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et al.

Publication Date

2011

Peer reviewed

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California Corridor

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Performance Measures for Complete, Green Streets: Initial Findings for Pedestrian Safety along a California Corridor

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Word count: 7,052 words (5,802 words, 4 tables, 1 graph)

1 **Performance Measures for Complete, Green Streets: Initial**
2 **Findings for Pedestrian Safety along a California Corridor**
3
4 **Abstract**

5 This paper reports on research conducted by the Safe Transportation Research and Education
6 Center and sponsored by the California Department of Transportation ("Caltrans") to establish
7 performance measures for pedestrian and bicycle safety and mobility along urban arterials.
8 Although historically focused on motorized vehicle mobility, Caltrans has recently joined in a
9 national trend to incorporate non-motorized transportation and community-level outcomes into
10 transportation decision-making frameworks, an approach known as "Complete Streets."
11 Recognizing that its current performance measurement system does not reflect this shift, Caltrans
12 worked with researchers at the University of California, Berkeley to create new measures that
13 more accurately gauge its progress toward these objectives. This paper discusses a field test of
14 the validity and ease of application of the proposed performance measures for pedestrian safety.
15 The test corridor was San Pablo Avenue, a 9.5-mile, multi-jurisdictional State Route in Northern
16 California. While the researchers developed the performance measures based on a broad
17 literature and best-practice review, the field-test determined that most of the initial performance
18 measures for pedestrian safety require adjustments to improve validity and facilitate their broad
19 adoption by Caltrans. This paper demonstrates the value of small-scale field-testing of
20 performance measures before their adoption, particularly for subject areas with little institutional
21 measurement history, like pedestrian and bicyclist safety and mobility. The paper concludes
22 with discussion of the next steps of the performance measures development process and future
23 research on the topic.
24
25

1   **INTRODUCTION**
2   Communities throughout the United States are rethinking street design in their downtowns and
3   around their neighborhoods. Citing the adverse effects of high volumes of motorized traffic
4   (e.g., decreased roadway safety, walkability, and bikability, and increased air and water pollution
5   levels due to vehicle emissions), many communities desire transportation corridors that support
6   local needs as well as throughput needs, and that safely accommodate multiple travel modes.
7   Although efforts to enhance the quality of life within communities are increasingly supported by
8   city planners, designers, transportation engineers, and public health practitioners, professionals
9   lack a framework to comprehensively measure progress toward this broad objective.
10   Recognizing this gap within their measurement system, the California Department of
11   Transportation sponsored research at the University of California, Berkeley to develop such a
12   framework.
13   Simultaneously, there is growing direction from the federal and state government for
14   transportation agencies to be more accountable for funds and to provide defensible measures of
15   effectiveness. State departments of transportation routinely use performance measures to assess
16   their transportation systems, but assessment is generally based in the traditional highway
17   engineering perspective of providing for automobiles, or is limited to monitoring whether
18   departmental goals are achieved cost effectively or generate quantifiable net benefits. Although
19   corridor design elements that support livable and sustainable communities have been identified
20   through research, few defensible performance measures exist for assessing their effects on user
21   safety, multimodal mobility, and environmental quality; certainly, no comprehensive framework
22   of such measures presently exists.
23   This paper reports on the initial findings from field research aimed to create such a
24   performance measurement framework to assist transportation agencies in assessing allocation of
25   funds and efforts to enhance pedestrian and bicycle safety and mobility. Based upon defensible
26   research findings and best practices, the framework was created specifically for urban arterials,
27   which constitute 26% of the urban roadway network in California and carry high amounts of
28   local traffic, particularly pedestrians and bicyclists, due to their density of attractions such as
29   businesses, restaurants, and stores. Although designed specifically for Caltrans, the framework
30   is adaptable to arterial roadways throughout the U.S., and usable by local agencies aspiring to
31   create multimodal, sustainable streets.
32   The framework is strongly influenced by national Complete Streets principles, which
33   urge that transportation facilities be "planned, designed, operated, and maintained to provide safe
34   mobility for all users, including bicyclists, pedestrians, transit riders, and motorists appropriate to
35   the function and context of the facility" *(1)*. The framework was also shaped by the Green
36   Streets movement, which advocates for sustainable street design that maximizes permeable
37   surfaces, tree canopy, and landscaping elements in order to capture and filter stormwater and
38   increase urban green space *(2)*. While the framework covers several areas, this paper presents
39   only the findings for pedestrian safety.
40   The UC Berkeley project has operated in three phases. Phase I involved a broad
41   literature review of research on transportation corridor roadside design features and their effects
42   on user safety and behavior, health, community and economic vitality, and the environment.
43   Phase II included a review of performance measures in theory and practice, a review of policies
44   and plans that guide Caltrans' project selection and design, and the development of the proposed
45   *Complete, Green Streets Performance Measures Framework*. Phases I and II are only briefly
46   described in the following section. The full reports for both Phase I and II can be found online at

