Case Studies on Implementing the Safe System Approach in the U.S.

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A Community of Transportation Professionals

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Cover Image. Example of a Protected Intersection in Chicago, IL, USA that applies separating users in space and time as part of the Safe System Approach. Source: Sarah Abel/ITE.

1. Introduction

The Safe System Approach aims to reduce serious injury and fatal crashes by designing and operating roadways in a manner that anticipates human error and accommodates human injury tolerances. Safe System applications vary based on roadway conditions, type, and safety interventions necessary, and they range from separating users in space or time to increasing attentiveness to reducing impact forces. The following case studies outline the Safe System Approach applied on some of the more common types of roadway serious injuries and fatalities in the United States. The case studies outline on-the-ground practices in the following three areas of need: major thoroughfares, intersections, and pedestrians. While few U.S. states or cities are comprehensively using the Safe System Approach, the case studies outline key elements of the Safe System Approach applied by public agencies, both large and small, across the United States.

2. The Safe System Approach to Retrofitting Major Thoroughfares

In this case study, you will learn how cities are retrofitting major thoroughfares using elements of the Safe System Approach to reduce serious injury and fatal crashes.

Many agencies are starting to map high injury networks[1], using data to determine streets that have a high number of serious injuries and fatalities, which are often major thoroughfares, arterials, and collectors. These are typically finalized and mapped as a High Injury Network (HIN). Once an agency has determined a high-injury street, the next step is to understand crash causation and begin to make design decisions that prevent future occurrences of those crashes or to design the road so that if a crash occurs, the injuries are less severe. While the HIN is a mostly-reactive safety strategy, based on historical collision trends, often when agencies analyze their high injury networks, the results show crashes and roads illustrative of key crash and contextual typologies that can be systemically extrapolated.

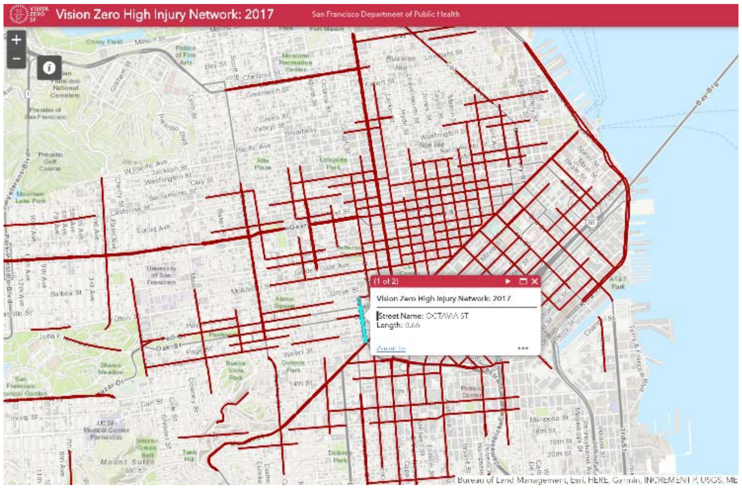

Figure 1. Screenshot of San Francisco, CA, 2017 High Injury Network GIS Map showing Octavia Boulevard Source: San Francisco Department of Public Health/ERSI.

In **San Francisco, CA,** the development of a HIN and Traffic Fatalities Map uncovered trends and informed Vision Zero improvements. Critically, the HIN features locations with both high crash numbers and high collision rates, to address exposure more fully in the data analysis. The City has been conducting a focused multi-modal safety study on many of the corridors identified through the HIN, such as the high-speed arterials of 6th Street and Taylor Street in the South of Market to Tenderloin neighborhoods, and Octavia Boulevard near freeway off ramps.

