INFO BRIEF

Safety-Based Prioritization for Youth Pedestrian Travel Planning

Applying systemic pedestrian safety analysis to youth travel

Vision Zero for Youth

Pedestrian and Bicycle Information Center
www.pedbikeinfo.org

Children and youth travel around their communities for school, play, work and a variety of other reasons. Sometimes they walk because they prefer to and at other times it is their only option. Addressing safety concerns in places where youth walk – or might walk if conditions were better – is critical to protecting young people and supporting their independence and mobility. Funds for safety improvements are always limited, so a framework for decision making is needed to identify the locations that require the most urgent attention.

A traditional approach to road safety includes a strong focus on road user (pedestrian, bicyclist, and driver) behavior through education, regulation and enforcement. Where roadway engineering is considered, the focus is typically on treating locations with high crash rates. When considering youth, the approach has historically been to focus on a few key school routes where students are likely to walk. A growing number of cities and states are now applying a systemic approach to addressing pedestrian crashes, which is more proactive and comprehensive when compared to traditional approaches. Systemic analysis identifies not only where severe or fatal crashes have already occurred, but also locations that have similar roadway and environmental characteristics where the risk of future crashes is higher. Applying systemic analysis to child and youth crashes means that communities will have tools to identify and address safety problems before a child is injured or killed.

The role and opportunity for Vision Zero for Youth

Around the world, communities are committing to eliminating traffic fatalities and serious injuries using Vision Zero. A growing group of these cities is focused on improving safety around schools and other places where children and youth walk and bicycle.

Prevention of youth pedestrian crashes deserves special consideration. These crashes do not necessarily happen at the same locations as overall pedestrian crashes and the risk factors involved can be different.

Vision Zero for Youth recognizes that starting by addressing youth safety can be the catalyst to build community and political support for Vision Zero and lead to improving safety for road users of all ages.

Read more at **www.visionzeroforyouth.org**.

While the systemic approach is becoming more widely used in transportation planning, it has never been applied specifically to understanding youth travel risks. The *National Cooperative Highway Research Program (NCHRP) Research Report 893 -Systemic Pedestrian Safety Analysis*[1] *(Systemic Pedestrian Safety Analysis)*, describes a process for identifying and prioritizing high risk locations and applying countermeasures to prevent serious pedestrian crashes. This information brief applies the steps in the *Systemic Pedestrian Safety Analysis* report to present a process for assessing high risk locations for youth pedestrian crashes specifically. It also draws heavily on participation in the development of the *Systemic Pedestrian Safety Analysis* report, knowledge gained from the Pedestrian and Bicycle Information Center (PBIC) Vision Zero for Youth Demonstration Project with the city of Philadelphia using a systemic approach for compiling data and assessing risk factors for youth pedestrian crashes; and the work of the PBIC and National Center for Safe Routes to School to understand and prevent child pedestrian and bicyclist injuries and deaths.

Vision Zero, Safe System, and systemic planning

Vision Zero is a strategy to eliminate all traffic fatalities and severe injuries while increasing safe, healthy, equitable mobility for all.[2] A Safe System approach serves as the foundation.

A Safe System accepts that human errors are inevitable but fatalities and serious injuries are not. The concept proposes that road design take into account these errors and uses proactive measures to reduce the frequency and severity of crashes.[3] Creating a Safe System is a coordinated effort between policymakers, transportation planners/designers, and road users to prevent future severe injuries and deaths from traffic crashes.

A core element of Vision Zero and a Safe System is a **proactive, systemic** approach to planning. A systemic approach uses crash and roadway data to identify high-risk roadway characteristics that correlate with crashes. While agencies have traditionally relied on crash history data to identify locations with high crash frequency, severe crashes are often widely dispersed, and their location and occurrence can change over time. Systemic analysis helps agencies identify locations that are at risk for severe crashes, even if there is not a high crash frequency, and provides agencies with information to identify and focus resources on the highest-risk locations.[4]

Principles of a Safe System

- Humans make errors
- Humans are vulnerable to injury
- Responsibility is shared
- No death or serious injury is acceptable
- Proactive vs. reactive

The systemic approach applies a layer of risk analysis that can strengthen traditional approaches to youth travel planning (including Safe Routes to School efforts) and expand the benefits to the larger community.

Applying a systemic pedestrian safety process for youth travel

In 2019 the PBIC with Toole Design Group partnered with the city of Philadelphia to implement a Vision Zero for Youth Demonstration Project (subsequently referenced as "Demonstration Project" for brevity within this document). One part of the project involved piloting a methodology to provide city staff with an understanding of risk factors for youth pedestrian crashes to support future analysis and recommendations for a youth-focused approach to advance safety for all road users. As a demonstration project, the broader goal was to offer a way to make proactive prevention of youth crashes more practicable and attainable by jurisdictions across the United States.

The systemic approach described below follows the steps outlined in *Systemic Pedestrian Safety Analysis* report and then uses Geographic Information Systems (GIS) data to understand high-risk locations for youth pedestrian travel. Each step includes youth-specific considerations.

Steps include:

Step 1 - Define the study scope
Step 2 - Compile data
Step 3 - Determine the risk factors
Step 4 - Identify potential treatment sites
Step 5 - Select potential countermeasures
Step 6 - Refine and implement treatment plan
Step 7 - Evaluate program and project impacts

Step 1: Determine the study scope

The first step is to identify a focus, or targeted risk problem that serves as the base for subsequent steps. This includes defining the network area (the complete network of streets within a defined area) and identifying pedestrian crash location types (e.g. intersections or segments) and crash types (e.g. vehicle and pedestrian movements) for analysis. The *Systemic Pedestrian Safety Analysis* report recommends using either all pedestrian crashes or all fatal and injury crashes to allow an adequate sample of crashes for analysis. While systemic analysis typically begins with an assessment of crashes, local pedestrian crash data may be limited in both quality and detail. If adequate crash data is not available, high risk locations may still be assessed by using risk factors for serious injury or fatal pedestrian crashes. See Step 2, Roadway Data, for a description of these risk factors.

