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Pedestrian and Traffic Safety in Parking Lots at SNL/NM: Audit Background Report

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Abstract

This report supplements audit 2008-E-0009, conducted by the ES&H, Quality, Safeguards & Security Audits Department, 12870, during fall and winter of FY 2008. The study evaluates slips, trips and falls, the leading cause of reportable injuries at Sandia. In 2007, almost half of over 100 of such incidents occurred in parking lots. During the course of the audit, over 5000 observations were collected in 10 parking lots across SNL/NM. Based on benchmarks and trends of pedestrian behavior, the report proposes pedestrian-friendly features and attributes to improve pedestrian safety in parking lots. Less safe pedestrian behavior is associated with older parking lots lacking pedestrian-friendly features and attributes, like those for buildings 823, 887 and 811. Conversely, safer pedestrian behavior is associated with newer parking lots that have designated walkways, intra-lot walkways and sidewalks. Observations also revealed that motorists are in widespread noncompliance with parking lot speed limits and stop signs and markers.

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GLOSSARY OF TERMS

Attribute	behavior observed, or characteristic of a feature, such as the direction of a sidewalk or parking aisle
Behavior-Based Safety	discipline that uses behavioral data to change worker behavior to prevent occupational injuries and illnesses
Bias	tendency for observers to consciously or unconsciously affect data collection and study results
Close Call	incident in which minor or no personal injury was sustained but which could have easily escalated to recordable or serious injury
Compliance	being in accordance with established rules and requirements
Confidence Interval	confidence in measurements expressed as range based on population sampled
Controls	used in gathering scientific information to eliminate alternate explanations of experimental results by isolating variables and limiting bias
Crosswalk	lane marked for pedestrians to use when crossing a street
Designated Walkway	unmarked lane designated for pedestrian traffic and separated from motor vehicle lanes by space or barrier
Eyes on Path	attribute used in behavior-based safety as a measure of pedestrian attentiveness to surroundings.
Feature	a sidewalk or crosswalk, or other design aspect used to enhance pedestrian safety
Homogeneous	population of like elements
Intralot Sidewalks	sidewalks constructed inside parking lots
Pace	attribute used in behavior-based safety to measure how hurried a pedestrian appears
Pedestrian Right of Way	condition during which motorists must yield to pedestrians
Perceived Risk	subjective conscious or subconscious assessment of risk by an individual
Qualitative Observation	subjective observations, or those that cannot or were not be confirmed by measurement
Remediation	removing snow and ice or adding salt or sand to surfaces to render them safer for motorists and pedestrians
Statistical Methods	collection, organization, and interpretation of numerical data, especially the analysis of population characteristics by inference from sampling
Stop Marker	“STOP” painted on the surface of the road at the end of parking aisles
Uncertainty	estimated amount or percentage by which an observed or calculated value may differ from the true value
Unmarked Crosswalk	unmarked zone used by pedestrians to cross parking lot two-way traffic lanes at right angles
Vehicle Right of Way	condition designating which vehicle movement is undeterred and to which pedestrians and other motorists must yield
Yield	giving undeterred movement to motorist or pedestrian

1. INTRODUCTION

This report provides background information supporting audit 2008-E-0009, conducted by ES&H, Quality, Safeguards & Security Audits Department, 12870, during the fall and winter of FY 2008. Phil Newman, director, ES&H and Emergency Management Center, requested the audit to identify factors contributing to slips, trips and falls, the leading cause of reportable injuries at Sandia National Laboratories (SNL).

In 2007, SNL experienced over 100 cases of slips, trips and falls. Almost half of these cases described curb, parking lot, or parking bumper/barrier as the cause of the mishap. About 40% of the total cases included inclement weather, such as rain, ice or snow, as a contributing factor. Therefore, with the concurrence of Traffic Safety Committee members, the Division 10000 Behavior Based Safety group, and Department 12870, the audit focused on pedestrian and motorist safety behavior in parking lots. This report identifies trends and provides benchmarks for both pedestrian and motorist safety behavior, based on over 5000 observations made during the audit.

Auditors recorded observations of pedestrians and motorists walking and driving in 10 parking lots across SNL/NM.¹ Figure 1 graphs the overall results for the 16 pedestrian and motorist behaviors observed as part of the study. While the combined data identify overall trends, auditors noted that important differences among parking lots affected pedestrian and motorist behavior. These differences included parking lot design and size, pedestrian-friendly features, such as designated crosswalks and walkways, and traffic signs.

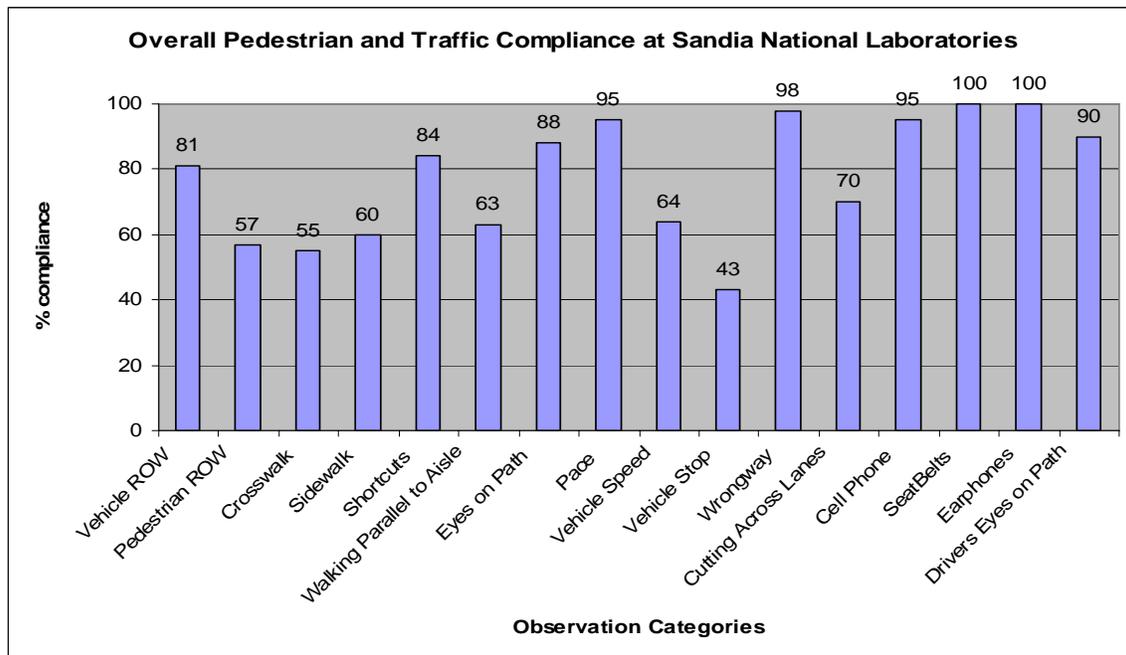


Figure 1: Cumulative percent compliance for pedestrian and motorist behaviors.

¹ Parking lots, identified by buildings nearest to them, include 823/825, 821/825, 887, 810, 811/802, 898, 897, 962 and 960 in Tech Area IV, and 6585 in Tech Area V.

1.1. Purpose

This purpose of this report is to more completely document the methodology and discussion of audit results presented in audit report 2008-E-0009. Appendix A presents parking lot diagrams for all 10 parking lots rather than the five selected examples presented in the audit report. Appendix B presents the informal procedure developed for the audit to collect the data. Appendix C presents graphical and tabular results for most behaviors to show differences between parking lots. Another purpose of this report is to establish a baseline against which results of similar, future studies may be assessed. The procedure is documented to ensure that such follow-up observations are collected in a comparable manner.

1.2 Methodology

Motor vehicle traffic and pedestrian behavior criteria are based on requirements in SNL's ES&H *Manual* (SNL, 2008) and *Quick Reference Traffic Guide* (SNL, 2003). These documents define site specific requirements such as the 10 mile per hour (mph) speed limit in parking lots and the required use of sidewalks by pedestrians. Other requirements are based on New Mexico Motor Vehicle Laws (2007). Examples of pedestrian compliance criteria included whether pedestrians looked before they crossed crosswalks, whether they used crosswalks and sidewalks, or took short cuts across landscaping. Behavior-based behavior criteria such as eyes on path and pace are based on training at SNL.

Over 5000 observations, collected in the 10 parking lots, are divided almost equally between pedestrian behaviors and motorist behaviors. These observations were recorded during late fall 2007, during peak activity, from 7:00 a.m. to 9:00a.m.; from 11:30 a.m. to 1:00 p.m.; and from 3:00 p.m. to 5:00 p.m. Weather conditions were mostly clear, cold, and windy, with only a fraction of the observations collected during slight drizzles. While the majority of the observations were recorded during good weather conditions, the study does include limited observations of changes in behavior due to a snow storm.

Appendix B contains the procedure used by the audit team to make observations. Based on the criteria defined for each of the 15 pedestrian and motorist behaviors, observations were recorded as either safety compliant or non-safety compliant. Some of behaviors were inherently subjective, such as looking before crossing a crosswalk. Videos of such behaviors were developed and reviewed prior to the data collection to minimize the effect of subjectivity between observers.²

Behaviors are expressed as percentages, such as the percentage of motorists that stop at stop signs versus those that do not. These percentages are presented in Appendix A with parking lot diagrams and may include additional site-specific information. Appendix C presents graphical and/or tabular results to show differences between parking lots. Appendix C, Tables C1 through

² This video and videos taken during the audit are located in an audit archival system, TeamMate, within the ES&H, Quality, Safeguards & Security Audits Department.

C11, have accompanying graphs because data in the tables varied significantly between parking lots. Because the data contained in Tables C-12 through C-15 in Appendix C are fairly uniform, graphs are not included.

Confidence intervals for percentage point estimates are reported for each parking lot (Appendix C). To quantify the subjectivity introduced by subjectivity of the observers, two independent observers made observations in the same parking lots during the same time periods (Appendix C, Table C16). Independent observations of five of six behaviors varied less than 6%. The behavior most subject to interpretation was eyes on path, where independent observer results varied by 14%. Consistent with behavior-based data analysis, point estimates in the tables are used to make coarse comparisons of results to draw conclusions.

2. RESULTS AND DISCUSSION

The overall results shown in Figure 1 are useful for indicating some trends and simple data analysis. However, important differences in some safety-compliant behaviors were observed between parking lots and are discussed in this section. Factors such as parking lot design and size, pedestrian-friendly features, and traffic signs differed among parking lots. Consequently, in these cases, lot-specific data must be analyzed individually. The general description for each parking lot is contained in Section 2.1; data for each observation category (Figure 1) are discussed in Sections 2.2.1 through 2.2.11.

2.1 Description of Parking Lots

The parking lots observed during this study are identified here by nearby building number(s). The lots vary in design, in engineering features, and traffic markings. Descriptions of the parking lots follow.

- 823/825. This large parking lot is located in front of building 823 and Gate 21. Features include unmarked crosswalks, pavement stop markers on parking aisle ends, and unposted, two-way access to Gate 21. There are no sidewalks or designated walkways. Parking aisles are oriented mostly perpendicular to or at an angle to pedestrian destinations, such as the building 823 entrance. N Street bisects the parking lot as a two-way traffic lane with posted 15 mph speed limit (Appendix A, Diagram A1).
- 821/825. This small parking lot is located in front of building 821 and Gate 10. Features include unmarked³ crosswalks, no pavement stop markers on parking aisle ends, and a relatively wide bumper spacing that pedestrians used as a walking path. There are no sidewalks or designated walkways. Parking aisles in the main lot are oriented parallel to

³ An unmarked crosswalk is a crosswalk that is not marked but requires that pedestrians use as a marked crosswalk, as in crossing perpendicular to the street being crossed.

pedestrian destinations. No parking bumpers are on the south side of building 825. N Street has a posted speed limit of 15 mph (Appendix A, Diagram A2).