1 http://escholarship.org/uc/item/12047015, and http://escholarship.org/uc/item/6q85b8d6,
2 respectively.
3   This paper elaborates on the initial findings from Phase III, in which data to measure and
4 test the proposed performance measures was gathered and is being analyzed via regression
5 modeling. This field-test of the proposed performance measures is being used to test both their
6 validity and ease of application. Both of these factors will be used to revise the performance
7 measures and inform Caltrans' decision as to whether each will be implemented as part of their
8 broader performance measurement system.
9
10 **BACKGROUND**
11 This section briefly describes the Phase I literature review and the development of the proposed
12 performance measures during Phase II. The proposed performance measures for pedestrian and
13 bicyclist safety are also listed in this section, along with an explanation of how they relate to
14 Caltrans' current performance measurement system.
15
16 **Overview of the Phase I Literature Review**
17 The purpose of the Phase I literature review was to gather the latest scholarship and best
18 practices on which the proposed *Complete, Green Streets Performance Measures* would be
19 based. The literature review focused on the effects of transportation corridors' roadside design
20 features on the following macro categories: pedestrian and bicyclist safety; pedestrian and
21 bicyclist mobility; community and economic vitality; environmental sustainability; and public
22 health. Literature searches were conducted in major transportation, economic, urban planning,
23 and public health databases, and approximately 180 studies and best practices were reviewed.
24 Although validity, replicability, and ability of findings to be generalized were considered in the
25 review, some of the selected studies had small sample sizes and/or were less robust than the most
26 rigorous science demands. While the authors relied heavily on the more robust studies in
27 developing the proposed *Complete, Green Streets Performance Measure Framework*, the smaller
28 studies were used if there were no better studies available on the specific subject matter (for
29 example, there is relatively little research on the effects of roadside design features on economic
30 vitality). Validity and quality of the measures will be ultimately controlled through Phase III
31 field testing.
32   Key findings for pedestrian and bicyclist safety included:
33 • Higher driving speeds were found to be more associated with vehicle crashes and
34   fatalities than slower speeds *(3)*. Higher speeds also increase the chance that pedestrians
35   and cyclists will suffer serious injuries if they are hit *(4)*.
36 • Street sections with landscaping and amenities, where low speed is communicated
37   through design, are often found to have fewer vehicular collisions and fewer pedestrian
38   and bicyclist injuries and fatalities *(5-6)*.
39 • Pedestrian crosswalk installation has been generally positively associated with increased
40   usage by pedestrians and slightly decreased driver speed approaching the intersection,
41   particularly if ancillary traffic safety treatments are installed *(7-9)*.
42 • To help prevent the risk of driver misunderstanding at crosswalks, marked crosswalks at
43   unsignalized locations should be installed with supplementary measures such as flashing
44   lights, in-pavement lighting, or red beacons on all multi-lane roadways and in areas with
45   high volumes of or fast-moving traffic *(10-15)*.

- Pedestrian countdown signals have been positively associated with increased pedestrian compliance with signalization, leading to safer crossing behavior *(16)*.
- Leading pedestrian intervals have been associated with reduced crash rates at intersections allowing right turns on red *(17)*.

Overview of the Phase II Review of Plans, Policies and Legislation
The second phase of the project involved the development of the proposed *Complete, Green Streets Performance Measures* for Caltrans, and, as such, necessitated an examination of the many layers of policy, planning, and legislation affecting the Department. The Phase II review found a growing body of adopted material, ranging from California State Senate Bill 375 (*Regional Planning for Greenhouse Gas Reduction*) to Caltrans' Strategic Plan, which indicates the State's intention and responsibility to address pedestrian and bicyclist safety and mobility, as well as environmental issues, through more community-serving transportation facility design *(18-19)*. There has been a particular focus on Complete Streets principles, building upon federal and state policies that promote the development of multimodal, community-serving streets – notably the 2007 California Complete Streets legislation that requires a city or county to identify how it provides for the routine accommodation of all roadway users, including pedestrians, bicyclists, individuals with disabilities, seniors, transit riders, and motorists, when the circulation element of a general plan is updated *(20)*. In addition, Caltrans' Deputy Directive 64-R1 Complete Streets recognizes "bicycle, pedestrian, and transit modes as integral elements of the transportation system," and that Caltrans "provides for the needs of (all) travelers…in (all) planning, programming, design, construction, operations, and maintenance activities and products on the State highway system" *(1)*. This political and professional momentum heavily influenced the development of the proposed framework, as did best practices in performance measurement from around the United States.

Caltrans' Current Use of Performance Measures
To monitor the state's transportation system, Caltrans currently uses performance measures based on five high-level goals related to safety, mobility, delivery, stewardship, and service *(19)*. Each goal is accompanied by objectives that have numerical targets and timeframes coordinated with the Strategic Plan that Caltrans adopts every five years. At the end of each fiscal year, performance is measured and compared with the results of previous years, allowing Caltrans to gauge overall progress toward objectives. Caltrans' current measurement system focuses on motorized travel: it contains no objectives or measures concerned with the safety and mobility of non-motorized travelers, and none concerned with environmental quality, other than litter clean-up. Clearly, momentum exists within Caltrans for taking a more holistic approach to maintaining the transportation system; however, this vision has not been comprehensively adopted.

The proposed *Complete, Green Streets Performance Measure Framework* fills the gap for pedestrian and bicycle safety and mobility, and contributes to evaluating environmental stewardship (more research is needed before an entire range of performance measures can be formed for this area). The authors note that transit, although an essential element of a complete street, was excluded from this proposal because of the need to focus the scope. By combining the new framework with its existing measures, the Department would take a major step toward creating a meaningful and comprehensive system to measure progress toward a multimodal and community-serving transportation network.

1   **Proposed Complete, Green Streets Objectives and Measures**
2   To facilitate incorporation of the new objectives and measures, the proposed framework was
3   developed using Caltrans' existing structure and format. The proposed objectives and
4   performance measures, labeled "CGS objectives" (for Complete, Green Streets), and "PM",
5   respectively, are listed as they would be if incorporated into Caltrans' Strategic Plan. In several
6   places, an "X" is used as a placeholder for a year or target where more work is needed before a
7   finite target year or level (i.e., reduce injury rate to 1 per 1 million vehicle miles traveled) could
8   be set.
9   The proposed objectives and measures for pedestrian and bicyclist safety are listed in
10   Table 1 on the following page. Note that these performance measures are those tested in Phase
11   III of the project, and are not presented as a finalized set. The research team, together with
12   Caltrans, decided to focus on the safety and mobility goals for the third phase of the project; the
13   proposed performance measures for the stewardship and service goals will be tested at a later
14   date and are therefore not described in this paper. The proposed mobility measures will be tested
15   this fall and are therefore listed in the "next steps" section of this paper.
16
17

