Systemic Safety Analysis

2014-2023

Fatal Crashes

at Intersections

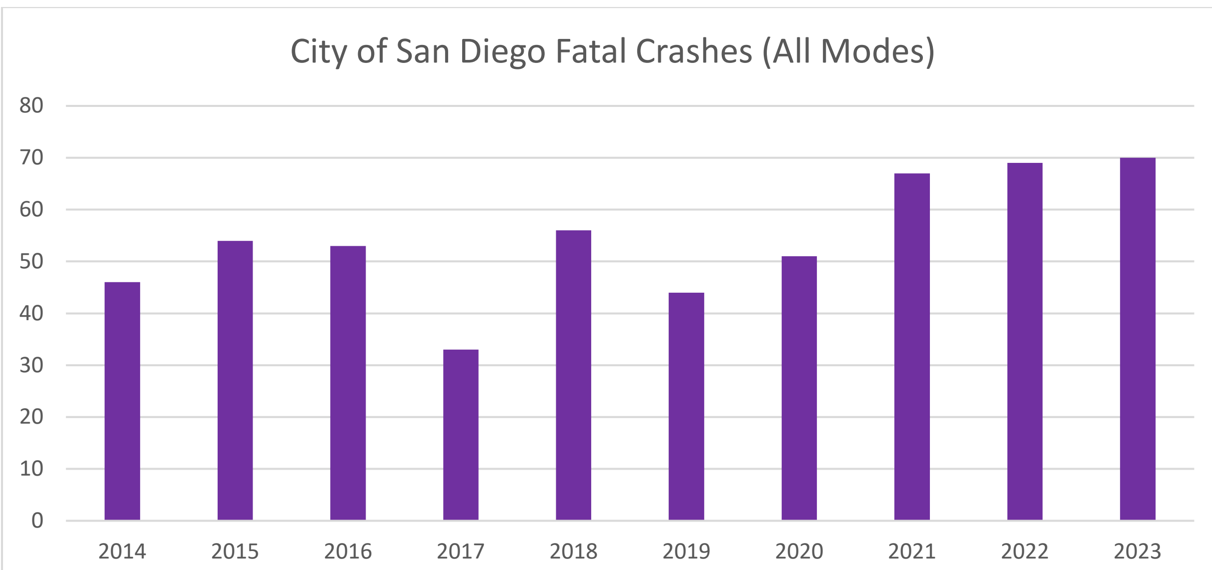
City of San Diego

July 2024

Executive Summary: *This analysis evaluated ten (10) years of crashes and has identified intersection characteristics associated with elevated risk of fatal crashes in the City. It can then be reasonably extrapolated that the fastest way to address factors that contribute to fatal crashes in the City of San Diego is to install Safe Systems improvements at intersections that have the following characteristics: intersections between 4-lane and 2-lane streets that are also on transit routes and with three (3) or more injury crashes in ten (10) years. One quarter ($1/4^{th}$) of fatal crashes at intersections happen at these locations, but they make up less than $1/30^{th}$ of the intersections in the City. Similar results were also found for 2-lane streets intersecting 2-lane streets that are also on transit routes with 2 or more injury crashes in 10 years.*

Additional Systemic Analysis for San Diego

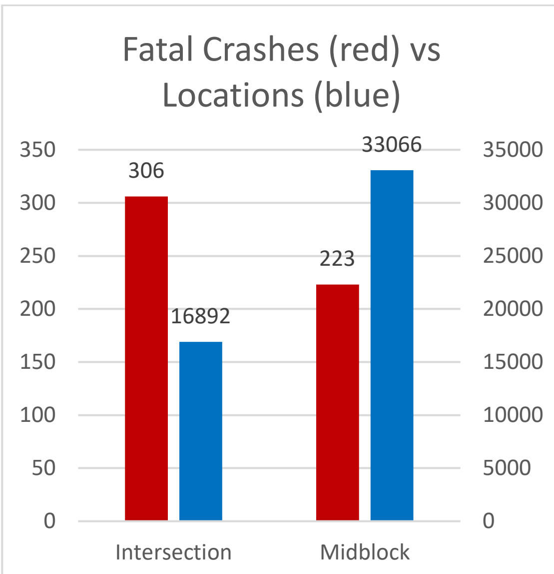
The City of San Diego made a Vision Zero commitment in 2015 and has made a significant investment in safety over the last ten (10) years. In 2019 Traffic Engineering Division completed a first of its kind Systemic Analysis of **injury** crashes over a three-year period (2014-2016). This report is not an update of that one. It uses similar methods but focuses on **fatal** crashes. Systemic analyses are more broadly applicable than the specific incident crash data they are based upon because they are not limited to those locations where crashes occurred. They are applicable wherever similar intersection traits are found across the City. In 2019 there weren't enough fatal crashes to identify clear patterns. This analysis uses a ten-year period to search for systemic and significant patterns. Additionally, it uses newly developed GIS capability and citywide maps that quantify the frequency of various traits citywide, providing an estimate of the risk for each trait identified. The results of the 2019 study of injury crashes are still valid and worth relying on (https://www.sandiego.gov/sites/default/files/systemic-safety-the-data-driven-path-to-vision-zero.pdf). This study supplements those results with the goal of eliminating fatal crashes as quickly as possible, focusing on project location and countermeasure effectiveness.