Anticipates Human Error

Accommodates Human Injury Tolerance

[1] https://visionzeronetwork.org/hin-for-the-win/

After analyzing the four fatal crashes near Octavia Boulevard since 2014—three of which were pedestrian crashes at intersections—the City of San Francisco Municipal Transportation Agency (SFMTA) took a systemic approach to reducing pedestrian crashes by reducing the turning speed of vehicles at intersections. To reduce the impact forces of crashes at intersections near Octavia Boulevard, the city installed sidewalk curb extensions and pedestrian islands, hardened curb radii, and installed ladder-style crosswalk markings to reduce speeds of vehicles and increase visibility of pedestrians. These strategies increase attentiveness by improving the visibility of pedestrians and reduce speeds to minimize the consequences if a crash occurs. The SFMTA also installed median islands to provide refuge areas and shorten crossing distances for pedestrians at intersections. Strategies that separate users in either space or time are examples of applying the Safe System Approach. The City also implemented leading pedestrian intervals for pedestrian crossings, an example of a strategy for separating users in time. To learn more about the ongoing Octavia Boulevard project, visit https://www.sfmta.com/projects/octavia-boulevard-enhancement-program.

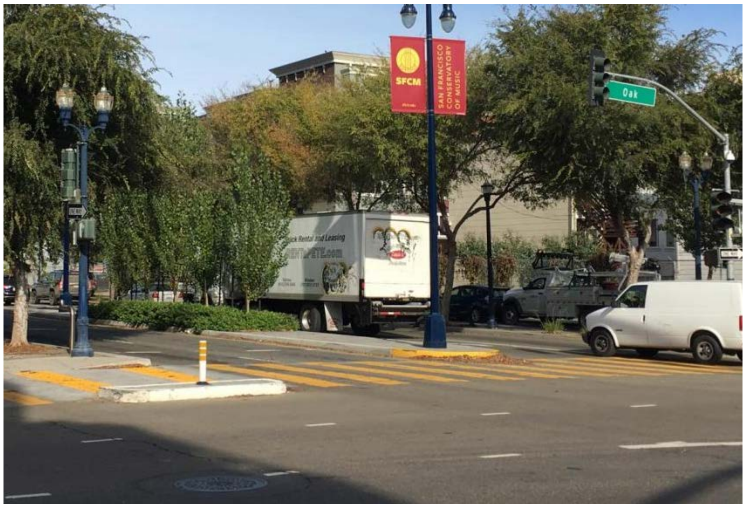

Figure 2. Completed curb extensions, pedestrian islands, LPI crossings at Octavia and Oak in San Francisco, CA, USA. Source: SFMTA.

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Another systemic approach to retrofitting major thoroughfares is the multi-phase redesign of Queens Boulevard in **New York City, NY**. New York City Department of Transportation (NYCDOT) analyzed the types of crashes that were occurring along Queens Boulevard and made context-specific safety improvements that reduced the severity of the crashes, taking Queens Boulevard from what was referred to as the “boulevard of death” to a safer thoroughfare for all road users.

Looking at the types and causes of fatal crashes, NYCDOT knew that pedestrians were some of the most vulnerable road users on this corridor. From 1993 to 2000, 72 pedestrians were killed crossing Queens Boulevard.[2] The redesign, which started in 2015, improves crossings and access for pedestrians and bicyclists, allowing for enhanced pedestrian crossings that are more frequent, and providing a lower stress bicycle infrastructure. The countermeasures installed on Queens Boulevard include high-visibility crosswalks, leading pedestrian intervals, and pedestrian islands with concrete barriers to increase safety of crossing pedestrians, and limit conflicts between vulnerable road users and vehicles by separating users in space and time. The Queens Boulevard redesign also incorporates separated bike lanes, more signalized intersections, reduced speed

Figure 3. Queens Boulevard pedestrian improvements, bike lanes, and physical barriers that separate users in space. Source: NYCDOT

limits, and increased enforcement programs to slow traffic and reduce kinetic forces if a crash were to happen. The conversion from an arterial to a multimodal boulevard is the Safe System Approach as it incorporating safe roads, safe speeds, and safe road users to prevent future crashes. This Safe System Approach contributed to reducing crashes by 35 percent since 2017. To learn more about the ongoing improvements to make Queens Boulevard safer, visit the NYCDOT project page: https://nycdotprojects.info/queens-blvd.