- 887/885. This large parking lot is located in front of buildings 887 and 885. Features include unmarked crosswalks, pavement stop markers on parking aisle ends, and two-way access lanes off of G Avenue. There is no posted speed limit, and there are no sidewalks or designated walkways. Parking aisles are oriented perpendicular to or at angles to pedestrian destinations (Appendix A, Diagram A3).
- 810. This narrow parking lot is a Kirtland Air Force Base (KAFB) maintained lot used to access Sandia Tech Area I through Gate 17. Features include unmarked crosswalks, stop signs at parking aisle ends, landscape barriers, and no parking bumpers. The 7th Street speed limit is posted at 15 mph. There are sidewalks adjacent to 7th Street, and aisles are parallel with pedestrian destinations (Appendix A, Diagram A4).
- 802/811. This parking lot is south of Hardin Field and is used to access Gate 4 and Buildings 802 and 811. Features include unmarked crosswalks, stop markers at the ends of parking aisles, and two-way access off F Street. There are no posted speed limits, sidewalks, or designated walkways. Parking aisles are oriented perpendicular to or at angles to pedestrian destinations (Appendix A, Diagram A5).
- 897/858. The parking lot is located in front of Building 897, used by personnel to access the building 858 complex. Pedestrian-friendly features include marked, designated walkways that lead to crosswalks and intralot sidewalks. There are also unmarked crosswalks. Half the parking lot has parking aisle stops, and the other half has no markers (yield only). N Street bisects the parking lot as a two-way traffic lane and a speed limit of 15 mph posted. The two-way traffic lane accesses S Street at a stop light. Parking aisles and pedestrian walkways are oriented parallel to most pedestrian directions (Appendix A, Diagram A6).
- 898. The parking lot is located in front of building 898 with no posted speed limit on the two-way traffic access lane off of Hardin Blvd. Pedestrian-friendly features include sidewalks leading to marked crosswalks at an intersection with stop signs, unmarked crosswalks occur at the ends of parking aisles, and stop markers at the end of the aisles. The lot is landscaped. Parking aisles are oriented parallel to pedestrian destinations in half of the parking lot and at angles elsewhere. N Street bisects the parking lot (Appendix A, Diagram A6).
- Tech Area IV, 962. The parking lot is located in front of building 962 and is bordered by three two-way access lanes with no posted speed limits. Features include unmarked crosswalks, no parking aisle stops, parking lot landscaping, a mid-lot walking path, and stop signs on two-way lanes surrounding the parking lot. Parking aisles are oriented parallel to pedestrian destinations in half of the parking lot and at an angle in the far north area of the parking lot (Appendix A, Diagram A7)
- Tech Area IV, 960. The parking lot is located in front of building 960, bordered on the east by the Z-machine facility. Half of the parking aisles have stop markers at the ends of the aisles, and the other half are not marked; vehicles do not have to stop, only yield to pedestrians or other vehicles. Other features include marked and unmarked crosswalks, mid-lot sidewalks and three two-way lanes, no speed limit posted, and stop signs, two of

which were missing at the time the observations there were made. Parking aisles are oriented parallel to observed pedestrian destinations (Appendix A, Diagram A7).

- Tech Area V, 6585. This is the parking lot in front of building 6585. Features include unmarked crosswalks, stop markers on parking aisle ends, mid-lot sidewalks, landscaping, two-way lanes with stop signs and no posted speed limit, and no parking bumpers. The sidewalks lead to the entrance of building 6585 (Appendix A, Diagram A8).

2.2 Baseline Observations

2.2.1. *Vehicle Right of Way*

Sandia motorists are required to yield the right of way to pedestrians. In general, motorists observed yielded by slowing and/or braking for pedestrians in their path (81%). Compliance ranged from 67% to 100%, suggesting that the population of parking lots is not homogeneous (see Appendix C, Table C1). For example, parking lot design, length of parking aisles or signage may differ between parking lots. Non-safety compliant behavior included vehicles not slowing when passing pedestrians in parking aisles or not slowing for pedestrians within unmarked or marked crosswalks. Section 2.2.3 notes that pedestrians often do not take the shortest path across two-way streets where there are no marked crosswalks. Instead of crossing at right angles from a parking aisle to a sidewalk, pedestrians tended to walk diagonally across two-way streets, providing more opportunities for motorists to interact with pedestrians. Motorist behavior varied with parking lot design and size, traffic speed, and traffic density. Traffic density increased, particularly during the early morning arrival time.

A high rate of compliance in the building 898 parking lot (94%) is biased because the majority of observations occurred at a four-way stop with marked crosswalks (Appendix A, Diagram A6). At parking lot 897, compliant behavior was 76% where observations occurred at a four-way stop with crosswalks. This compares to unmarked crosswalks alone (67%). In Tech Area V, a 100% compliant rate is based on limited data due to fewer motorist and pedestrian interactions.

Three close calls were observed when motorists used rolling stops or otherwise failed to yield to other motorists. One close call occurred at the west end of the building 825 parking lot, at a stop marker on the end of a parking aisle that accesses N Avenue. A motorist rolling past that stop caused a west-bound motorist on N Avenue to break suddenly. The second close call involved a motorist exiting the east end of a parking lot 897 aisle (no stop marked on end). This motorist did not yield to another motorist entering the parking lot off 20th Street, and the action resulted in sudden braking. A third close call involved a motorist making a rolling stop at the exit of the 810 parking lot onto 7 Street. The locations of these close calls are marked (Appendix A, Diagrams A1, A4, and A6).

Section 2.2.3 will discuss a natural diagonal unmarked crosswalk at Gate 17 in parking lot 810. Traffic coming traveling south to north on 7th street reduce their speed and stop because of the presence of a stop sign. However, there is no stop sign for traffic travelling in the other direction where K Avenue makes a ninety degree turn at across this unmarked crossing ((Appendix A, Diagram A4). While no motorists were observed not yielding the right-of-way, drivers traveling

east on K Avenue do not have a clear line of sight of Gate 17 pedestrians until very close to the crossing.

2.2.2. Pedestrian Right of Way

Pedestrians are required to exercise caution when entering a crosswalk, make eye contact with drivers when crossing streets or crosswalks, and avoid blindly stepping off curbs into traffic.

Approximately 60% of the pedestrians observed appeared to look before crossing streets surrounding parking lots (Figure 1; Pedestrian ROW). The majority of noncompliances occurred at unmarked crosswalks crossing two-way traffic lanes within or on the perimeter of parking lots. Marked crosswalks are rare at Sandia, so their influence on pedestrian and motorist behavior was tested where possible (Appendix C, Table C2).

Higher safety compliances were observed when one or more safety parking lot features were present:

- Observation of 78% safety-compliant behavior at parking lot 810 (overall 63%) occurred at a diagonal unmarked crossing at Gate 17. Although unmarked, the presence of a stop sign seemed to account for increased pedestrian awareness (Appendix A, Diagram A4).
- Observation of 68% safety-compliant behavior at parking lot 897 was associated with an intralot sidewalk that funneled pedestrians to a marked crosswalk across N Avenue (Appendix A, Diagram A6). The parking layout at building 897 is also associated with other positive behaviors, discussed in other sections.
- Observation of 66% safety-compliant behavior at parking lot 898 was influenced by many observations at a four-way stop that included a marked crosswalk (Appendix A, Diagram A6).

In general, the least safety-compliant behaviors occurred in parking lots with unmarked crosswalks, such as parking lots 823/825 and 887. (See Appendix A, Diagrams A1 and A3.) However, data suggest unmarked crosswalks alone do not influence noncompliant behavior. Perceived risk appears also to be a factor. For example, pedestrians crossing N Avenue, across from the parking lot 821/825, appeared to be influenced by a relative increase in traffic and faster vehicle speed (Appendix A, Diagram A2). That is, these pedestrians seemed more aware with a heavier volume of traffic. Pedestrians also appeared to be more safety compliant on 7th Street, at parking lot 810, due to higher traffic speeds (Appendix A, Diagram A4). Low compliance in Tech Area V may also be explained by a perception of less risk, as traffic density and speed are lower.

Despite the presence of marked crosswalks, the overall low safety compliance at parking lot 960 (58%) was not that much higher than the unmarked parking lot 962 (49%). However, the presence of marked crosswalks did influence safety-compliant perpendicular crossing behavior (see Section 2.2.3). Overall, pedestrian right-of-way compliance appeared better at crosswalks with stops signs.

2.2.3. Crosswalk

Overall, only about 55% of observed pedestrians used crosswalks deliberately, to cross a street safely (Figure 1). In general, pedestrians crossing unmarked crosswalks showed the lowest compliance. At unmarked crosswalks, crosswalk behavior was considered safety compliant if pedestrians crossed the street along a path perpendicular to semi-perpendicular to the other side (Appendix A, Diagrams A1, A3 and A5). In general, pedestrians observed appeared unaware of the presence of unmarked crosswalks. The tendency was to take diagonal approaches across two-way traffic lanes. (See Appendix A, Diagrams A1 through A8.)

The relatively low percentage of safety-compliant behavior is hard to generalize; behaviors observed varied between 30 % to over 90 % (Appendix C, Table C3). In general, pedestrians crossing unmarked crosswalks showed the lowest compliance, ranging from 30% to 47%. Lower compliance percentages are associated with parking lots with only unmarked crosswalks, such as parking lots 887 (Appendix A, Diagram A3), 802/811 (Appendix A, Diagram A5), and 962 (Appendix A, Diagram A7).

Some crosswalk data in Appendix C, Table C3, combine both marked and unmarked observations and are biased by higher compliance rates at marked crossings. Some of these marked crosswalks had additional features and attributes that appeared to encourage compliance. Observations indicate the use of unmarked or marked crosswalks (and sidewalks) appeared to be heavily influenced by the pedestrian's destination and parking lot design. If aligned with the pedestrian's destination, intra-lot walking paths or sidewalks aimed at crosswalks seemed to influence better pedestrian safety-compliant behavior. In Tech Area V (Appendix A, Diagram A8), sidewalks are aligned with unmarked crosswalks, and pedestrians exhibited a higher compliance rate (74%) there. At Building 898 (Appendix A, Diagram A6), the sidewalk leading from the parking lot to the building funnels pedestrians to the marked crosswalk at the four-way stop (68%). Compliance was much lower at unmarked crossings in the building 898 parking lot.

Counting the marked crossings only at building 897, the compliance rate for safe behavior by pedestrians was 90% (Appendix C, Table C3). Crosswalk usage is noticeably greater in parking lot 897 where an intralot walkway and lot layout naturally funnels pedestrians directly to a crosswalk and toward the pedestrian's destination (Figure 2). Compliance was 54% at unmarked crossings in the building 897 parking lot (Appendix A, Diagram A6).

Another aligned unmarked crosswalk is a diagonal crossing point from the building 810 parking lot to Gate 17 (Appendix A, Diagram A4). Half the pedestrians observed took a shortcut across 7th Street to the sidewalk and didn't use the diagonal crossing. The other half of the pedestrians walked north along the north-south oriented parking aisles to the Gate 17 unmarked crossing. Pedestrian compliance measured 69% at this unmarked crossing, compared with 44 % crossing unmarked crossings across 7th Street (Appendix C, Table C3).

The marked crosswalks at T-City showed a high usage and therefore safety-compliant behavior (85%) (Appendix A, Diagram A1; Appendix C, Table C3). This higher rate influenced the overall rate of 59% for the 823/825 parking lot, where pedestrians crossed unmarked crosswalks correctly well below 50%.

The presence of a marked crosswalk does not guarantee its use. Many pedestrians were observed walking diagonally, across the street, toward marked crosswalks. Pedestrians using the building 960 parking lot (Tech Area IV) did not use several aligned marked crosswalks, shown in parking lot diagram A7, Appendix A (46%). However, because of the alignment, over 70% of the pedestrians crossed adjacent unmarked crosswalks correctly. This is high compared to 47% in the unmarked crosswalk in the parking lot at building 962 (Appendix A, Diagram A7).

2.2.4. Sidewalk

Overall, 68% of pedestrians observed used sidewalks. Ranging from 50% to 81%, the observations combine different populations (Appendix C, Table C4). Some parking lots have no sidewalks or designated walking paths. In larger parking lots, the nonuse of sidewalks is influenced by the tendency for pedestrians, parking farther away from their destination, to take a semi-diagonal path to diagonal path across the parking lot toward their destination (see Section 2.2.5). Pedestrians tend to take a diagonal path across traffic lanes (see Section 2.2.3). In such cases, the pedestrian is not using the sidewalk and might even be considered to be walking in the street. Parking lots such as the building 823/825 and the far north 962 parking lots of Tech Area IV are examples where sidewalks are not conveniently located for many pedestrians who have parked their cars far away from their destination (Appendix A, Diagrams A1 and A7). These parking lots also have the lowest usage rates, 55% and 50%, respectively.



Figure 2: Example of marked crosswalk and intralot walkway, features associated with highly safety-compliant behavior in the building 897 parking lot.

In smaller parking lots, the orientation of parking aisles and the presence of intralot sidewalks or walking paths seem to influence the use of sidewalks or designated walk paths. At the building 897 and 898 parking lots, intralot sidewalks are close for many parking motorists (Appendix A, Diagram A6). Pedestrians observed were more likely to use the sidewalk. However, as the

parking lots filled, observed pedestrians began to take shortcuts across the parking lot, sometimes diagonal to the parking aisles (see Section 2.2.5). In the building 810 parking lot, half the pedestrians observed crossed 7th Street to the sidewalk. (Note: In many cases, non-safety compliant behavior was observed See Section 2.2.3.). In the building 821/825 parking lot, pedestrians tended to use a sidewalk adjacent to building 825 (65%) and a natural walking path between parking bumpers (Appendix A, Diagram A2). This sidewalk and walking path naturally lead to their destinations at Gate 10 and Building 823 (Figure 3). In Tech Area V, the lot is small, and most motorists park near intra-lot sidewalks leading directly to the entrance of building 6585 (81%). The building 960 parking lot (Tech Area IV) is also smaller and has several intralot sidewalks leading to greater sidewalk compliance (78%).



Figure 3: Example of pedestrians using natural spacing between bumpers as walkways, when the walkways are oriented in the direction of the pedestrian's shortest route to their destination.

2.2.5 Shortcuts Through Landscaping and Parking Aisles

Landscaping. Overall, the pedestrians observed avoided shortcuts through landscaping (84%). Parking lot plots show where shortcuts across landscaping were observed. The parking lot showing the least compliance (50%) was the building 810 parking lot (Appendix C, Table C5). Parking lot landscaping included concrete aisle dividers filled with gravel instead of parking bumpers. About half the pedestrians observed took shortcuts across this landscaping feature. The other half walked parallel to the north-south aisle towards Gate 17 and avoided this landscape feature. The parking lot also had concrete islands filled with gravel at the ends of the parking aisles. Pedestrians observed frequently walked across these landscape features (Appendix A,

Diagram A4). The parking lot with highest compliance rate was Tech Area V, where shrubbery is thick and high and acts as a barrier to pedestrians (Appendix A, Diagram A8).