Youth considerations

For putting this approach into context to address youth travel, this means defining a network area that captures locations where youth are likely to walk and using youth pedestrian crash data. For some locations, it may be necessary to use all-ages pedestrian crash history to have an adequate sample size. Later steps provide ways to consider risk factors in the analysis that increase the potential for severe injuries and fatalities, as well as ways to focus on youth.

It may be helpful to first obtain a count of, and then map, all-ages pedestrian crashes over a five-year period, then create a separate map of youth pedestrian crashes to determine differences in magnitude and location. This process may reveal differences or similarities between youth pedestrian and all-ages pedestrian crash distribution throughout the study area.

The Demonstration Project identified the School District of Philadelphia (which spans the entire city) as the network area and determined the crashes for youth under age 18 to be a sufficient sample size (Figure 1). Crashes were not separated by location and type. While simplicity of approach is one benefit, it also makes the process possible for jurisdictions that lack crash type information. Moreover, because there has not been much research on youth pedestrian crashes, many of the existing pedestrian crash types may be irrelevant or infrequent relative to youth pedestrians and could lead to over-filtering the crashes without leading to significant insights on crash patterns or key risk areas.

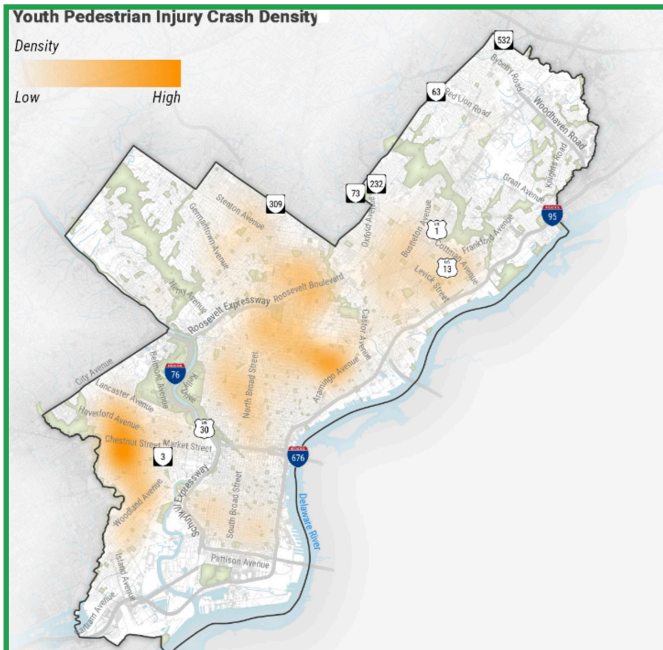

Figure 1. Philadelphia Youth Pedestrian Crash Density, 2014-2018

Step 2: Compile data

Because a systemic approach is inherently data-driven, it is necessary to compile data to use for subsequent steps to determine risk factors and identify potential treatment sites (Steps 3 and 4). This includes roadway data, pedestrian volume or exposure proxy data and land use and socioeconomic data.

Roadway data

Roadway characteristics will be used in later steps to identify potential risk factors and treatment sites. The *Systemic Pedestrian Safety Analysis* report lists specific roadway factors for intersections and segments, but several of the factors listed include specific traffic controls and/or other data elements that may not be readily available to most jurisdictions for GIS analysis at a large scale.

Risk factors for serious injury or fatal pedestrian crashes have been identified through professional experience and published transportation research including the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual, Federal Highway Administration research studies, NCHRP reports, and Transportation Research Board (TRB) papers. Research indicates that multi-lane roads, higher motor vehicle speeds and traffic volumes in places where people are likely to be walking create greater risk of serious injury or fatal pedestrian crashes. This is particularly true in locations that lack adequate pedestrian safety infrastructure.[5]

Youth considerations

The pedestrian risk variables for youth may be different than those for the general population. For example, more youth crashes may occur on local roads or roads with lower speed limits. The Demonstration Project used available roadway data and research, and focused on the following short list of key roadway characteristics for future risk determination with the understanding that a high-level determination of risk can still be used to identify potential treatment sites and additional data collection can be obtained at those sites in future steps through field work:

- **Posted speed limit**
  If speed studies have been completed on all identified roadways, then actual speed data is preferred. However, if speed studies are only conducted on parts of the network, then posted speed limits may be used but should not be combined with actual speeds data.
- **Traffic volume/average annual daily traffic (AADT)**
  Functional road classification may be used as a proxy if AADT is not available.[6]
- **Number of traffic lanes**
  Functional road classification or roadway width may be used as a proxy if the number of lanes is not available. Residential roads may be assumed to be a proxy for non-multi-lane roads (although this is not always the case) and narrower roads may indicate fewer lanes.
- **Sidewalk coverage**
  Recognizing that many jurisdictions may not have this information in GIS form, it is possible to pursue the risk analysis using only the three roadway characteristics listed above. However, it is recommended that jurisdictions consider collecting this data for improved pedestrian safety planning in the future.

Pedestrian volume or exposure proxy variables

If available, pedestrian count data is the most accurate indicator of pedestrian exposure, but most agencies do not have this data available network wide. Several proxy measures of pedestrian activity exist but may not be applicable for youth pedestrians. For example, employment density is a common proxy for pedestrian exposure but is more applicable to adult travel than youth travel.