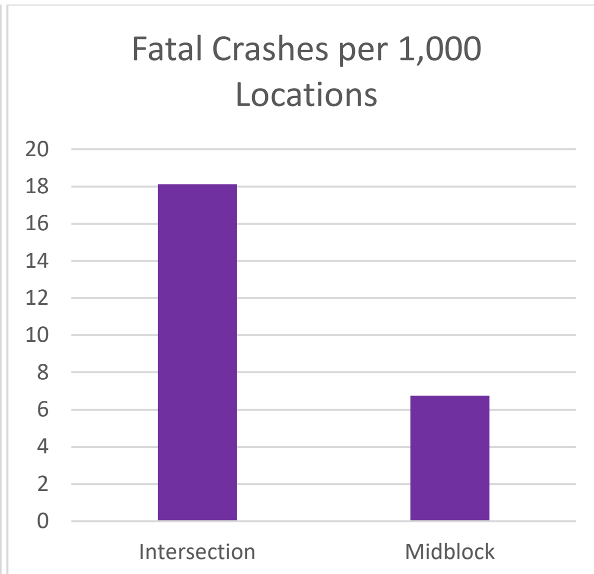


There are many contributing factors in fatal crashes and there is no one perfect solution from the all the various tools at our disposal, from engineering, education, enforcement, encouragement, equity and evaluation. Within the realm of engineering improvements there is always some lag between investment and outcome, and there is also a strong tendency to locate projects where fatal crashes have already occurred. This systemic analysis provides a guide to also complete projects where the risk of a fatal crash is high based on common intersection traits. The lag between investment and outcome can be reduced using quick-build projects which are particularly suited to address systemic issues. Countermeasures like leading pedestrian intervals and roundabouts are proven to reduce and eliminate fatal crashes because they rely on Safe Systems principles.

Data Analysis and Location Categorization

Although breaking any data set into smaller pieces can make patterns harder to find, sometimes keeping two different data sets together can also make their unique patterns harder to find. The most significant categories are intersection and midblock. The transportation industry separates safety improvements into these categories and provides information on an improvement's effectiveness within its category. The following charts show how fatal crashes in San Diego have been distributed between intersection and midblock over the last decade (2014-2023).