Walking Parallel or Diagonal to Parking Aisles. While some parking lot layouts encourage walking parallel to aisles and avoiding parking bumpers, other designs encourage pedestrians to take diagonal, subangular or perpendicular paths to their destination. In parking lots without designated walkways, pedestrians taking a path across parking bumpers increase their exposure to slips, trips and falls. Currently, specific locations of slips, trips and falls necessary to prove a correlation does not exist in SNL's injury and illnesses or incident database. Location trends should theoretically show an increased incidence in certain parking lots or specific locations in parking lots.

Parking lot diagrams in Appendix A show observed tendencies for pedestrians to take specific paths within specific parking lots. The graph associated with Appendix C, Table C5, shows a measure of the tendency for pedestrians to walk parallel or diagonal to aisles. Parking lots with lower percentages mean more pedestrians are negotiating parking bumpers, often associated with descriptions of slips, trips and falls in parking lots.

Parking lots in which pedestrians observed took fewer shortcuts across parking bumpers include the following the features:

- Parking aisles are oriented parallel to the main destination.
- Parking lots are smaller and compartmentalized with intralot sidewalks or walking paths.

Parking lots in which pedestrians observed took more shortcuts across parking bumpers include the following the features:

- Parking aisles are oriented perpendicular to the main destination.
- Parking lots are large with no intralot features to encourage using sidewalks or pathways that avoid parking bumpers.
- Large parking lots where walking to a sidewalk significantly lengthens the route to a pedestrian's destination.

Even in parking lots that have pedestrian-friendly features and encourage pedestrians to walk parallel to aisles, pedestrians observed still tended to take the shortest distance to their destination. Consequently, as parking lots fill, and pedestrians have farther to walk, shortcutting across parking bumpers increases. In the building 823/825 parking lot, 80% of pedestrians observed took a more diagonal path towards their destination. In the building 898 parking lot, which is smaller and has a sidewalk, 50% of the pedestrians observed took a more diagonal path also, as their distance to the sidewalk increased as the parking lot filled. The same behavior was observed in the far north half of the Tech Area IV parking lot near building 962. Parking lots 887 and 802/811 are larger parking lots, and 56% and 38% of pedestrians observed walked diagonally toward their destinations (Appendix A, Diagrams A3 and A5). The lower percentages of safety-compliant behavior in these lots may be attributed to the orientation of the lot to the general destination of the pedestrians observed. Parking lot diagrams for parking lots 821/825, 897, 960 and Tech Area V show that parking aisles are aligned parallel with the majority of the pedestrian's destinations and show better compliance. Parking lot 810 is also oriented parallel to

the pedestrians destination toward Gate 17. However, because of the proximity of the sidewalk on 7th Street, half the pedestrians walk diagonally toward the sidewalk across a landscaped barrier.

See Section 2.3 for a description of how this behavior changed during and after a snowstorm.

2.2.6 Eyes on Path and Pace

Eyes on path and pace are terms used by the Behavior-Based Safety initiative; Figure 1 shows a high rate of safety-compliant behavior for pedestrians observed. Data across all parking lots included in this study are fairly consistent. Of pedestrians observed, 88% kept eyes on path in area observed, and 95% of those pedestrians kept a pace that was safety compliant. Results specific to individual parking lots observed are shown in Appendix C, Tables C6 and C7. One observation worth conveying is that a number of pedestrians do walk with their head down, but this study revealed that, unless completely distracted, these pedestrians had their eyes on path (crosswalks excluded). Examples of distractions included reading, organizing papers or purses, and using cell phones.

See Section 2.3 for a description of how this behavior changed during and after a snowstorm.

2.2.7 Speeding

Unless otherwise posted, the speed limit in parking lots is 10 miles per hour. Figure 1 shows widespread lack of motorist regard for the parking lot speed limit, with 64% of motorists observed exceeding the speed limit. Qualitative⁴ observations of vehicle speed included parking aisles and two-way traffic lanes within parking lots. Overall, this result may not be representative of all Sandia parking lots because motorists displayed different driving behaviors in different parking lots (Appendix C, Table C8) and because subpopulations existed within the parking lots. A speed gun was not available to corroborate observations, only very noticeable speeding in two-way traffic lanes within parking lots could be confidently noted. In general, speeds appeared safe within parking aisles, so noncompliant percentages are biased by observations on two-way traffic lanes.

Appendix A, diagrams A1 through A8 indicate where speeding appeared prevalent. The following are general observations:

- 823/825 and 821/825 parking lots. The majority of obvious speeding occurred on N Avenue (posted 15 mph speed limit). Other speeding also occurred in the traffic lanes in front of building 823 and the east side of building 825 (10 mph).
- 887 parking lot. Separate rates were determined for parking aisles (70% compliant) and the two-way entrance off of G Avenue (39% compliance). Speeds entering G Avenue, which has no speed limit posted, appeared higher than 15 mph.

⁴ Qualitative observation used here means observations of motor vehicle speed unconfirmed by a measurement.

- 810 parking lot. The study estimated that two of every three cars observed appeared to be speeding on 7th Street, which has a posted 15 mph speed limit.
- 802/811 parking lot. This parking lot showed a very high compliance rate (82%); a majority of observations occurred within parking aisles. Limited data suggest 43% of the vehicles entering off of F Avenue, where no speed limit is posted, are exceeding the speed limit.
- 897 parking lot. The majority of speeding observed in this lot occurred on N Avenue, where drivers sped to attain a green light at the traffic signal at 20th Street. The posted speed limit is 15 mph.
- 898 parking lot. Speeding occurs on the two-way access road entering the parking lot from Hardin Blvd. The speed limit is not posted.
- Tech Area IV. The majority of observations were made of two-way traffic lanes on the perimeter of the building 962 parking lot. This included S Avenue and another two-way traffic lane on the west of the 962 parking lot. Speed limits are not posted.
- Tech Area V. Speeding occurs predominately on the unposted, two-way entrances off Pennsylvania Ave.

Section 2.2.2 indicates that many pedestrians do not look before crossing two-way traffic lanes, and many do not cross directly. Motorists speeding at peak traffic times arguably present an increased risk to these pedestrians.

2.2.8 Stopping

Overall, observed motorists showed poor compliance with stop signs or stop markers at the ends of aisles (43%) (Figure 1). However, the range of stopping behavior varies extremely from parking lot to parking lot (23% to 70%). Parking lot-specific results are reported in Appendix C, Table C9. The study suggests parking lot-specific markings and design differentiate parking lots into different populations. Parking lots vary in stop markings and stop signs, traffic rate and overall design as follows (Appendix A, Diagrams A1 through A8):

- The building 823/825 parking lot has stop markers at the ends of all aisles (41%). Observations also included stop signs. The adjacent building 821/825 parking lot has no stop markers (intended yield only). Observations at building 821/825 were only at stop signs (50% compliance).
- The building 898 parking lot has a four-way stop with marked crosswalks and stop markers at the ends of aisles. The majority of observations occurred at the four-way intersection (70% compliance). The adjacent building 897 parking lot has half of its aisles marked with stops (at one end only), and half do not have stop markers (intended yield only). All observations were taken on the side with stop markers, where the aisles intersect N Avenue (57% compliance).
- Building 802/811 and 887 parking lots have stop markers. The compliance rates were 23% and 43 %, respectively, with motorists observed slowing more predictably at pavement stop markers.

- The building 810 parking lot, which is a KAFB-maintained parking lot, has stop signs located at the ends of parking aisles. Like the other parking lots with longer aisle lengths, motorists routinely failed to stop at these stop signs. Combined with observations at the stop sign on 7th Street at Gate 17, the compliance rate was low (32% compliance).
- Tech Area IV. There no stop markers on the building 962 side (intended yield only). On the building 960 side, there are no stop markers in the front parking lot (intended yield only), while the back parking lot had stop markers on one end of the aisles. This parking lot also has several two-way traffic lanes with stop signs (note: two are missing) and no posted speed limit. The majority of observations were at building 962 stop signs (44 % compliance). Yielding at unmarked aisle ends was measured in the 962 parking lot (73% compliance), but the speed around turns without stop markers appeared faster than speeds around turns where stops were marked.
- In Tech Area V, there are stop markers at the ends of the aisles. Possibly because of the low rate of traffic activity, motorists had a relatively low rate of compliance (26%).

The compliance rate for a complete stop still is low. In general, the study suggests the safest yields occur more frequently at stops signs. The study suggests the next safest yields occur at marked parking aisle stops. The most unsafe yields occur on the ends of parking aisles that are unmarked. The most compliant stopping behavior occurs at stop signs with crosswalks.

Failure to fully stop or yield vehicle right of way to other motorists resulted in three close calls involving other motor vehicles. See Appendix A, Diagrams A1 (823/825), A4 (810), and A6 (897) for these locations and the discussion under vehicle-right-of-way section.

2.2.9 Driving the Wrong Way

Overall, observed motorists drive in the correct direction within parking lots. The compliance measure in Figure 1 is considered representative of a single population of drivers observed (98%). Parking lot-specific results are reported in Appendix C, Table C10. Note that in Tech Area V (96% compliant), six out of 56 drivers were able to drive the wrong way because the lot has no parking bumpers that act as barriers.

Tech Area V has an additional wrong way driving behavior. At the request of the building manager for building 6585, the study looked at wrong-way driving in the main road accessing Tech Area V. To avoid speed humps in the road, 16 out of 48 drivers were observed driving in the opposite lane to go around humps (67% safety compliance). Appendix A, Diagram A8 shows the location of two cars driving toward each other momentarily in the same lane, resulting in a close call. The behavior is deliberate and often involved a line of cars following a leader around the humps.

2.2.10 Crossing Parking Aisles

Crossing parking aisles is not an issue in parking lots with concrete bumpers. However, two parking lots in this study do not have parking bumpers: building 821/825 and Tech Area V (Appendix A, Diagrams A2 and A8). This study showed that parking lots without parking

bumpers enable other noncompliant behaviors, such as crossing parking aisle lanes (70%) and driving the wrong way (Appendix C, Table C11).

2.2.11 Cell Phones, Seat belts, Ear Phones and Eyes on Path

The study showed motorists' high compliance with use of cell phones, seat belts, and ear phones while driving. Drivers also appear attentive. The overall compliance rates in Figure 1 can be considered a representative baseline as there is very little variation among parking lots. Parking lot specific data are presented in Appendix C, Tables C12 through C15.

2.3 Observations After Winter Snowstorm

Observations after a snowstorm were made in 823/825 parking lot when it was covered in ice and snow as morning traffic arrived. Pedestrians responded to the icy conditions with safety-compliant behaviors.⁵ The pedestrian tendency to walk across parking bumpers noticeably reversed. During ice and snow conditions, about 80% of the pedestrians walked parallel to the aisles to the nearest safe sidewalk. This included walking between parking bumpers, where snow was fresh and not slippery. Only the area in front of the building 823 entrance appeared treated by sand. The remaining parking aisles were extremely hazardous, as were some sidewalks.

In the building 823/825 parking lot the following day, pedestrians again began to take diagonal paths across parking bumpers. Figure 4 shows how icy conditions persisted between the parking



Figure 4: Remaining snow and ice between parking bumpers following the snowstorm.

⁵ Pedestrians took shorter steps and other actions consistent with guidance about walking on ice. The guidance appeared in the Porcelain Press and other ES&H messages to employees.

bumpers, probably a result of pedestrians walking between the parking bumpers on the previous day. Presumably, the probability for slipping would increase as pedestrians walked across the parking bumpers. Notably, there were no ice-related slips reported either day.

Figures 4 and show a common observation in the building 823, 898, 887 and 802/811 parking lots: ice not only remained between parking bumpers, but also where pedestrians exit their vehicles. We observed no evidence of sand or salt remediation for these areas. Arguably, applying salt may not be effective if the ice melts, since the water may not evaporate and refreezes over night, especially in an uneven parking lot that has no internal drainage features.



Figure 5: Remaining snow and ice on parking spaces one day following the weather event.

One week after the storm, two incidents occurred. One involved a worker stepping off the sidewalk onto the parking lot asphalt and slipping on a patch of ice. The other involved a contractor walking around the back of the truck and slipping on ice. The exact locations of the incidents are not required for trending, so no correlations with parking lot design or within the context of specific features are available for discussion.

3. CONCLUSIONS

The following are general conclusions and recommendations, some of which may be similar to issues and comments in the ES&H/S&S/QA audit report, 2008-E-0009. The conclusions and recommendations in this audit report are those of the author of this study and are not official results of the audit.

3.1 Variability in Parking Lot Design

Variability in parking lot design, layout, and size appears to influence observed pedestrian walking paths and pedestrian behavior, some of which may be important to the occurrence of slips, trips and falls. Sandia could make a policy to redesign or improve the older and larger parking lots, those with larger percentages of non-safety compliant behaviors. The policy could direct design to incorporate pedestrian-friendly features, recognizing pedestrian behaviors.

Pedestrian-features recommended as a result of this study include intra-lot sidewalks and pathways, redesign of parking bumper spacing to allow room for designated walkways, encourage their use, and facilitating snow removal and ice remediation. Consideration should include alignment of parking aisles and crosswalks with the pedestrian's natural walking paths and destinations to encourage safety.