[2] https://en.wikipedia.org/wiki/Queens_Boulevard

A third example of the Safe System Approach on a major thoroughfare is North Avenue in **Wauwatosa, WI**. The city installed designated bike lanes with high visibility pavement markings along the main thoroughfare through the town after seeing an increase of bicyclists and associated crashes caused by motor vehicles and bicyclists trying to access area businesses. Since many of the conflicts occurred at intersections near the business district, the city installed bicycle boxes and detections to allow bicyclists a designated area to stop at traffic signals ahead of motor vehicles, separating the users in space and time at the intersections. The treatments were installed at intersections both with and without crash history following a systemic implementation approach. No fatal crashes on the thoroughfare have occurred since the bicycle infrastructure improvements were installed, despite a continuing increase in bicycle ridership. Full details of the systemic safety improvements on Wauwatosa's North Avenue can be found at https://www.ayresassociates.com/project/wauwatosa-east-north-avenue-bike-lane-plan/.

Figure 4. High-visibility bike box on North Avenue in Wauwatosa, WI, USA. Source: wisconsinbikefed.org

Anticipates Human Error

3. The Safe System Approach to Intersections

In this case study, you will learn how the Safe System Approach to intersection design can reduce serious injury and fatal crashes at intersections. A core element of the approach is understanding how crash causes and the types of crashes at intersections can determine safety solutions.

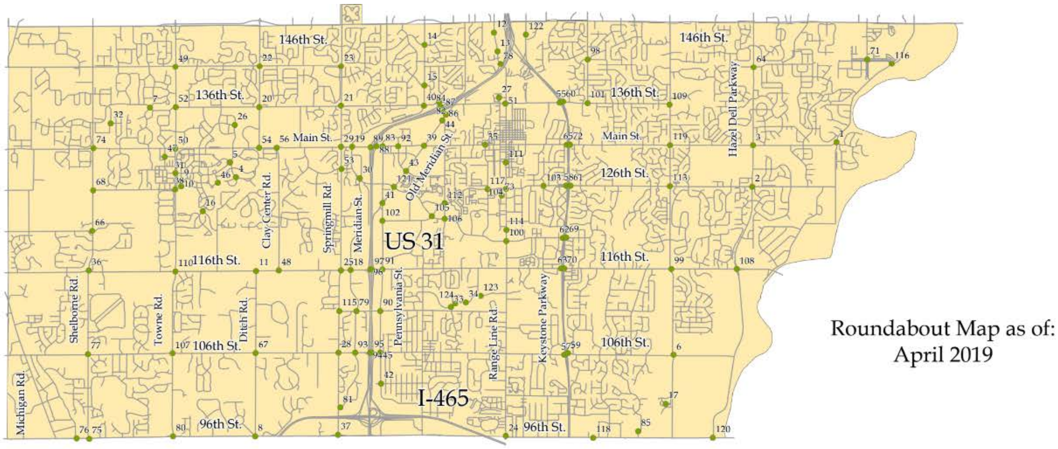

Figure 5. Map of Carmel, IN, USA with over 125 roundabouts (shown as green dots) across the city. Source: city of Carmel, IN.

According to the National Highway Traffic Safety Administration (NHTSA), about 40 percent of crashes that occurred in the United States are intersection-related.[3] Some jurisdictions across the United States are beginning to deploy the Safe System Approach to intersection design, from the roundabout program in Carmel, IN to "turn hardening" programs in New York City, NY, and Washington, DC. Two other examples of the Safe System Approach to intersections involve a system-wide daylighting and parking restriction resolution passed in San Francisco, CA, and an intersection video analytics system used by engineers to review crashes at key intersections in Bellevue, WA.

Figure 6. Aerial photo of the latest roundabout in Carmel, IN, at 96th Street and Gray Road, which was fully operational in October 2019. Source: City of Carmel Government Facebook.