Youth considerations

With a focus on youth travel it is important to consider proxies that are likely to capture where youth walk.

Data on two youth pedestrian exposure proxy variables were collected because individually each may not fully represent youth pedestrian volumes:

- **Household density** (Census data)
- **Proximity to schools**

The Demonstration Project also incorporated an equity variable to represent traditionally underserved populations (see "Equity in Transportation Planning" feature box[7]). The project team started with low income household density, measured using Census data/federal poverty level, but intends to expand to other equity measures, including race and ethnicity, later in the project.

Additional variables that may inform risk

Additional variables that may inform risk determination include proximity to transit and school bus stops, roadway lighting, and the existing treatments at marked pedestrian crossings. The Demonstration Project used data on key roadway, pedestrian exposure proxy, and equity variables that were representative of pedestrian crash risk and for which GIS data was more available for the full street network with the intent to assess additional risk variables at priority locations in later steps.

Step 3: Determine the risk factors

Now it is time to analyze the data collected in Step 2 to identify which risk variables are associated with higher crash frequencies and determine which of those variables are considered treatable risk factors that could be applied systemically. The *Systemic Pedestrian Safety Analysis* report provides a comparison of the strengths and limitations of three methods for determining risks to use in a systemic pedestrian safety process: count models, research/local judgment, and frequency-based method.

The most rigorous approach is developing crash count models to determine risk variables specifically associated with the types of crashes that have been occurring in the study area. However, this approach requires modeling expertise and detailed crash data that may not be available in all jurisdictions. Risk factor determination based on a combination of prior research and local judgment does not require modeling expertise or extensive crash data, but it assumes that risk factors are similar to those from other studies or jurisdictions. Therefore, local knowledge and expertise is required to determine relevant risk factors, and to apply weighting factors for prioritization. Risk factor estimation using the frequency-based method uses historical crash data for the entire network to identify types of locations where target crash types have occurred, and then identifies prevalent characteristics of those locations. While data needs may be similar to crash modeling, the frequency-based approach is relatively simple; however, it is not as accurate a predictor of where crashes may occur, and expert judgment is still needed to make risk determinations.

Equity in Transportation Planning

People of color, older adults, and residents of low-income communities are over-represented in pedestrian crashes. In the United States, communities with high concentrations of people of color are frequently underserved by transportation investments and are subjected to side effects associated with highway projects, such as pollution and displacement. Giving precedence to locations with higher concentrations of people of color or lower-income households can help to address historical inequalities and the current discrepancies in crash risk that these historical inequalities have helped create. This work requires engagement with community members to understand their needs and concerns.

Youth considerations

A combination of prior research and local judgment and the frequency-based method to determine risk factors for youth pedestrian crashes was piloted as part of the Demonstration Project in Philadelphia.

First, risk thresholds for the roadway and pedestrian exposure data identified in Step 2 were established. These thresholds were based on a review of prior research on pedestrian crashes with subsequent adjustment of some of the risk factor thresholds to better reflect age-appropriate abilities of youth. For example, while thresholds for traffic volume risk typically start at 10,000, AADT of greater than 5,000 vehicles were considered higher risk for this project. Similarly, multi-lane thresholds typically start at more than three lanes (sometimes five or more lanes) but more than two bi-directional lanes or more than one one-way lane were established as an appropriate risk threshold for youth.[8]

The risk factor thresholds established for the Demonstration Project are as follows:

- **Posted speed limit > 25 mph.** Research has shown that speeds greater than 25 mph significantly increase risk of death when pedestrians are struck by motor vehicles.[9]
- **AADT greater than 5,000.** Youth have less cognitive ability to navigate roads with higher traffic volumes compared to adults.
- **Multi-lane roads (more than two lanes bi-directional, more than one lane on one-way roads).** Multi-lane roads (more than two travel lanes) increase the exposure time of pedestrians in the roadway and may be more complicated for youth to safely navigate.
- **Lack of sidewalks (less than 50% coverage on either side of the road).** Roads that have risk variables described above but no pedestrian infrastructure have higher crash risk.[10] However, use caution when interpreting sidewalk data. Often sidewalk data only indicates the presence of a sidewalk, and not its quality or the width of a buffer between the sidewalk and higher speed roads. Significant crash risk may remain on segments with low quality sidewalks and higher-risk roadway features.
- **Household density (top 20% densest weighted area of households within 200 ft of a road).** It was anticipated that youth pedestrian travel was likely to occur within residential areas, and household density was used as a proxy to identify areas that may have the greatest number of youth pedestrians.
- **Concentrated areas of poverty (top 20% densest weighted areas of households in poverty within 200 ft of a road).** This risk factor was used to better understand transportation equity issues across the city and the possibility of higher youth pedestrian crash risk in areas of concentrated poverty.
- **Proximity to one or more schools (within .25 miles of a crash).** It was anticipated that youth pedestrian travel was likely to occur within typical school walk zones and aimed to better understand associated impacts on youth pedestrian crash risk.

After establishing the risk factor parameters, an Excel spreadsheet was created and performed cross tabulations to determine the degree of risk factor association with prior crashes. Some agencies may choose to map their crashes and high risk variables and make decisions based on their interpretation of the patterns seen.

First, the roadway network was analyzed based on how many miles of road, and the percentage of the overall road network where each roadway risk factor—or combination of roadway risk factors—is present (Figure 2). This included an assessment of roads with none of the identified risk factors and roads with any of the identified risk factors.