3.2 Pedestrian Behavior: Baseline and After Snowstorm

Although the newer, smaller, compartmentalized parking lots with pedestrian-friendly features generally result in more safety-compliant pedestrian behavior, use of designated walkways and promotion of compliant behavior must be reinforced. The tendency remains for pedestrians to take the shortest path to their destinations, across parking bumpers, landscaping, ice, and snow.

During the snowstorm, pedestrians observed were vigilant and took the safest paths available to the nearest sidewalk. However, observed pedestrians exhibited more complacent behaviors during the days following the snow. That patches of ice may actually increase in size due to melting and refreezing and remain a hazard for a long period of time needs to be communicated so that pedestrians remain vigilant.

3.3 Speeding Motorists and Crossing Unmarked Crosswalks

Requirements for unmarked crosswalks do not appear to be well known among Sandians and are not defined in the *ES&H Manual*, Section 4K, and the associated traffic guide. In unmarked crosswalks, pedestrians should cross streets at right angles and minimize their time in the roadway. Observations show that pedestrians tend to cross two-way traffic lanes diagonally, in some cases resulting in pedestrians sharing the lane with flowing traffic. Because motorists were frequently observed exceeding the speed limit in parking lots, non-safety-compliant behavior places pedestrians more at risk.

3.4 Moving Violations

Observed motorists routinely exceeded parking lot speed limits, particularly within the two-way traffic lanes that access or bisect the parking lot. Sandia has no traffic enforcement, so the parking lots should have the 10 mile-per-hour speed limit posted; reminders through other media have been less than effective.

In addition, observed motorists also routinely exhibit non-safety-compliant behavior by failing to observe stop signs and aisle markers. The close calls observed during the fieldwork for this report were a result of rolling stops or failure to yield. Stop markers at the ends of parking lot aisles need to be consistently posted since Sandia has no traffic enforcement.

3.5 Locations of Slips, Trips and Falls

The incident tracking system used to track slips, trips and falls may record general location information when a slip, trip or fall incident occurs. However, specific locations are not available for trend analysis relevant to parking lot locations or specific parking lot features. This study suggests that pedestrian behaviors in certain parking lots and parking lot locations may be related to slips, trips and falls. Recording specific locations of slip, trip or fall incidents could result in several benefits besides validating hypotheses proposed in this study. Recording and sharing specific locations with other groups, such as facilities and the general work force, could lead to better awareness and parking lot-specific improvements.

3.6 Snowstorm and Snow/Ice Remediation

Guidance directing pedestrians to use designated walkways is useful. However, parking lots should also have pedestrian-safe features. Designated walkways are particularly desirable during inclement conditions. In addition, when parking lots are only sparsely sanded, this study concluded that conditions in the larger parking lots were dangerous for pedestrians.⁶

More effective use of sand to provide safe walking paths is a minimum proposed solution. Improvements for walkways include

- an above-grade pathway wide enough for application of sand or salt by motorized equipment, and
- a walkway slightly sloped to allow for drainage into drains. Currently, ice tends to melt, migrate and refreeze, and icy locations can exist for weeks following the event.

The older and larger parking lots also appear to have other drainage issues. Some areas drain better than others, but are no drains in the parking lots. This observation is specific to parking lots such as 823/825, 887, and 802, but could be present in other older parking lots, regardless of size.

⁶ The same conditions also occur in older, smaller parking lots that were not part of the study. The emphasis here is on larger parking lots because of the larger populations of pedestrians and longer paths. Nevertheless, older, smaller parking lots also present a risk.

4. REFERENCES

SNL (2008), ES&H Manual Section 4K, Traffic Safety, MN471001, Issue K, January 21, 2008, Willie Johns, ES&H Manual, Sandia National Laboratories, Albuquerque, NM.

SNL (2003), Quick Reference Traffic Guide for Sandia National Laboratories, New Mexico, issued by Sandia National Laboratories, Albuquerque, NM

New Mexico Motor Vehicle Laws (2007), Institute of Public Law University of New Mexico School of Law, Albuquerque, NM and New Mexico Department of Transportation Traffic Safety Bureau, Santa Fe, NM.

APPENDIX A: PARKING LOT DIAGRAMS

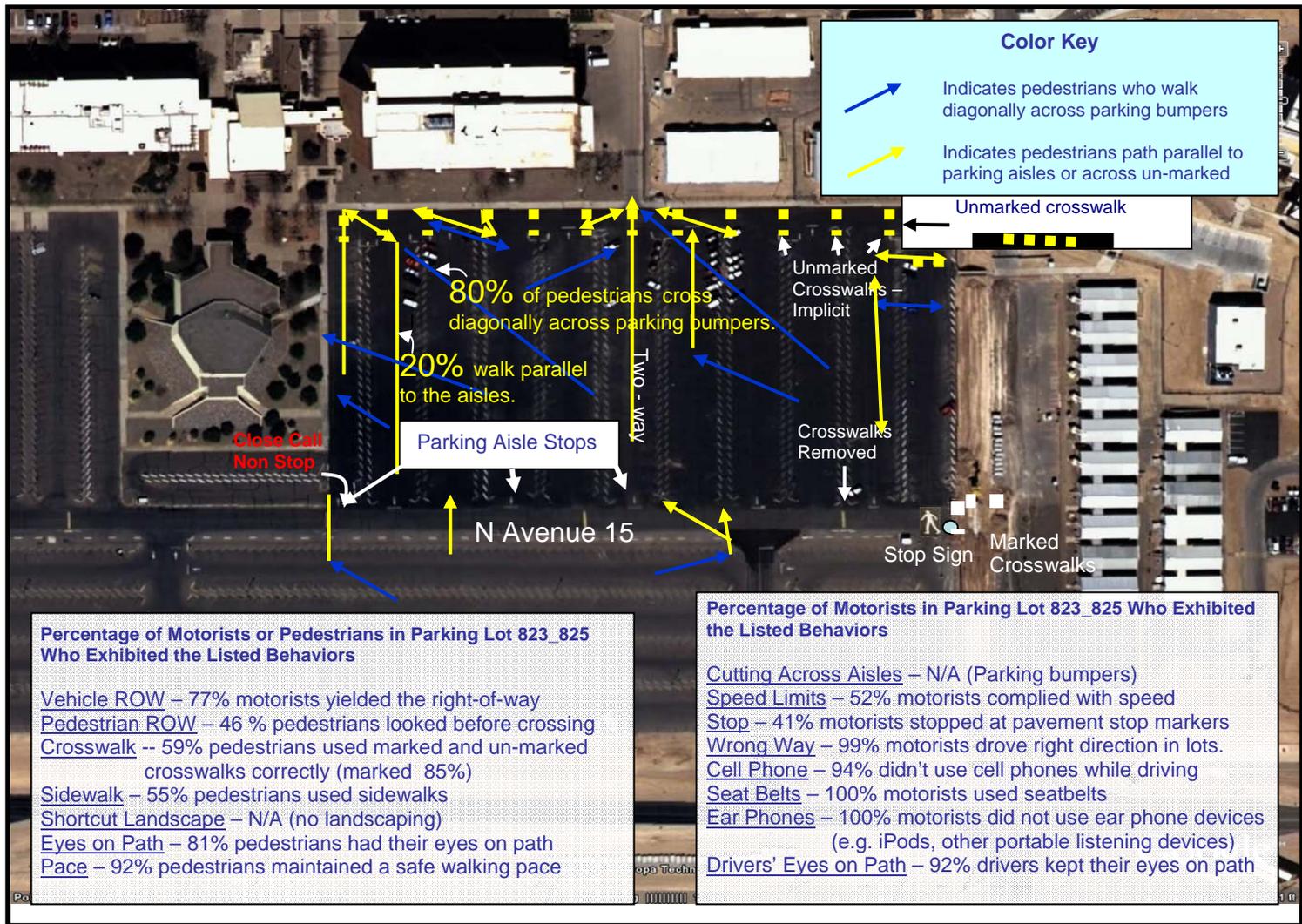


Diagram A1: The Building 823/825 parking lot layout includes no designated pedestrian walkways within the parking lot, no marked crosswalks, and parking aisles oriented so that 80% of pedestrians walk across parking bumpers.

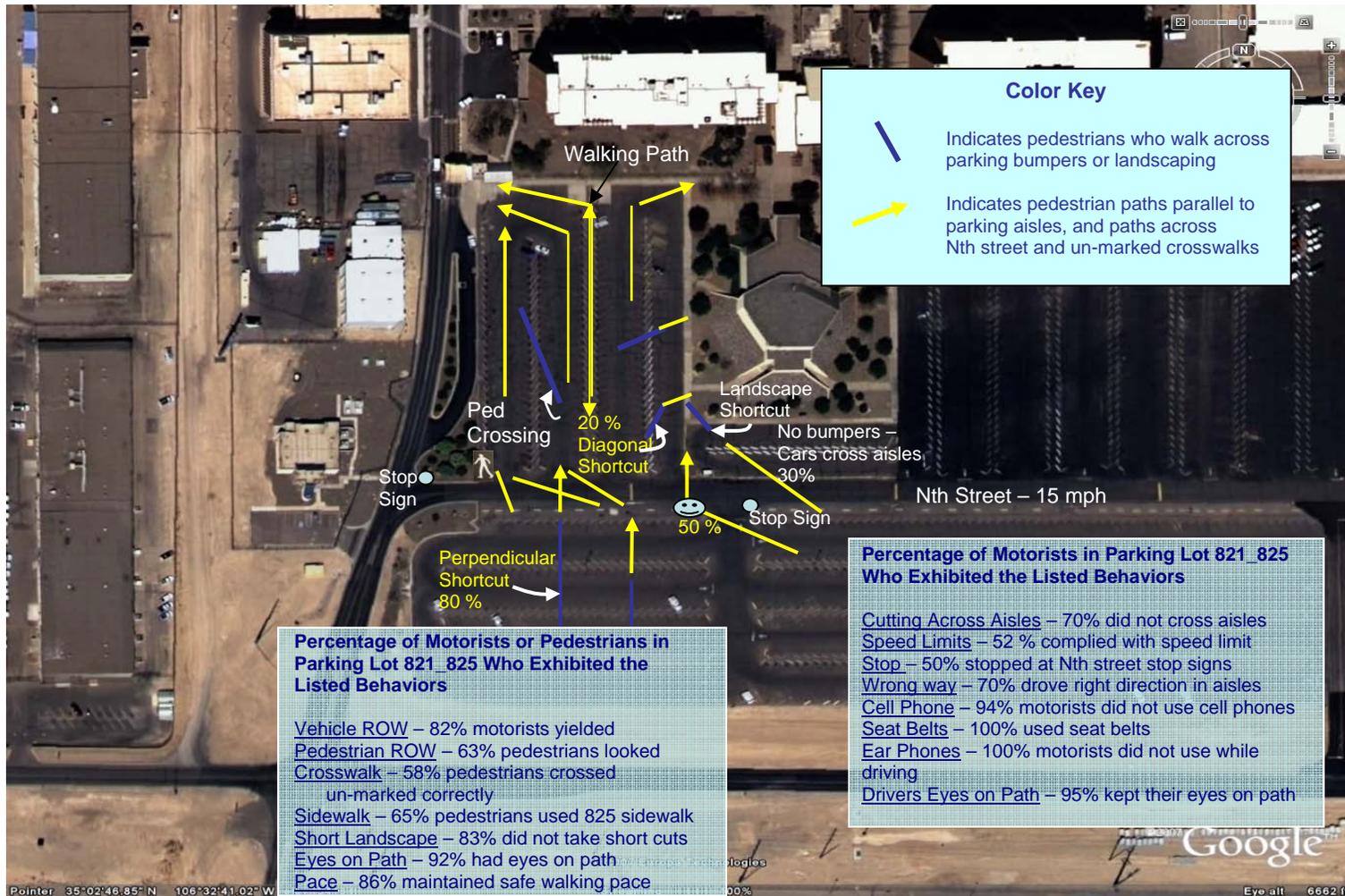
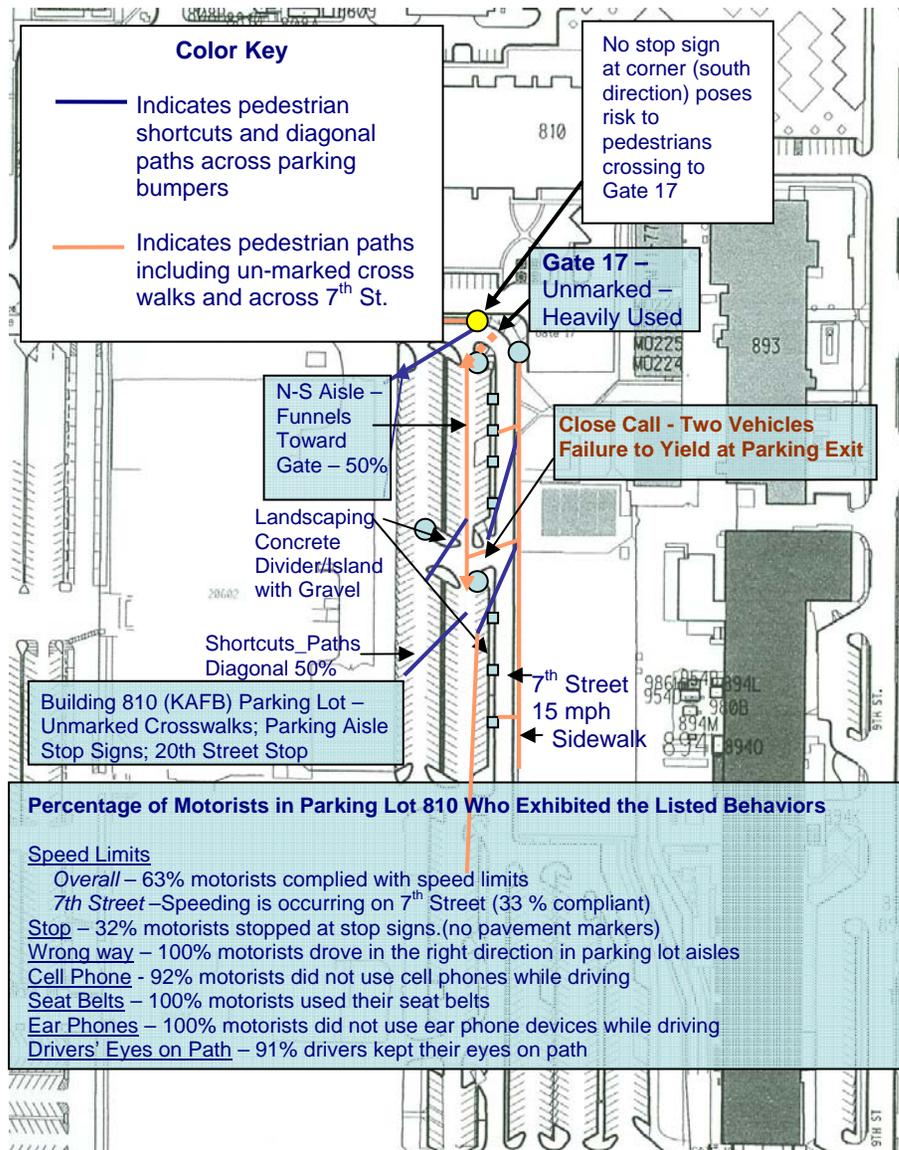