Since 1997, **Carmel, IN,** has taken the Safe System Approach to intersection design by installing roundabouts at intersections wherever possible. The city of Carmel took a systemic approach by converting more than 125 intersections to roundabouts to improve safety citywide, regardless of crash history.[4]

Anticipates Human Error

Roundabouts move people through intersections more

Accommodates Human Injury Tolerance

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[3] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811366

[4] https://www.smartcitiesdive.com/news/roundabouts-carmel-in-mayor-jim-brainard-uscm/571074/

efficiently and safer than stop signs or signalized intersections.[5] With roundabouts now at so many of the city's intersections, Carmel has seen serious injury crashes reduced by about 80 percent.[6] The Mayor of Carmel instituted the comprehensive roundabout program to prioritize safety after learning from Europe that roundabouts eliminate right angle and head on crashes, and reduce pedestrian conflict crashes. In addition, roundabouts slow the speed of vehicles maneuvering through an intersection, thus reducing the kinetic forces and crash severity if a crash occurs.

In the fall of 2019, the city of Carmel took the Safe System Approach one-step further at the roundabouts by converting the 15-mph yellow speed advisory signs in the roundabouts to white posted speed limit signs, making the speed limit of vehicles in the roundabout enforceable. Carmel is also moving forward on an ordinance that will require cars to stop at all crosswalks if a pedestrian is about to cross, rather than just if a pedestrian is already in the roadway.[7] Both additional safety measures will further enhance safety at roundabouts and throughout Carmel, a city that already has one of the lowest transportation fatality and car insurance rates in the country.[8] [9]

Accommodates Human Injury Tolerance

Figure 7. Graphic and image of left turn hardening using flex posts and pavement markings at two one-way streets intersecting in New York City, NY, USA. Source: NYCDOT.

Another Safe System Approach element for intersection design is a comprehensive "turn hardening" program. **New York City, NY,** began installing turn hardening measures, using mostly flex posts and pavement markings as a key element of their Vision Zero strategy. The devices were installed at intersections where data analysis identified that left turns resulted in death and serious injuries for people walking and biking three times as often as right-hand turns.[10] Evaluation of the left-turn hardening treatments showed a marked reduction in median speeds (24 percent lower) and of drivers crossing the double yellow line (98 percent fewer).

The District Department of Transportation (DDOT) in **Washington, DC**, identified high-injury intersections where turning movements resulted in serious injury and fatal crashes, then analyzed crashes at those intersections and conducted site visits to observe actual intersection conditions.[11] Implemented Safe System elements ranged

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[5] https://www.wsdot.wa.gov/Safety/roundabouts/benefits.htm
[6] http://carmel.in.gov/department-services/engineering/roundabouts
[7] http://youarecurrent.com/2019/09/17/carmel-mayor-proposes-lowering-roundabout-speed-limits-requiring-cars-to-stop-at-crosswalks/
[8] https://www.startribune.com/are-roundabouts-really-safer-than-traditional-intersections/561251111
[9] http://youarecurrent.com/2014/05/12/study-carmel-has-some-of-the-lowest-car-insurance-costs-in-indiana/
[10] https://www1.nyc.gov/html/dot/html/about/leftturnstudy.shtml
[11] https://ddot.dc.gov/sites/default/files/dc/sites/ddot/page_content/attachments/2016%20High%20Crash%20Intersection%20Site%20Visits%20Final%20Report.pdf

from separating users in space by installing left turn hardening posts, separating users in time by instituting no turn on red movements, and reducing kinetic forces by slowing speeds of turning vehicles through tighter corner radii or slip lane removal.[12]

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San Francisco, CA, has used Safe System elements at intersections by "daylighting intersections." This involves restricting on-street parking close to intersections to improve driver and pedestrian visibility at crosswalks. In May 2019, the city passed a resolution creating a comprehensive approach to removing on-street parking spaces that block intersection sight angles on high injury corridors or at intersections where visibility restrictions contributed to crashes. This Safe System element anticipates human error associated with limited sight lines. To learn more about the intersection daylighting approach in San Francisco, CA, including how the City worked to implement parking restrictions in support of safety, visit https://sfbos.org/sites/default/files/r0248-19.pdf.