2	Philadelphia VZY Demonstration Project - Systemic Pedestrian Safety Analysis Pilot - May 27, 2020	Street Network Miles	
3	Risk Factor Group	#	%
4	None	1831	65.8%
5	Any	953	34.2%
6	**Total**	**2784**	**100.0%**
7			
8	AADT	612	22.0%
9	Multilane	344	12.4%
10	Speed	460	16.5%
11	Sidewalk Gaps	373	13.4%
12	AADT and Multilane	295	10.6%
13	AADT and Speed	381	13.7%
14	AADT and Sidewalk Gaps	101	3.6%
15	Multilane and Speed	258	9.3%
16	Multilane and Sidewalk Gaps	69	2.5%
17	Speed and Sidewalk Gaps	106	3.8%
18	AADT, Speed, and Sidewalk Gaps	77	2.8%
19	AADT, Multilane, and Speed	229	8.2%
20	AADT, Multilane, and Sidewalk Gaps	59	2.1%
21	Multilane, Speed, and Sidwealk Gaps	58	2.1%
22	AADT, Multilane, Speed, and Sidewalk Gaps	51	1.8%

Figure 2. Philadelphia Roadway Network Analysis – Street Network Miles per Risk Factor

	Philadelphia VZY Demonstration Project - Systemic Pedestrian Safety Analysis Pilot - May 27, 2020	Street Network Miles		Youth Ped All Injury Crashes	
3	Risk Factor Group	#	%	#	%
4	None	1831	65.8%	974	48.7%
5	Any	953	34.2%	1028	51.3%
6	**Total**	**2784**	**100.0%**	**2002**	**100.0%**
7					
8	AADT	612	22.0%	967	48.3%
9	Multilane	344	12.4%	382	19.1%
10	Speed	460	16.5%	618	30.9%
11	Sidewalk Gaps	373	13.4%	161	8.0%
12	AADT and Multilane	295	10.6%	371	18.5%
13	AADT and Speed	381	13.7%	599	29.9%
14	AADT and Sidewalk Gaps	101	3.6%	127	6.3%
15	Multilane and Speed	258	9.3%	318	15.9%
16	Multilane and Sidewalk Gaps	69	2.5%	83	4.1%
17	Speed and Sidewalk Gaps	106	3.8%	95	4.7%
18	AADT, Speed, and Sidewalk Gaps	77	2.8%	93	4.6%
19	AADT, Multilane, and Speed	229	8.2%	317	15.8%
20	AADT, Multilane, and Sidewalk Gaps	59	2.1%	82	4.1%
21	Multilane, Speed, and Sidewalk Gaps	58	2.1%	65	3.2%
22	AADT, Multilane, Speed, and Sidewalk Gaps	51	1.8%	64	3.2%

Figure 3. Philadelphia Roadway Network Analysis – Youth Pedestrian Crashes by Risk Factor

	Philadelphia VZY Demonstration Project - Systemic Pedestrian Safety Analysis Pilot - May 27, 2020	Street Network Miles		Youth Ped All Injury Crashes		
3	Risk Factor Group	#	%	#	%	Crashes Per Mile
4	None	1831	65.8%	974	48.7%	0.53
5	Any	953	34.2%	1028	51.3%	1.08
6	**Total**	**2784**	**100.0%**	**2002**	**100.0%**	**0.72**
7						
8	AADT	612	22.0%	967	48.3%	1.58
9	Multilane	344	12.4%	382	19.1%	1.11
10	Speed	460	16.5%	618	30.9%	1.34
11	Sidewalk Gaps	373	13.4%	161	8.0%	0.43
12	AADT and Multilane	295	10.6%	371	18.5%	1.26
13	AADT and Speed	381	13.7%	599	29.9%	1.57
14	AADT and Sidewalk Gaps	101	3.6%	127	6.3%	1.26
15	Multilane and Speed	258	9.3%	318	15.9%	1.23
16	Multilane and Sidewalk Gaps	69	2.5%	83	4.1%	1.20
17	Speed and Sidewalk Gaps	106	3.8%	95	4.7%	0.90
18	AADT, Speed, and Sidewalk Gaps	77	2.8%	93	4.6%	1.21
19	AADT, Multilane, and Speed	229	8.2%	317	15.8%	1.38
20	AADT, Multilane, and Sidewalk Gaps	59	2.1%	82	4.1%	1.39
21	Multilane, Speed, and Sidwealk Gaps	58	2.1%	65	3.2%	1.12
22	AADT, Multilane, Speed, and Sidewalk Gaps	51	1.8%	64	3.2%	1.25

Figure 4. Philadelphia Roadway Network Analysis -Youth Pedestrian Crash Rate by Risk Factor

Next, the number and percentage of youth pedestrian crashes that occurred on roads with these risk factors (Figure 3) were calculated. This allowed for examination of any single roadway risk variable—or combination of variables—that represented an elevated number or percentage of crashes.

Crash rates (the number of youth pedestrian injury crashes per mile) were then calculated to see if a higher number of crashes occurred after accounting for differences in the number of miles of road with each risk variable present (Figure 4). Without comparing crash rates, it is possible that a higher number or percentage of crashes captured by a given risk variable could simply reflect a high percentage of the roadway network having that risk variable present. By comparing the crash rates, it is possible to see which risk variables were associated with more crashes once the number of miles of road are normalized.

Finally, pedestrian exposure proxy variables were added to the spreadsheet, including the number and percentage of youth pedestrian injury crashes associated with each variable, as well as the percentage of all youth pedestrian injury crashes (Figure 5).