Diagram A2: The Building 823/825 parking lot layout is smaller and mostly aligned with destinations. Only 20% of pedestrians walk across parking bumpers in the northern lot. Pedestrians walk parallel to parking aisles and within a walkway between parking bumpers. Conversely, 80% of pedestrians cross the parking bumpers in the south lot, as pedestrians naturally take the shortest walking path. About half cross N Avenue correctly at the smiley face in line with the 825 sidewalk. The other half cross diagonally.



Percentage of Motorists or Pedestrians in Parking Lot 810 Who Exhibited the Listed Behaviors

Vehicle ROW – 78% motorists yielded overall

Pedestrian ROW

Overall - 63% pedestrians looked before crossing
Gate (Stop sign) – 78% pedestrians looked before crossing un-marked crosswalk with stop sign

Crosswalk

Overall – 44% pedestrians used un-marked crosswalks across 7th street correctly
Gate – 69% pedestrians used the un-marked crosswalk at the gate correctly

Sidewalk – 63% pedestrians used sidewalk parallel to 7th street

Shortcuts – 50% pedestrians took shortcuts across the divider or landscaping

Eyes on Path – 96% pedestrians had eyes on path

Pace – 89% pedestrians maintained safe walking pace

Diagram A4: The Building 810 KAFB parking lot is small with parking aisles oriented in the direction of Gate 17.

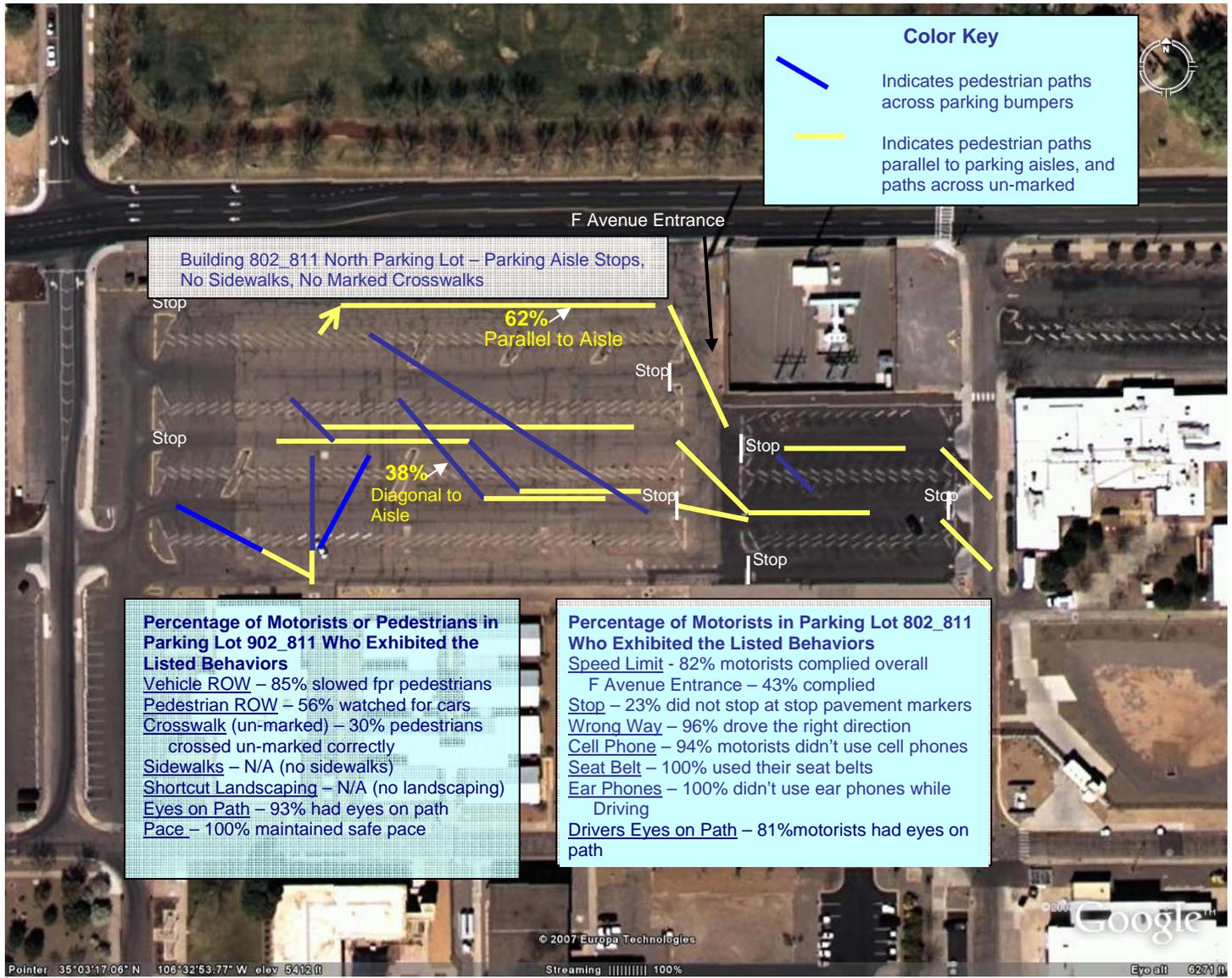


Diagram A5: The Building 802/811 parking lot, like the building 823/825 parking lot, includes no pedestrian walkways and no marked crosswalks. Pedestrians are more prone to walk across parking bumpers than newer parking lots with intralot walkways and sidewalks.

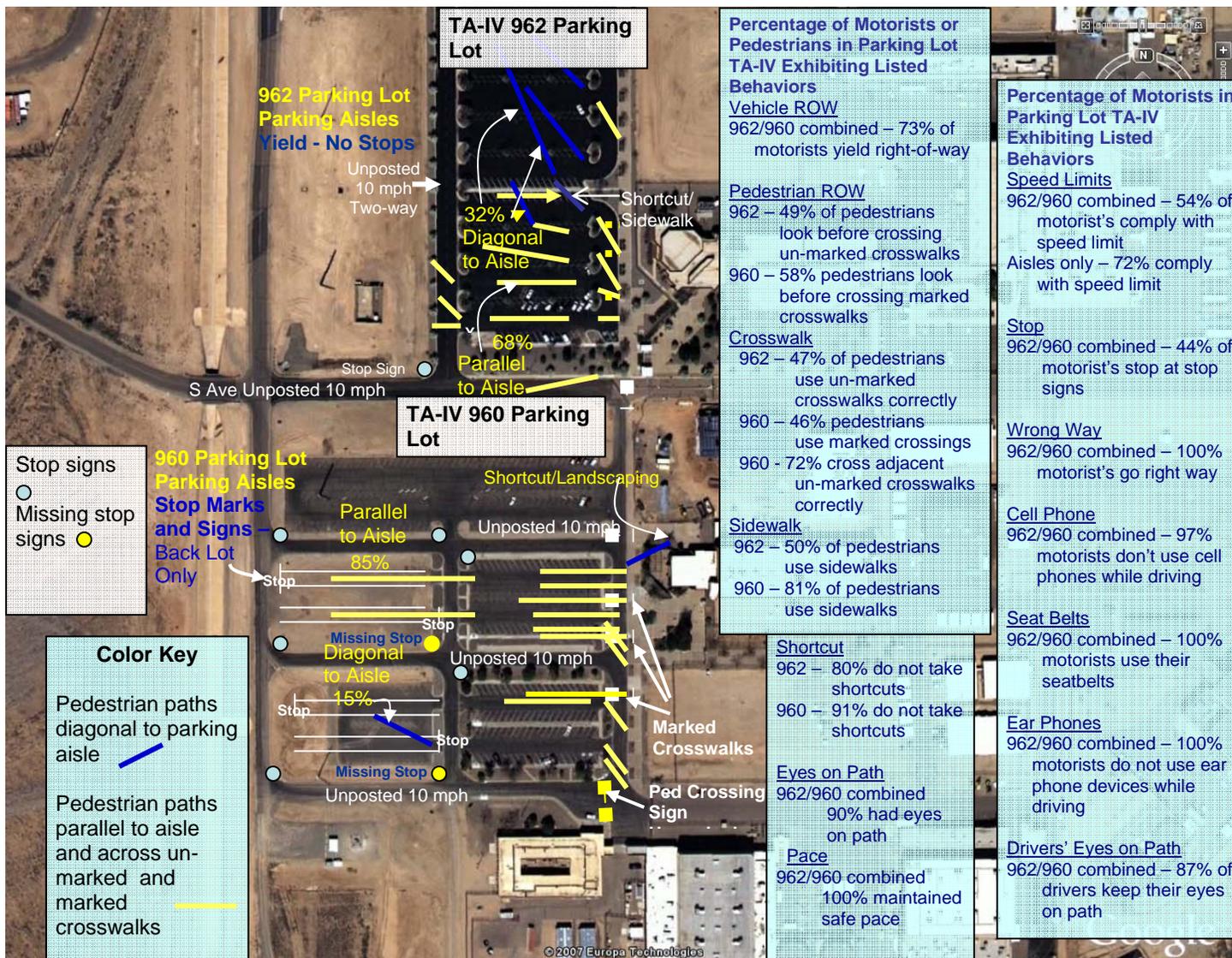


Diagram A7: The Building 962 and 960 parking lots are newer parking lot incorporating pedestrian friendly features. Aisle orientation affects differences between parking lot pedestrian paths taken between parking lots and destinations.

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APPENDIX B: PEDESTRIAN AND MOTORIST OBSERVATION PROCEDURE

Objective – Obtain baseline of *ES&H Manual*, Section 4K, “Traffic Safety,” compliance and behavior-based safety in parking lots (or other locations noted).

Requirements – Data must be collected consistently, with reproducible results. The recording of the observations must be systematic and standardized. All data is collected in the same manner. Observers ensure they use the same techniques for data collection.

Hypothesis – Motorists and pedestrians obey rules and requirements and exhibit safe behaviors.

Test – Observe and record multiple well-defined behaviors. Record both positive and negative behaviors on data collection sheets.

Procedure - Use criteria on the following page and guidance below.

1. Record observations for one or two related activities at 6-minute intervals to ensure data are collected for all 15 attributes.
[Lesson-Learned – In practice, several observations were common and several could be recorded concurrently (wrong way, speed, stop or pedestrian ROW, crosswalk, sidewalk and pace). Because some behaviors were less common (such as vehicle right-of-way with respect to pedestrians), the six minute intervals was consistently used.]
2. Record some data from vantage point above grade if possible (e.g., right of way, stop and yield, red light, crosswalk, wrong way, cutting across lanes, pedestrian eyes on path, pace, slip trip).
[Lesson-Learned - Could not use the roof because of fall protection requirements, so only a few lots were observed from upper stories. However, sometimes the vision was obscured, so most data taken from ground level from a discrete location. Sometimes walking around is necessary but should be avoided to prevent biasing the pedestrian or motorist behavior.]
3. Record some at grade level (e.g., cell phones, ear phones, seat belts, driver eyes on path) or record some data from vantage point or at grade (right of way, crosswalk, stop yield, red light, pedestrian eyes on path, pace).
4. Compile data on form using the following notation:

 means observation taken and is compliant

X means observation taken and NOT compliant

Requirements

Vehicle Right of Way

Drivers reduce speed, sees or looks for pedestrians BEFORE entering turn or pedestrian path, , and yields by braking or slowing to pedestrian during crossing (**or car yields to other cars**)

X Driver does not yield or not **slow down to pedestrian** during crossing

Pedestrian Right-of-way in marked or unmarked intersections or across parking lane aisle junctions

Pedestrian looks up and checks before entering (**full stop not required**);

X Pedestrian assumes ROW; does not look up or both ways.