1 **TABLE 1 Proposed Complete, Green Streets Objectives and Measures for Pedestrian**
2 **Safety on Caltrans Urban Arterials**

CALTRANS SAFETY GOAL: Provide the safest transportation system in the nation for users and workers.	
CGS Objectives	CGS Performance Measures
1.1: By 2012, reduce the annual pedestrian and bicycle injury and fatality rates to the following levels, and continuously reduce annually thereafter with the goal of having the lowest rates in the nation: – Pedestrian fatality rate target: X per X walking trips. – Pedestrian injury rate target: X per X walking trips. – Bicyclist fatality rate target: X per X bicycling trips. – Bicyclist injury rate target: X per X bicycling trips.	PM 1.1a: Rate of pedestrian fatalities per walking trips. PM 1.1b: Rate of pedestrian injuries per walking trips. PM 1.1c: Rate of bicyclist fatalities per bicycling trips. PM 1.1d: Rate of bicyclist injuries per bicycling trips.
1.2: By 2017, double the percentage of people who feel safe using non-motorized modes on urban arterials. By 2022, increase this percentage to XX%.	PM 1.2: Percentage of Californians who feel safe using non-motorized modes on urban arterials.
1.3: By 2012, all Caltrans urban arterial projects (new expenditures) are designed to increase safety for non-motorized users in accordance with Complete Streets principles. By 20XX, all Caltrans urban arterials are designed for safety according to these principles.	PM 1.3a: Percent of signalized intersections along urban arterials with marked crosswalks and one or more of the following: countdown signals, leading pedestrian intervals, bulb-outs, or pedestrian refuge islands. PM 1.3b: Percent of unsignalized 4-way (multilane) intersections along urban arterials with marked crosswalks and one or more of the following: HAWK signal[*], yield to pedestrian signage, user-activated overhead warning lights. PM 1.3c: Percent of urban arterial intersections with one or more of the following improvements geared toward bicyclists: bike box[*], painted bicycle lane through the intersection[*], bicycle signal, bicycle detectors, bicycle left turn lane. PM 1.3d: Percent of urban arterials on which the 85th percentile driving speed is no greater than 25 mph.
1.4: By 2012, annually reduce the number of pedestrian and bicycle hotspots (high collision concentrations) on urban arterials.	PM 1.4a: Overall number of pedestrian collision hotspots on urban arterials. PM 1.4b: Overall number of bicycle collision hotspots on urban arterials.

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1   **PHASE III METHODOLOGY**
2   The third phase of the project has focused on gathering data to field-test the proposed *Complete,*
3   *Green Streets Performance Measures* for safety and mobility. This section describes the field
4   study area and the data gathering process.
5
6   **Study Area**
7   The research team selected San Pablo Avenue, a 9.5-mile, multi-jurisdictional corridor in the
8   East San Francisco Bay of California, as the test corridor for the project. San Pablo Avenue is a
9   historic State Route (123) that acts as an urban arterial, so it is under the jurisdiction of Caltrans
10 as well as several cities in the area. This guaranteed that there would be some consistency in the
11 street layout and operation, but also a variety of design conditions that may affect pedestrians
12 and bicyclists, such as landscaping, context sensitive paving, public seating, etc. Table 2
13 describes some of the variety in the street conditions along San Pablo Avenue.
14
15 **TABLE 2 Description of Street and Intersection Conditions along San Pablo Avenue**

Intersection Conditions: Crossings	• Sixty-two percent of all intersections had at least three crosswalk legs (including a sidewalk); only 24% had a crosswalk on each leg. • Thirty-seven percent of all intersections had at least one pedestrian signal (countdown or not); twenty-seven percent of all intersections had pedestrian signals in at least 3 directions. • Fourteen percent of intersections had a crossing speed of over 3.5 feet/second in at least one direction.
Intersection Conditions: Other	• Approximately 63% of intersections had at least one dedicated left turn lane. • Approximately 60% of intersections had on-street parking up to the intersection on at least one side. • Twelve percent of intersections had pedestrian signage.
Sidewalk Conditions	• Over 53% of sidewalks were between 5' and 7'11" wide. • Only 15% of street segments had significant impediments. Forty-four percent of segments had no impediments.
Segment Conditions: Landscaping	• Fifty percent of the street segments had regularly spaced street trees on both sides; approximately 65% had regularly spaced trees on at least one side. • Approximately 62% of the street segments had gardens or planters on at least one side. • Nearly 70% of street segments had landscaped medians; only one median had no landscaping.
Segment Conditions: Other	• Approximately 40% of street segments had at least one trashcan • Around 25% of street segments had public seating on at least one side. • Nearly 70% of street segments had time-restricted parallel parking on at least one side. • Around 37% of street segments had 1-2 retail locations on at least one side; approximately 23% of street segments had at least 3 retail locations on either side. • Approximately 11% of the corridor had 5 or more driveways on at least one side of the street. There was an average of 2 driveways per side of the street. • School zones were present along 20% of street segments.

