks will increase or decrease pedestrian safety at crossing locations that are not controlled by a traffic signal or stop sign. When citizens request the installation of marked crosswalks (with the assumption that marked crosswalks will increase their ability to cross the street safely), some engineers and planners still refer to the 1972 study by Bruce Herms (3) as justification for not installing them at uncontrolled locations. That study found an increased incidence of pedestrian collisions in marked crosswalks, compared with unmarked crosswalks at 400 uncontrolled intersections in San Diego, California. Questions have been asked about the validity of that study, and the study results have sometimes been misquoted or misused. Some have misinterpreted the results of that study; the study did not conclude that all marked crosswalks are "unsafe," and school crosswalks were not included in the study.

A few other studies since the Herms study have tried to address this issue. Some are not conclusive because of their methodology or sample size problems, and some have fueled the disagreements and confusion on the issue. Further, most of the previous crosswalk studies have analyzed the overall safety effects of marked crosswalks but did not investigate their effects in the presence of various numbers of lanes, different traffic volumes, or other roadway features. Like other traffic control devices, crosswalks should not be expected to be equally effective or appropriate under all roadway conditions.

Where Are Crosswalks Typically Installed?

The practice of deciding where to install crosswalks differs considerably from one jurisdiction to another across the United States, and engineers have been left to use their own judgment (sometimes influenced by political or public pressure) in reaching decisions. Some cities have developed their own guidelines. At a minimum, many cities tend to install marked crosswalks at signalized intersections (particularly urban areas), at school crossing locations (such as where adult crossing guards are used), and also at intersections controlled by a stop sign.

Some agencies rarely, if ever, choose to install marked crosswalks at uncontrolled locations (i.e., sites not controlled by a traffic signal or stop sign), whereas others have installed them at selected pedestrian crossing locations. Some towns and cities have chosen to supplement selected crosswalks with pedestrian warning signs, flashing lights, "Stop for Pedestrians in Crosswalk" signs, supplemental pavement markings, or a combination of these measures.

STUDY PURPOSE AND OBJECTIVE

Many highway agencies routinely mark crosswalks at school crossings and signalized intersections. Although questions have been raised about marking criteria at these sites, most of the controversy on

whether to mark crosswalks has pertained to the many uncontrolled locations in U.S. towns and cities.

The purpose of this study was to determine whether marked crosswalks at uncontrolled locations are safer than unmarked crosswalks under various traffic and roadway conditions. Another objective was to offer recommendations on how to provide safer crossings for pedestrians.

The results of this study should not be misused as a justification for doing nothing to help pedestrians safely cross streets. Instead, pedestrian crossing problems and needs should be routinely identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark or not mark crosswalks is only one consideration in meeting that objective.

This paper is based on a major research study for FHWA conducted by the University of North Carolina's Highway Safety Research Center (4). The study compared the safety of marked crosswalks versus unmarked crossings.

DATA COLLECTION AND ANALYSIS METHODOLOGY

An ideal study design would involve removing all crosswalks in several test cities and randomly assigning sites for crosswalk marking and sites to serve as unmarked control sites. However, it would be impossible to get the level of cooperation from the cities needed to conduct such a study because of liability considerations. Also, such random assignment of crosswalk markings would result in many crosswalks not being marked at the most appropriate locations.

Thus, because of real-world constraints, a treatment and matched comparison site methodology was used to quantify the pedestrian crash risk of marked versus unmarked crosswalks. This allowed for selection of a large sample of study sites in cities throughout the United States where marked crosswalks and similar unmarked comparison sites were available. At intersections, typically the unmarked crosswalk comparison site was the opposite leg of the intersection selected as the marked crosswalk site. For each marked midblock crosswalk, a nearby midblock crossing location was chosen as the comparison site on the same street (usually a block or two away) where pedestrians were observed to cross. (Even though an unmarked midblock crossing is not technically or legally a crosswalk, it was a suitable comparison site for a midblock crosswalk). The selection of a matched comparison site for each crosswalk site (typically on the same route and very near the crosswalk site) helped to control for the effects of vehicle speeds, traffic mix, and a variety of other traffic and roadway features.

A before and after experiment was not considered to be practical because of regression-to-the-mean problems, limited sample sizes of new crosswalk installations, and so on. A total of 1,000 marked crosswalk sites and 1,000 matched unmarked comparison sites in 30 cities across the United States was selected for analysis. Test sites were chosen without any prior knowledge of their crash history. School crossings were not included in this study because of crossing guards, special school signs and markings, or both, that may increase the difficulty of quantifying the safety effects of crosswalk markings.

Test sites were selected from the following cities:

- East: Cambridge, Massachusetts; Baltimore, Maryland (city and county); Pittsburgh, Pennsylvania; Cleveland, Ohio; Cincinnati, Ohio.
- Central: Kansas City, Missouri; Topeka, Kansas; Milwaukee, Wisconsin; Madison, Wisconsin; St. Louis, Missouri (city and county).

- South: Gainesville, Florida; Orlando, Florida; Winter Park, Florida; New Orleans, Louisiana; Raleigh, North Carolina; Durham, North Carolina.
- West: San Francisco, California; Oakland, California; Salt Lake City, Utah; Portland, Oregon; Seattle, Washington.
- Southwest: Austin, Texas; Ft. Worth, Texas; Phoenix, Arizona; Scottsdale, Arizona; Glendale Arizona; Tucson, Arizona; Tempe, Arizona.

Detailed information was collected at each of the 2,000 sites, including pedestrian crash history (average of 5 years per site), daily pedestrian volume estimates, average daily traffic (ADT) volume, number of lanes, speed limit, area type, type of median, type and condition of crosswalk marking patterns, location type (midblock versus intersection), and other site characteristics. Various crosswalk marking patterns are given in the MUTCD (2).

Crosswalk marking patterns found at the study sites included standard (parallel lines), solid (painted within the parallel lines), dashed, ladder, zebra, and continental style. Each of the 1,000 marked crosswalks had one of these marking patterns. Very few of the marked crosswalks had any type of supplemental pedestrian warning signs. Furthermore, none of the test sites had traffic-calming measures or special pedestrian devices (e.g., in-pavement flashing lights).

Estimates of daily pedestrian volumes at each crosswalk site and unmarked comparison site were determined based on pedestrian volume counts at each site, which were expanded to estimated daily pedestrian volume counts based on hourly adjustment factors. Specifically, at each of the 2,000 crossing locations, trained data collectors conducted on-site counts of pedestrian crossings and classified pedestrians by age group based on observations. Pedestrian counts were collected simultaneously for 1 h at each of the crosswalk and comparison sites. Full-day (8- to 12-h) counts were conducted at a sample of the sites and used to develop adjustment factors by area type (urban, suburban, fringe) and by time of day. The adjustment factors were then used to determine estimated daily pedestrian volumes in a way similar to that used by many cities and states to expand short-term traffic counts to average annual daily traffic.

This methodology was intended to measure relative pedestrian exposure at the crosswalk and comparison sites for use as a control variable in the analysis. Collecting the volume counts simultaneously at each crosswalk and matched comparison site helped to control for time-related influences on pedestrian exposure.

The crash data periods varied somewhat from city to city, and averaged approximately 5 years per site (typically from about January 1, 1994, to December 31, 1998). Police crash reports were obtained from each of the cities (except for Seattle, where detailed computer printouts were obtained for each crash). Crashes were carefully reviewed to assign a crash type and to ensure accurate matching of the correct location, that is, at or within 6.1 m (20 ft) of the marked or unmarked crossing of interest.

Standard pedestrian crash typology was used to review police crash reports and to determine the appropriate pedestrian crash types (e.g., multiple threat, midblock dart-out, intersection dash), as discussed later. All treatment (crosswalk) and comparison sites were chosen without prior knowledge of crash history. All sites used in this study were intersection or midblock locations with no traffic signals or stop signs on the main road approach (i.e., uncontrolled locations). This study focused on pedestrian safety and, therefore, data were not collected on vehicle-vehicle or single-vehicle collisions, even though it is recognized that marking crosswalks may increase vehicle stopping, which may also affect these collision types.

The selected analysis techniques were deemed to be appropriate for the type of data in the sample. Because of relatively low numbers of pedestrian crashes at a given site (e.g., there were many sites with zero pedestrian crashes in a 5-year period), Poisson modeling and negative binomial regression were used in the analysis of the data. Using these analysis techniques allowed for determining statistically valid safety relationships. In fact, there were a total of 229 pedestrian crashes at the 2,000 crossing sites over an average of 5 years per site. This translates to an overall average of one pedestrian crash per crosswalk site every 43.7 years.

All analyses of crash rates at marked and unmarked crosswalks took into account traffic volume, pedestrian exposure, and other roadway features (e.g., number of lanes, median type). To supplement the pedestrian crash analysis, a corresponding study by Knoblauch et al. (5) was conducted on pedestrian and driver behavior before and after marked crosswalks were installed at selected sites in California, Minnesota, New York, and Virginia.

STUDY RESULTS

Significant Variables

Poisson and negative binomial regression models were fit to pedestrian crash data at marked and unmarked crosswalks. These analyses showed that several factors in addition to crosswalk markings were associated with pedestrian crashes. Traffic and roadway factors found to be related to a greater frequency of pedestrian crashes included higher pedestrian volumes, higher traffic ADT, and a greater number of lanes (i.e., multilane roads with three or more lanes had higher pedestrian crash rates than two-lane roads). For this study, a center two-way left-turn lane was considered to be a travel lane and not a median.

The presence of a raised median (or raised crossing island) was associated with a significantly lower pedestrian crash rate at multilane sites with both marked and unmarked crosswalks. Further, on multilane roads, medians that were painted (but not raised) and center two-way left turn lanes did not offer significant safety benefits to pedestrians, compared with multilane roads with no median at all. These results were in basic agreement with a major study by Bowman (6) as well as a study by Garder (7), which found that raised medians and refuge islands, respectively, provided safety benefits for pedestrians.

There was also a significant regional effect; that is, sites in western U.S. cities had a significantly higher pedestrian crash rate than eastern U.S. cities (after controlling for pedestrian exposure, number of lanes, median type, and other site conditions). The reason(s) for these regional differences in pedestrian crash rate is not known, although it could be related to regional differences in driver and pedestrian behavior, higher vehicle speeds in western cities, differences in pedestrian-related laws, variations in roadway design features, other factors, or a combination.

Nonsignificant Variables

Factors having no significant effect on pedestrian crash rate included area type (e.g., residential, downtown), location type (i.e., intersection versus midblock), speed limit, traffic operation (one-way or two-way), condition of crosswalk marking (excellent, good, fair, or poor), and crosswalk marking pattern (e.g., parallel lines, ladder type, zebra stripes).

Surprisingly, after controlling for other factors (e.g., pedestrian volume, traffic volume, number of lanes, median type), speed limit was not significantly related to pedestrian crash frequency. Certainly, one might expect that higher vehicle speed would be associated with an increased probability of a pedestrian crash (all else being equal). However, the lack of association found in this analysis between speed limit and pedestrian crashes may be because there was not much variation in the range of vehicle speed or speed limit at the study sites [i.e., 93 percent of the study sites had speed limits of 40.2 to 56.3 km/h (25 to 35 mph)].

Another possible explanation, as hypothesized by Garder (personal correspondence, Oct. 7, 1999, and March 2000), is that pedestrians may be more careful when crossing streets with higher speeds; that is, they may avoid short gaps on high-speed roads, which may minimize the effect of vehicle speed on pedestrian crash rates. In terms of speed and crash severity, the analysis showed that speed limits of 56.3 km/h (35 mph) and greater were associated with a higher percentage of fatal and A-type (serious or incapacitating) injuries (43 percent) compared with sites having lower speed limits (23 percent of crashes resulting in fatal or A-type injuries).

Marked versus Unmarked Crosswalk Comparisons

All of the variables related to pedestrian crashes (i.e., pedestrian volumes, traffic ADT, number of lanes, median existence and type, and region of the country) were then included in the models for determining effects of marked versus unmarked sites. Binomial comparisons were produced for marked versus unmarked crosswalks

within subsets by ADT, median type, and number of lanes, as shown in Figure 1. The results revealed that on two-lane roads, there were no significant differences in pedestrian crashes for marked versus unmarked crosswalk sites. That is, pedestrian safety on two-lane roads was not found to be different, whether the crosswalk was marked or unmarked. This conclusion is based on a sample of 914 crossing sites on two-lane roads (out of 2,000 total sites.)

On multilane roads with ADTs of 12,000 or less, there were also no differences in pedestrian crash rates between marked and unmarked sites. On multilane roads with no raised medians and ADTs greater than 12,000, sites with marked crosswalks had higher pedestrian crash rates than unmarked crossings. On multilane roads (roads with 3 to 8 lanes) with raised medians and vehicle ADTs greater than 15,000, a significantly higher pedestrian crash rate was associated with marked crosswalk sites compared with unmarked sites.

Best-fit curves on multilane undivided roads were produced for pedestrian crashes (per million pedestrian crossings) at marked and unmarked crosswalks as a function of traffic ADT, as shown in Figure 2. Similar analyses were conducted for multilane divided roads. This analysis for multilane undivided roads revealed the following:

- For traffic volumes (ADTs) of about 10,000 or less, pedestrian crash rates were about the same (i.e., approximately 0.25 pedestrian crashes per million pedestrian crossings) at marked and unmarked crosswalks.
- For ADTs greater than 10,000, the pedestrian crash rate for marked crosswalks became increasingly worse as ADT increased. The crash rate at unmarked crossings increased only slightly as ADT increased.