Driving wrong way

Driver drives correct direction for diagonal parking or in two-way. Driver obeys pavement directional arrows

X Driver drives in wrong direction for diagonal parking or in two-way. Driver does not obey pavement directional arrows

Speed

Driver appears to be using safe speed.

X Driver appears to be going WELL ABOVE safe speed

Stop and Yield Signs (yield - unmarked stops TA-IV parking aisle)

V Driver makes **hesitated stop at stop signs**. Driver **yields** by slowing considerably.

X Driver **does not make hesitated stop**. Driver does not **yield** by slowing and waiting

Crosswalk

Pedestrian uses sidewalk

X Pedestrian does not use sidewalk

Sidewalks

Pedestrian walks on sidewalk (**sidewalks**)

X Pedestrian does not walk on sidewalk (**sidewalks**)

Short Cuts

A Pedestrian does not cut across landscaping

X Pedestrian cuts across landscaping

Cutting Across Parking Aisles

Pedestrian walks parallel to parking aisles, avoiding parking bumpers

X Pedestrian walks diagonal to parking aisle, taking a path across parking bumpers

Cell Phone

Driver not talking on cell phone

X Driver talking on cell phone

Seatbelts

/Driver wearing seat belts

X Driver not wearing seat belts

Ear Phones

Pedestrian/driver not wearing earphones

X Pedestrian/driver wearing earphones

Behavior

Eyes on Path (pedestrian)

Pedestrian aware of parked/moving cars, aware of parking bumpers

X Pedestrian reading, unaware of parked or moving cars, reading. Lesson Learned - subjective: looking down. Pedestrians are able to perceive an ellipse around them looking down, so considered noncompliant only if they appeared distracted or "not aware"

Eyes on Path (driver)

Driver paying attention to pedestrians while driving (noncompliances on vehicle right of way includes driver's eyes on path)

X Driver distracted, eating, smoking; careless backing up or turning

Pace (parking lot motor vehicle pace is speed limit 10 MPH)

Driver or pedestrian - walking/driving noticeably faster than the rest of the people/cars

X Driver and pedestrian – walking/driving normal with respect to other people/cars

Slips, Trips, Falls

Pedestrian – pedestrian does not slip, trip, or fall

X Pedestrian – pedestrian slips, trips or fall

	Right-of-Way	Wrong Way/ Arrows	Speed	Stop and Yield Signs	Cutting Across Empty Spaces	Cross Walk	Side Walks/	Short Cuts	Red Light	Eyes on Path	Pace	Slip or Trip (Where-why?)	Cell Phone	Seat belts	Ear Phones	Eyes on Path (driver)
1 Car																
2 Person																
3 Car																
4 Person																
5 Car																
6 Person																
7 Car																
8 Person																
9 Car																
10 Person																
11 Car																
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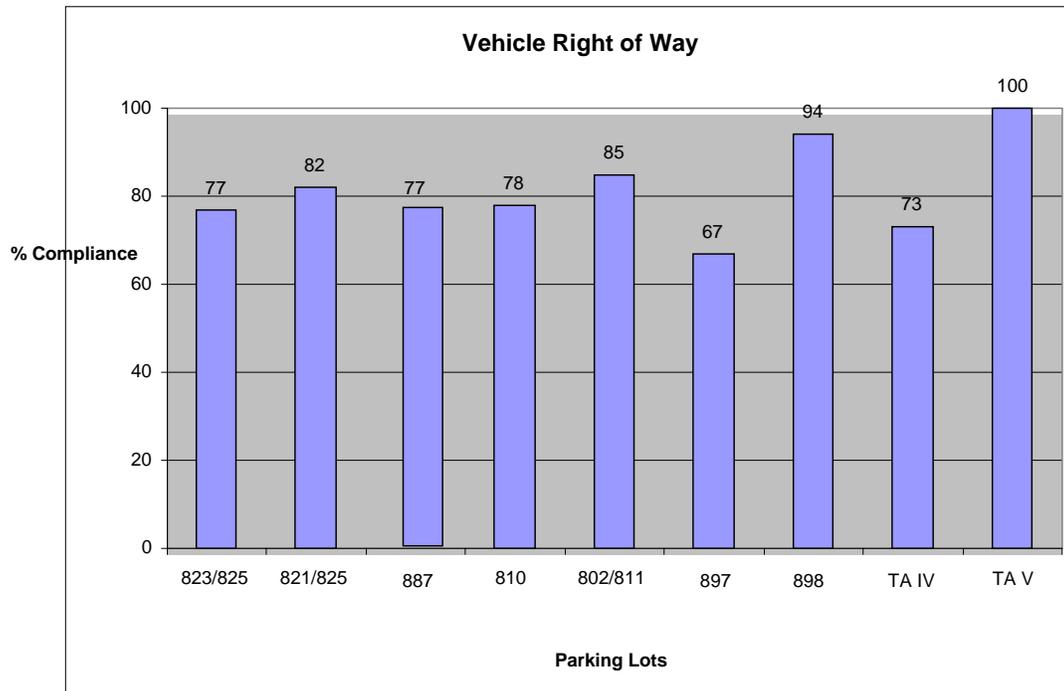
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APPENDIX C: GRAPHICAL AND TABULAR RESULTS OF STUDY

The following graphs and tables show the results of observations, per category, made during the study. Confidence limits for 100% compliance are shown as “na” because statistical methods are not valid for compliance values close to zero or 100%.

Table C1: Vehicle Right of Way (254 Observations)

Vehicle Right of Way	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	77	44	34	(0.63, 0.88)
Parking Lot 821/825	82	28	23	(0.64, 0.94)
Parking Lot 887	77	13	10	(0.46, 0.95)
Parking Lot 810	78 (83) ⁷	45	35	(0.64, 0.88)
Parking Lot 802/811	85	7	6	(0.42, 0.99)
Parking Lot 897	67 (76) ⁸	55	37	(0.55, 0.77)
Parking Lot 898	94	35	33	(0.82, 0.99)
Parking Lot 962/960 TA IV	73	22	16	(0.50, 0.88)
Parking Lot 6585 TA V	100	5	5	na



⁷ At parking lot 810, results are biased by observations at Gate 17 where pedestrians crossed at a stop sign situated at the gate. Vehicle right of way at stop sign is 83 %.

⁸ At parking lot 897, results are 76% measured at marked crosswalks compared to un-marked crosswalks alone (67%).

Table C2: Pedestrian Right of Way (480 Observations)

Pedestrian Right of Way	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825 (Unmarked only)	46	63	29	(0.34, 0.58)
Parking Lot 821/825 (Unmarked only)	63	43	27	(0.47, 0.76)
Parking Lot 887 (Unmarked only)	51	86	44	(0.41, 0.61)
Parking Lot 810 (Gate 78%)	63 (78)	51	32	(0.50, 0.74)
Parking Lot 802/811 (Unmarked only)	56	39	22	(0.40, 0.72)
Parking Lot 897	68	50	34	(0.55, 0.79)
Parking Lot 898	66	61	40	(0.54, 0.76)
Parking Lot 962 TA IV (Unmarked only)	49	55	27	(0.37, 0.62)
Parking Lot 960 TA IV (Marked)	58	57	33	(0.45, 0.70)
Parking Lot 6585 TA V	47	32	15	(0.30, 0.64)

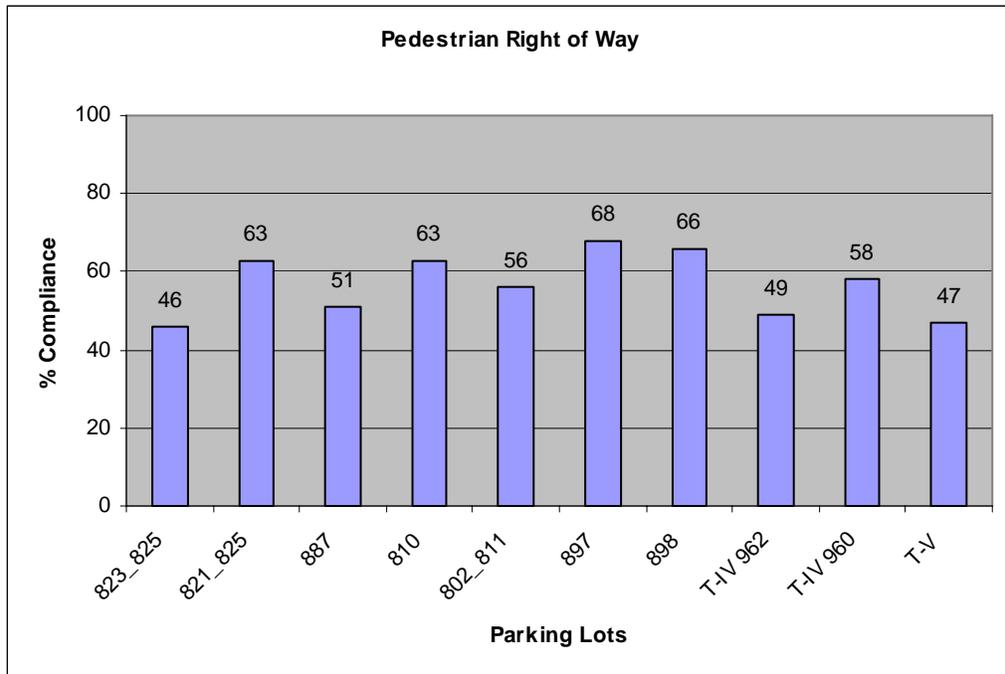


Table C3: Crosswalks (534 Observations)
 (Note: Graph combined with and follows Table C4)

Crosswalk	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825 Unmarked and Marked (Marked)	59 (85) ⁹	37	22	(0.42, 0.74)
Parking Lot 821/825 (Mostly unmarked - biased by 50% compliance at stop sign – Diagram A2)	58	48	28	(0.44, 0.72)
Parking Lot 887 (Unmarked only)	38	64	24	(0.26, 0.49)
Parking Lot 810	44 (69) ¹⁰	63	28	(0.34, 0.55)
Parking Lot 802/811 (Unmarked only)	30	27	8	(0.14, 0.50)
Parking Lot 897	54 (90) ¹¹	89	48	(0.46, 0.62)
Parking Lot 898 (Mostly unmarked - biased by high compliance at marked intersection with stop sign – Diagram A6)	68	80	54	(0.59, 0.75)
Parking Lot 962 TA IV (Unmarked only)	47	55	26	(0.34, 0.60)
Parking Lot 960 TA IV Marked (Unmarked)	46 (70)	48	22	(0.33, 0.59)
Parking Lot 6585 TA V	74	23	17	(0.52, 0.89)

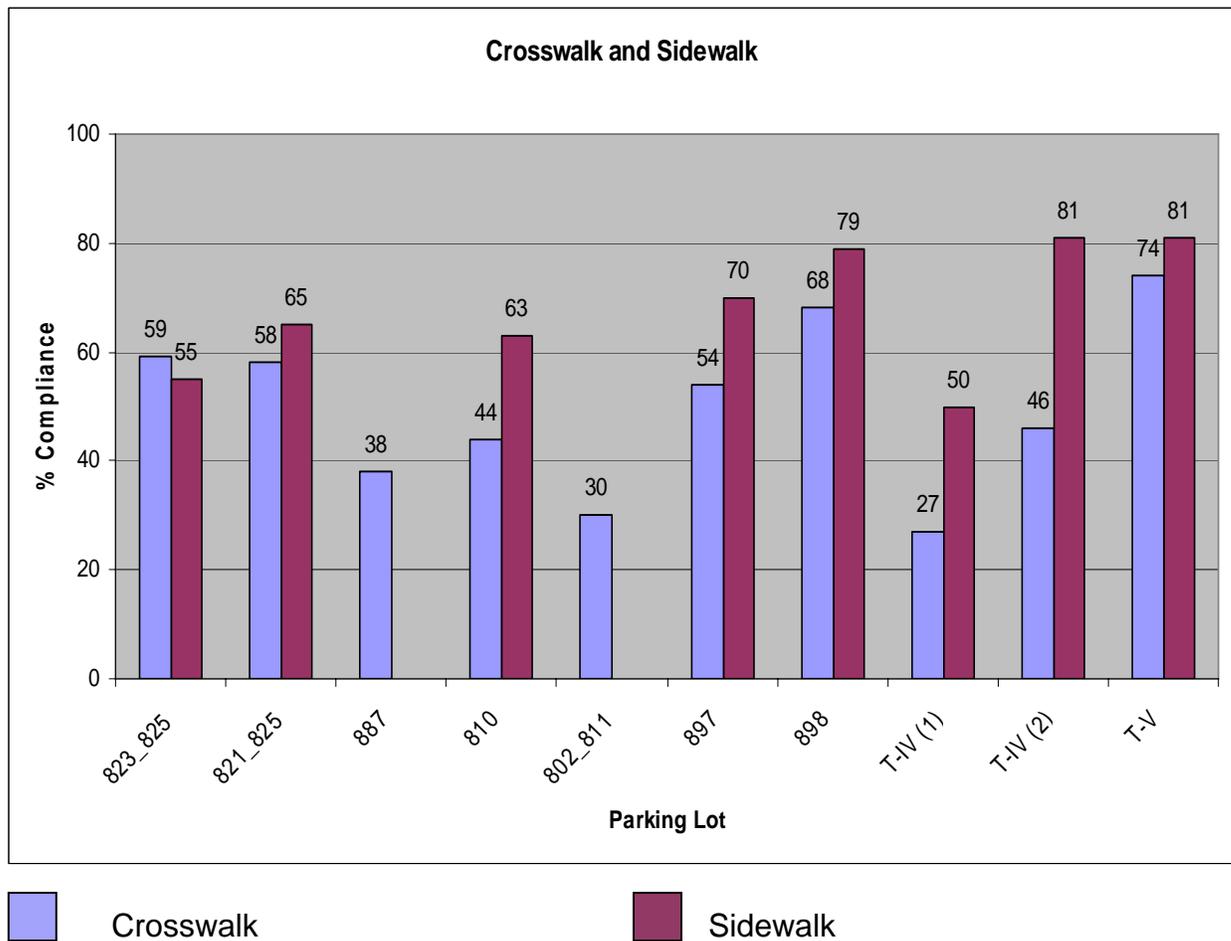
⁹ Result is biased by greater compliance at the marked crosswalk leading to T-City (85%), compared to the value reported for both un-marked and marked (59%). The 85% compliance appears influenced by the stop sign co-located at the crosswalk and the fact that ES&H staff use this crosswalk to T-City.