1 **Data Gathering & Processing**
2 A checklist was developed to facilitate gathering the data needed to test the proposed
3 performance measures. The checklist also included elements needed to perform a multimodal
4 LOS assessment on the corridor. This was done in order to double-check any conclusions the
5 research team could draw about the framework with an accepted LOS method. The San
6 Francisco Pedestrian Environmental Quality Index was also used for the facility analysis, as it
7 measures some of the necessary information to test the proposed performance measures. In
8 addition, the research team reviewed the pedestrian and bicycle plans of each city and county
9 with jurisdiction over San Pablo Avenue, and added the most common elements of the plans to
10 the facility checklist as a way to evaluate the impact of policies on the design of the corridor.
11   Data was gathered from October, 2009 – June, 2010, depending on the weather. The lead
12 author and two undergraduate researchers drove to the research site and collected the data on
13 paper forms, using standard engineering measuring wheels and stopwatches to enable
14 measurement of distance and time. There are approximately 180 intersections along the test
15 corridor, and the data was gathered for each intersection and its corresponding southern roadway
16 section (both sides of the street segment were measured separately). In this way, data for each
17 intersection and roadway section were attached to a unique ID in the analysis. The researchers
18 spent about 15-20 minutes gathering the data for each intersection and corresponding roadway
19 section. After the data was gathered manually, it was input into a Microsoft Excel™ spreadsheet
20 and checked for accuracy through a combination of Google Maps Street View™ and Google
21 Earth™. When the data was questionable and could not be corroborated through online tools,
22 new data was obtained through a second trip to the site.
23   The original data set contained 181 intersections along San Pablo Avenue as determined
24 by each city's GIS files, and researchers at SafeTREC coded each intersection with the total
25 number of pedestrian and bicycle injuries and fatalities from the years 1997-2007. The crashes
26 were determined from the California Highway Patrol Statewide Integrated Traffic Records
27 System (SWITRS), and were coded to the nearest intersection along the corridor. When
28 gathering the physical data for analysis, the researchers were unable to match some of the
29 intersections in the GIS files to intersections on the ground, resulting in the deletion of 11
30 intersections from the data set; 170 intersections remained.
31   After the data set was finalized in Excel, the file was transformed into a database file for
32 analysis using the statistical software package STATA. The first stage of analysis focused on
33 pedestrian safety only. Due to the low number of pedestrian fatalities in the dataset (n=9), the
34 research team elected to combine the pedestrian injuries and fatalities for the outcome variable in
35 the regression analysis. Although the data is count data, it did not fit the traditional Poisson
36 distribution, given that the variance was several times greater than the mean. A comparison of
37 distributions suggested that a negative binomial distribution was more appropriate for regression
38 (corroborated by a goodness-of-fit test in STATA). In order to account for exposure, pedestrian
39 volumes were estimated according to a model based on the work of Schneider et al. *(21)*, which
40 was derived using data including several of this study's intersections.
41   Table 3 describes the range and distribution of the various street treatments variables
42 tested in the pedestrian crash model. The variables were entered one by one in the negative
43 binomial regression model, keeping only those with a *p* value of less than 0.10. To control for
44 collinearity, variables were compared for correlation and only one variable of highly correlated
45 pairs was entered into the regression model. While the regression model was able to clearly

1 demonstrate insignificance for some of the proposed performance measures, a final version is
2 not presented in this paper due to the need for further testing.
3
4 **TABLE 3 Frequency of Various Street Treatments & Events along San Pablo Avenue**

Description	Mean	Range / SD
Combined pedestrian incidents	1.52	Range: 0 to 10 SD: 2.14
On-street parking up to intersection – east (west)	0.59 (0.62)	Range: 0 to 1 [0 = no on-street parking; 1 = on-street parking]
Percent sidewalk "fair or better" – east (west)	95.36 (93.50)	Range: 30 to 100 (10 to 100) SD: 11.11 (13.79)
Percent sidewalk ADA compliant – east (west)	96.14 (95.65)	Range: 0 to 100 (40 to 100) SD: 11.17 (10.74)
Context sensitive crosswalk legs		Range: 0 to 4
Trashcans – east (west)	0.50 (0.62)	Range: 0 to 4 (0 to 5) SD: 0.72 (0.94)
Pedestrian trips	9361.48	Range: 4987 to 55,436 SD: 6292.89
Driveways – east (west)	2.05 (1.81)	Range: 0 to 12 (0 to 10) SD: 2.14 (2.07)
Street trees – east (west)		Range: 0 to 2 [0 = no street trees; 1 = sporadic street trees; 2 = regular street trees]
Gardens/planters – east (west)		Range: 0 to 1 [0 = no gardens/planters; 1 = gardens/planters]
Public seating – east (west)		Range: 0 to 1 [0 = no public seating; 1 = public seating]
Sidewalk buffer – east (west)		Range: 0 to 3 [0 = no buffer; 1 = bicycle lane; 2 = unrestricted parallel parking; 3 = time-restricted parallel parking]
Storefronts – east (west)		Range: 0 to 2 [0 = no storefronts; 1 = 1 or 2 storefronts; 2 = 3 or more storefronts]
Public art or historical site – east (west)		Range: 0 to 1 [0 = no public art or historical sites; 1 = public art or historical sites]
Graffiti – east (west)		Range: 0 to 1 [0 = little to no graffiti; 1 = graffiti]
Litter – east (west)		Range: 0 to 1 [0 = little to no litter; 1 = litter]
Pedestrian-scaled lighting – east (west)		Range: 0 to 3 [0 = no lighting; 1 = private lighting; 2 = public lighting; 3 = private & public lighting]
Construction – east (west)		Range: 0 to 1 [0 = no construction; 1 = construction]

Abandoned buildings – east (west)		Range: 0 to 1 [0 = no abandoned buildings; 1 = abandoned buildings]
Left turns at intersection	0.91	Range: 0 to 2 SD: 0.80
Raised median		Range: 0 to 1 [0 = no median; 1 = median]
Regular median width	9.44	Range: 4 to 18 SD: 5.93
Median width when left turn lane is present	2.53	Range: 0 to 9 SD: 2.16
Landscaping on median		Range: 0 to 1 [0 = no landscaping; 1 = landscaping]
Median landscaping type		Range: 0 to 7 [0 = none; 1 = grass; 2 = shrubs; 3 = trees; 4 = grass, shrubs; 5 = grass, trees; 6 = shrubs, trees; 7 = grass, shrubs, trees]
Passability of median		Range: 0 to 1 [0 = not passable; 1 = passable]
Mid-block crossing		Range: 0 to 1 [0 = no mid-block crossing; 1 = mid-block crossing]
Mid-block crossing sign		Range: 0 to 1 [0 = no signage; 1 = signage]
Standard crosswalks	2.69	Range: 0 to 5 SD: 1.04
Ladder crosswalks	0.17	Range: 0 to 4 SD: 0.73
Crosswalks (either type)	2.77	Range: 0 to 5 SD: 0.99
Pedestrian signals with countdowns	0.39	Range: 0 to 5 SD: 1.15
Pedestrian signals without countdowns	0.79	Range: 0 to 5 SD: 1.39
Pedestrian signals (either type)		Range: 0 to 1 [0 = no pedestrian signal; 1 = pedestrian signal(s)]
Intersection legs > 4		Range: 0 to 1 [0 = four or fewer legs; 1 = more than four legs]
Crosswalk length - north	81.38	Range: 71 to 152 SD: 11.38
Crosswalk length – south	79.54	Range: 24 to 156 SD: 9.56
Crosswalk length – east	44.49	Range: 21 to 113 SD: 17.48
Crosswalk length – west	48.05	Range: 21 to 135 SD: 21.93