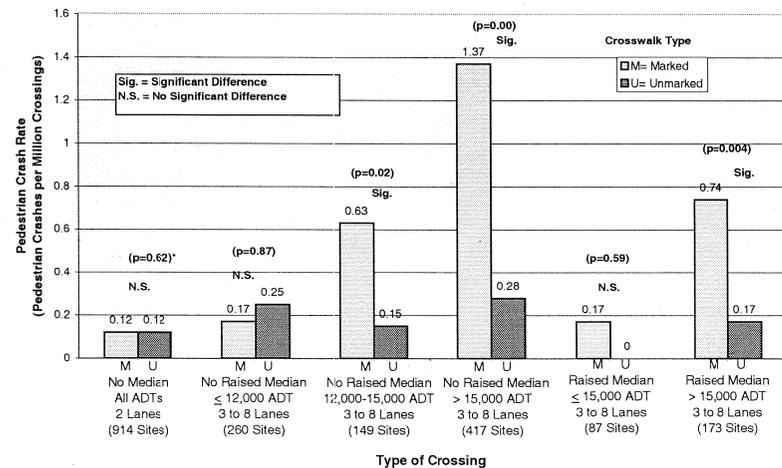


FIGURE 1 Pedestrian crash rate versus type of crossing (levels of significance between marked and unmarked crosswalks are based on binomial pedestrian crash modeling).

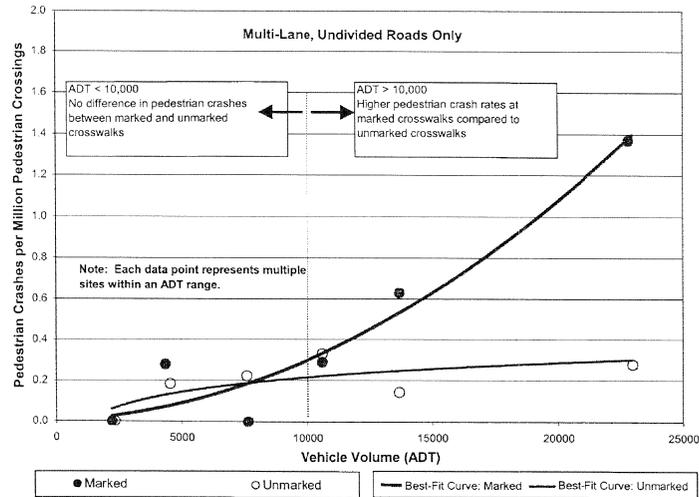


FIGURE 2 Pedestrian crash rates by traffic volume for multilane crossings with no raised medians—marked versus unmarked crosswalks.

Note that each point on the graph represents dozens of sites; that is, all of the sites corresponding to the given ADT group. For example, the data points for marked and unmarked crosswalks with ADTs greater than 15,000 correspond to more than 400 sites. All analyses in this study took into account the differences in pedestrian crossing volume, traffic volume, and other important site variables.

The results given above suggest that wide multilane streets are difficult for many pedestrians to cross, particularly if there are an insufficient number of adequate gaps in traffic because of heavy traffic volume and high vehicle speed. Furthermore, although marked crosswalks in themselves may not increase measurable unsafe pedestrian or motorist behavior [based on the Knoblauch study (5)], one possible explanation is that installing a marked crosswalk may increase the number of at-risk pedestrians (particularly children and older adults) who choose to cross there instead of at the nearest signal-controlled crossings.

The pedestrian crossing counts at the 1,000 marked crosswalks and 1,000 unmarked comparison crossings from this study may partially explain the difference. Overall, 66.1 percent of the observed pedestrians crossed at marked crosswalks versus 33.9 percent at unmarked crossings. More than 70 percent of pedestrians under age 12 and above age 64 crossed at marked crosswalks; about 35 percent of pedestrians in the 19- to 35-year-old range crossed at unmarked crossings. The age group of pedestrians was determined from on-site observation.

An even greater percentage of older adults (81.3 percent) and young children (76.0 percent) chose to cross in marked crosswalks on multilane roads compared with two-lane roads. Thus, installing

a marked crosswalk alone at an already undesirable crossing location (i.e., wide, high-volume street) may increase the chance of a pedestrian crash occurring at a site if a few at-risk pedestrians are encouraged to cross where other adequate crossing facilities are not provided. This explanation might be evidenced by the many calls to traffic engineers from citizens who ask that a marked crosswalk be installed so they can cross the dangerous street near their houses. Unfortunately, often simply installing a marked crosswalk without other more substantial crossing facilities does not cause most motorists to stop and yield to pedestrians, contrary to the expectations of many pedestrians.

On three-lane roads (i.e., one lane in each direction with a center two-way left-turn lane), the crash risk was slightly higher for marked crosswalks compared with unmarked crosswalks, but this difference was not significant (based on a sample size of 148 sites).

Pedestrian Crash Types

The greatest difference in pedestrian crash types between marked and unmarked crosswalks involved "multiple-threat" crashes. A multiple-threat crash involves a driver stopping in one lane of a multilane road to permit pedestrians to cross, and an oncoming vehicle (in the same direction) strikes the pedestrian who is crossing in front of the stopped vehicle. This crash type involves both the pedestrian and driver failing to see each other in time to avoid the collision. To avoid multiple-threat collisions, drivers should slow down and look around stopped vehicles in the travel lane, and pedestrians should stop at the

outer edge of a stopped vehicle and look into the oncoming lane for approaching vehicles before stepping into the lane.

A total of 17.6 percent (33 out of 188) of the pedestrian crashes in marked crosswalks were classified as multiple threat. None of the 41 pedestrian crashes in unmarked crosswalks were multiple threat. This finding may be partly attributable to the fact that drivers may be more likely to stop and yield to pedestrians in marked crosswalks compared with unmarked crossings; at least one motorist must stop for a pedestrian to set up a multiple-threat pedestrian collision. Also, some pedestrians in some instances may be more likely to step out in front of oncoming traffic in a marked crosswalk (particularly after the first vehicle stops) than at an unmarked location.

Motorists failing to yield (on through movements) represented a large percentage of pedestrian crashes in marked crosswalks (41.5 percent) and unmarked crosswalks (31.7 percent). Likewise, vehicle turn and merge crashes, also generally the fault of the driver, accounted for 19.2 percent (marked crosswalks) and 12.2 percent (unmarked crosswalks). These results indicate a strong need for improved driver enforcement and education programs that emphasize the importance of yielding to or stopping for pedestrians. More pedestrian-friendly roadway designs may also be helpful in reducing such crashes by slowing vehicles, providing pedestrian refuge (e.g., using raised medians), and giving better warning to motorists about pedestrian crossings.

A substantial proportion of pedestrian crashes involved dart-out, dash, and other types of crashes in which the pedestrian stepped or ran in front of an oncoming vehicle at unmarked crosswalks (23 of 41, or 56.1 percent) and a lesser proportion occurred at marked crosswalks (41 of 188, or 21.8 percent). These results are indicative of a need for improved pedestrian education programs, which is in agreement with recommendations of other important studies related to improving the safety of vulnerable road users (8). Further, in addition to unsafe pedestrian behaviors, speeding drivers can often be a contributing factor in dart-out crashes. Creating more pedestrian-friendly crossings, such as crossings with curb extensions, traffic calming measures, and so on may also be useful in reducing many of these crashes (to be discussed in a later section).

Pedestrian Crash Severity

An analysis was conducted to compare pedestrian crash severity in marked versus unmarked crosswalks. Crash severity did not differ significantly between marked and unmarked crosswalks on two-lane roads. On multilane roads, there was evidence of more fatal plus A-type injury pedestrian crashes at marked crosswalks compared with unmarked crosswalks. This result probably reflects the fact that older pedestrians are more likely than any other age group to walk in marked rather than unmarked crosswalks, as discussed previously. Furthermore, they are much more likely to sustain fatal and serious injuries than younger pedestrians.

Lighting and Time of Day

Nighttime pedestrian crash percentages were about the same at marked and unmarked crosswalks (approximately 30 percent). In terms of time of day, the percentage of pedestrian crashes in marked crosswalks tended to be higher than for unmarked crosswalks during the morning (6 to 10 a.m.) and afternoon (3 to 7 p.m.) peak periods, but lower in midday (10 a.m. to 3 p.m.) and evening (7 p.m. to mid-

night) periods. This is probably because pedestrians are more likely to cross in marked crosswalks than in unmarked crossings during peak traffic periods (e.g., walking to and from work) than at other times. Adequate nighttime lighting should be provided at marked crosswalks to enhance the safety of pedestrians crossing at night.

Age Effects

A separate analysis of pedestrian crashes and crossing volumes by age of pedestrian was conducted. For virtually every situation studied, pedestrians age 65 and older were overrepresented in pedestrian crashes compared with their relative crossing volumes. Figure 3 shows the relative proportion of crashes and exposure for various age groups for marked crosswalks on two-lane and multilane roads. For a given age group, when the proportion of crashes exceeds the proportion of exposure, then crashes are overrepresented; that is, pedestrians in that population group are at greater risk of being in a pedestrian crash than would be expected from their volume alone.

The pedestrian age groups younger than 65 showed no clear increase in crash risk compared with their crossing volumes. One possible reason that young pedestrians were not overinvolved in crash occurrence is the fact that many crashes involving young pedestrians (particularly ages 5 to 9) occur on residential streets. However, this study did not include school crossings, and most sites were drawn from collector and arterial streets (where marked crosswalks exist), which are less likely to be frequented by unescorted young children.

Some of the possible reasons that older pedestrians are at greater risk when crossing streets compared with other age groups include the fact that older adults are more likely (as an overall group) than younger pedestrians to have the following problems or impairments:

- Slower walking speeds (and thus greater exposure time);
- Visual or hearing impairments or both;
- Difficulty in judging the distance and speed of oncoming traffic;
- More difficulty keeping track of vehicles coming from different directions, including turning vehicles; and
- Inability to react (e.g., stop, dodge, or run) as quickly as younger pedestrians to avoid a collision under emergency conditions.

Pedestrian and Motorist Behavior at Crosswalks

To help gain a better understanding of the effects of marked crosswalks versus unmarked crossings, Knoblauch (5) conducted a complementary study on pedestrian and motorist behavior and also vehicle speed before and after crosswalk installation at sites in California, Minnesota, New York, and Virginia (on two-lane and three-lane streets). The study results revealed that very few motorists stopped or yielded to pedestrians either before or after marked crosswalks were installed. After marked crosswalks were installed, there was a small increase in pedestrian scanning behavior (before stepping out into the street). Also, there was a reduction in vehicle speed of approximately 1.6 km/h (1 mph) after the marked crosswalks were installed (3).

These behavioral results from the Knoblauch study tend to contradict the "false sense of security" claims attributed to marked crosswalks, since observed pedestrian behavior actually improved after marked crosswalks were installed at the study sites. However, it should also be remembered that measures of "pedestrian awareness" and "pedestrians' expectation that motorists will stop for them"

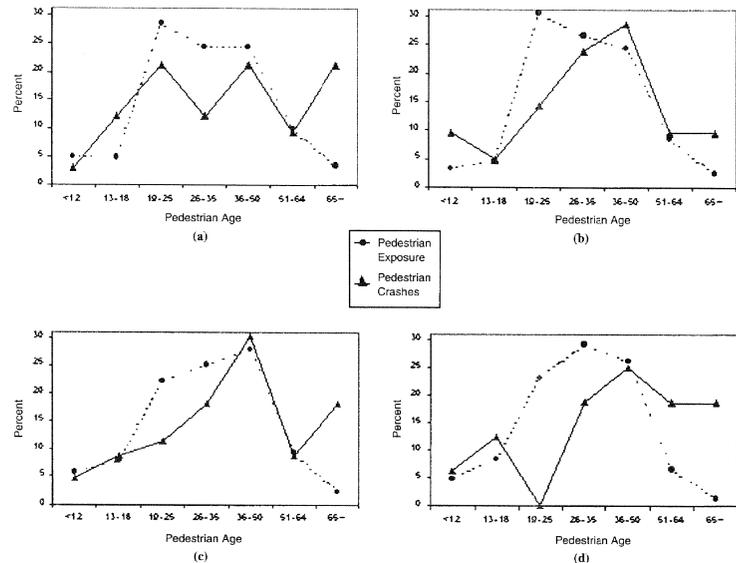


FIGURE 3 Percentage of crashes and exposure by pedestrian age group and roadway type at uncontrolled marked and unmarked crosswalks: (a) two-lane roads, marked crosswalks; (b) two-lane roads, unmarked crosswalks; (c) multilane roads, marked crosswalks; (d) multilane roads, unmarked crosswalks.

cannot be collected by field observation alone. It should also be mentioned that installing marked crosswalks or other measures can affect pedestrian level of service if they increase the number of motorists who stop and yield for pedestrians. Future studies using focus groups of pedestrians as well as questionnaires completed by pedestrians in the field could shed further light on such measures.

STUDY CONCLUSIONS AND RECOMMENDATIONS

Pedestrian needs in crossing streets should routinely be identified, and appropriate solutions should be selected to improve pedestrian safety and access. Deciding where to mark crosswalks is only one consideration in meeting that objective.