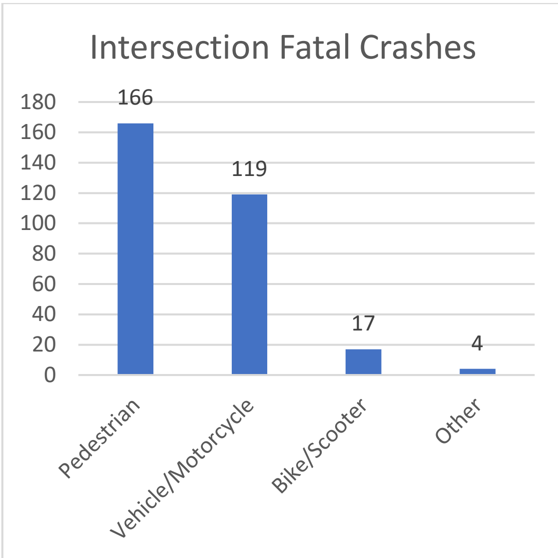


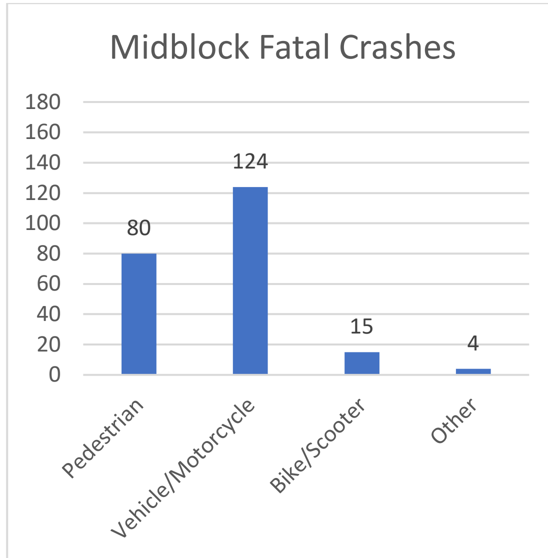


Intersections

Intersections are common crossing locations between vehicles and pedestrians and bicycles. There is more traffic within an intersection than on any of its legs, with far denser turning conflicts and potential for mistakes than midblock portions of the street. Intersections are also relatively small compared to road segments. This makes intersection improvement projects more affordable and quicker to complete compared to full roadway projects. This was described in the 2019 systemic report and over 60 traffic signals have been improved with Leading Pedestrian Intervals, countdown timers, and high-visibility crosswalks as a direct result since then. In addition, installing roundabouts at several intersections in a row has a knock-on effect for the whole corridor, improving midblock safety between intersections by reducing speeds for about a quarter mile at each one (NCHRP Report 772). Roundabouts also eliminate unnecessary waiting, thus often improving travel time in spite of slower speeds at the intersections. This combination makes intersections the obvious place to invest for maximum progress toward systemic safety and the City's Vision Zero goal.

The following charts show how fatal crashes in San Diego have been distributed between travel modes over the last decade (2014-2023).





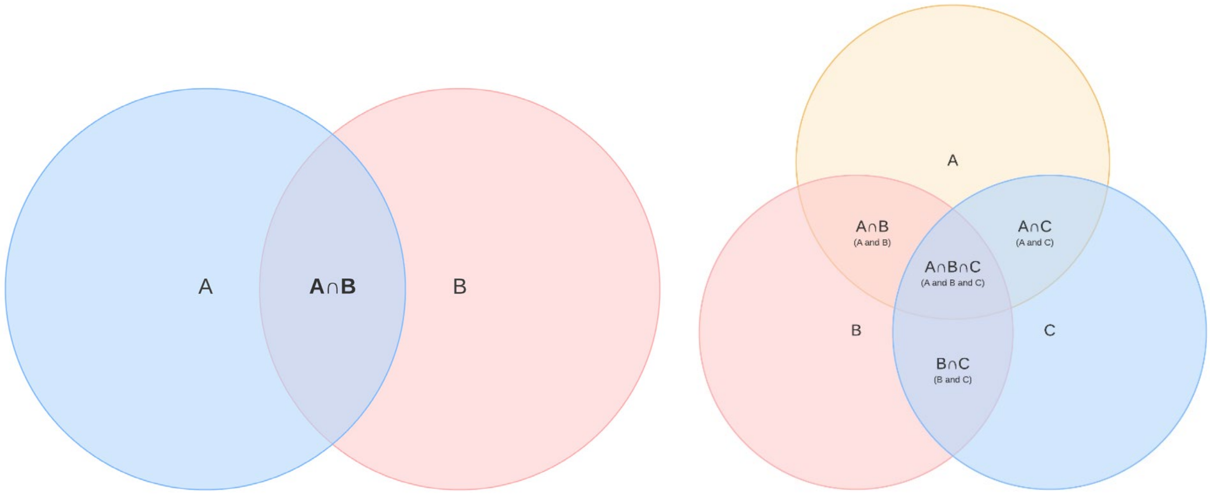
While this report will investigate patterns in fatal crashes at intersections, a subsequent report will investigate patterns in midblock crashes.

Where is the risk of fatal crashes high?

Analysis results found that fatal crashes rarely happen in the same place twice. In the last decade, out of 306 fatal crashes that happened at intersections, only 5 happened at the same intersection as another fatal crash. Thus, it stands that to save lives, locations all around the city, even those without previous crash histories, must be improved with systemic level changes to give those completed projects an opportunity to be effective, prior to the occurrence of a fatal crash.

Maximizing the number of fatal crashes prevented per dollar every year means investing in highly effective improvements at high-risk locations, *whether a fatal crash has already happened there or not*. To do this, fatal crash locations must be grouped to isolate traits that those locations have in common. This is not unlike the identification of comparable sales in Real Estate using traits like room count, living area, style, and condition. Common intersection traits will point to similar locations before a fatal crash happens. However, some of those traits may also be common throughout the City. Systemic countermeasures are lower cost and intended to be installed at all or most of the locations that share a trait. The more common a trait is across the City, the more locations would need countermeasures to prevent a fatal crash, making for very slow progress. The goal is to find traits that are more common at intersections with fatal crashes and are also less common at intersections in the City overall.

The example Venn diagrams below show a blue circle for intersections with fatal crashes, and a red circle for intersections that have a particular trait. The overlap represents the fatal crash locations that share that trait. The more intersections that share the trait in the red circle, the greater the quantity of safety improvements that would have to be installed to prevent the fatal crashes represented by the overlap. If a second trait were added, as shown by the yellow circle on the right, the quantity of improvements shrinks to just the intersections that share both traits, the overlap between the yellow and red circles. However, the number of fatal crashes that can be prevented by those improvements also shrinks to the overlap of all three circles in the middle.