1

Crossing speed over 3.5 feet/second		Range: 0 to 1 [0 = crossing speed under 3.5 ft/sec; 1 = crossing speed over 3.5 ft/sec]
Average crosswalk length – north/south	80.46	Range: 62.5 to 138 SD: 9.0
Average crosswalk length – east/west	46.47	Range: 21 to 117.5 SD: 18.47
Right turns on red prohibited		Range: 0 to 2
Intersection traffic-calmed		Range: 0 to 1 [0 = no traffic calming; 1 = traffic calming]
Pedestrian signs at intersection		Range: 0 to 1 [0 = no pedestrian signs; 1 = pedestrian signs]
Vehicle speed posted		Range: 0 to 1 [0 = no speed limit sign; 1 = speed limit sign]
School zone		Range: 0 to 1 [0 = no school zone; 1 = school zone]
Sidewalk width – east (west)		Range: 0 to 3 [0 = less than 5 feet; 1 = 5 to 7 feet, 11 inches; 2 = 8 to 12 feet; 3 = over 12 feet]
Sidewalk impediments – east (west)		Range: 0 to 3 [0 = no sidewalk; 1 = no impediments 2 = few impediments; 3 = significant impediments]
Sidewalk obstructions – east (west)		Range: 1 to 3 [1 = no obstructions; 2 = temporary obstructions; 3 = permanent obstructions]

1
2   Once the data were analyzed, the proposed performance measures were judged for their
3   validity and ease of application. Validity was determined differently for the various performance
4   measures. For measures that examine relationships between design elements and safety
5   (measures 1.3a-d), validity was assessed by whether or not the measurement proved
6   significantly related to pedestrian safety in the crash model. For measures that examine
7   quantities of incidents (measures 1.1a-b and 1.4a), validity was determined by whether or not
8   that quantity made sense as the selected measurement of the subject area. Ease of application
9   was determined after evaluating the amount of time and effort the task took the research team to
10 complete.
11
12 **FINDINGS**
13 This section elaborates on the findings regarding the validity and ease of application of the
14 pedestrian safety-related performance measures proposed in Phase II of the project.
15
16 **CGS Performance Measures 1.1a - 1.1b: Rates of Injury and Fatality**
17 The guiding objective for performance measures 1.1a and 1.1b was modeled after Caltrans'
18 objective for vehicular safety:

19 **By 2012, reduce the annual pedestrian and bicycle injury and fatality *rates to the**
20 **following levels, and continuously reduce annually thereafter with the goal of having the**
21 **lowest rates in the nation.**

1   **– Pedestrian fatality rate target: X per X walking trips.**
2   **– Pedestrian injury rate target: X per X walking trips.**
3   **– Bicyclist fatality rate target: X per X bicycling trips.**
4   **– Bicyclist injury rate target: X per X bicycling trips.**
5   *Rates not set due to the need to establish a baseline number.

6   It is well-established that accounting for exposure is the most accurate way to assess
7   pedestrian risk *(22-23)*. Measuring the number of crashes without accounting for exposure could
8   give the impression that a reduction in crashes is due to safer behavior on the roadway, when in
9   reality, the number of pedestrians could be declining. Similarly, measuring only overall numbers
10   may give the impression that an intersection with zero crashes is very safe, when in reality, it
11   could be so unsafe that no one dare cross it. Both of these scenarios reinforce the need to
12   measure incidence rate, rather than a cumulative incident number, to accurately gauge pedestrian
13   risk. However, gathering pedestrian volumes is a task that transportation agencies may not
14   prioritize, so pedestrian safety may or may not be measured through other ways. For example,
15   Caltrans currently measures combined traveler safety: pedestrian and bicycle fatalities are
16   combined with vehicle fatalities, and then divided by 100 million VMT in order to gauge the rate
17   of collisions on state highways (including those that run through cities as urban arterials) *(19)*.
18   Whether there were 10 or 1,000 pedestrian fatalities, the actual picture of pedestrian safety would
19   be unclear due to having been combined with other modes. Although Caltrans' current Strategic
20   Highway Safety Plan proposes to measure pedestrians and bicyclists separately from motorized
21   vehicles, the SHSP proposes measuring overall amounts, which, without exposure, will not allow
22   California to truly measure risk to pedestrians or bicyclists *(24)*.
23   Proposed CGS performance measures 1.1a (*rate of pedestrian fatalities per walking trips*)
24   and 1.1b (*rate of pedestrian injuries per walking trips*) have the potential to provide a much more
25   specific and accurate picture of the risk pedestrians face on the roadway. To "test" these
26   measures, the overall number of pedestrian injuries and fatalities were compared to the rate of
27   injuries and fatalities per weekly intersection crossings (a proxy for pedestrian trips). As shown
28   in Figure 1, intersections with the same number of incidents can have dramatically different
29   crash rates. In this case, a person crossing the intersection with the highest rate has more than
30   twice as much risk of being hit as a person crossing the intersection with the lowest rate. This
31   demonstrates that a reliance on total number could wrongly suggest that certain intersections are
32   safer or more dangerous than they actually are. For this dataset, fatalities and injuries were
33   combined due to a low number of fatalities (n=9). Likewise, if Caltrans were to measure
34   individual corridors in the future, performance measure 1.1a may be modified to measure both
35   fatalities and injuries. However, in the case of a system-wide evaluation, it is recommended that
36   separate performance measures are evaluated for pedestrian injuries and fatalities, in order to
37   fully understand the level of each type of risk to pedestrians.
38
39
40