¹⁰ At parking lot 810, compliance at all un-marked crosswalks is low (44%) compared to the un-marked crosswalk at Gate 17 (69%). Again, a stop sign is located there and the north south aisles appear to funnel more pedestrians to this natural crossing.

¹¹ At parking lot 897, crosswalk compliance is noticeably greater where an intra-lot walkway and lot layout naturally funnels pedestrians directly to crosswalks and toward the pedestrian's destination.

Table C4: Sidewalks¹² (328 Observations)

Sidewalk	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	55	66	36	(0.42, 0.66)
Parking Lot 821/825	65	23	15	(0.43, 0.83)
Parking Lot 887	na	Na	Na	na
Parking Lot 810	63	48	30	(0.49, 0.74)
Parking Lot 802/811	na	Na	Na	na
Parking Lot 897	70	20	14	(0.47, 0.87)
Parking Lot 898	79	48	38	(0.67, 0.88)
Parking Lot 962 TA IV	50	44	22	(0.36, 0.64)
Parking Lot 960 TA IV	78	36	29	(0.62, 0.89)
Parking Lot 6585 TA V	81	43	35	(0.68, 0.90)

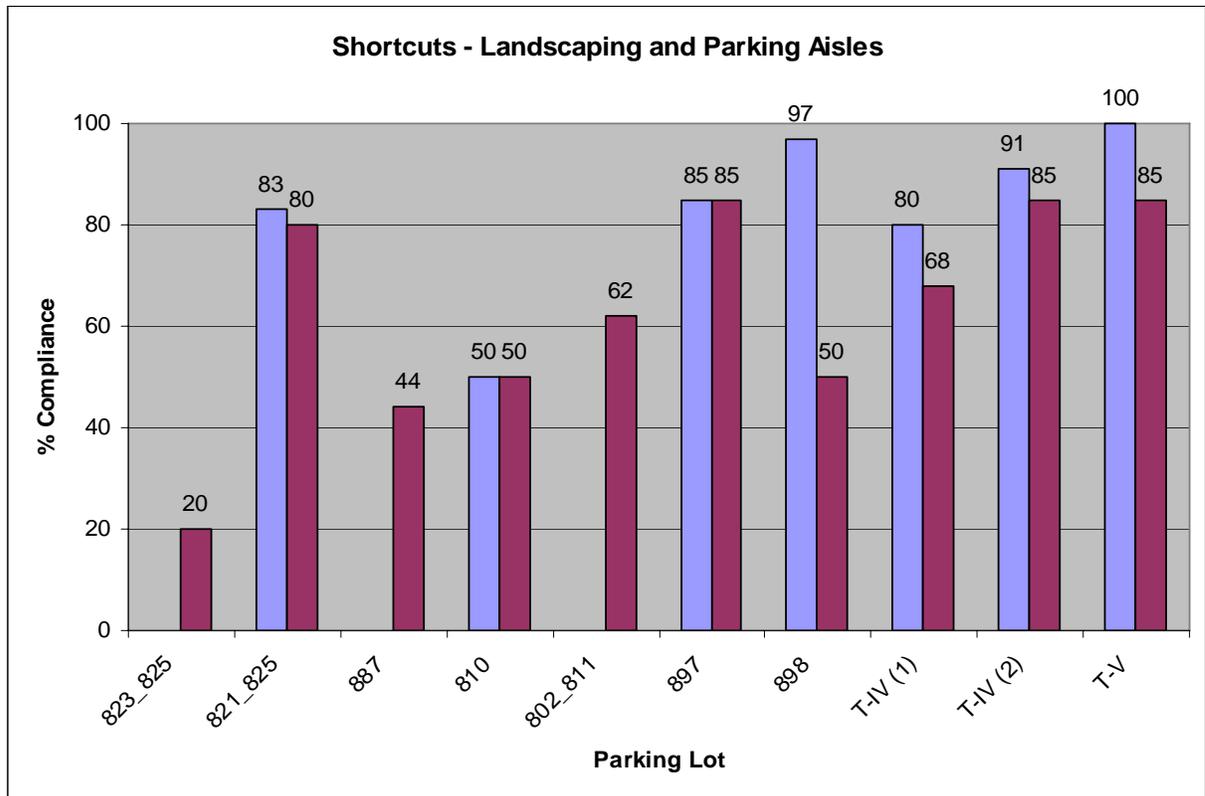


¹² There are no sidewalks at parking lots 887 and 802/811.

Table C5: Shortcuts (541 Total Observations)

NOTE: Shortcuts include those taken across landscaping and parking aisles.

Shortcut	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	n/a	n/a	n/a	n/a
Parking Lot 821/825	83	23	19	(0.61, 0.95)
Parking Lot 887	n/a	n/a	n/a	n/a
Parking Lot 810	50	34	17	(0.34, 0.66)
Parking Lot 802/811	n/a	n/a	n/a	n/a
Parking Lot 897	85	20	17	(0.63, 0.96)
Parking Lot 898	97	48	45	(0.84, 0.98)
Parking Lot 962 TA IV	80	47	38	(0.75, 0.96)
Parking Lot 960 TA IV	91	36	33	(0.78, 0.98)
Parking Lot 6585 TA V	100	43	43	na



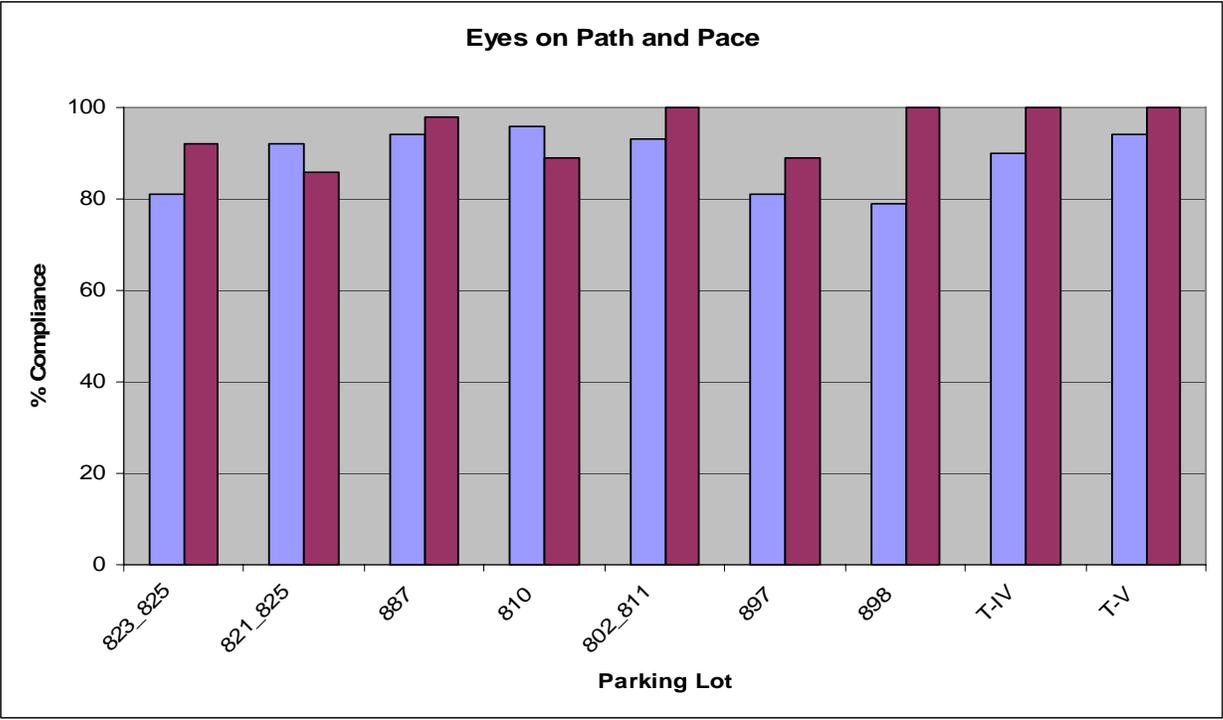
Landscape Shortcut (284 Observations)
 Parking Aisles (257 Observations)

Table C6: Pedestrian Eyes on Path (312 Observations)

Eyes on Path	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	81	37	30	(0.65, 0.92)
Parking Lot 821/825	92	26	24	(0.75, 0.99)
Parking Lot 887	94	53	50	(0.84, 0.99)
Parking Lot 810	96	26	25	(0.81, 0.99)
Parking Lot 802/811	93	30	28	(0.78, 0.99)
Parking Lot 897	81	27	22	(0.63, 0.93)
Parking Lot 898	79	39	31	(0.65, 0.90)
Parking Lot 962/960 TA IV	90	42	38	(0.66, 0.89)
Parking Lot 6585 TA V	94	32	30	(0.80, 0.99)

Table C7: Pace (300 Observations)

Pace	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	92	39	36	(0.80, 0.98)
Parking Lot 821/825	86	21	18	(0.64, 0.97)
Parking Lot 887	98	53	52	(0.90, 0.99)
Parking Lot 810	89	27	24	(0.71, 0.97)
Parking Lot 802/811	100	30	30	na
Parking Lot 897	89	27	24	(0.72, 0.97)
Parking Lot 898	100	38	38	na
Parking Lot 962_960 TA IV	100	33	33	na
Parking Lot 6585 TA V	100	32	32	na



 Eyes on path  Pace

Table C8: Speeding (466 Observations)

Speeding	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825 (N St. Low Compl.)	52	73	38	(0.40, 0.63)
Parking Lot 821/825	52	58	30	(0.39, 0.64)
Parking Lot 887	51 (39) ¹³	68	35	(0.40, 0.63)
Parking Lot 810 (7 th St - 2/3 NC)	63	40	25	(0.47, 0.76)
Parking Lot 802/811 (Off F Avenue – 43%)	82 (43)	28	23	(0.64, 0.94)
Parking Lot 897 (N Avenue)	68	50	34	(0.55, 0.79)
Parking Lot 898 (Hardin access lower compliance)	87	39	34	(0.73, 0.95)
Parking Lot 962/960 TA IV (Aisles 72%)	54	54	25	(0.33, 0.60)
Parking Lot 6585 TA V (Parking lot access)	63	56	35	(0.33, 0.57)

Table C9: Stopping (470 Observations)

Stopping	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825 (stop sign and aisle stops)	41	111	45	(0.32, 0.49)
Parking Lot 821/825 (stop signs; aisle yield)	50	30	15	(0.32, 0.68)
Parking Lot 887 (no stop signs; aisle stops)	43	47	20	(0.28, 0.57)
Parking Lot 810 (stop signs)	32	58	19	(0.23, 0.44)
Parking Lot 802/811 (no stop signs; aisle stops)	23	22	5	(0.08, 0.45)

¹³ In the 887 parking lot, separate rates were determined for parking aisles (70% compliant) and the two-way entrance off of G Avenue (39% compliance). In general, speed results are biased by low compliance on two-way traffic lanes as indicated in the table.