The metric to evaluate each trait or combination of traits is the ratio between the number of fatal crashes that can be prevented, and the number of improvements needed to do so.

Since roundabouts are 90%-100% effective at eliminating fatal crashes for all modes, they are a good example to rank the traits and combinations. If another improvement were to be used, such as Leading Pedestrian Intervals, the metric would need to be reduced by the lower effectiveness and limited to the mode or modes of fatal crashes that that improvement can prevent. If it costs less and can be installed faster, that may allow it to overcome its lower effectiveness, supporting its application.

Considerable time was spent trying various intersection traits to predict fatal crash risk. Here are several traits that did not correlate strongly with fatal crashes at intersections:

Schools, Senior Centers, Speed Limits, Volumes, Bus Stops

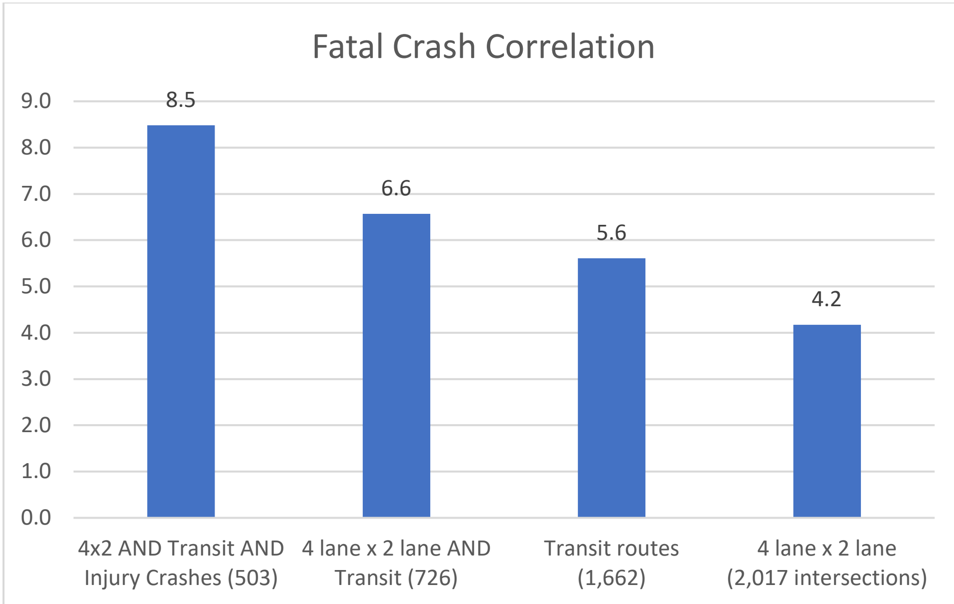
Speed Limits was an unexpected result. It appears that fatal pedestrian crashes peak at posted speed limits of 30mph and 35mph, while fatal vehicle crashes continue to increase slightly when increasing the speed limit, but fatal crashes of all modes were distributed across all speed limits such that no group stood out.

The following traits showed some promise but were not the most effective:

Business Improvement Districts, Functional Classifications

These traits appeared to be very effective at first but proved to be either ambiguous in practical use or involved a very small proportion of the fatal crashes and are mostly contained within the other traits.

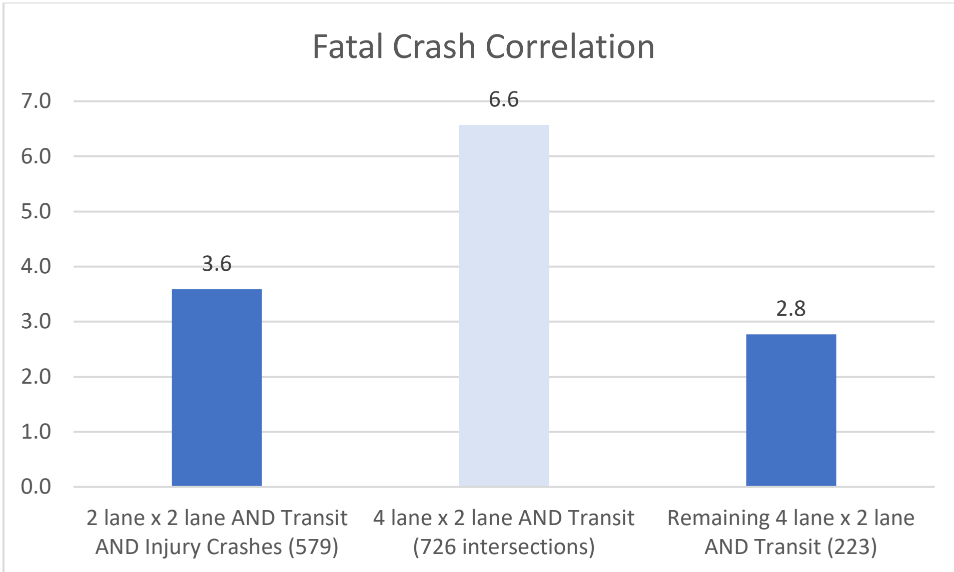
The analysis found that ***the most common traits for predicting the risk of a fatal crash are intersections on a transit route, intersections between a 4-lane street with a 2-lane street, and intersections with a history of prior injury crashes.***