1   **FIGURE 1 Rate of Pedestrian Fatalities & Injuries at San Pablo Avenue Intersections With**
2   **Identical Fatality and Injury Counts, 1997-2007**
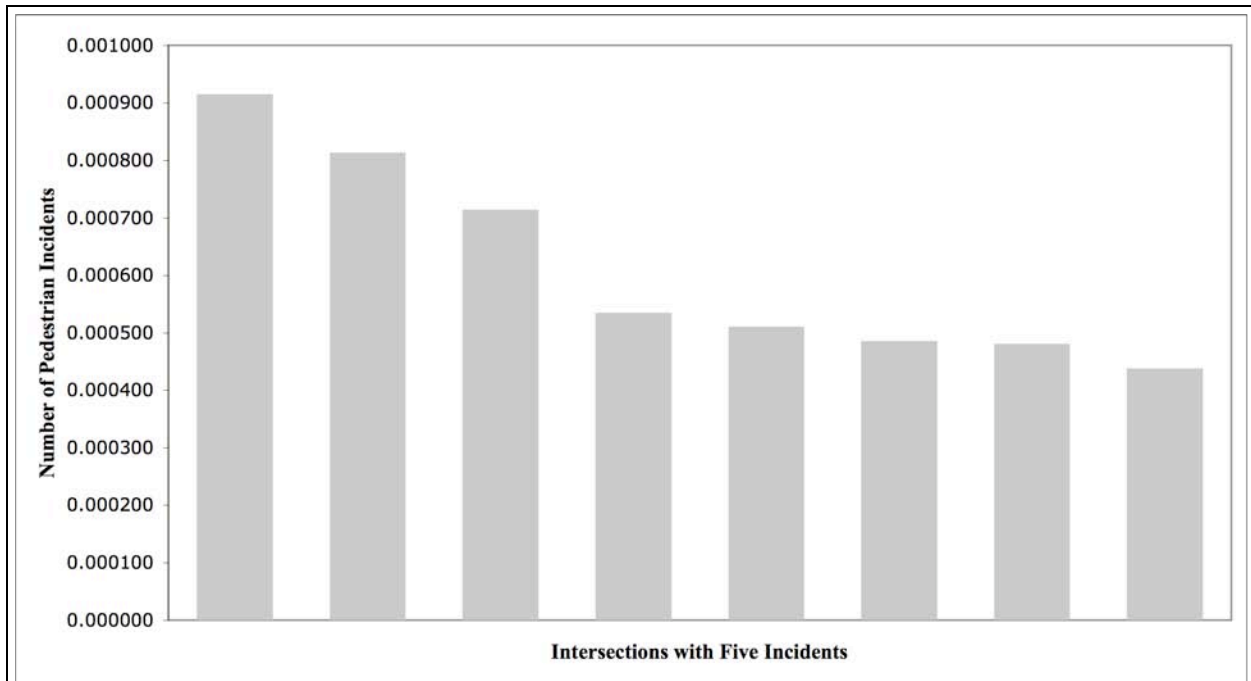
4
5   *PM1.1a & 1.1b Conclusions*
6   <u>Validity</u>: The proposed performance measures evaluate the intended quantity, and are the most
7   accurate measures for the subject area.
8   <u>Ease of Application</u>: The research team concluded that the ease of application for this
9   performance measure is reasonably high. The data needed for these performance measures
10   includes: 1) the number of incidents in the system, and 2) the corresponding number of
11   pedestrian trips (or a proxy, such as the number of pedestrian crossings per intersection). The
12   challenges to obtaining this data are explained below.
13   1) The number of incidents on Caltrans' roadways can be obtained through the CHP
14   SWITRS database. The data must be filtered for pedestrian crashes and road type, and
15   then separated by year and injury type before it can be summed; however, all of these
16   functions can be done using readily available desktop software. The research team spent
17   only a few hours doing this task for the research project; using database tools, this task
18   can be scaled with minimal additional staff effort.
19   2) Pedestrian exposure data is difficult and expensive to gather. However, this project is
20   currently testing the validity of using pedestrian count models in the place of on-the-
21   ground pedestrian counts. Count models use geographic information and data from the
22   U.S. Census to give estimates of pedestrian volumes that can be used as a proxy for
23   actual exposure, facilitating the application of this performance measure.
24
25   **CGS Performance Measure 1.2: Perceptions of Safety**
26   This measure is currently being evaluated.
27
28
29

1 **CGS Performance Measures 1.3a - 1.3d: Complete Streets**
2 The guiding objective for performance measures 1.3a – 1.3d is:

3 **By 2012, all Caltrans urban arterial projects (new expenditures) are designed to increase**
4 **safety for non-motorized users in accordance with Complete Streets principles. By 20XX,**
5 **all Caltrans urban arterials are designed for safety according to these principles.**