Stopping	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 897 (no stop signs; aisle stops in part)	57	28	16	(0.39, 0.74)
Parking Lot 898 (stop sign and crosswalk)	70	103	72	(0.63, 0.76)
Parking Lot 962/960 TA IV (stop signs)	44	18	8	(0.22, 0.66)
Parking Lot 6585 TA V (no stop signs; aisle stops)	26	53	13	(0.15, 0.36)

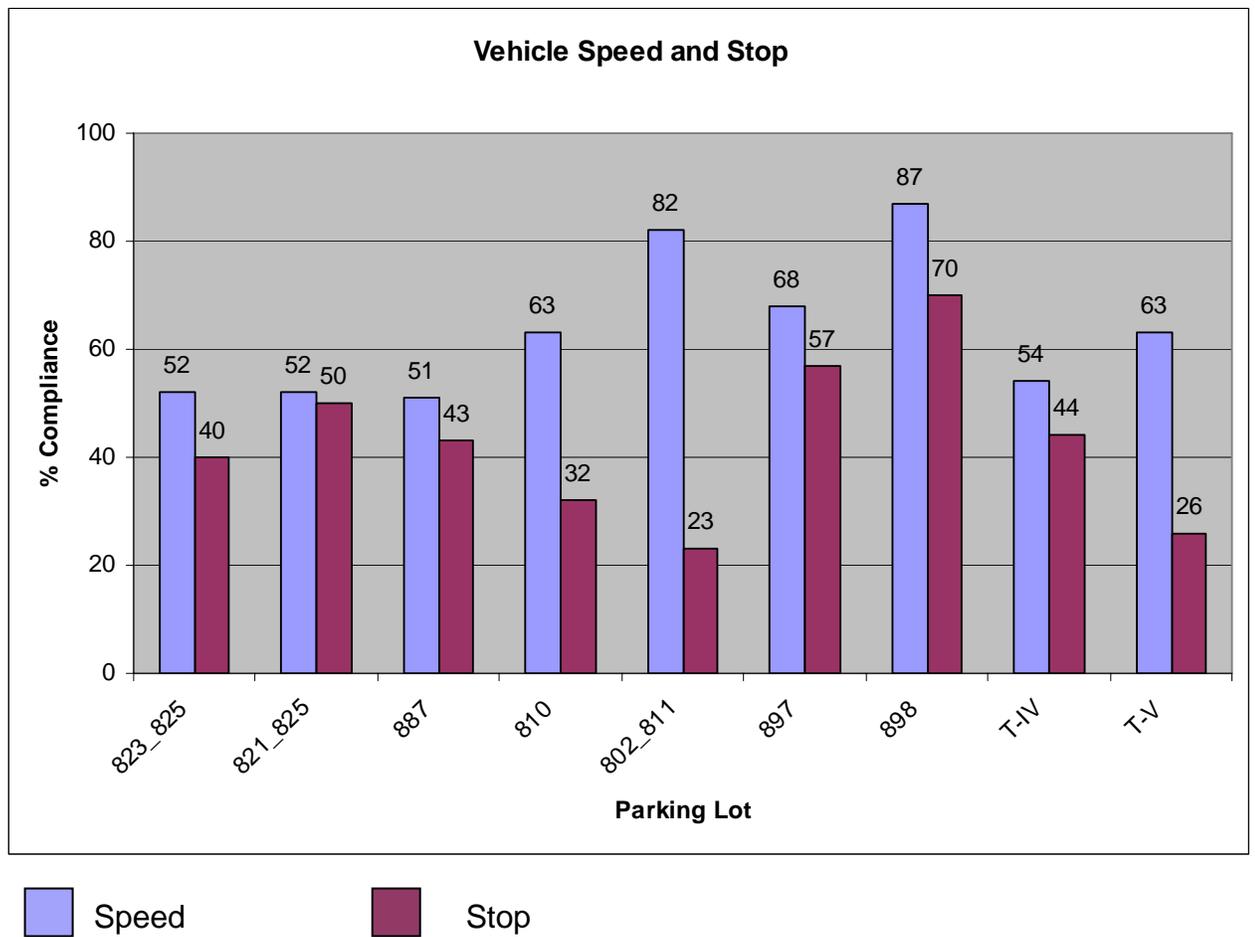


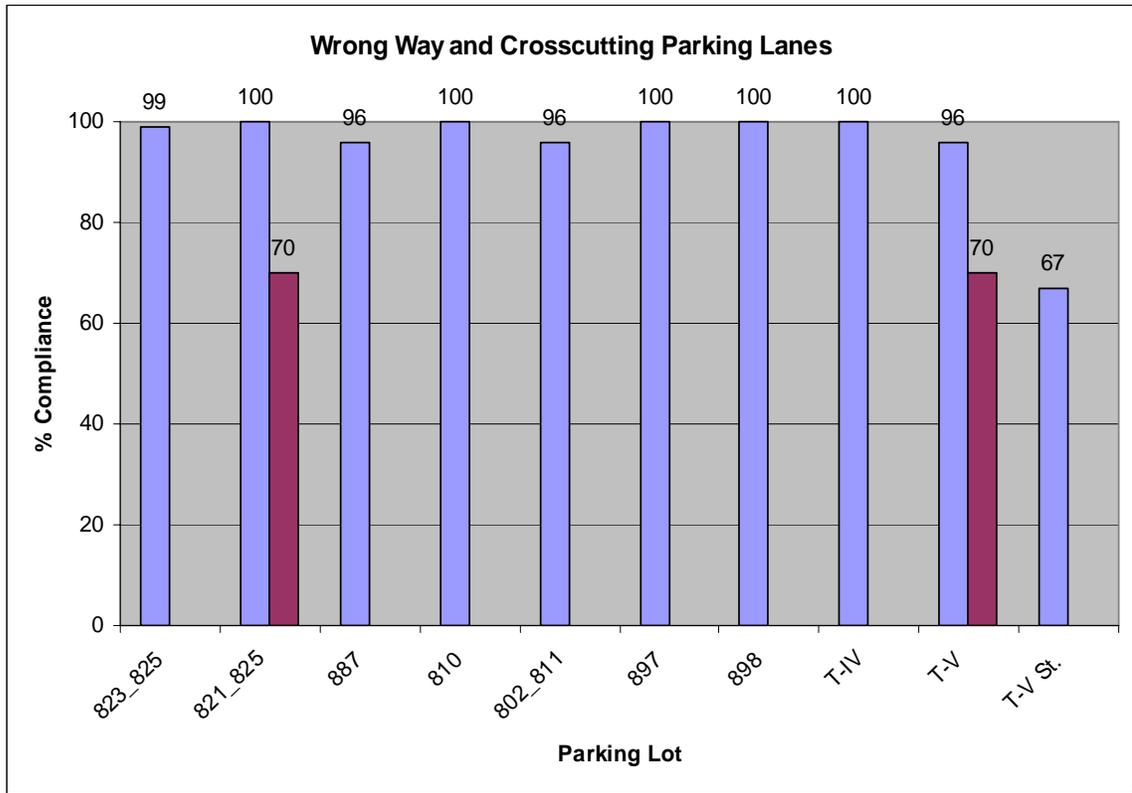
Table C10: Wrong Way (including Tech Area V Street) (444 Observations)¹⁴

Wrong Way	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	99	73	72	(0.93, 0.99)
Parking Lot 821/825	100	73	73	na
Parking Lot 887	96	27	26	(0.81, 0.99)
Parking Lot 810	100	40	40	na
Parking Lot 802/811	96	28	27	(0.83, 0.99)
Parking Lot 897	100	50	50	na
Parking Lot 898	100	39	39	na
Parking Lot 962/960 TA IV	100	54	54	(0.90, 0.99)
Parking Lot 6585 TA V (Parking Lot)	96	56	50	(0.80, 0.95)
Parking Lot 6585 TA V (Street)	67	48	32	(0.56, 0.76)

Table C11: Cutting Across Parking Aisles (64 Observations)

Cutting Across Parking Aisles	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 821/825	70	10	7	(0.44, 0.86)
Parking Lot 6585 TA V	70	54	38	(0.58, 0.80)

¹⁴ Wrongway for parking lots, except Tech Area V, where 67% drove wrong way in street to avoid speed turtles (close call observed). Cutting across parking aisles is not applicable to parking lots with bumpers. Only applicable to south of Building 825 and Tech Area V.



 Wrong-Way Driving

 Crosscutting

Table C12: Cell Phone

Cell Phone Use	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	94	32	30	(0.80, 0.99)
Parking Lot 821/825	94	17	17	(0.73, 0.99)
Parking Lot 887	94	32	30	(0.80, 0.99)
Parking Lot 810	92	12	11	(0.63, 0.98)
Parking Lot 802/811	94	17	16	(0.73, 0.99)
Parking Lot 897	97	29	28	(0.84, 0.99)
Parking Lot 898	91	34	31	(0.79, 0.97)
Parking Lot 962/960 TA IV	100	19	19	na
Parking Lot 6585 TA V	96	27	26	(0.82, 0.99)

Table C13: Seat Belts

Seat Belt Use	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	100	32	32	na
Parking Lot 821/825	100	17	17	na
Parking Lot 887	100	32	32	na
Parking Lot 810	100	12	12	na
Parking Lot 802/811	100	17	17	na
Parking Lot 897	100	29	29	na
Parking Lot 898	100	34	34	na
Parking Lot 962/960 TA IV	100	19	19	na
Parking Lot 6585 TA V	100	27	27	na

Table C14: Ear Phones

Ear Phone Use	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	100	32	32	na
Parking Lot 821/825	100	17	17	na
Parking Lot 887	100	32	32	na
Parking Lot 810	100	12	12	na
Parking Lot 802/811	100	17	17	na
Parking Lot 897	100	29	29	na
Parking Lot 898	97	34	33	(0.87, 0.99)
Parking Lot 962/960 TA IV	100	19	19	na
Parking Lot 6585 T-V	100	27	27	na

Table C15: Driver's Eyes on Path

Driver Eyes on Path	% Compliance	Observations	# Compliant	Confidence Limits
Parking Lot 823/825	92	36	33	(0.80, 0.97)
Parking Lot 821/825	91	22	20	(0.73, 0.98)
Parking Lot 887	95	21	20	(0.78, 0.99)
Parking Lot 810	91	22	20	(0.73, 0.98)
Parking Lot 802/811	81	16	13	(0.56, 0.95)
Parking Lot 897	90	29	26	(0.75, 0.97)
Parking Lot 898	91	35	32	(0.79, 0.97)
Parking Lot 962/960 TA IV	87	33	29	(0.74, 0.95)
Parking Lot 6585 TA V	96	27	26	(0.82, 0.99)

Table C16: Observation Method Validation

Vehicle ROW	% Compliance	Observations	# Compliant
Parking Lot 887	77	13	10
Parking Lot 887 (Validation)	83	47	39

Stop	% Compliance	Observations	# Compliant
Parking Lot 887 (no stop signs; aisle stops)	43	47	20
Parking Lot 887 (Validation)	38	48	18

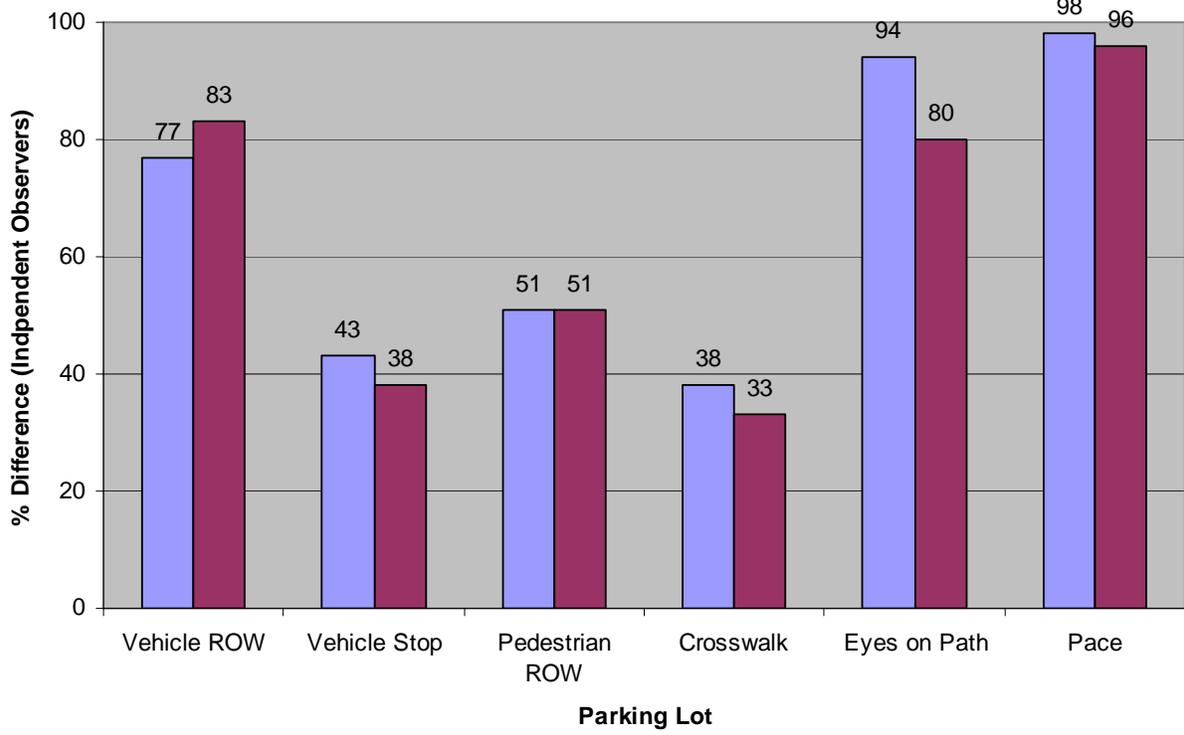
Pedestrian ROW	% Compliance	Observations	# Compliant
Parking Lot 887 (un-marked only)	51	86	44
Parking Lot 887 (Validation)	51	78	40

Crosswalk	% Compliance	Observations	# Compliant
Parking Lot 887 (un-marked only)	38	64	24
Parking Lot 887 (Validation)	33	101	46

Eyes on Path	% Compliance	Observations	# Compliant
Parking Lot 887	94	53	50
Parking Lot 887 (Validation)	80	45	36

Pace	% Compliance	Observations	# Compliant
Parking Lot 887	98	53	52
Parking Lot 887 (Validation)	96	45	43

Method Validation



Observer 1 Observer 2

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