Street crossing locations should be routinely reviewed to consider the following available options:

- Option 1: No special provisions needed.
- Option 2: Provide a marked crosswalk alone.
- Option 3: Install other crossing improvements (with or without a marked crosswalk) to reduce vehicle speeds, shorten crossing distance, increase likelihood of motorists stopping and yielding, or produce other outcomes or a combination of these outcomes.

Because sites in this study were confined to those having no traffic signal or stop sign on the main road approaches, it follows that these results do not apply to crossings controlled by traffic signals, stop or yield signs, traffic-calming treatments, or other devices. They also do not apply to school crossings, because these sites were purposely excluded from the site-selection process.

Conclusions Regarding Marked Crosswalks at Uncontrolled Locations

The results of this study have some clear implications on the placement of marked crosswalks and the design of safer pedestrian crossings at uncontrolled locations. These include the following:

1. Pedestrian crashes are relatively rare at uncontrolled pedestrian crossings (1 crash every 43.7 years per site in this study); however, the certainty of injury to the pedestrian and the high likelihood of a severe or fatal injury in a high-speed crash makes it critical to provide a pedestrian-friendly transportation network.
2. Marked crosswalks alone (i.e., without traffic calming treatments, traffic signals with pedestrian signals when warranted, or other substantial crossing improvements) are not recommended at uncontrolled crossing locations on multilane roads (i.e., 4 or more lanes)

where traffic volume exceeds approximately 12,000 vehicles per day (with no raised medians) or approximately 15,000 ADT (with raised medians that serve as refuge areas). This recommendation is based on the analysis of pedestrian crash experience, exposure data and site features described earlier.

3. The authors of this study also recommend against installing marked crosswalks alone on roadways with speed limits higher than 64.4 km/h (40 mph). In fact, Germany, Finland, and Norway do not allow uncontrolled crosswalks on roads with high speed limits (8). It is also important for motorists to understand their legal responsibility to yield to pedestrians at marked and unmarked crosswalks. Furthermore, pedestrians should use proper caution when crossing streets, regardless of who has the legal right-of-way, since it is the pedestrian who suffers the most physical injury in a collision with a motor vehicle.

4. On two-lane roads and lower volume multilane roads (ADTs less than 12,000), marked crosswalks were not found to have any positive or negative effect on pedestrian crash rates at the study sites. Marked crosswalks may encourage some pedestrians to cross the street at such sites. However, it is recommended that crosswalks alone (without other substantial crossing improvement) not be installed at locations that may pose unusual safety risks to pedestrians. Pedestrians should not be encouraged to cross the street at sites with limited sight distance, complex or confusing designs, sites with certain vehicle mixes (many heavy trucks), or other dangers, without first providing them with adequate design features, traffic control devices, or both.

5. At uncontrolled pedestrian crossing locations, installing marked crosswalks should not be regarded as a magic cure for pedestrian safety problems. However, they should also not be considered as a negative measure that will necessarily increase pedestrian crashes. Marked crosswalks are appropriate at some crossing locations (e.g., at low-speed two-lane streets at downtown crossing locations) to help channel pedestrians to preferred crossing locations, but other roadway crossing improvements (e.g., raised medians, traffic signal) should also be provided when used at other locations.

6. For three-lane roads, adding marked crosswalks alone (without other substantial crossing improvement) is generally not recommended for ADTs greater than 12,000, although exceptions may be allowed under certain conditions (e.g., lower-speed roads).

7. If nothing else is done beyond marking crosswalks at an uncontrolled location, pedestrians will not experience increased safety (under any situations included in the analysis). Research from Europe shows the need for pedestrian improvements beyond uncontrolled crosswalks (8, 9).

8. In some situations (e.g., low-speed, two-lane streets in downtown areas), installing a marked crosswalk may help consolidate multiple crossing points. Engineering judgment should be used to install crosswalks at preferred crossing locations (e.g., at a crossing location at a street light as opposed to an unlit crossing point nearby). Also, to minimize the overuse of marked crosswalks, higher priority should be placed on providing marked crosswalks where the pedestrian crossing volume exceeds 20 per peak hour (or 15 or more elderly pedestrians or children per peak hour).

What Are Possible Measures to Help Pedestrians Cross Streets Safely?

Although simply installing marked crosswalks by themselves cannot solve pedestrian crossing problems, the safety needs of pedestrians

must not be ignored. More substantial engineering and roadway treatments need to be considered, as well as enforcement and education programs. Transportation and safety engineers have a responsibility to consider all types of road users in roadway planning, design, and maintenance. Pedestrians must be provided with safe facilities for travel.

1. A variety of pedestrian facilities have been found to improve pedestrian safety and the ability to cross the street under various conditions (8–20). Examples of some of these pedestrian improvements include the following:

- Provide raised medians or crossing islands on multilane roads.
- Install traffic signals with pedestrian signals, where warranted.
- Reduce the effective street crossing distance for pedestrians by
 - Providing curb extensions;
 - Providing raised pedestrian islands at intersections; and
 - Reducing four-lane undivided road sections to two through lanes with dual left-turn lane or left-turn bays (plus sidewalks and bicycle lanes).
- Consider installing traffic-calming measures. They may be appropriate on certain streets to slow vehicle speeds, reduce cut-through traffic, or both. Such measures may include the following (16):
 - Raised crossings (raised crosswalks, raised intersections);
 - Street-narrowing measures (chicanes, slow points, “skinny street” designs); and
 - Intersection designs (traffic mini-circles, diagonal diverters).

Some of these traffic-calming measures may not be appropriate on major collector or arterial streets.

- Provide adequate nighttime lighting for pedestrians, particularly at marked crosswalks and areas near churches, schools, and community centers with nighttime pedestrian activity.
- Design safer intersections for pedestrians (e.g., crossing islands, tighter turn radii).
- Provide narrower widths, access management, or both (e.g., consolidation of driveways).
- Use various pedestrian warning signs, flashers, and other traffic control devices to supplement marked crosswalks. However, the effects of supplemental signs and other devices at marked crosswalks are not well known under various roadway conditions. According to the MUTCD, pedestrian crossing signs should be used only at locations that are unusually hazardous or at locations where pedestrian crossing activity is not readily apparent (2).
- Build narrower streets in new communities to achieve desired vehicle speeds.
- Increase the frequency of two-lane or three-lane arterials when designing new street networks so that fewer multilane arterials are required.

2. Whenever a marked crosswalk is installed on an uncontrolled multilane road (i.e., three or more lanes), consideration of an advance stop line is recommended at a point up to approximately 9.1 m (30 ft) in advance of the crosswalk along with the sign “Stop Here for Crosswalk.” According to a study by Van Houten (17), this measure can cause motorists to stop further back from the crosswalk, thereby improving sight distance and stopping distance for approaching motorists in the adjacent lanes. This could logically reduce the likelihood of pedestrian multiple-threat collisions on multilane roads.

3. It is recommended that parking be eliminated on the approach to uncontrolled crosswalks to improve vision between pedestrians and motorists.

4. Some agencies provide railings in the medians of multilane roads that direct pedestrians to the right and increase the likelihood of pedestrians looking for vehicles coming from their right in the second half of the street.

5. Proper planning and land use practices should be applied to benefit pedestrians. For example, busy arterial streets should be used as a boundary for school attendance or school busing. Major pedestrian generators should not be separated from each other or from their parking facilities by a busy street.

6. The current MUTCD pedestrian signal warrant should be reviewed to determine whether the warrant should be modified to more easily allow for installing a traffic signal at locations where pedestrians cannot safely cross the street (and where no alternative safe crossing exists nearby). Consideration must always include pedestrians with disabilities, and proper accommodations must be provided to meet Americans with Disabilities requirements.

7. There should be continued research, development, and testing of innovative traffic control and roadway design alternatives that could provide improved access and safety for pedestrians attempting to cross streets. For example, in-pavement warning lights, variations in pedestrian warning and regulatory signs (including signs placed in the centerline to reinforce motorists yielding to pedestrians), roadway narrowing, traffic-calming measures, automated speed-monitoring techniques, and so on deserve further research and development to determine their feasibility under various traffic and roadway conditions.

More details about these and other pedestrian facilities are given in the *Pedestrian Facilities User's Guide: Providing Safety and Mobility*, recently developed for FHWA (18); in the ITE publication *Design and Safety of Pedestrian Facilities* (19); and in *The Traffic Safety Toolbox*, (Chapter 19 "Designing for Pedestrians") (20).

ACKNOWLEDGMENTS

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DISCUSSION

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This paper addresses the long-standing conflict between enabling pedestrians to exercise their right to cross a street and reducing the number of motorists striking them as they do so. Previous studies showed a difference in collision frequency between marked and unmarked crosswalks. As this paper notes, although many questions were raised about the methodology of those studies and other issues, many communities removed crosswalk markings. This paper answers some of those questions and illustrates productive areas for future research.

METHODOLOGY

One question raised in previous studies concerned the matching between those pedestrians who use marked crosswalks versus those who do not. For meaningful results, the case and control should be equal or controlled for statistically. This study shows that case and control are unequal—pedestrians self-select and the results vary markedly with the age of the pedestrian.

With an equal number of marked and unmarked locations, 66.1 percent of the observed pedestrians crossed at marked crosswalks versus 33.9 percent at unmarked crossings. Controlling for self-selection may be difficult, though this paper shows that pedestrian age is one factor. There may be other factors, including risk taking.

This study shows that much of the observed danger of marked crosswalks results from the inability of pedestrians age 65 and older to cross unharmed, in contrast to the ability of 19- to 25-year-olds to use unmarked crossings. Possibly this danger results from mobility impairment, however, this study indicates "a substantial proportion of pedes-

trian crashes involved dart-out, dash, and other types of crashes in which the pedestrian stepped or ran in front of an oncoming vehicle," despite the fact that most injured parties are middle-aged or older. Future research on this issue should control for mobility impairment, and also visual, cognitive, and alcohol-induced impairment and risk-taking behavior. We need to understand how a given pedestrian, with given crossing abilities, can cross a street.

SCOPE

It is a false dichotomy to limit research to marked and unmarked crosswalks, when neither approach alone prevents these collisions. This study suggests other possibly desirable approaches to reducing motorist versus pedestrian collisions, including more visible crossings and better conveyance to motorists of their responsibility to stop. Although these approaches may be rare in practice, future research should examine many different types of crossings, and provide guidance on effective techniques. With a collision rate of 1 every year per 43.7 sites, both marked and unmarked crosswalks endanger pedestrians unduly.

MOTORIST BEHAVIOR

The analysis is silent on the motorist's role in collision avoidance. Legally, motorists must exercise due care to avoid colliding with any pedestrian at all locations, but they also have a special obligation to yield right-of-way at intersections and marked midblock crosswalks. The observation that a collision is less likely to occur outside an intersection or marked crosswalk implies that the pedestrian is the only party undertaking collision-avoiding behavior. Instead of unmarking crosswalks, designers should look toward making crosswalks more visible and communicate to motorists their responsibility to yield.

UNINTENDED CONSEQUENCES

Anecdotal evidence suggests that police may fail to properly note the presence of a crosswalk if it is unmarked. Collision reports should be reviewed to investigate this serious concern, which would reduce the victim's legal rights and society's ability to detect and punish dangerous drivers.

In addition, the fact that fewer people use unmarked crossings causes concern. This study found that 66.1 percent of the observed pedestrians crossed at marked crosswalks versus 33.9 percent at an equal number of unmarked crossings that were determined to be otherwise equal. Discouraging people from walking reduces exercise and increases congestion, both of which are serious public concerns.

CONCLUSION

At this time and state of knowledge, it appears inappropriate to remove crosswalk markings. This study shows that unmarked crossings have fewer collisions because of the agility of youngsters, whereas more than half of the pedestrians in this study struck by motorists are middle aged or older. Designers should follow this paper's recommendations and look to make crossings more visible, not less so, and better convey to motorists their responsibilities.

DISCUSSION

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As in other studies in the past, the authors found that the mere marking of crosswalks without additional improvements either did not reduce pedestrian crashes or increased them. They suggest stricter driver compliance, raised medians, traffic signals, and various other remedies. During the presentation of the study at the TRB January 2001 meeting, a participant suggested the removal of marked crosswalks, as some jurisdictions already had done. This comment is written to support that suggestion and to propose the repeal of crosswalk laws.

Before the adoption of statutory right-of-way rules, all road users had equal and mutual rights to be exercised under common law so as not to interfere unreasonably with the rights of others. Drivers had to look out for pedestrians and other traffic and have their vehicles under such control that they could avoid a collision. All had to avoid causing unnecessary obstruction and use such care for their own safety as a reasonable person would under the circumstances (21). The supreme rule of the road was the rule of mutual forbearance (22).

Crosswalks built of solid materials were originally not meant to protect pedestrians but to help them get from one paved sidewalk to another across a muddy unpaved road (23). In the 1880s, even before the automobile arrived, the courts began to rule in civil negligence cases that riders and drivers had to exercise special caution at crosswalks, where the presence of pedestrians was to be anticipated (24).

In the early 1910s municipalities began to issue ordinances that were intended to reinforce pedestrians' safety by giving them the right-of-way on crosswalks. Elsewhere pedestrians had to yield the right-of-way to vehicles.