6   The core of this objective, "accordance with Complete Streets principles," refers to the
7 Complete Streets goal of providing "safe mobility for all users" *(1)*. While "safe mobility" may
8 be simple enough to imagine, developing a succinct, practical performance measure for the
9 concept has proven more difficult. Based on research showing the effect of vehicle speed and
10 various street design treatments on pedestrian safety, the research team developed four
11 performance measures to capture the essence of the objective *(5, 8-19)*.
12   The first measure, 1.3a, pertains to the *Percent of signalized intersections along urban*
13 *arterials with marked crosswalks and one or more of the following: countdown signals, leading*
14 *pedestrian intervals, bulb-outs, or pedestrian refuge islands.* San Pablo Avenue does not have
15 any leading pedestrian intervals, so the validity of this part of the measure could not be tested.
16 However, the remainder of the measure, separately (standard and high visibility crosswalks,
17 pedestrian signals with and without countdowns, bulb-outs, and refuge islands) and in
18 combination, was not found to be significant (cutoff of $p = 0.10$) in the regression model. At this
19 time, it is not quite clear why this is, given past research that has found a combination of these
20 treatments to enhance pedestrian safety *(8-11, 13)*. The research team is currently investigating
21 the matter further. It is possible that parts of the measure, while perhaps beneficial for pedestrian
22 safety, are counteracted by unmeasured forces. For example, upon further examination of the
23 data, the researchers noted that pedestrian refuge islands were common in locations with right
24 turn slip lanes, which have been found to negatively impact pedestrian safety *(27)*.
25
26 *PM1.3a Conclusions*
27 <u>Validity</u>: This performance measure must be revised before it can be recommended.
28 <u>Ease of Application</u>: Give that the measure may be modified significantly from its current state,
29 an evaluation of the ease of application is not possible at this time.
30
31   The second measure, 1.3b, focuses on the *percent of unsignalized 4-way (multilane)*
32 *intersections along urban arterials with marked crosswalks and one or more of the following:*
33 *HAWK signal, yield to pedestrian signage, user-activated overhead warning lights.* HAWK
34 signals are not currently allowed in California, so the effectiveness of this part of the measure
35 could not be tested. However, as before, the remainder of the measure, separately (standard and
36 high visibility crosswalks, pedestrian signage, and user-activated warning lights) and in
37 combination, was not found to be significant in the regression model. Similar to the measure for
38 signalized intersections, it is not clear why these aspects were insignificant; the research team is
39 currently investigating the matter further.
40
41 *PM1.3b Conclusions*
42 <u>Validity</u>: This performance measure must be revised before it can be recommended.
43 <u>Ease of Application</u>: Give that the measure may be modified significantly from its current state,
44 an evaluation of the ease of application is not possible at this time.
45

1   The third measure, pertaining to bicycle treatments, is currently being evaluated. The
2   fourth measure, *percent of urban arterials on which the 85th percentile driving speed is no*
3   *greater than 25 mph*, is based on research showing the non-linear relationship between risk of
4   injury or death and vehicle speed *(5)*. Unfortunately for both the research and pedestrians along
5   San Pablo Avenue, no sections of the corridor passed this performance measure, so it is unclear
6   how it would have been related to pedestrian safety. This is due in part to a posted speed limit of
7   30 mph throughout the corridor, which influenced the average speed (just over 34 mph), and the
8   85th percentile speed (average of 37.5 mph). While it may seem that a measure seeking speeds
9   around 25 mph does not fit a corridor with a 30 mph speed limit, it is precisely the danger to
10 pedestrians from the average and 85th percentile speeds that necessitates some kind of
11 acknowledgement of the risk inherent in the corridor's design speed.
12
13 *PM1.3d Conclusions*
14 Validity: This performance measure must be evaluated on a separate corridor before it can be
15 recommended.
16 Ease of Application: The data needed for this performance measure is available through routine
17 speed surveys along Caltrans corridors, thus enabling implementation of the measure.
18
19 **CGS Performance Measures 1.4a: Hotspots**
20 The final performance measure for pedestrian safety is guided by the objective:
21 **By 2012, annually reduce the number of pedestrian and bicycle hotspots (high collision**
22 **concentrations) on urban arterials.**
23 PM 1.4a gauges the *overall number of pedestrian collision hotspots on urban arterials* as
24 a way to ensure that high collision locations are specifically examined even when the location
25 may have a lower rate of pedestrian collisions due to exposure. This mirrors Caltrans' practice
26 with motorized vehicles. This measure was "tested" through evaluation of incidence rate versus
27 overall number of incidents, similar to PM 1.1a and 1.1b. In this dataset, for example, the
28 intersection with the 9th highest rate had the 3rd highest number of collisions. While the rate
29 suggests that it should be a lower priority, it still merits attention given the total number of
30 crashes.
31
32 *PM1.4a Conclusions*
33 Validity: The proposed performance measure evaluates the intended quantity and is the most
34 appropriate measure for the subject area.
35 Ease of Application: The data needed for this performance measure is the SWITRS crash data –
36 the same data needed for proposed performance measures 1.1a-b. The research team thus
37 concludes that the ease of application for this performance measure is reasonably high.
38
39 **LIMITATIONS OF THE RESEARCH**
40 As this research is still in progress, care should be used in extending the performance measures
41 evaluated and conclusions reached in this paper to other situations. In addition, it should be
42 noted that, although the test corridor has nearly 200 intersections and a variety of conditions, the
43 intersections cannot be assumed to be entirely independent due to being under the jurisdiction of
44 Caltrans and carrying the same traffic for at least parts of the corridor.
45
46

1 **CONCLUSIONS**
2 This article presented the initial findings of the field-tests for the pedestrian safety components of
3 the *Complete, Green Streets Performance Measures Framewo*rk being developed to provide
4 Caltrans with the measures needed to monitor pedestrian and bicyclist safety and the
5 environmental health of its urban arterials. The findings of the Phase III field tests suggest that
6 several of the performance measures developed after Phase I and II of the project adequately
7 measure pedestrian safety, and should be retained for future use. However, other measures
8 should be revised and tested further before being recommended for use by Caltrans. Table 4
9 summarizes the conclusions about the proposed performance measures.
10
11 **TABLE 4 Relative Validity and Ease of Application of the Performance Measures for**
12 **Pedestrian Safety Proposed in Phase II of the Project**