1/4 mi buffer for each exposure proxy variable

	Philadelphia VZY Demonstration Project - Systemic Pedestrian Safety Analysis Pilot - May 27, 2020	Street Network Miles		Youth Ped All Injury Crashes			Youth Ped All Injury in Top Quintile of Household Density		
3	Risk Factor Group	#	%	#	%	Crashes Per Mile	#	%	% all youth ped injury crashes
4	None	1831	65.8%	974	48.7%	0.53	326	65.9%	16.3%
5	Any	953	34.2%	1028	51.3%	1.08	169	34.1%	8.4%
6	**Total**	**2784**	**100.0%**	**2002**	**100.0%**	**0.72**	**495**	**100.0%**	**24.7%**
7									
8	AADT	612	22.0%	967	48.3%	1.58	158	31.9%	7.9%
9	Multilane	344	12.4%	382	19.1%	1.11	61	12.3%	3.0%
10	Speed	460	16.5%	618	30.9%	1.34	84	17.0%	4.2%
11	Sidewalk Gaps	373	13.4%	161	8.0%	0.43	16	3.2%	0.8%
12	AADT and Multilane	295	10.6%	371	18.5%	1.26	60	12.1%	3.0%
13	AADT and Speed	381	13.7%	599	29.9%	1.57	78	15.8%	3.9%
14	AADT and Sidewalk Gaps	101	3.6%	127	6.3%	1.26	12	2.4%	0.6%
15	Multilane and Speed	258	9.3%	318	15.9%	1.23	40	8.1%	2.0%
16	Multilane and Sidewalk Gaps	69	2.5%	83	4.1%	1.20	11	2.2%	0.5%
17	Speed and Sidewalk Gaps	106	3.8%	95	4.7%	0.90	2	0.4%	0.1%
18	AADT, Speed, and Sidewalk Gaps	77	2.8%	93	4.6%	1.21	2	0.4%	0.1%
19	AADT, Multilane, and Speed	229	8.2%	317	15.8%	1.38	40	8.1%	2.0%
20	AADT, Multilane, and Sidewalk Gaps	59	2.1%	82	4.1%	1.39	11	2.2%	0.5%
21	Multilane, Speed, and Sidwealk Gaps	58	2.1%	65	3.2%	1.12	1	0.2%	0.0%
22	AADT, Multilane, Speed, and Sidewalk Gaps	51	1.8%	64	3.2%	1.25	1	0.2%	0.0%

	Risk Factor Group	Youth Ped All Injury in Top Quintile of Population Density			Youth Ped All Injury Road Risk Factor in Top Quintile of HH in Pov			Youth Ped All Injury Road Risk Factor Near 1+ Schools			Youth Ped All Injury in Top Quintile of HH in Pov and Near 1+ Schools		
3	Risk Factor Group	#	%	% all youth ped injury crashes	#	%	% all youth ped injury crashes	#	%	% all youth ped injury crashes	#	%	% all youth ped injury crashes
4	None	379	62.1%	18.9%	293	44.3%	14.6%	770	49.3%	38.5%	250	45.8%	12.5%
5	Any	231	37.9%	11.5%	368	55.7%	18.4%	792	50.7%	39.6%	296	54.2%	14.8%
6	**Total**	**610**	**100.0%**	**30.5%**	**661**	**100.0%**	**33.0%**	**1562**	**100.0%**	**78.0%**	**546**	**100.0%**	**27.3%**
7													
8	AADT	220	36.1%	11.0%	349	52.8%	17.4%	746	47.8%	37.3%	282	51.6%	14.1%
9	Multilane	69	11.3%	3.4%	129	19.5%	6.4%	258	16.5%	12.9%	87	15.9%	4.3%
10	Speed	118	19.3%	5.9%	196	29.7%	9.8%	457	29.3%	22.8%	148	27.1%	7.4%
11	Sidewalk Gaps	16	2.6%	0.8%	49	7.4%	2.4%	108	6.9%	5.4%	35	6.4%	1.7%
12	AADT and Multilane	69	11.3%	3.4%	127	19.2%	6.3%	251	16.1%	12.5%	86	15.8%	4.3%
13	AADT and Speed	113	18.5%	5.6%	190	28.7%	9.5%	439	28.1%	21.9%	142	26.0%	7.1%
14	AADT and Sidewalk Gaps	10	1.6%	0.5%	38	5.7%	1.9%	86	5.5%	4.3%	28	5.1%	1.4%
15	Multilane and Speed	52	8.5%	2.6%	102	15.4%	5.1%	212	13.6%	10.6%	67	12.3%	3.3%
16	Multilane and Sidewalk Gaps	9	1.5%	0.4%	27	4.1%	1.3%	51	3.3%	2.5%	17	3.1%	0.8%
17	Speed and Sidewalk Gaps	2	0.3%	0.1%	21	3.2%	1.0%	60	3.8%	3.0%	14	2.6%	0.7%
18	AADT, Speed, and Sidewalk Gaps	2	0.3%	0.1%	21	3.2%	1.0%	59	3.8%	2.9%	14	2.6%	0.7%
19	AADT, Multilane, and Speed	52	8.5%	2.6%	102	15.4%	5.1%	212	13.6%	10.6%	67	12.3%	3.3%
20	AADT, Multilane, and Sidewalk Gaps	9	1.5%	0.4%	27	4.1%	1.3%	51	3.3%	2.5%	17	3.1%	0.8%
21	Multilane, Speed, and Sidwealk Gaps	1	0.2%	0.0%	15	2.3%	0.7%	36	2.3%	1.8%	8	1.5%	0.4%
22	AADT, Multilane, Speed, and Sidewalk Gaps	1	0.2%	0.0%	15	2.3%	0.7%	36	2.3%	1.8%	15	2.7%	0.7%

Figure 5. Philadelphia Roadway Network Analysis - Youth Pedestrian Crashes by Risk Factor and Pedestrian Exposure Proxy Variables