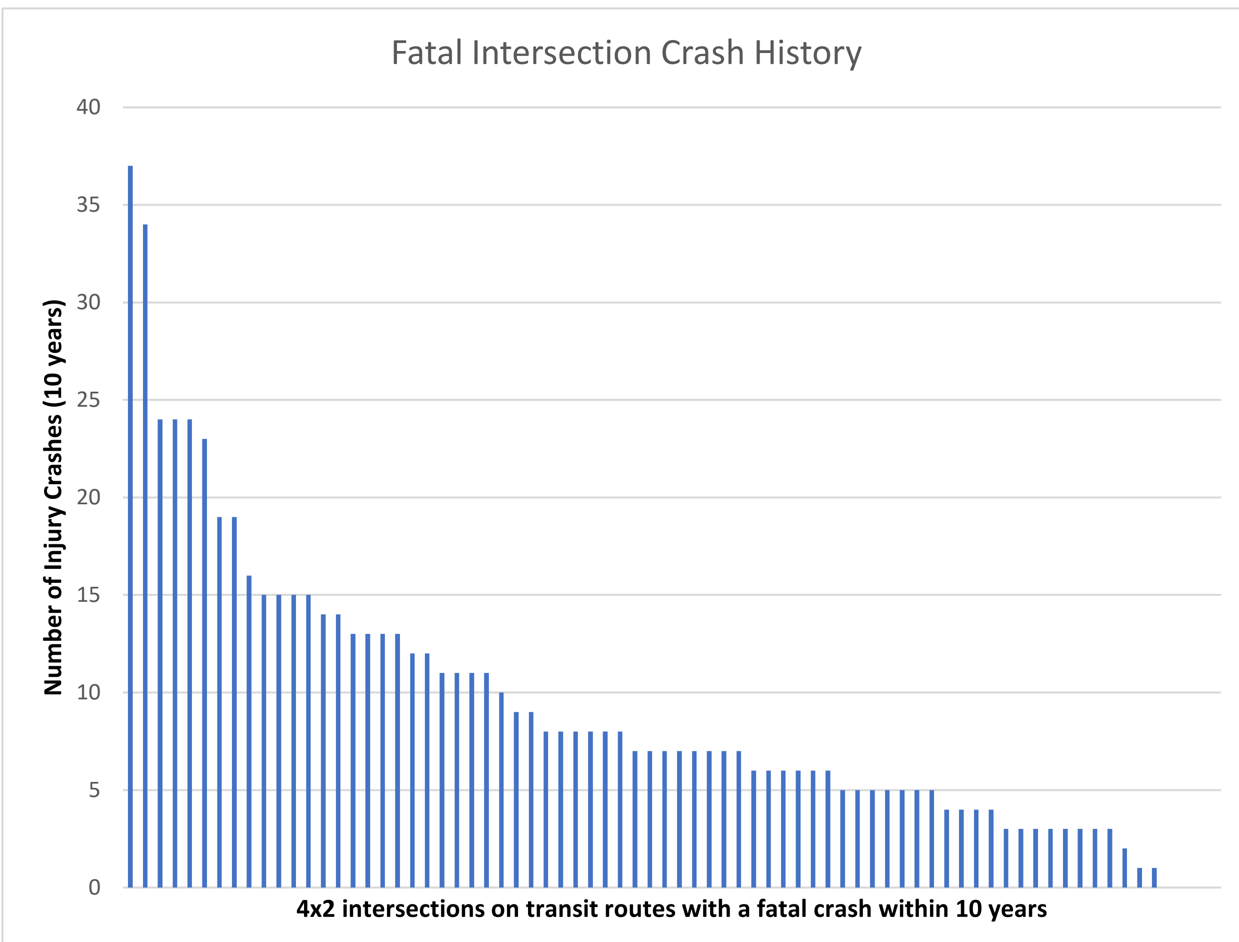
The value at the top of each bar represents the % of crashes at intersections with the mentioned traits (overlap of all three circles above) divided by the % of City intersections that have all those traits (overlap of yellow and red circles above). Values greater than 1 indicate a positive correlation between that trait or combination of traits and fatal crashes. The greater the value, the higher the risk of a fatal crash. In the case of the highest number here, based on 10 years of crashes:

$$\frac{\text{(76 fatal crashes at intersections with all traits / 301 fatal crashes at intersections)}}{\text{(503 intersections with all traits / 16,892 intersections)}} = 8.5$$

The same calculation for 2-lane streets intersecting with 2-lane streets along transit routes with a history of injury crashes (37 fatal crashes and 579 intersections) results in a value of 3.6. It might seem better to continue with investments at 4x2 intersections along transit routes that don't have a history of injury crashes since that value is 6.6, but without the intersections that have already been improved, that category has 223 intersections left, 11 of which had fatal crashes, so its value drops to 2.8, meaning it is better to address 2x2 intersections next.