Like other traffic regulations, these ordinances, which were later written into the rules of the road of state codes, were adopted without study of their effects on safety and mobility. As pedestrians had the right-of-way at intersectional and other crosswalks, they were led to believe that intersections were the safest locations at which to cross, and that marking a crosswalk with paint enhanced safety, two beliefs still widely held today.

The flaws in the crosswalk law become apparent when we compare the pedestrian's right-of-way with that of a side-street driver who must wait at a stop sign for a gap until it is safe to cross. The law gives pedestrians the opposite instruction. Their right-of-way on crosswalks tells them they may do what is forbidden to the side-street driver—to get in the way of moving traffic. We need no statistics to demonstrate that it is safer to cross a street after the cars on it have passed than to cross in front of them.

The poorer safety record of the marked crosswalk has often been ascribed to the false sense of security it induces. For example, inadequate scanning and heavy reliance on driver compliance with the strict California crosswalk law, combined with an "alarmingly high rate of accidents at marked crosswalks," was reported from San Francisco (25).

Walk Alert and similar safety programs try to correct this behavior. Adopted by the U.S. Department of Transportation, the National Safety Council, and many other organizations, Walk Alert tells pedestrians not to rely on traffic controls but to wait before crossing until they find an adequate gap.

The need for safety programs that teach people how to avoid the dangers of acting in accordance with the law shows that the law is defective. It seems somewhat naive to give people a right-of-way that is meant to protect them from danger and then tell them to forgo that right as soon as the danger arises. The wisdom of having crosswalk laws is altogether questionable. Pedestrians need only be taught "Cross when it is safe. Don't cross when it is not safe." In the District of Columbia, drivers rarely yield to pedestrians, so that our instinct of self-preservation has long trained us to do what Walk Alert and the many similar pedestrian safety programs are trying to teach us.

It also seems counterproductive to designate "safe" crossing places that allow drivers to be less careful elsewhere. The courts have held that the pedestrian's duty of caution was greater outside crosswalks and that of the driver correspondingly less (26, 27). The driver who hits a pedestrian outside a crosswalk does not violate the law. It is the pedestrian who appears in the police report as the violator for failure to yield, even if the driver could have avoided the collision. It is one thing to advise pedestrians to be careful and not step in front of moving vehicle but quite another to have a legal mandate that makes the pedestrian a violator of the law, *prima facie* negligent in a civil case, and carrying the burden of proof that the motorist could have avoided the collision.

Normally, the right of one person ends when it unreasonably intrudes on the rights of another. Except in self-defense one may not kill someone who committed an illegal act. A householder who uses excessive force and kills a burglar is liable to prosecution. By contrast, the law tolerates that motorists run down pedestrians without fear of penal consequences, provided they did not do it deliberately and committed no other offense at the same time (24).

Past attempts to improve driver compliance by making crosswalks more conspicuous or through stricter law enforcement were found ineffective (28, 29). Better compliance with unsafe laws and their stricter enforcement are unlikely to lower the accident toll. The authors note that better compliance may cause more multiple-threat and rear-end crashes. Collisions between left-turners and opposing through-vehicles may also increase when pedestrian movements block left-turners within the intersection (24), a risk that may be aggravated when illuminated warning devices make crosswalks more conspicuous.

As a minimum, the *Manual on Uniform Traffic Control Devices* should mandate consideration of alternatives (primarily raised median refuges) to marked crosswalks, just as it requires consideration of alternatives to the traffic signal. A logical remedy would be to remove marked crosswalks, teach pedestrians to wait for adequate gaps, repeal the driver-pedestrian statutory right-of-way laws, place the initial presumption of negligence and the onus to disprove it on the motorist in civil cases (30), and educate drivers to respect the pedestrian's right to life.

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AUTHORS' CLOSURE

RESPONSE TO COMMENTS BY KENNETH TODD

We would like to thank Todd for his comments on our paper. We would first add that the topic of where to add or not add crosswalks and the related legal and safety implications has been a topic of considerable disagreement for many years in the United States. Part of the controversy stems from U.S. crosswalk laws, the enforcement or nonenforcement of such laws, and their inconsistencies as well as differences in motorist and pedestrian behaviors across the country. Also, there is clearly a lack of understanding of who must legally yield the right-of-way to whom under different roadway situations. Further, more aggressive driving in many cities continues to worsen and, with it, concern by many about pedestrian rights. In the battle for space between a motorist and a crossing pedestrian, the motorist too often refuses to yield to the pedestrian, even when the pedestrian is in a legal crosswalk.

Todd proposes to remove all marked crosswalks and teach pedestrians to wait for gaps. His logic is that it is counterproductive to designate "safe" crossing places that allow drivers to be less careful elsewhere. In response to this point, we do agree that pedestrians should be trained to wait for gaps in traffic and to not step into the street directly in the path of an approaching motor vehicle. However, this does not require that all marked crosswalks be removed. Education and marked crosswalks are not mutually exclusive. In an ideal world, all motorists would stop and yield to pedestrians at all crosswalks in all cases, regardless of whether the crosswalk is marked or not. However, even a well-meaning motorist may not always see a pedestrian in time to stop, particularly at night or in complex driving situations.

We also disagree with Todd's claim that marked crosswalks are counterproductive in terms of causing drivers to be less cautious where the crosswalk is not marked. If all marked crosswalks are removed, there is nothing to suggest that drivers will be more careful elsewhere. Also, the same logic that says that marked crosswalks allow drivers to be less careful elsewhere could be used to argue that all crosswalks should be marked.

Todd recommends the repeal of the driver and pedestrian statutory right-of-way laws. His reasoning is that since drivers entering at a side street must wait for a gap, so should pedestrians. We disagree with this opinion for several reasons. First of all, it should not be assumed that the same rules should apply to both drivers and pedestrians. Whereas in some cases this may be true, in many other cases it is not. For example, because of their ability to quickly accelerate to high speeds, motorists require much smaller gaps than pedestrians to safely cross the street. Because pedestrians require larger gaps than motorists to cross the street, pedestrians find fewer adequate gaps than motorists. This is especially problematic on busy streets, where pedes-

trians may become tired of waiting for an adequate gap and may decide to "make a run for it," thereby exposing themselves to the risk of being struck by a motor vehicle. Pedestrians have the flexibility of crossing on either side of an intersection and can do it in two phases if there is a median. Motor vehicles lack this flexibility. Motorists are often turning right or left onto a roadway, which is a different movement than that of the pedestrian who is crossing the roadway to get to the other side. In other words, there are fundamental differences between the behavior and abilities of drivers and pedestrians. It is illogical to simply assume that the same rules should apply. Finally, the vulnerability of pedestrians and the fact that they include people of all ages (kids, seniors, people with disabilities, etc.) suggest that there should be some additional legal protection for pedestrians at crosswalks.

Todd also suggests that the initial presumption of negligence in a pedestrian and motor vehicle collision should be placed on the motorist and that drivers should be better educated. The assumption here is that drivers are more careful in avoiding collisions with pedestrians. We agree that motorists must be made accountable for collisions with pedestrians in cases where they are at fault. This goal could be better accomplished if police and the judicial system would do a better job of properly assigning fault to the at-fault driver in the many types of collisions where the driver is currently not charged. In other words, properly enforcing existing crosswalk laws would go a long way toward correcting this problem. It is not clear to the authors how repealing the crosswalk law would accomplish the goal of holding at-fault drivers accountable. In fact, in the absence of a law that specifies who must yield the right-of-way in various situations, officers and the courts may assign fault more often to the pedestrian and less often to the motorist than is currently the case. Thus, if crosswalk laws were repealed, drivers might be found less accountable, not more.

We would agree that one of the messages of the Walk Alert program did in fact convey to pedestrians that they should not rely totally on traffic control devices to protect them. Unfortunately, one of the reasons to convey such a message to pedestrians is that many motorists run red lights or fail to yield to pedestrians while turning at intersections. Asking pedestrians to be aware of their environment when crossing streets does not in any way condone illegal or unsafe driver behavior. It is simply a necessary ingredient to improve pedestrian safety. Walk Alert also has strong components of education and enforcement aimed at drivers and engineering recommendations to help make the roadway environment safer for travel by foot.

RESPONSE TO COMMENTS BY PETER JACOBSEN

As Jacobsen correctly points out, one of the difficulties to properly conducting a study of marked versus unmarked crosswalks (or for evaluating any roadway treatment) is the need for case and comparison sites (i.e., marked and matched comparison sites) to be equal or statistically controlled for. In the real world, no two sites are exactly alike, so extensive efforts were made to select a suitable comparison site for each of the 1,000 marked crosswalk sites and to statistically control for the differences. In a majority of these cases, the comparison site selected for the treated (marked crosswalk) site was the opposite leg of the same intersection. Pedestrian count data were separately collected by age group for each of the marked and unmarked crosswalk sites, along with other geometric and site characteristics, and

statistical methods were used to control for the relevant factors in determining the crash effects of marked versus unmarked crosswalks.

Unfortunately, it is not possible to know the detailed characteristics and behaviors of every driver and pedestrian who passes through the 2,000 test sites in the 30 cities. However, we were able to determine the distribution of pedestrian crossing activity by age group, for example, which helps us to better understand choices that different age groups make on whether they cross at a marked or unmarked crosswalk. In addition to the pedestrian-crash analyses discussed in detail in this paper, we also had a parallel study conducted by a subcontractor (Center for Applied Research), which included a detailed analyses of motorist and pedestrian behavior at sites in four states before and after marked crosswalks were installed. As reported in our paper, in this companion study Knoblauch et al. (5) found that marking a crosswalk was not associated with any increase in unsafe pedestrian behavior but actually resulted in slightly better "search behavior" by pedestrians at marked crosswalks than at unmarked crosswalks. Vehicle speeds also dropped slightly after the marked crosswalks were installed.

We would add that although our crash-based study, combined with the companion study on pedestrian and motorist behavior, does provide a considerable amount of new information on the effects of marked versus unmarked crosswalks, there is certainly more that we can learn about why certain pedestrians and motorists exhibit certain behaviors that lead to crashes. For example, further research could attempt to quantify pedestrian and motorist risk-taking behavior as a function of mobility, visual, cognitive, and alcohol impairments.

Jacobsen also states that "it is a false dichotomy to limit research to marked and unmarked crosswalks, when neither approach alone prevents these collisions. This study suggests other possibly desirable approaches to reducing motorist versus pedestrian collisions, including more visible crossings and better conveyance to the motorists of their responsibility to stop."

We agree that other pedestrian roadway improvements need to be considered to improve pedestrian safety, not just whether to mark crosswalks. This is why we spent much of the later portion of our paper recommending considerations of specific pedestrian treatments. Also, our study on marked versus unmarked crosswalks was only one of a series of parallel studies that were conducted simultaneously for FHWA on pedestrian safety and mobility by the University of North Carolina Highway Safety Research Center. In several other studies, pedestrian-related measures were examined, such as overhead crosswalk signs, "pedestrian safety cones" (i.e., regulatory signs placed at the roadway centerline requiring motorists to stop for pedestrians), illuminated pedestrian signs (push-button activated with illuminated messages such as "Stop for Pedestrians in Crosswalk"), automated pedestrian detectors (at signalized intersections), and various traffic calming devices. The results of some of these pedestrian facility evaluations are published in another *Transportation Research Record* (31-33). We would also mention that the results of numerous other research studies on pedestrian facilities in the United States and pedestrian safety research synthesis reports from Canada, Sweden, Australia, the Netherlands, and the United Kingdom (as part of the same FHWA study) may be found at the Pedestrian and Bicycle Information website (www.walkinginfo.org/rd/index.htm).

Jacobsen appropriately elaborates on the motorist's role in collision avoidance. In the paper, we discuss the causes of pedestrian crashes from our crash analysis, including the involvement of various types of fault by the driver, such as failing to yield to pedestrians at crosswalks. The paper goes on to say that "these results indicate a strong need for improved driver enforcement and education

programs that emphasize the importance of yielding to or stopping for pedestrians."

Jacobsen also states that instead of unmarking crosswalks, designers should make crosswalks more visible and communicate to motorists their responsibility to yield. We agree with this; in fact, we strongly suggest that if there is a marked crosswalk that is "unsafe," the first response should be to explore installing other treatments, not simply to have it removed. One response should always be to consider looking for ways to make a crossing more visible. However, there may be situations where, after all other possibilities have been exhausted, a marked crosswalk should be removed.

Jacobsen further states that removing marked crosswalks may result in fewer people walking, and discouraging people from walking reduces exercise and increases congestion. We agree that an objective of state and local agencies should be to increase the amount of safe walking (and bicycling), in accordance with the National Bicycling and Walking Study (34). Therefore, we recommended that agencies should systematically consider a wide range of facility options to increase pedestrian safety and mobility, not just whether to install or take out marked crosswalks.