Four high-level takeaways resulted from the risk factor analysis of youth pedestrian crashes in the city of Philadelphia. This information was considered in updates to the City's Three-Year Vision Zero Action Plan:

1. Youth pedestrian crash rates are two to three times higher on roads with any of the following risk variables: posted speed greater than 25 mph; AADT of 5000 or greater; or more than one lane in each direction, than those roads without.
   - These roads accounted for 51% of crashes but represent 32.4% of the roadway network.
   - 66% of these crashes occurred at intersections.
   - Roads with AADT above 5,000 and posted speed limit above 25 mph represent 14% of Philadelphia's roadway network but are associated with 30% of youth pedestrian all injury crashes.
   - While the analysis did not find this same level of crash risk with sidewalks, there is strong evidence for the safety benefit of sidewalks and that they play a critical role in accessibility.
2. More than one-half (56%) of youth pedestrian crashes that occurred on roads with any risk variables (posted speed greater than 25 mph; AADT of 5000 or greater; or more than one lane in each direction; or lacking sidewalk coverage) were in areas of concentrated poverty. These areas were defined as the top 20% most dense areas of households in poverty in the city.
3. Almost one-half (49% or 974 crashes) of youth pedestrian crashes occurred on roads with 25 mph or lower posted speeds; one or fewer lanes in each direction; AADT under 5000; and sidewalk coverage over 50% along both sides of the street.
   - These roads are under-represented in youth pedestrian crashes; they make up 66% of Philadelphia's roadway network but are associated with 49% of youth pedestrian crashes. As such, these roads carry approximately half the crash rate of roads with posted speed greater than 25 mph; AADT of 5000 or greater; or more than one lane in each direction.
   - Nearly all (92%) occurred on local or collector roads.
   - Most crashes (70%) occurred mid-block.
   - These crashes are dispersed throughout the city; not concentrated in any single neighborhood or planning district.
4. 78% of youth pedestrian crashes occurred within 1/4 mile of a school.

While this high-level risk assessment provided valuable takeaways for the city of Philadelphia and identified a subset of potential "riskier" roads, additional analysis is required to determine a more specific focus on treatable risk factors that may be applied to identify locations for potential treatment in Step 4. This may include looking at differences between intersection and midblock crashes within the subset of "riskier" roads.

Step 4: Identify potential treatment sites

Once the subset of risk factors associated with higher crash frequencies are determined in Step 3, the next step is to screen the network to identify candidate sites for countermeasure treatment. These will include locations that have a prior crash history as well as locations that do not, but for which the identified risk factors for pedestrian crashes exist.

The *Systemic Pedestrian Safety Analysis* report describes two approaches to generating an initial list of candidate sites for countermeasure treatment: identification based on risk factor presence, and identification based on estimated crash rankings. The method used for this application of youth pedestrian safety involves identification based on the presence of risk factors, due to its ease of use. Site identification based on risk factor presence involves filtering sites throughout the network based on the presence of the subset of risk factor variables identified in Step 3, including pedestrian exposure. Crash history (total prior observed crashes) may also be used to filter sites and may be useful in determining priority locations.

If crash typing was not conducted on all crashes in Step 1 and if adequate crash data exist, crashes on the "riskier" roads identified in Step 3 may be further evaluated to better understand the crashes, such as whether they occurred at an intersection or midblock, and (if available) motor vehicle and pedestrian movements. This information may lead to further refinement of potential treatment sites and will allow greater clarity for countermeasure selection in Step 5. However, if crash data is incomplete, or if crash data was not used to identify specific risk variables for a jurisdiction (i.e. applied research risk factors associated with pedestrian crashes), fieldwork conducted at a sample of locations along identified "riskier" roads – including both intersection and midblock – may provide additional information or lead to inferences on crash types.

Youth considerations

For a focus on youth pedestrians, these sites should be related to youth pedestrian crashes and pedestrian exposure variables and have the key roadway risk factors identified. For example, this may mean a focus on intersections on roads with AADT of 5,000 or greater and posted speed limit of more than 25mph, located within concentrated areas of poverty and within one-quarter mile of a school.

As a first step, it may be helpful to narrow the list by eliminating locations where there are pending or planned projects. Then query the GIS database to filter a list of locations throughout the network that contain the risk variables and pedestrian exposure proxy variables identified in Step 3. An additional query may be applied to filter a list of locations that have the risk variables identified and have prior crash history to identify high-crash locations that may warrant special attention.

Step 5: Select potential countermeasures

After youth pedestrian crash risk variables have been determined (Step 3) and locations across the network that have those sites have been identified (Step 4), the next step is to identify appropriate countermeasures or combinations of countermeasures that could be applied systemically to address identified risks.

The *Systemic Pedestrian Safety Analysis* report provides guidance on how to select potential countermeasures, including first developing a framework for selecting countermeasures. Potential criteria for countermeasure selection include:

- Countermeasures should be related to the targeted risk problem and (if available) crash type identified in Step 1.
- Countermeasures should be supported by crash-based evidence of reducing pedestrian crashes or reducing pedestrian conflict or exposure.[11]
- Countermeasure cost (absolute cost, cost-effectiveness or cost benefit and funding available) should factor into treatment selections considered for systemic application.

- Countermeasure feasibility (such as political concerns, community priorities, the need for public or stakeholder engagement, equity concerns) should factor into treatment selections considered for systemic application.

The criteria established will then guide the development of a list of potential systemic countermeasures that may be suitable for systemic implementation. The Systemic Pedestrian Safety Analysis report provides a list of pedestrian crash countermeasures for potential systemic application that meet some of the basic criteria described above that may serve as a starting point for jurisdictions in applying selection criteria, and these countermeasures treatments are described and visualized in the report appendix. In addition, Tables 15-17 of the report provide additional detail on how they relate to crash risks, crash types and expected crash reduction countermeasures.