90% of the intersections that experienced a fatal crash had 3 or more injury crashes in the same 10-year period.



Intersections on transit routes involving two 2-lane streets experienced a similar increase in effectiveness when limiting the locations with fatal crashes to locations with prior injury crashes. However, in the case of 2-lane streets intersecting with 2-lane streets, 75% of the intersections had 2 or more injury crashes in the same 10-year period. This indicates that the number of injury crashes may act as a surrogate for exposure, with intersections along narrower, lower-volume 2-lane streets requiring a lower threshold than intersections along wider, higher-volume 4-lane streets.

What countermeasure projects are effective?

There are several countermeasures that have been proven to reduce or eliminate fatal crashes for certain modes. The City of New York found that leading pedestrian intervals reduced fatal and severe pedestrian and bicycle crashes by 56%.

Roundabouts have been proven to eliminate 90% to 100% of fatal crashes for all modes at intersections. In fact, there are over 10,000 roundabouts in the United States, many in place for over a decade now, and although there have been 6 fatal pedestrian crashes and 4 fatal bicycle crashes at roundabouts in the US (https://usa.streetsblog.org/2022/09/21/study-some-roundabout-designs-slash-crash-injuries-up-to-85), there has never been a fatal pedestrian or bicycle crash at a roundabout crosswalk in the US.

This level of safety is achieved because crosswalks at roundabouts fully embody Safe Systems principles (low crash energy and redundancy against mistakes), so it is easy to see why they are such an important option to consider when selecting an effective project. Roundabouts have traditionally cost millions and been slow to construct, but recent innovations in curb materials and installation methods have cut the potential cost below $100,000 at locations with enough space and the right traffic conditions. That cost continues to drop as the industry continues to innovate. It is now possible to consider roundabouts as a systemic countermeasure and apply them preventatively where fatal crashes haven't happened yet. Roundabouts have also been proven to reduce fuel consumption and emissions, are included in the Climate Action Plan, are good for the economy (https://trid.trb.org/View/775405), and continue working when the power goes out, providing climate resilience to the City's transportation network.

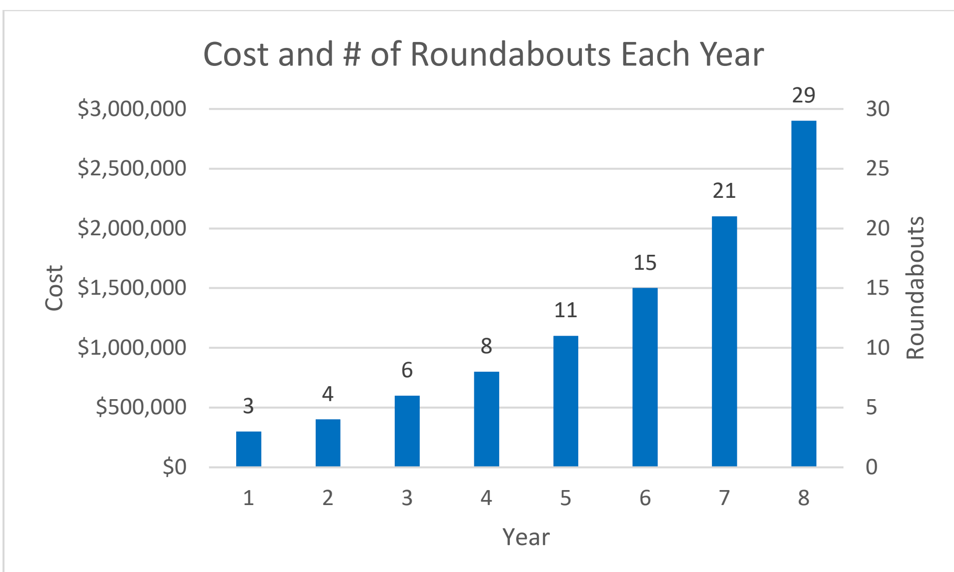
Potential Improvements Based on This Analysis

Each systemically identified location must be evaluated for the appropriateness of each type of proposed improvement, and the level of investment in these improvements is subject to change every year. This section describes possible improvement types and potential screening considerations for application.