<table>
<tr><td rowspan="3">Relative Validity</td><td>High</td><td></td><td>• PM 1.1a-b: Rate of Pedestrian Injuries & Fatalities</td><td>• PM 1.4a: Pedestrian Hotspots</td></tr>
<tr><td>Low (Requires adjustment)</td><td>• PM 1.3a-b: Complete Streets (Intersection Design)</td><td></td><td></td></tr>
<tr><td>Unknown Based on Field Test</td><td></td><td></td><td>• PM 1.3d: Complete Streets (85th Percentile Speed)</td></tr>
<tr><td></td><td></td><td>**Low (Requires adjustment)**</td><td>**Medium (Potentially data intensive)**</td><td>**High**</td></tr>
<tr><td></td><td colspan="4">**Relative Ease of Application**</td></tr>
</table>

13
14   Only one of the proposed performance measures falls into the optimal 'High Validity' &
15 'High Ease of Application' category. While the designation of "low validity" is not a final
16 judgment, it does indicate that several of the measures require some form of adjustment before
17 they can be recommended for use by Caltrans. This finding speaks to the risk of developing
18 performance measures based solely on literature review, policy evaluation, and best practices,
19 particularly for areas with little institutional measurement history and practice, like pedestrian
20 and bicyclist safety. It also emphasizes the value of conducting even small-scale field-testing of
21 proposed performance measures, through providing the opportunity for critical feedback on the
22 validity and implementation potential of the measures.
23   In addition to needing to improve their validity, some of the performance measures
24 described in this paper may be modified to improve their ease of implementation. It should also
25 be noted that there are ways to ease the implementation of some of the proposed performance

1   measures as they currently exist. Caltrans can continue to fund research that develops tools to
2   facilitate data gathering for all types of analysis. This could include, for example, improved
3   pedestrian count models and databases of critical street design information (e.g., width of
4   sidewalks, presence of crosswalks, etc.). Such work could be carried out through existing
5   partnerships with University Transportation Centers. In addition, Caltrans can make use of
6   community volunteers and advocacy groups who may be willing to gather the information
7   needed to evaluate aspects of safety and mobility. For example, volunteers were used to gather
8   the data necessary to develop the pedestrian count model used in this paper *(21)*. While the
9   research team has an opinion about the "relative ease of application" of the proposed
10   performance measures, the final judgment belongs to the Caltrans employees who will be
11   performing the analysis in the future.
12   Field testing proposed performance measures has been a critical step in the development
13   of Caltrans' *Complete, Green Streets Performance Measures Framework for Urban Arterials.*
14   Field tests revealed that performance measures based on the latest research may be neither valid
15   nor easy to implement. While this is not a shocking finding, some organizations may wish to
16   develop performance measures without expending the time or costs associated with field tests. It
17   is possible, as was the case with this project, that their metrics will prove to be suboptimal.
18   While this may be discovered early, particularly with issues related to ease of implementation, it
19   may also be some time before issues are identified and performance measures are revised or
20   discarded. This project demonstrates that relatively small-scale field tests can contribute
21   significantly to the development of performance measures that are valid and easy to apply in
22   practice.
23
24   **NEXT STEPS**
25   The next steps for the project include continuing to hone the pedestrian crash model and revise
26   the proposed performance measures for pedestrian safety. In addition, the researchers will
27   analyze the effectiveness of the measures for bicyclist safety, and for pedestrian and bicyclist
28   mobility. These proposed performance measures include:
29   *PM 1.2: Percentage of Californians who feel safe using non-motorized modes on urban*
30   *arterials.*
31   *PM 1.3c: Percent of urban arterial intersections with one or more of the following improvements*
32   *geared toward bicyclists: bike box[*], painted bicycle lane through the intersection[*], bicycle*
33   *signal, bicycle detectors, bicycle left turn lane.*
34   *PM 1.4b: Overall number of bicycle collision hotspots on urban arterials.*
35   *PM 2.1a: On urban arterials, ratio of sidewalk mileage to centerline roadway mileage,*
36   *bidirectionally.*
37   *PM 2.1b: On urban arterials, ratio of Class II bicycle facility mileage to centerline roadway*
38   *mileage, bidirectionally.*
39   *PM 2.1c: On urban arterials, percentage of intersections that are ADA compliant.*
40   *PM 2.1d: Percentage of urban arterial projects designed as Complete Streets.*
41   *PM 2.1e: Number of pedestrian trips on urban arterials.*
42   *PM 2.1f: Number of bicycle trips on urban arterials.*
43
44   Key to understanding the relationship between mobility and the facility data is the
45   pedestrian and bicycle intercept survey that will be conducted in early fall 2010. As the

1 proposed performance measures are analyzed for applicability and effectiveness, they will be put
2 through the same field-testing process described in this paper. As was the case for the pedestrian
3 safety measures, issues will be identified and addressed before the performance measures are
4 recommended for use by Caltrans. In doing so, the researchers plan to deliver a valid and
5 relatively easy to implement set of measures for Caltrans' *Complete, Green Streets Performance*
6 *Measures Framework for Urban Arterials.* The research team aims to have the framework ready
7 for adoption by spring 2011. At that time, Caltrans can begin to set targets and gather the data
8 necessary to measure the performance of its network with regard to pedestrian and bicyclist
9 safety and mobility.
10   The result of implementing the proposed *Complete, Green Streets Performance Measures*
11 *Framework for Urban Arterials* should be a Caltrans roadway system that better accommodates
12 pedestrians and bicyclists and contributes to environmental sustainability and community vitality
13 through increased multimodal mobility, and ultimately, more holistic street design. While the
14 objectives will naturally take time to be reached, the adjustment toward such a system provides
15 taxpayers a way of holding the government accountable in their role as stewards of valued
16 community spaces, and allows Caltrans to demonstrate significant leadership regarding livability
17 within the transportation field.
18
19 **ACKNOWLEDGEMENTS**

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