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APPENDIX D

ENVIRON' s Evaluation of UC Berkeley Health Impact Assessment Recommendations

(Responses to Rajiv Bhatia Letters of March
22 and 23, 2006, and undated
Recommendations)

**EVALUATION OF UC BERKELEY HEALTH IMPACT ASSESSMENT
RECOMMENDATIONS FOR THE OAK TO NINTH PROJECT**

Prepared for:

Signature Properties
Pleasanton, California

Prepared by:

ENVIRON International, Corporation
Emeryville, California

May 26, 2006
03-15847A

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ACRONYMS

AC	Alameda-Contra Costa
ARB	Air Resources Board
BART	Bay Area Rapid Transit
CCERP	Central City East Redevelopment Plan
CDURP	Central District Urban Renewal Plan
CEQA	California Environmental Quality Act
EIR	Environmental Impact Report
FEIR	Final Environmental Impact Report
HAD	Health Development Agency
HIA	Health Impact Assessment
HVAC	Heating, Ventilation and Air Conditioning
MTC	Metropolitan Transportation Commission
NAS	Naval Air Station
TDMP	Transportation Demand Management Plan
UCBHIG	UC Berkeley Health Impact Group
UCLA	University of California, Los Angeles
UK	United Kingdom

1.0 INTRODUCTION

The purpose of this report is to address to the following three letters and one short two-page document recently sent to the Oakland City Council from the Dr. Rajiv Bhatia and the UC Berkeley Health Impact Group (UCBHIG) pertaining to the Oak to Ninth Project:

1. February 28, 2006. **RE: Health Impact Assessment of the Oak to Ninth Proposal.** Letter to Honorable Jane Brunner from the UC Berkeley Health Impact Group.
2. March 22, 2006. **RE: Air Quality and Noise Related Health Effects of the Oak to Ninth Proposal.** Letter to Honorable Jane Brunner from Rajiv Bhatia, For the UC Berkeley Health Impact Group.
3. March 23, 2005(6). **RE: Air Impact Assessment of the Oak to Ninth Proposal.** Letter to Honorable Jane Brunner from Rajiv Bhatia, For the UC Berkeley Health Impact Group.
4. Undated. **Oak to Ninth Avenue Development: Priority Recommendations for Health Promotion and Illness and Injury Prevention.** The UC Berkeley Health Impact Group.

In the February 28, 2006 letter, the UCBHIG announced that they were conducting a Health Impact Assessment (HIA) on the Oak to Ninth Project. The UCBHIG emerges from a graduate school seminar on HIA at the UC Berkeley School of Public Health. According to this letter, the UCBHIG would provide the Oakland City Council with a draft HIA report in April 2006, including health-based recommendations for the Oak to Ninth Project. The March 22 and 23, 2006 letters, which are very similar to each other, address air quality and noise issues related to the nearby I-880 freeway. The short two-page document provides eight recommendations made by the UCBHIG on a number of issues including housing affordability, air quality, noise, person-to-person contact, social relationships and social capital.

This report is divided into six sections. Section 1.0, Introduction, describes the purpose and scope of this report. Section 2.0, Air Quality Issues, addresses the air quality issues raised in the March 22 and 23, 2006 letters identified above. In response to the February 28, 2006 letter, Section 3.0, General Health Impact Assessment Issues, provides a context for understanding what an HIA is, its intended uses, and whether it is relevant to the Oak to Ninth Project. Section 4.0, Response to UCBHIG Recommendations, provides comments on the eight recommendations made in the short two-page document identified above. Section 5.0, Conclusions, provides our summary remarks and conclusions on the documentation received to date from the UCBHIG. Section 6.0, References, includes all references cited in this report.

2.0 RESPONSE TO AIR QUALITY ISSUES (LETTERS DATED MARCH 22 and 23, 2006)

According to the commenter (Dr. Rajiv Bhatia) of the letters, the following key points are made:

- The City has a responsibility to study freeway related air quality and noise health impacts and their feasible mitigations under the California Environmental Quality Act (CEQA);
- The Project creates potentially significant environmental impacts on air quality by locating a residential use in proximity to Interstate 880;
- The FIER for the Oak to Ninth Project fails to fully acknowledge the potential health impacts due to compromised air quality and fails to document that the wintertime winds can blow from the freeway over the Project;
- Oak to Ninth residents are likely to experience some adverse health effects due to freeway related traffic noise;
- Project design changes can potentially mitigate and prevent health impacts due to noise and poor air quality.

The commenter correctly states that the California Air Resource Board (ARB) Air Quality and Land Use Handbook (2005) (“Handbook”) provides recommendations of separation between sensitive land uses and land uses that may be a source of toxic air contaminants. The Handbook includes the general recommendation that sensitive land uses (including residential uses) not be located within 500 feet of a freeway. The individual studies mentioned by the commenter were all used in support of the ARB Handbook. As such, this response is intended to address not only the specific comment that residences should not be located within 500 feet of a freeway, but also the cites that the commenter takes from the Handbook in support of repeating the Handbook recommendation.

While the general recommendation of the Handbook is provided, the commenter does not provide the context of the Handbook when he cites the Handbook’s general recommendation. The Executive Summary of the Handbook clearly states,

“These recommendations are advisory and should not be interpreted as defined ‘buffer zones (emphasis added).’ We recognize the opportunity for more detailed site-specific analyses always exists, and that there is no ‘one size fits all’ solution to land use planning.”

Some of the support used to develop the Handbook’s recommendation on freeways was based on the measurement of pollutants downwind from two large freeways in Southern California. The directionality of the winds, therefore, is critical as to whether it is likely that a freeway will impact nearby locations. Accordingly, a more site-specific analysis is presented below.

Figure 1 shows the planned residential developments and the Nimitz Freeway. As shown in Figure 1, the nearest residences are approximately 200 feet from the edge of the closest general travel lane of the freeway.

Figure 2 reproduces a figure from the Handbook that shows measurements of total particulate number as a function of downwind distance from the freeway for two freeways in the Los Angeles area: one has relatively high diesel traffic (I-710) and the other has relatively low diesel traffic (I-405). For the freeway with the higher fraction of diesel trucks, the total particle number drops to background, between 200 and 300 feet from the freeway. The distance would be less if the winds were not blowing directly from the freeway.

Figure 3 shows an aerial of the proposed development and available meteorological data stations. Three meteorological stations are roughly equidistant from the development: Port of Oakland, Oakland Sewer Treatment Plant, and Alameda Naval Air Station (NAS). Figure 4 shows annual wind roses from all three stations for a three year period. As can be seen, the three stations show similar wind directions. Therefore, for the remainder of this analysis we will be using the Alameda NAS as a representative station.

Figure 5 and 6 show the wind directions from the Alameda NAS meteorological station for 1994 through 1996. Figure 5 shows the winds for the entire year. Figure 6 shows the winds between 5AM and 9PM, when the traffic on the freeway is likely to be significant, and is therefore, more relevant for this evaluation. The wind from the North-Northwest through the East-Southeast have the potential to blow emissions from I-880 to the residents who may be residing in the proposed development, although winds from the North through the East have the greatest potential to impact residences. Table 1 shows the fraction of time that winds blow from I-880 towards the residences. As can be seen, winds have the greatest potential to blow from the freeway towards potential residents only 9.1% of the time during the hours when traffic is most likely to be significant.

Table 1: Frequency of Winds from Freeway to Proposed Development

	<i>Potential to Impact</i>	<i>Likely to Impact</i>
All Hours	20%	11%
Likely Traffic Hours (5 AM to 9 PM)	18%	9.1%

As a result of the low rate of winds blowing from the freeway towards the residents, this housing development near the freeway is less likely to be impacted by emissions from the freeway than are other areas where winds blow with a higher frequency from the freeways to the residential areas.

The health risk assessment presented in the EIR evaluated diesel particulate matter. Available data, as presented in the Handbook and reproduced above, indicates that all elevated particulate matter (both from diesel and gasoline-burning sources) is unlikely to persist at levels greater than background for more than between 300 feet downwind from the edge of the freeway. Again, accounting for the small fraction of winds from the freeway to the proposed residences, the annual average distances that elevated particulate matter would persist above background in this location is likely less than the distance cited in the Handbook.

The commenter also states that the “EIR fails to disclose that, based on a 20-year analysis of wind at Lake Merritt, wintertime winds often blow from the Southeast and Northwest and winds

are calm over 40% of the year”. A review of the cited reference shows that the commenter is incorrect in his cite, on several grounds. First, the cited reference actually refers to data taken from the Alameda NAS from 1950 to 1970, before the advent of the most modern meteorological equipment. Furthermore, the commenter is incorrect in stating that the reference reports that the winds are calm for over 40% of the year. The document actually shows that the fraction of calm winds vary by quarter from 15.7% in the fall to 4.7% in the summer, for an annual average of approximately 10%. An analysis of newer data shows a lower fraction of calms, at 5.8% over a 10-year period from 1987 through 1996. The fraction of calm winds decrease as the low wind detection limit decreases with the advent of the use of modern meteorological equipment.

As shown above, winds are only relevant from the North-Northwest through the East-Southeast, and not from the Northwest or the Southeast. The reference cited by the commenter shows only a small fraction of winds from the relevant directions, consistent with the more recent data from the Alameda NAS, as described above.

The commenter’s claims that particulate matter from the development will affect residents of Jack London Square, Chinatown, Downtown, Lower San Antonio and around Lake Merritt. The alleged increase in traffic volume that the commenter mentions will likely be indiscernible from the background produced by the existing mobile sources. Furthermore, the Project related traffic is likely to be emitted from gasoline burning vehicles and not diesel vehicles.

Based on information on the project in the EIR and the analysis conducted here, the commenter does not raise any new issues that require further study. The site-specific analysis conducted in the EIR is supported by the additional evaluation presented here.

3.0 RESPONSE TO GENERAL HEALTH IMPACT ASSESSMENT ISSUES (LETTER DATED FEBRUARY 28, 2006)

In their February 28, 2006 letter, the UCBHIG stated that it would provide the Oakland City Council with a draft HIA report in April 2006, including health-based recommendations for the Oak to Ninth development. This section provides a context for understanding what an HIA is, its intended uses, and whether it appropriately pertains to the Oak to Ninth Project.

3.1 WHAT IS AN HIA?

A HIA is defined as being “a multidisciplinary process within which a range of evidence about the health effects of a proposal is considered in a structured framework.” This framework is “based on a broad model of health which proposes that economic, political, social, psychological, and environmental factors determine population health.” (Northern and York Public Health Observatory, 2001). The goal of the HIA is to “provide unbiased information to policy-makers and the public, not to make decisions for them based on health criteria that would trump other social goals” (University of California, Los Angeles [UCLA] School of Public Health - HIA project: www.ph.ucla.edu/hs/health-impact/aboutus.htm). Many HIAs focus on policy issues such as the health effects of local “living wage” ordinances, health benefits of state-funded after-school programs, and the health consequences of a set of agricultural subsidies. HIAs are not a fundamental framework used by most environmental or health agencies and, are not regulatory or enforceable.

3.2 HIA PROCESS AND USES

The process of conducting HIAs is fairly new in the United States, with a review of the National Library of Medicine article database showing only two HIAs in peer-reviewed journals (Cole et al., 2004). As stated on the Health Impact Assessment Web Site prepared by the University of California, Los Angeles School of Public Health (UCLA School of Public Health - HIA project: www.ph.ucla.edu/hs/health-impact/aboutus.htm): “There is no such thing as a “HIA” methodology. The HIA borrows from a wide variety of fields including risk analysis, economics, and other fields, adapting and applying methodologies as dictated by available information needs of policy-makers and stakeholders.” Regardless of the methodology, most HIA’s follow the same general sequence of steps:

- scanning,
- screening,
- scoping,
- impact assessment,
- reporting and review.

Scanning is the process used to identify projects or policies on which to focus an HIA. Once a project is found, a screening process is conducted in order to assess whether a HIA would be appropriate. Some key aspects involved in the screening process are whether conducting a HIA

would significantly improve a population's health, whether there is sufficient data available to conduct a HIA, and whether the HIA will contribute significantly to the policy-making process. The screening process can be in depth; should review data, reports, and other resources relevant to the projects; and, with this information, be used to determine whether a HIA is necessary for a given project. The scoping step determines what key elements the HIA will focus on and how the HIA will be conducted. Next, the HIA is conducted, examining the key elements identified in the scoping step in both a quantitative and qualitative manner. It should be noted that health risks assessed in a HIA can be evaluated in a subjective manner, based on public perception of those risks, and do not necessarily need to be substantiated by technical data. Finally, findings, suggestions, and limitations are reported and provided to all parties affected by the HIA.

According to the United Kingdom (U.K.) Health Development Agency (HAD), there is a growing interest in monitoring the outcomes of a HIA – whether the adoption of recommendations has resulted quantifiable health outcomes, the accuracy of health-related predictions, and the assumptions behind the recommendations. “But suitable methods and techniques capable of tracking whether a HIA accurately predicted health impacts have not yet been developed and tested” (Taylor et al, 2003). An HAD review of HAIs in 2002 concluded that “There is currently no review-level evidence available to demonstrate if and how the HIA approach informs the decision making process, and, in particular if it improves health and reduces health inequalities.” (Taylor and Quigley, 2002).

In a recent article published in the British Medical Journal (Parry and Stevens, 2006), the authors evaluated whether HIAs in their present form can reliably inform better decision making. According to the authors:

“The advocates of health impact assessment make it predominantly a predictive rather than an empirical research tool, and its claims are substantial – to be able to inform policy and decision making to maximize benefits and minimize negative impacts on health. The definitions accorded to health impact assessment and its proposed utility in terms of modifying policy imply an objective, sophisticated, and apolitical process. The perception is that the estimation of health impacts has been achieved through the application of robust methods and is of sufficient validity to enhance the decision making process. However, we would argue that at present health impacts assessment is excessively subjective, subject to political drivers, and insufficiently rigorous to make any robust assumptions on the magnitude or even the direction of the health impacts of policy interventions.” The authors conclude that although HIA is an intuitively appealing and simple concept, there is a gap between the objectives of the HIA and the methods currently adopted by practitioners.