Quick-build Roundabouts

Quick-build roundabouts cost 10 times less than their traditional counterparts. They should be widely installed at systemically identified locations because of their 90%-100% effectiveness at eliminating fatal crashes of all modes.

Quick-build roundabouts are most effective at 4-leg, right-angle intersections along 4-lane streets where a single circulating lane can accommodate the volume of traffic. After evaluating all potential locations, on the order of 100 locations will likely be good candidates for quick-build roundabouts, out of about 500 that are at the highest risk of a fatal crash within approximately 17,000 intersections citywide. At about $100,000 for each quick-build roundabout, this represents roughly a $10 million investment to complete 100 roundabouts over several years. Each one is currently customized, so it will take a few years to ramp up installation with an efficient delivery pipeline. The following chart shows what this could look like in terms of the number and cost of quick-build roundabouts installed each year assuming a 50% annual increase in system capability.



Leading Pedestrian Intervals

Leading Pedestrian intervals (with their associated electronic signs that reduce conflicts between crossing pedestrians and vehicles turning right) are far less expensive than roundabouts, but they are also less effective at preventing fatal crashes.

Leading Pedestrian Intervals can only be installed at signalized intersections but can be effective at 4-leg and 3-leg intersections, and at intersections on 4-lane and 2-lane streets. After evaluating all potential locations and subtracting locations that already have this improvement (the City has been installing them for years) and subtracting locations that are planned for a quick-build roundabout, on the order of 200 locations will likely be good candidates for Leading Pedestrian Intervals (with electronic signs) out of about 500 that are at the highest risk of a fatal crash within approximately 17,000 intersections citywide. At $5,000 each, this represents roughly a $1 million investment. Since the City already has extensive experience installing them, no ramp is needed, and the 200 can be divided evenly over the same 8 years at 25 locations per year.

Since Leading Pedestrian Intervals are only 56% effective, and only prevents fatal crashes involving pedestrians and cyclists (about 60%), their effectiveness is diminished to 1/3rd that of a roundabout. However, at $5,000, their cost is 1/20th that of a quick-build roundabout, so it is also worth investing in these.

Comparing quick-build roundabouts to Leading Pedestrian Intervals, one might conclude that they should always be preferred. However, even if they were installed at every traffic signal, they are not effective at preventing fatal crashes that don't involve pedestrians or cyclists, and they cannot be installed at unsignalized intersections. This limits Leading Pedestrian Intervals to preventing at most 1/5th of fatal crashes at intersections (0.56 effectiveness x 0.60 ped/bike x 0.5 of fatal intersection crashes are at signals).

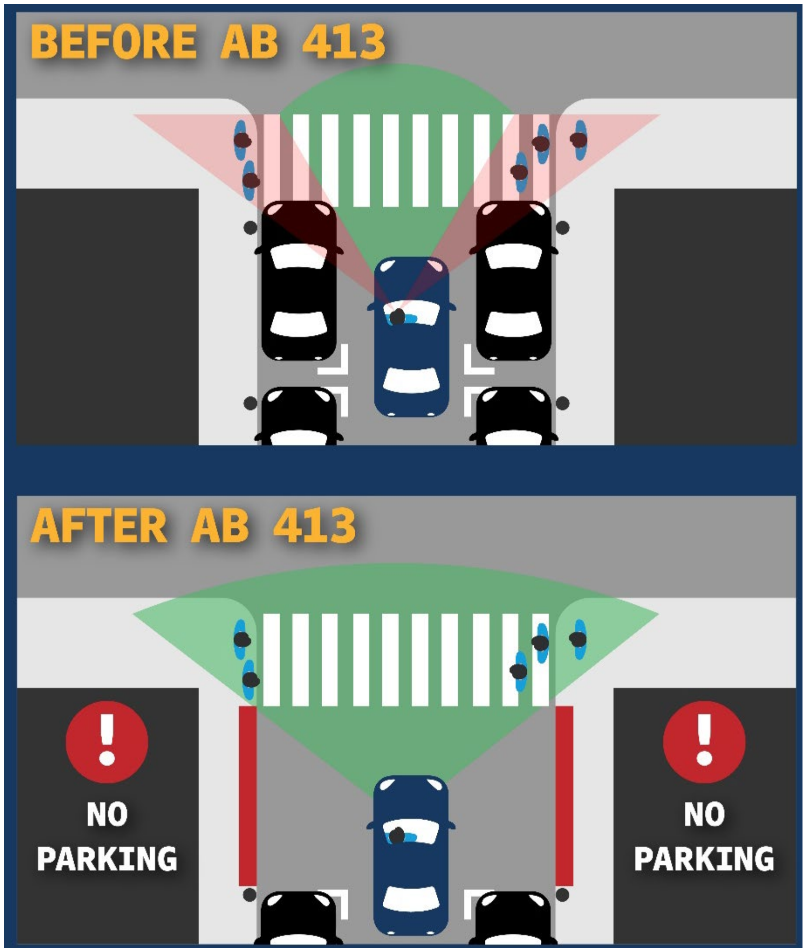
Quick-build Pedestrian Refuge Islands

Quick-build pedestrian refuge islands can be installed at 3-leg unsignalized intersections in the shadow of the left-turn pocket on the major street (common in Europe). At intersections along 4-lane streets with higher traffic volume, a Rectangular Rapid Flashing Beacon may be used to supplement the unsignalized crosswalk.