Youth considerations

Children's cognitive, social and physical development play a role in how they manage traffic situations and therefore also have implications for countermeasures. Most elementary school-aged students don't have the cognitive ability to make safe, consistent decisions about when to cross streets, generally due to speed and distance calculations and impulsivity. This means that multi-lane roadways, high-speed streets, and complex crossings will be difficult for children to navigate safely and they need a physical environment that is as forgiving of mistakes as possible. This should impact decisions about pedestrian safety countermeasures needed on roadways where youth travel.

In addition to age-appropriate abilities, children and youth also have special vulnerabilities that should be considered. They are not as visible to

Table A. Examples of Pedestrian Safety Countermeasures and Considerations for Youth

Pedestrian Safety Countermeasure	Considerations for Children and Youth
Crossing Islands	Children can have challenges when crossing wide, multi-lane streets compared to older, more-experienced pedestrians. Providing a raised island can simplify the crossing maneuver.
Signal Timing and Automatic Pedestrian Recall	Shorter signal cycles can result in shorter pedestrian wait times for the WALK interval. Pedestrian recall means that pedestrians get the WALK interval every cycle, without having to activate a push-button. Both features have obvious advantages for young pedestrians.
Protected Turn Phases	Providing protected turn phases, such as a protected left-turn phase, allows for pedestrians to cross during a WALK interval, without having to worry about conflicting left-turn traffic. Such a measure reduces the decision burden for young, inexperienced pedestrians when crossing the street at a busy intersection.
Leading Pedestrian Intervals (LPIs)	LPIs provide an interval of a few seconds at the beginning of each signal phase which gives pedestrians priority over turning vehicles. Such a separated interval has the potential to particularly benefit young pedestrians, who typically have added difficulty interacting with turning vehicles at intersections. [12]
Gateways and In-Street Pedestrian Crossing Signs	These have been shown to increase motorist yielding at pedestrian crossings, which would benefit young pedestrians and their challenge with judging vehicle speed and acceptable gaps.
Motor Vehicle Speed Reduction	Children have difficulty perceiving speed of oncoming vehicles and take longer to decide and proceed with crossing, putting them at added risk the faster vehicles are traveling.
Lighting	Lighting can benefit children who cross streets to get to or from a bus stop or school especially during times of the year when they may be traveling to or from school or other destinations in darkness.

Table A. Continued	
Parking Restrictions at Pedestrian Crossings	Since children are shorter than adults, this is a particular benefit for drivers and children to be able to see each other at intersections.
Corner Radius Reduction	This measure reduces the radius of a corner, creating a sharper turn for motor vehicle drivers, which reduces the speed of turning vehicles, while at the same time shortening pedestrian crossing distance at intersections. These are both beneficial features for children who cross such intersections.
Curb Extensions	This treatment shortens the crossing distance, reduces turning speeds, and improves sight distance between the driver and pedestrians, which can all benefit child pedestrians.
High-Visibility Crosswalks	These have been shown in a California study to be effective in reducing child pedestrian crashes in school zones, compared to parallel-line crosswalks.[13]
Hardened Centerlines and Turn Wedges	Hardened centerlines can reduce the length of the conflict area between pedestrian crossings and left-turn vehicles at intersections. Turn wedges serve a similar purpose as curb extensions, including shorter crossing distances and slower speeds of right-turning vehicles. Both measures can potentially benefit young pedestrians at intersections, and both are relatively new and low-cost measures.
No Turn on Red (NTOR) Signs	NTOR signs help to reduce the conflict from right-turning vehicles at intersections during the WALK interval, which can benefit young pedestrians.
Raised Crossings and Raised Intersections	Raised crossings typically slow the speeds of motor vehicles where pedestrians cross at intersections. Shorter, younger pedestrians can benefit from such speed reductions and from the vertical elevation provided by the raised crossing surfaces.
Posted Speed Limits	Posting speed limits, in addition to selective speed enforcement and other measures (e.g., traffic calming) is a part of an overall effort to keep vehicle speeds at reasonably safe levels, which is essential for safer travel by child pedestrians.
Automated Enforcement	This measure can involve enforcing signal compliance and/or compliance of speed limits, both of which are obviously important to safe walking by children.
Access Management	This measure, among other things, implies the careful placement of driveways and a reduction of conflict points between motorists and pedestrians, which is certainly beneficial to children who are walking on the sidewalk.
Road Diets and Lane Narrowing	Road diets involve eliminating a travel lane which slows vehicle speeds and shortens crossing distance. They have a proven safety benefit to overall crashes, not just pedestrian crashes. Lane narrowing can reduce vehicle speeds and shorten the street crossing distance. Both of these measures can be beneficial to child pedestrians, in particular.[14]
Crossing Guards	Particularly at intersections heavily used by young pedestrians, crossing guards can play an important role in determining an appropriate time for crossing and controlling the crossing of young pedestrians. Their presence also serves as a deterrent to speeding drivers.
Neighborhood Slow Zones	Neighborhood Slow Zones reduce the speed limit and add safety measures within a select area, for example where children are walking, in order to change driver behavior.

drivers because of their shorter height. School arrival hours and afterschool activities tend to occur at times when adequate lighting will be especially important at schools, key crossings near schools, bus stops, and destinations.

Table A highlights considerations relating to age appropriate abilities and special vulnerabilities of youth related to pedestrian safety countermeasures.