Many articles on the HIA process emphasize the importance of including stakeholders early in the HIA process. According to Scott-Samuel et al. (2001), “The process of HIA requires broad participation if a comprehensive picture of potential health impacts is to be established. The co-operation and expertise of a wide range of stakeholders (people who are involved in the project or will be directly affected by it) and key informants (people whose roles results in them having knowledge or information of relevance to the project and its outcome) will be needed. Public participation through the HIA is essential...”. These stakeholders include proponents (i.e., those

developing, planning or working on it) of the project. Additionally, the International Association for Impact Assessment encourages Environmental Impact Assessments to occur as early in the process as possible and this concept also logically applies to an HIA.

Even when preparing a rapid HIA, as appears to be the case for the UCBHIG assessment of the proposed Oak to Ninth development, stakeholder involvement is recommended. According to the U.K. – Health Impact Assessment Gateway, “Rapid appraisals are usually carried out with relatively minimal resources, but the preparation required for other important aspects of HIA such as stake holder – consultation, searching and compiling evidence and writing the recommendations should not be underestimated.”

(<http://www.publichealth.nice.org.uk/page.aspx?o=503303>).

The UCBHIG did not inform proponents of the Oak to Ninth development and the City about the HIA process being conducted by the UCBHIG for the Oak to Ninth development until shortly before the Planning Commission Hearing. This is true even though the class agenda for the UCBHIG graduate student seminar on HIA refers to the final product as a rapid “participatory” HIA and recommends that the students interview stakeholders

(<http://ehs.sph.berkeley.edu/china/edmund/hia/>). In their letter, the UCBHIG references a large scale HIA being conducted by the San Francisco Department of Public Health regarding rezoning in three neighborhoods. A review of the San Francisco Department of Public Health web site regarding this project clearly states that the project is a “deliberative, multi-stakeholder and consensus based approach” (<http://www.sfdph.org/phes/ENCHIA.htm>).

3.3 APPLICABILITY TO OAK TO NINTH PROJECT

Summary/conclusions regarding the application of a HIA to the Oak to Ninth development are as follows:

- HIAs are not a fundamental framework used by most environmental or health agencies and, are not regulatory or enforceable. HIAs are not a standard component of the CEQA process or an EIR.
- An HIA can assess health risks based on public perception, without substantiating technical data, rendering it inappropriate in the CEQA context.
- HIAs rely on factors outside the scope of CEQA for an individual project, such as psychological, political, and broad-based social and economic factors.
- Because the screening process did not include the stakeholders, it is not clear whether a HIA is appropriate for the Oak to Ninth development.
- Suitable methods and techniques capable of tracking whether a HIA accurately predicts health impacts have not yet been developed and tested (Taylor et al., 2003), so it is difficult to know if recommendations based on the process are supportable or cost effective.

- “Current HIA is insufficiently rigorous to make robust assumptions on the magnitude or even the direction of the health impacts or policy interventions.” (Parry and Stevens, 2006).
- The process of HIA requires broad participation if a comprehensive picture of potential health impacts is to be established. The process is meant to include the major stakeholders involved or affected by a project. Instead, the UCBHIG has used the HIA to oppose the Project.
- It is not clear whether the UCBHIG considered the EIR when evaluating the Oak to Ninth proposal, which incorporates many of the aspects of a HIA, including evaluation of air quality, water quality aesthetics, cultural resources, land use and planning, noise, recreation, public transportation, population and housing, and public services.
- As with other impact assessments, an HIA would be expected to occur early in the decision process. According to the UCBHIG letter, a draft report would be provided to the Oakland City Council in April 2006, well after the comment period for the EIR has passed and the final EIR has been completed.
- As HIA recommendations often deal with policy issues (i.e., much broader application than any one project), the recommendations may not be suitable for decisions at a project level at this time (e.g., a much larger group of stakeholders may need to be involved in decisions that would have broader application than just the Oak to Ninth Project).

4.0 RESPONSE TO UCBHIG RECOMMENDATIONS (UNDATED)

Although the HIA has not been received to date, the UCBHIG did send the City Council eight recommendations “to promote and protect the health of Oakland residents”. The recommendations given by UCBHIG come with little basis, supporting evidence, or reference to literature or policy documentation. Furthermore, all of the recommendations suggested by UCBHIG have been addressed in one form or another in the EIR (which is a publicly available document). Mitigation measures were recommended as part of the EIR wherever necessary.

The following are the recommendations made by the UCBHIG for the Oak to Ninth Project, followed by responses to these recommendations.

Recommendation I: Oak to Ninth should model ethnic and economic integration by providing housing affordable so that 1) the distribution of housing costs reflects the current household income distribution of Oakland, 2) at least 25% of housing is affordable to low income and very low income households, and 3) an additional 25% of housing is affordable to households earning the area’s median income

***Human Health Rationale:** Policies such as zoning and redevelopment can either facilitate or prevent segregation. Residents of low-income economically segregated communities in Oakland and elsewhere now live about six fewer years and experience a much greater burden of chronic disease than those in non-poverty neighborhoods. Research has demonstrated that reductions in life expectancy are caused by many place based factors including air pollution, violence, traffic hazards, poor schools, the absence of parks, and limited economic opportunity and mobility. In contrast, mixed income neighborhoods are assured the health benefits of access to healthier foods, better schools, better public transit, safer neighborhoods, park access and cleaner environments. In addition, based on MTC (Metropolitan Transportation Commission) data and the Air Resources Board URBEMIS, higher levels of affordability will significantly reduce traffic congestion and reduce vehicle air pollution emissions.*

Response:

This recommendation specifies the commenter’s opinion as to how housing costs should reflect the household income distribution of Oakland, without any substantiation whatsoever as to the selected numbers. The recommendation does not acknowledge that the project is located within a redevelopment area that requires affordable housing.

The Project EIR discusses housing values in Chapter IV, Part A: Land Use, Plans and Policies, on page 28 under the sub-section called Redevelopment plans. In accordance with the California Community Redevelopment Law, Oakland established the Central City East Redevelopment Plan (CCERP) in July 2003. The area covered under the CCERP extends through a portion of the Project site; lying East of Lake Merritt Channel. The CCERP “requires that at least 15 percent of all housing developed in the CCERP Project Area by non-Agency entities be affordable to very-low/low- and moderate-income households. Of these affordable units, at least 40 percent must be affordable to very-low income households.” Approximately 2,800 market-rate units being developed in the Project site will fall within the CCERP. Based on CCERP

requirements, 420 units will be designated as low- to moderate- income residences, and would be constructed within 10 years of the start of the Project. At least 168 of these units will be designated as very-low-income residences.

Additionally, the project sponsor has agreed to provide Lots F and G for sale to the Redevelopment Agency for affordable housing and to provide a per unit contribution to the Agency for each affordable unit. Thus, the Project will provide the potential health benefits associated with a mixed-income development.

Recommendation II: Project should maximize accessibility to waterfront natural areas and recreation for Oakland residents by 1) modifying the project's footprint and bulk to create some unobstructed views of the water and open spaces from the Embarcadero OR by re-aligning the Embarcadero between residential uses and the shoreline park, 2) requiring high quality bicycle and pedestrian trails between the waterfront and neighborhoods and transit stations east of I-880, 3) providing infrastructure and facilities for diverse recreational uses identified through outreach with residents in surrounding neighborhoods, 4) requiring safe, frequent public transportation to the site, and 5) creating an oversight body with citywide membership for Oak to Ninth's waterfront park.

***Human Health Rationale:** Contact with and views of natural landscapes reduce stress and depression, reduce violent and anti-social behaviors, and improve the ability to focus, pay attention, work, and learn. Access to open space facilitates physical activity reducing population levels of obesity, diabetes and hypertension.*

Responses:

This recommendation supplies no documentation for the rationale presented and no technical support showing that the recommended actions will have any significant positive effect on the health impacts claimed. Nothing about this rationale is specific to the Oak to Ninth Project. In addition, the accessibility to the waterfront natural areas and recreation for Oakland residents is discussed in detail in the EIR as follows:

- 1) As discussed in the EIR (Section IV. Environmental Setting, Impacts, and Mitigation Measures, Subsection A. Land Use, Plans and Policies, page IV.A-26), there are currently very limited views of the Oakland Estuary from points along the Embarcadero at the Project site due to existing buildings on the Project site, including the Ninth Avenue Terminal. The Project would align streets and site buildings of varied heights in an effort to create new and expanded views of the Estuary where none currently exist.
- 2 &4) Class I bicycle/pedestrian trails will connect to the existing trails that go to Lake Merritt, which will provides access to Bay Area Rapid Transit (BART) as well as Alameda-Contra Costs (AC) Transit lines. The proposed Transportation Demand Management Plan (TDMP) calls for the extension of AC transit to the site, a shuttle to BART, and ride share services as well as several bicycle and pedestrian measures.

These measures will also benefit accessibility to the waterfront and natural habitats along the waterfront for recreational users while increasing accessibility to public transit for commuters going to and from the development.

- 3) As discussed in the EIR (Chapter III, Part A: Project Location and Characteristics, page 14, under the subsection Proposed Parks, Open Space and Trails), the Project is proposing a mix of recreational areas, consisting of active and passive parks and open spaces that will cover about 44% of the Project site. The proposed park scheme will be about 20.7 acres, total, in size. Potential uses for the parks and open spaces include playgrounds, picnic areas, and gardens. A continuous pedestrian trail and Class I bicycle facility will connect all of the recreational areas and link to the Bay Trail. The trail connects eastwards to the Martin Luther King Regional Shoreline. It also connects east-west over the Lake Merritt Channel Bridge and allows for future improvements on connections between Lake Merritt and the estuary.

Additionally, the Oak to Ninth design guidelines include urban design principles and urban design concepts that call for a diverse network of public open spaces along the shoreline; the creation of an open space system that will serve as a city-wide and regional resource; and walkable, lively public streets, open space and pedestrian ways to provide visual and pedestrian links to the water.

- 5) The UCBHIG provides no health-based rationale or evidence to support this suggestion. The City has a Parks and Recreation Advisory Board that oversees city parks.

Recommendation III: The project should mitigate increases in the pedestrian injury rate caused by the project in the project area itself and in surrounding neighborhoods through: 1) crosswalk improvements (e.g. median islands), 2) sidewalk improvements (e.g. bulb-outs), and 3) grade separated bicycle and pedestrian trails and paths between the project, surrounding neighborhoods, and transit stations.

Human Health Rationale: Oakland currently has ~85 pedestrian injuries per year per 100,000 people which is about ~4 times the Federal objective. Our pedestrian injury impact analysis shows that the project would contribute to 5 additional injuries per year in the surrounding neighborhoods, and when combined cumulatively with other projects, to an additional 20 injuries per year, generating medical and lost productivity costs of roughly \$3 to 13 million dollars annually.

Response:

As demonstrated in the project EIR and the attached Fehr and Peers memorandum, the commenter has failed to establish that the Project would have the claimed adverse pedestrian impacts.

- 1 & 2) Improvements to mitigate pedestrian injury are discussed in EIR Chapter IV, Part B: Transportation, Circulation, and Parking. This section discusses intersection improvements such as installation of crosswalks, bulb-outs to decrease distance to cross

the street, and pedestrian signal heads. As documented in the EIR, the project will promote pedestrian safety through the inclusion of pedestrian crosswalks in the Project area, new pedestrian trails and sidewalks in the project area, and new traffic signals with pedestrian signal heads at certain off-site locations and Project access points.

- 3) Bicycle and pedestrian trails and paths are discussed in the EIR Chapter III, Part A: Project Location and Characteristics pages 12-16, under the subsection Proposed Parks, Open Space and Trails. The Project includes new pedestrian and Class I bicycle trails along the shoreline, connecting all of the parks and open spaces, and also connecting to the San Francisco Bay Trail. Trails will also connect existing trails that go to Lake Merritt.

Recommendation IV: The project should mitigate adverse air quality impacts by: 1) building heating, ventilation and air conditioning (HVAC) systems with air intakes oriented away from particulate sources, 2) requiring all feasible and effective transportation demand management measures, and 3) advising future residents that living in proximity to a freeway can worsen asthma or other chronic respiratory conditions.

***Human Health Rationale:** According to the California ARB the project is likely to result in increased frequency of respiratory symptoms and asthma exacerbations among project residents because of its location adjacent to I-880. Winds blowing from the North and Northwest in the wintertime have the potential of concentrating freeway particulate matter emissions directly over the project area.*

Response:

First, the rationale for this recommendation needs to be corrected. The California ARB has never stated that the Project is likely to result in increased frequency of respiratory symptoms and asthma exacerbations among Project residents because of its location adjacent to I-880. Instead, this is the commenter's interpretation of ARB's policy. The commenter recommendations are addressed in Section 2.0 of this report, Air Quality issues, and below.