Although the City doesn't have enough experience with these to estimate the cost or benefit of these in combination, both improvements have separately been proven to prevent fatal crashes involving people crossing the street (https://www.cmfclearinghouse.org/study_detail.php?stid=652, https://highways.dot.gov/safety/proven-safety-countermeasures/guidance-memorandum-consideration-and-implementation-proven#8).

Daylighting

Daylighting was recently adopted into California law and includes removing parking near crosswalks to improve the visibility of and for people crossing and vehicles turning onto or crossing the street. This is a very low-cost improvement (higher when accounting for the cost of lost parking). Red curb or no-parking signs can be evaluated for at every 4-lane and 2-lane intersection with 2-lane streets along transit routes with a history of injury crashes. Even if another improvement is planned, this improvement can likely be done sooner and will complement each of the other improvements mentioned here.



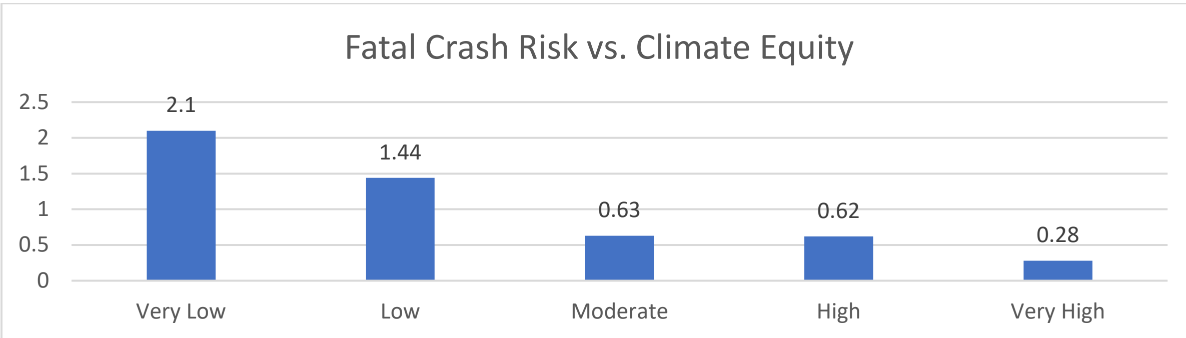
The City is embarking on its full implementation of the provisions of Assembly Bill 413 with details available here: https://www.sandiego.gov/parking/enforcement/daylighting.

Illumination

In addition to the ongoing evaluation for street lights at fatal crash, high-crash, and community requested locations, each of the about 500 high-risk locations in this analysis that don't already have street lights should also be evaluated for illumination, as it compliments each of the improvements mentioned here.

Finally, these improvements are not intended to be exhaustive, but priority should be given to those improvements with a track record for reducing fatal crashes and those that embody the safe system principles of low crash energy (low speed and conflict angle) and accommodation of human mistakes (direct, simple interaction that allows others to compensate).

To emphasize the importance of considering equity as memorialized in the Prioritizing of Capital Improvement Projects, Council Policy 800-14, the following chart shows the relative risk of fatal crashes across the five categories of access to opportunity.



Conclusion and Application

This report provides a robust and efficient alternative method to identifying locations and improvements that will reduce the risk of fatal crashes. It can be used in place of traditional methods of requesting and analyzing crash data for projects and plan updates. If there are locations that fit these descriptions within the impact area of a development or within a community plan, improvements that embody safe systems principles can be evaluated for inclusion at those locations without first doing extensive analysis of crash data to identify high-risk locations.

Credits

Thank you to the following City teams who provided technical analysis and expert advice, collected and organized roadway data, and verified crash reports and field conditions.

- Deputy Directors – Duncan Hughes, Maggie McCormick
- Program Manager – Everett Hauser
- Senior Traffic Engineers – Phil Rust, Joshua Lahmann
- Associate Engineer – Matthew Balan
- Junior Engineer – Sinan Daraji
- Geographic Information Systems Analysts – Trevor Merback, Christopher Nixon
- Interns – Zudai Farah, Vivian Park

XXX