Selecting appropriate countermeasures requires engineering judgment to assess the site conditions and context of identified locations. For sites which have experienced high-frequency youth crashes, this will involve site reviews to identify factors that may have contributed to those crashes and propose countermeasures to reduce or eliminate future crashes, to the extent possible. For "high-risk" locations across the network, systemic countermeasure selection should address specific risks identified in the risk assessment. For example, if identified locations for potential treatment include intersections along roads with AADT over 5,000 and posted speed limit greater than 25mph and near schools within areas of concentrated poverty, an agency may recognize that a number of the signalized intersections don't have pedestrian signals or have traditional pedestrian (WALK/DONT WALK) signals without countdown features. One potential systemic treatment at these locations may be to convert the signals to countdown pedestrian signals.[15] Likewise, an agency may find that there are youth pedestrian crashes at midblock locations. In such situations, it may be desirable to conduct a site review of those midblock crossings along the high-risk areas. Then, by reviewing youth pedestrian crashes at these sites, it may be possible to identify common crash causes and systemic treatments (e.g., neighborhood "slow zones" or road diets where traffic volumes allow), and/or to conduct a detailed site review of each midblock crossing to determine what site-specific treatments ae justified. The city of Seattle conducted an inventory of all of their unsignalized pedestrian crossings for the purpose of determining needs for infrastructure treatments, such as overhead lighting, installing enhanced signs or markings and installing traffic and pedestrian signals.[16]

The final selection of countermeasures for high-crash and high-risk sites will depend not only on the selection of appropriate treatments, but also on the previously discussed criteria developed by the jurisdiction, including considerations of cost and feasibility. Furthermore, some agencies may decide to implement non-infrastructure measures that benefit child pedestrians, such as adult crossing guards at either specific schools or city-wide.

Step 6: Refine and implement treatment plan

A systemic approach to pedestrian safety analysis is often iterative; each step allows for reflection and revisiting decisions made in prior steps to refine the process. Step 6 of *Systemic Pedestrian Safety Analysis* suggests consideration of additional community priorities and economic impacts, and possibly performing additional diagnostics before allocating funding and implementing projects.

Youth considerations

Consultation with school officials, families, local businesses, agency officials and other key stakeholders can provide valuable input on underlying issues that might impact countermeasure selection and implementation. This may include gaining an understanding of any resistance that may exist and the need to explain the importance of changes to community members before installation begins. Of course improvements related to youth pedestrians should be conducted within a larger framework of pedestrian safety for all ages, and an agency's overall highway safety improvement program, since the safety of all road users is the ultimate goal.

Step 7: Evaluate program and project impacts

Systemic Pedestrian Safety Analysis describes systemic evaluation as consisting of both process and project evaluation. Process evaluation involves reviewing the steps and methodologies applied to determine each was implemented as planned. Were each of the six steps carried out? What were the barriers and how can they be addressed (e.g. data limitations, training needs, etc.)? How many locations in the study scope were identified and for what percentage of those were countermeasures recommended and implemented? Project evaluation should include safety impacts and be assessed at all treatment sites where similar treatments were implemented. However, the potential effects on crashes may take several years to assess so alternative impact measures, such as operating speed and conflict reduction, are valuable to understand project impacts systemically as well as at different locations.

Youth considerations

When evaluating the systemic process and project impacts specifically, it will be important to perform assessments at times when youth pedestrians are using the network. For example, evaluation of countermeasure treatments near schools should be performed during a typical school day or days during the school year and at times when motorist and youth pedestrians are interacting.

Conclusion

Cities can benefit from including a focus on youth when addressing pedestrian crashes both in terms of understanding risk factors and selecting treatments. Youth crash characteristics can be lost within the overall pedestrian crash data. The Demonstration Project with the city of Philadelphia revealed that youth pedestrian crashes did not necessarily occur in the same locations as overall pedestrian crashes and risk factors and appropriate treatments can be different. Additionally, a focus on youth can enable communities to select treatments that need public support, such as automated enforcement, slow zones and citywide lowered speed limits.

While the systemic approach is becoming more widely used in transportation planning, this is the first time that the approach has been applied specifically to understanding youth travel risks. For most communities, child crashes are fortunately rare events. Examining small numbers of crashes could, however, lead to incorrect understandings of crash patterns or key risk areas. Using the systemic approach to understand key risk factors can provide a better understanding of what to address and where. Proactive, safety-based planning provides an opportunity to expand travel safety for children, families and other community members, playing a critical role in saving lives on a community's roads.

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Since its inception in 1999, the Pedestrian and Bicycle Information Center's mission has been to improve the quality of life in communities through the increase of safe walking and bicycling as a viable means of transportation and physical activity. The Pedestrian and Bicycle Information Center is maintained by the University of North Carolina Highway Safety Research Center with funding from the U.S. Department of Transportation Federal Highway Administration.

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11 See FHWA Crash Modification Clearinghouse, **http://www.cmfclearinghouse.org**

12 Case Study: NYC showed crash reductions, for example on a two-way protected bike lane along a park, which offers cyclists a safer space, but also serves the dual purpose of reducing lane width, thereby slowing traffic. Leading pedestrian intervals were installed on a service road leading to an expressway, allowing pedestrians to get a head start crossing a street before traffic proceeds. Parking regulations along the corridor were overhauled, extending the 'no-standing' zone during school drop off and pick up hours, and removing several spaces to improve visibility. Slow zones were added, as well as stop controlled high visibility crosswalks. The merge of the two streets was also improved.

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15 Studies have found that converting to countdown pedestrian signals are associated with a significant (25%) reduction in pedestrian crashes. Markowitz, F., Sciortino, S., Fleck, J.L., & Yee, B.M. (2006). Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation. *Institute of Transportation Engineers*. ITE Journal, 76,(1), 43.

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