- 1) Although not stated in this recommendation, it is assumed that "particulate sources" refers to the freeway. Based on the infrequent winds blowing from the freeway to the proposed development (see details in Section 2.0 of this report), this recommendation is not required.
- 2) The EIR discusses various driving alternatives to mitigate increases in automobile traffic that will likely result from this Project. Mitigation measures include AC Transit bus service, shuttle to BART, and rideshare/carpool services. Non-motorized alternatives will be encouraged by developing Class I bicycle/pedestrian trails connecting to existing trails, like the Bay trail, and also connecting to trails in Lake Merritt, which lead to the Lake Merritt BART station. The Project includes a comprehensive TDMP as outlined in the EIR.

- 3) The health risk assessment presented in the EIR evaluated diesel particulate matter. Available data, as presented in the California ARB Air Quality and Land Use Handbook (2005) (“Handbook”), indicates that all elevated particulate matter (both from diesel and gasoline burning sources) is unlikely to persist at levels greater than background for more than between 300 feet downwind from the edge of the freeway. Again, accounting for the small fraction of winds from the freeway to the proposed residences, the annual average distances that elevated particulate matter would persist above background in this location is likely less than the distance cited in the Handbook. (See discussion in Section 2.0 of this report).

Recommendation V: The project should protect residents from outdoor environmental noise by 1) orienting building to buffer roadway noise in courtyards and open spaces and 2) considering a multi-level parking as an additional acoustical buffer.

Human Health Rationale: Exposure of 1400 residents to exterior noise levels up to 85 dBA in parcels A, F, G, K, and M will potentially results in mental stress, hypertension, speech disturbance, annoyance, and protest.

Response:

The EIR acknowledges potential noise impacts to the Project due to the proximity to the Embarcadero and I-880 freeway and has proposed mitigations plans.

In 1974, the California Commission on Housing and Community Development adopted noise insulation standards for multi-unit resident buildings (Title 24, Part 2, California Code of Regulations). The proposed mitigation measures would comply with the he requirement of Title 24 in order to achieve an acceptable interior noise level. These mitigation measures include sound-rated assemblies (i.e., windows, exterior doors, and walls) and require that they be incorporated into project building design.

The Oak to Ninth Design Guidelines provide that buildings on the lots adjacent to the Embarcadero should be set back from the roadway and include landscaping to mitigate freeway noise.

Recommendation VI: The Oak to Ninth Project should include an on-site elementary school.

Human Health Rationale: Neighborhood schools reduce traffic and air pollution, facilitate physical activity, promote parent involvement in schools and their children’s educational success.

Response:

This response supplies no documentation for the rationale presented and no technical support showing that the recommended actions will have any positive effects on the impacts claimed or that attendance at a nearby existing school will have any negative effects.

The EIR does discuss analysis of student generation and potential need for a new school as a result of the Project (EIR Chapter IV, Part L, pages 5-6, under subsection Student Generation and pages 13-15, under subsection Public School Impacts). The City generated an estimate using student generation rates developed by the California State Department of Education as well as rates based more specifically on the demographic represented by the Oak to Ninth target population. Based on the estimates generated specific to the local demographic, no new schools will be needed as a result of the Project. Two elementary schools are located near the Project: La Escuelita Elementary School, located about two-thirds of a mile from the Project; and Franklin Elementary School, located about 1.4 miles from the Project. The analysis done to determine Public School Impacts determined that existing area schools will be able to accommodate new students generated as a result of the Project.

Recommendation VII: The design and placement of housing units at Oak to Ninth design should support person-to-person contact, social relationships and social capital by 1) creating crossing points and common paths of access 2) providing common courtyards with benches, plants, and fountains.

***Human Health Rationale:** Social capital and community ties can promote and individual's sense of security and satisfaction, reduce stress and blood pressure levels, provide material and emotional support, and facilitate recovery from illness.*

Response:

This response supplies no documentation for the rationale presented and no technical support showing that the recommended actions will have any significant positive effects on the health impacts claimed. As discussed in the EIR, Chapter III: Project Description, Part A: Project Location Characteristics, pages 1-29, planning for Oak to Ninth includes development of several parks, both passive and active (i.e. playing fields, playgrounds, and picnic areas would constitute active parks while open fields and garden areas would constitute passive parks). The Project also incorporates continuation of the Bay Trail for pedestrians and bicyclists, as well as creation of new paths which will serve to interconnect the various parks within the Project as well as connect these parks to other neighborhoods. This system of pathways and parks will create natural venues for people to interact, congregate, and socialize.

Recommendation VIII: The City of Oakland should specifically document how the project design has been responsive or not to public concerns and constructive design change recommendations raised in numerous public meetings and hearings on the Oak to Ninth Project.

***Human Health Rationale:** Government responsiveness and accountability to needs articulated by the public is a critical determinant of population health. Meaningful participation means creating the opportunities for all affected people to understand what is at stake, to speak to their needs and concerns, and to have their needs addressed by people making the decision. A review of transcripts and public meeting summaries reveals that*

several concerns have been made repeatedly by diverse stakeholders at various stages of this process. Some of the most common statements are related to lack of attention to the existing Estuary Policy Plan, for affordable housing for lower-income individuals and families, preservation of open space and the 9th avenue terminal, and lack of meaningful and responsive public engagement.

Response:

The FEIR for the Oak to Ninth Project was published in February 2006. This report includes public commentary, responses to public commentary, and changes that were made either as a result of this commentary or other reasons. Additionally, a complete history of the Project is documented on the Project's website at:

<http://www.oaklandnet.com/government/ceda/revised/planningzoning/MajorProjectsSection/oaktoninth.html>

This website lists public meeting announcements and agendas, staff reports, postings for public outreach, and reports, among other items.

After responding to the above comments, it is not clear whether the UCBHIG reviewed the EIR when evaluating the Oak to Ninth Proposal, as many of the recommendations made by the UCBHIG were addressed in the EIR. Additionally, although the letter is not dated, it is noted that the comments made by the UCBHIG were received after March 23, 2006, well after public commentary for the proposed Project closed on October 28, 2005. With respect to the proposed HIA that is referred to at the bottom of page two of the UCBHIG undated letter, a HIA would be expected to occur early in the decision process for a proposed project. According to the UCBHIG, a draft report of their findings would be submitted to the Oakland City Council in April, 2006; and as of the date of this response, the report has not been received. In addition, the HIA process is meant to include all major stakeholders involved or affected by the project. This would include the City, the Port, the Redevelopment Agency and the Project sponsors. It is not clear based on this document that any group was involved in compiling these recommendations with the exception of the UCBHIG.

5.0 CONCLUSIONS

In their Health Impact Guidelines (September 2001), enHEALTH (the premier advisory body on environmental health in Australia) lists the following criteria for activities likely to require HIA or health assessment:

- the possibility of substantial change to the demographic or geographic structure of a community;
- potential exposure of individuals to hazardous products and processes, including substances that are clinical or infectious;
- changes to the environment that may impact on disease vectors or parasites;
- the potential to render recreational facilities or water resources unsafe;
- potential impact on land productivity for horticultural and/or pastoral activities;
- impact on the microbiological or chemical safety of food chains and food supplies;
- substantial increase in the demands on public utilities;
- increase traffic flow with increased risk of injury or significant increase in the release of pollutants;
- generation of a high level of public interest in and/or concern about public health issues;
- identified ecosystems which are vulnerable and damage to which may cause health effects;
- potential exposure to the public to contaminants; and
- potential impact on the incidence of illness or infection in the community, especially in relation to populations such as children and the aged.

The Oak to Ninth Project either does not fit in these categories or the potential impacts have already been evaluated and have been determined not to be significant. In fact, the UCBHIG seems to have ignored the positive impacts the Project will have on the community including:

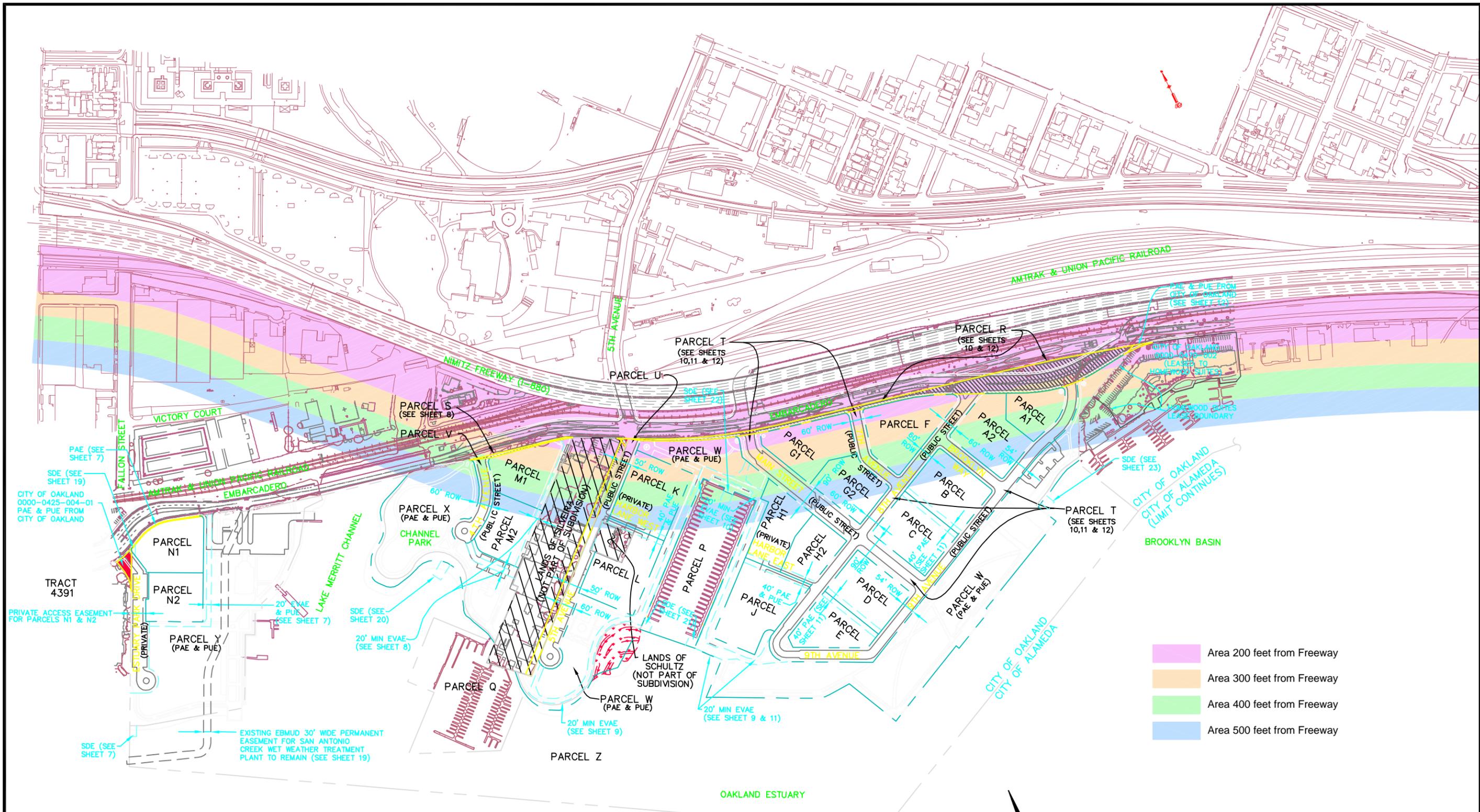
- The Project will remediate a contaminated site thereby protecting the physical environment, including the Estuary, and humans from the potential exposure to the harmful impacts of the contamination.
- The Project will transform a site with industrial uses and large vacant areas to a thriving mixed-use neighborhood.

- The Project will provide over 29 acres of new and improved parks, open space , and pedestrian and bicycle trails along the Estuary opening this area to all the residents of Oakland and the surrounding region.
- The Project will provide new housing and commercial space that meets current Code requirements, including health and safety regulations.
- The Project will provide significant construction and long-term job opportunities for Oakland residents, thereby providing economic opportunities for these workers and their families.
- The Project will provide significant opportunities for businesses to either locate on site or serve the new resident and business populations, thereby providing economic opportunities to local businesses.
- The Project will provide various traffic and roadway improvements and other infrastructure upgrades.
- The Project will generate a variety of fiscal benefits to the City and the Redevelopment Agency that will assist these agencies in providing services to Oakland residents.
- The Project will provide new affordable housing.

As acknowledged by the EnHealth Council, "[t]here is overwhelming evidence that development can have a beneficial effect on health and wellbeing; through the creation of employment, promotion of economic advancement and providing circumstances which can improve living standards." (Health Impact Assessment Guidelines, September 2001, p.vii) The significant health benefits of the Oak to Ninth Avenue Project are documented in the EIR and other evidence in the record. These benefits, based on factual evidence, define the health impact of this Project.

6.0 REFERENCES

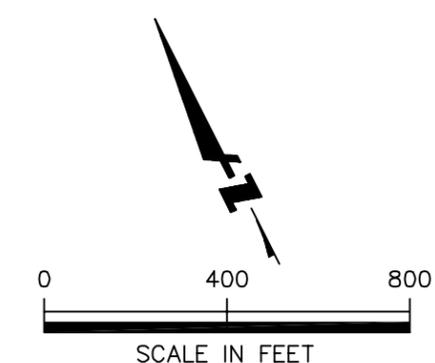
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- Area 200 feet from Freeway
- Area 300 feet from Freeway
- Area 400 feet from Freeway
- Area 500 feet from Freeway

CITY OF OAKLAND
CITY OF ALAMEDA
(LIMIT CONTINUES)

CITY OF OAKLAND
CITY OF ALAMEDA



BASEMAP SOURCE: BKF 03/08/06.