Anticipates Human Error

The city of **Bellevue, WA**, uses artificial intelligence (AI) to identify potential safety issues based on near miss metrics. Artificial intelligence uses machine learning to analyze footage collected from traffic cameras at intersections to identify patterns, determine safety thresholds, and find instances where the threshold is not met. This data allows engineers to determine safety

Figure 8. Video footage with analytics of a near miss crash at 108th Ave. that were used to analyze possible future safety improvements in Bellevue, WA, USA. Source: city of Bellevue, WA.

improvements to prevent reoccurring crashes. The use of AI technology allows engineers to study and understand crash causation in real-time rather than in a reactive way days later after law enforcement completes crash reporting. The real-time video footage allows more

[12] https://ddot.dc.gov/release/ddot-launches-new-safety-measures-support-mayor-bowsers-vision-zero-initiative

information for an engineer to make safety improvements to ensure future crashes are less severe. To learn more about how the intersection video analytics in Bellevue, WA, are being used to understand crash causation to prevent repeat crashes, visit https://bellevuewa.gov/city-government/departments/transportation/safety-and-maintenance/traffic-safety/vision-zero/video-analytics.

4. The Safe System Approach to Pedestrian Safety

In this case study, you will learn about Safe System elements that separate pedestrians in space and time from motor vehicles to reduce the risk of vulnerable road user severe injuries and fatalities.

Cities are starting to look at ways to protect pedestrians, knowing fatality rates of pedestrians involved in crashes continue to increase and pedestrians are particularly vulnerable to injuries based on kinetic forces.

Anticipates Human Error

The city of **Oakland, CA**, systemically uses Highway Safety Improvement Program (HSIP) applications for pedestrian countdown signals and signal mast arms in Downtown Oakland. This is one of the strongest examples of creatively using HSIP funds with a high benefit-cost ratio by addressing key locations where injuries and fatalities occurred while also treating locations that look similar through a downtown-wide implementation. In this example, the major issue was red light running and pedestrian collisions occurring as a result. The City of Oakland Department of Transportation (OakDOT) Strategic Plan contains more information about the systemic approach to safety in Downtown Oakland: http://www2.oaklandnet.com/w/oak060949.

Figure 9. An infographic from San Francisco Vision Zero depicts the likelihood of a pedestrian fatality involved in a crash based on speed. Source: SFMTA.

Another pedestrian safety example from Oakland is their signalization policy to accommodate pedestrians. As part of the International Boulevard Bus Rapid Transit project, the City needed to make decisions about where to place transit stops and how to treat pedestrian crossings at those stops. Rather than making decisions for just the corridor, the City created a policy for all signalized intersections in Oakland. The City developed thresholds for leading pedestrian intervals, protected left turns, scrambles, right-turn-on-red prohibition, and other countermeasures to consistently and systemically enhance pedestrian safety at signals in Oakland. The decision-making process consolidated Caltrans and federal standards as well as NACTO best practices where standards are not available. The OakDOT Oakland Walks Pedestrian Master Plan contains more information about the citywide crosswalk policy: http://www2.oaklandnet.com/oak/groups/pwa/documents/report/oak063431.pdf

Anticipates Human Error

The city of **Chicago, IL,** developed Tools for Safer Streets for pedestrians, including roadway improvements at intersections, corridors, and neighborhood streets where pedestrians are vulnerable to crashes. The City of Chicago's Pedestrian Plan includes systemic deployment of pedestrian safety countermeasures across the city. Most of the safety improvements were installed in a proactive strategy, using factors like pedestrians present, speed, and road type to select enhancement locations. The toolkit includes the following 16 pedestrian safety measures: marked crosswalks, in-road "State Law Stop for Pedestrians" signs, pedestrian refuge islands, signals and beacons, accessible pedestrian signals, pedestrian countdown timers, leading pedestrian intervals, lagging left turns, road diets, speed feedback signs, roundabouts, chicanes, vertical traffic calming, skinny streets, bump-outs, and neighborhood traffic circles. Most of the pedestrian safety improvements separate users in space and time, thus reducing the risk of serious injury or fatality of pedestrians. For example, installing refuge islands reduced pedestrian crashes by 56 percent. Many are also focused on traffic calming, which rationalizes speed and encourages safer behavior in locations with vulnerable road users. To learn more about the City of Chicago Tools for Safer Streets for pedestrians, view the Pedestrian Plan: https://www.chicago.gov/content/dam/city/depts/cdot/street/general/ToolsforSaferStreetsGuide.pdf.

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