ENVIRON

Proximity of planned residential developments to the Nimitz Freeway

DATE: 5/19/06	CONTRACT NUMBER: 03-15847A	FIGURE 1
DRAFTER: RS	APPROVED:	REVISED:

0315847A-AFFECTED-AREA-MAP.DWG

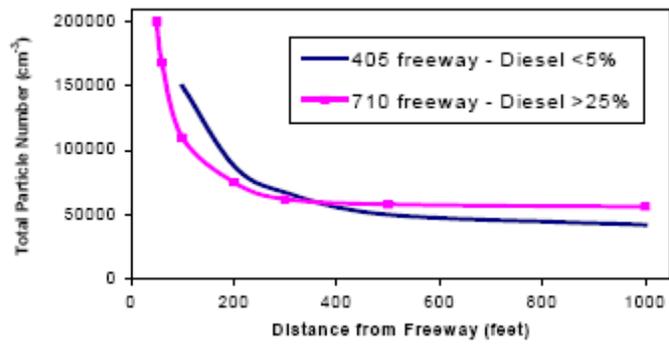
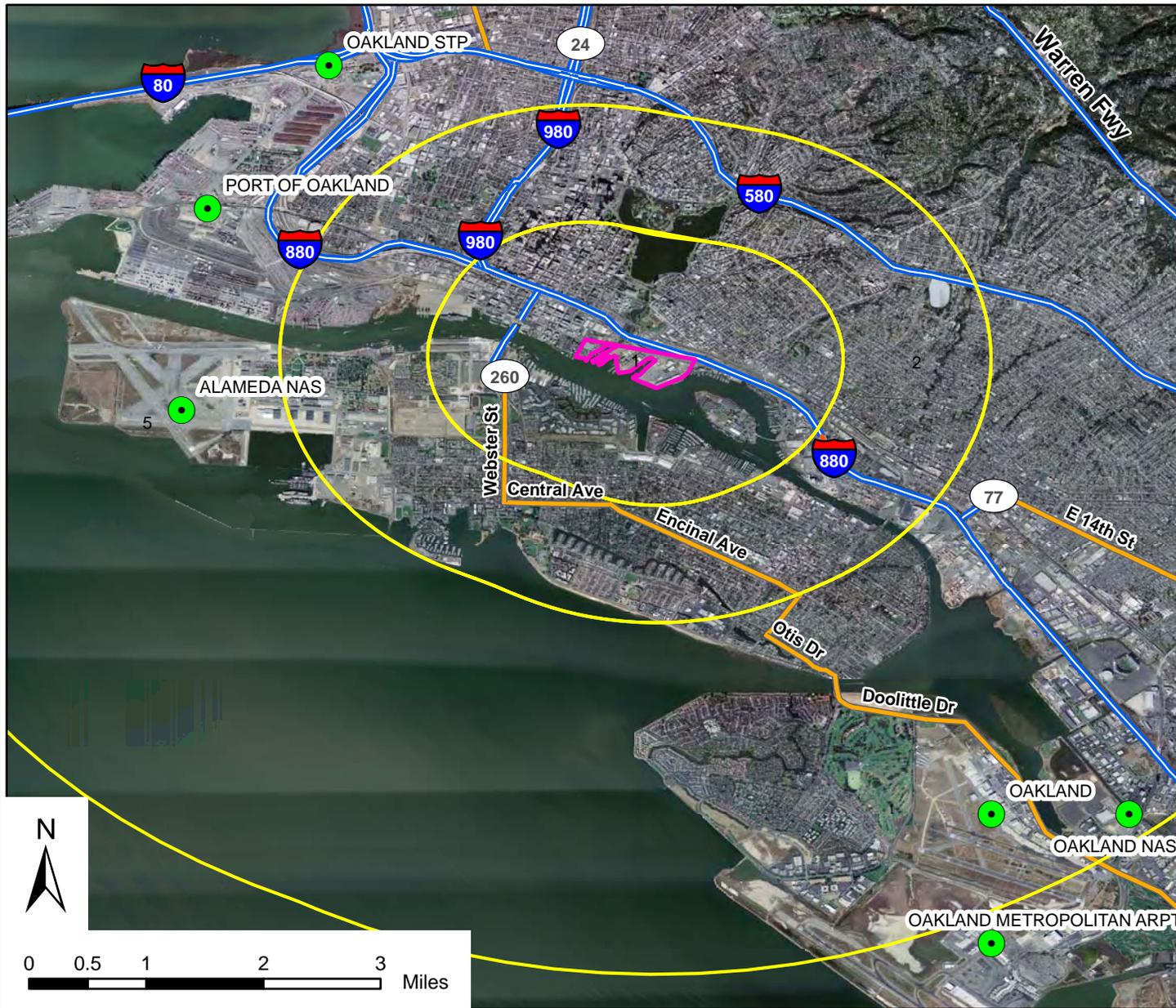


Figure 2: Particle Number vs. Downwind Distance from Freeway (ARB 2005)



- Legend**
- Meteorological Stations
 - Approximate Project Boundary

Notes:

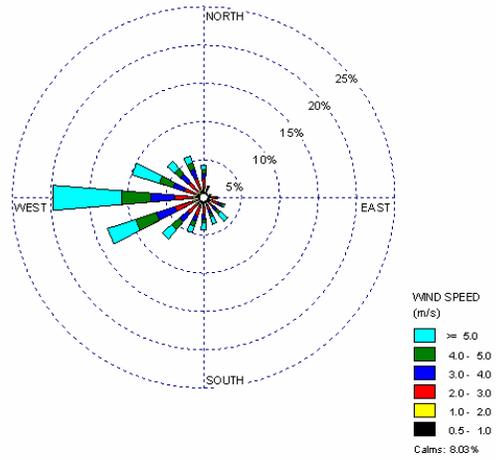
- 1, 2 and 5 mile distances from project boundary shown



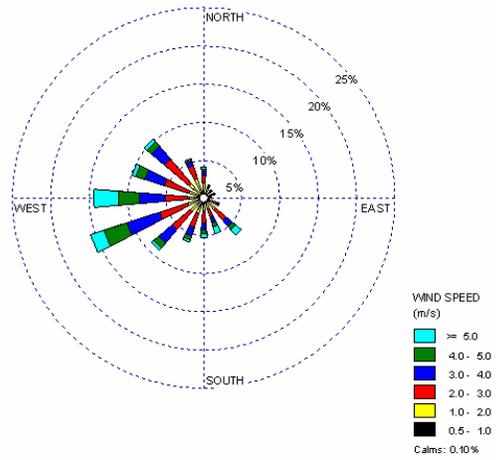
Meteorological Stations Near Proposed Oak to 9th Project Site

Figure
3

a)



b)



c)

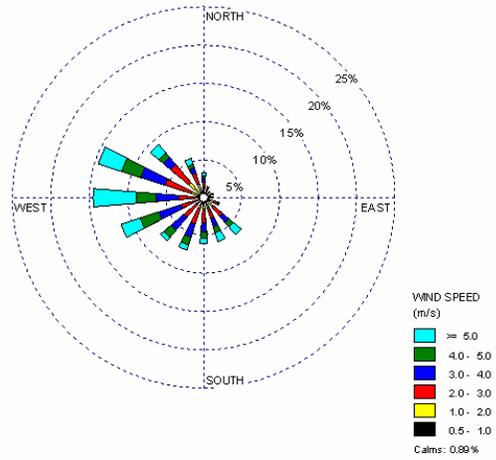


Figure 4: Three-year wind roses from a) Alameda NAS (1994-1997), b) Port of Oakland (1998 – 2000) and c) Oakland STP (1998-2000)

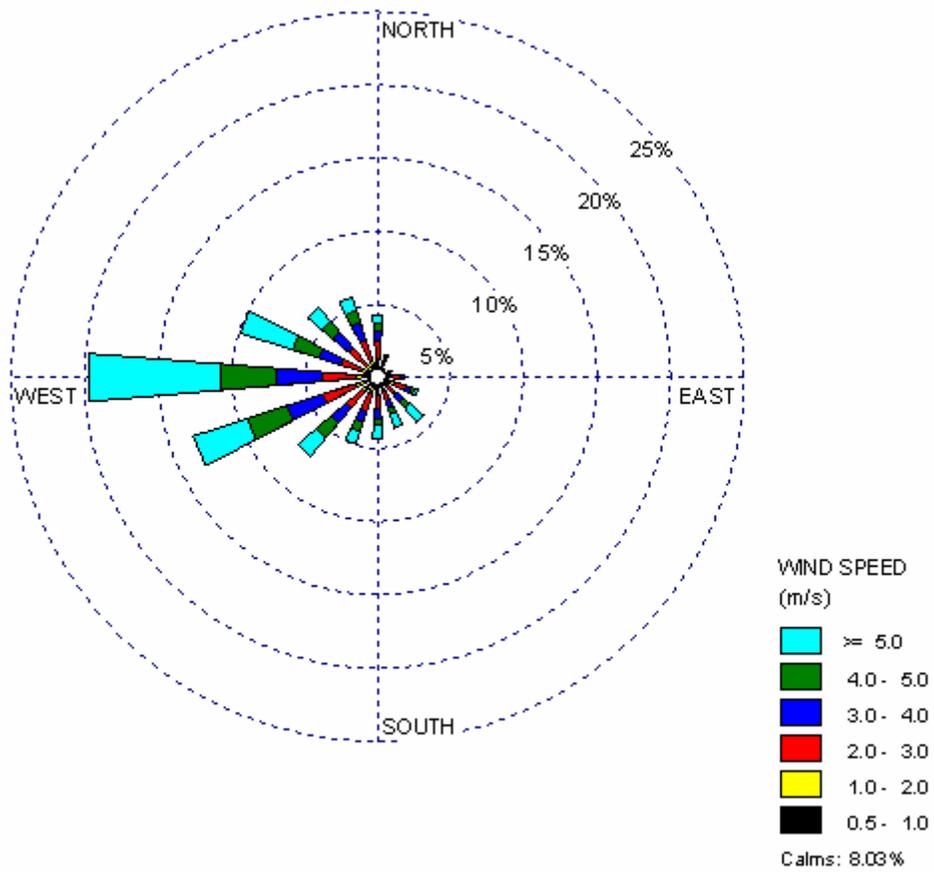


Figure 5: Wind directions at the Alameda NAS meteorological station for 1994 through 1996

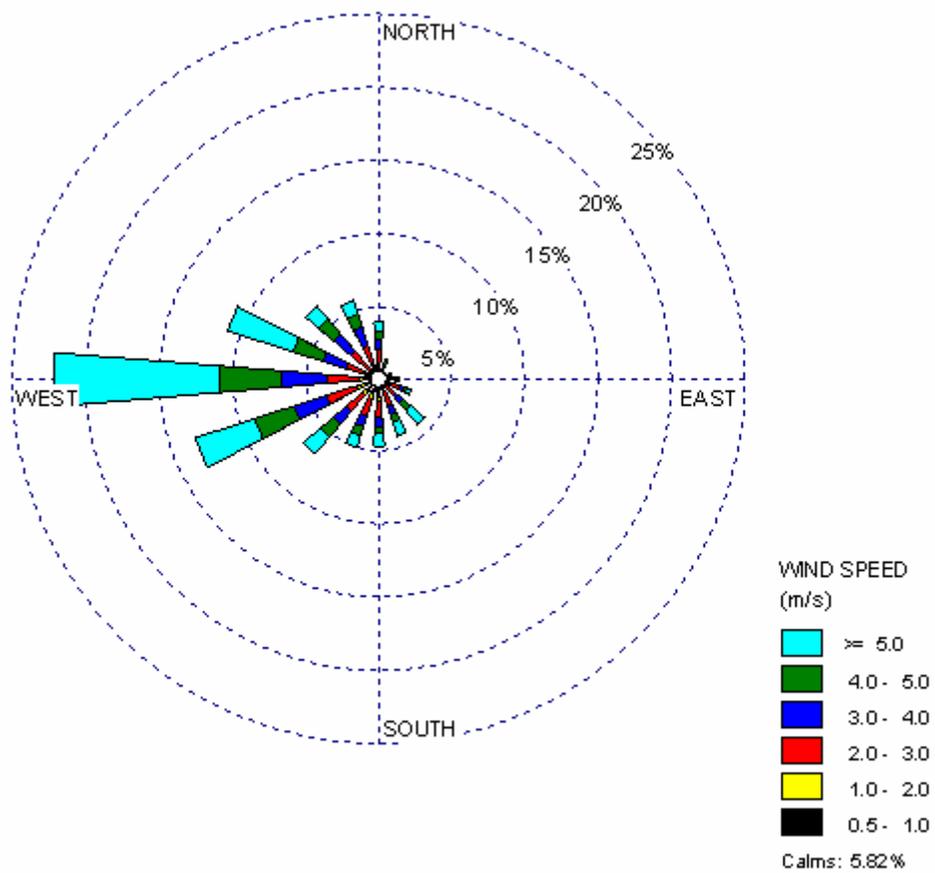


Figure 6: Wind directions at the Alameda NAS meteorological station for 1994 through 1996, winds between 5AM and 9PM