CYCLING AT A CROSSROADS

The Design Future of New York City Intersections

September 2018

VISION ZERO
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NEW YORK CITY DOT

CONTENTS

LETTER FROM THE COMMISSIONER

Dear Fellow New Yorker:

It is hard to believe that only a decade ago, New York City installed its first protected bike lanes along 9th Avenue on the West Side of Manhattan, separating bikes from other vehicle traffic along a major street for the first time. In the years since, lanes like the 9th Avenue bike lane have become a deeply ingrained part of the City's streetscape. In fact, lane miles dedicated to cyclists have expanded far beyond those two lane-miles in Chelsea to now more than 100 miles Citywide, including the addition of a record 25 protected lane-miles in 2017.

Since 2014, under the leadership of Mayor Bill de Blasio and his signature Vision Zero program, DOT has fast-tracked the construction of protected bike lanes. Simply put, these lanes have been central to the promising results we have had in reducing fatalities, which have declined in New York City for four-and-a-half years, bucking national trends. Our data clearly show that the addition of a new protected bike lane – that makes crosswalks shorter and narrows driving space -- increases street safety for all users: pedestrian, motorist, and cyclist alike.

However, as overall traffic fatalities have declined and cycling has increased within New York City under Vision Zero, the number of cyclists lost in fatal crashes has remained stubbornly and tragically high, with deaths actually increasing over the last several years.

With the goal of reversing that trend, DOT has taken a closer look at cyclist safety. And specifically, because 89 percent of crashes occur within intersections, our Transportation Planning and Management team was charged with doing a clear-eyed analysis of how we could further improve intersections to keep cyclists safe, especially as vehicles turn.

The study that follows, *Cycling at a Crossroads: The Design Future of New York City Intersections,* is a detailed and data-driven look at various designs, and keeps with the spirit with which DOT has generally approached Vision Zero. That is, we live in a diverse City with tens of thousands of intersections, and DOT plans to continue our aggressive pace of protected bike lane construction. Having transparent design guidelines is a must, because where safety and intersection design are concerned, one size most definitely will not fit all.

I want to thank the DOT planners who painstakingly constructed this study, another product of their passion for the safety of all New Yorkers. The recommendations they make here will inform future planning and design decisions, in the hope that we can continue the incredible progress New York City has made -- both around meeting our critical Vision Zero goals and becoming a safer and more welcoming city for cyclists.

Polly Trottenberg
Commissioner

EXECUTIVE SUMMARY

STUDY OVERVIEW

With turning vehicle conflicts combined with the high demand for street space, intersections remain one of the primary design challenges for creating a safe and comfortable bicycle network in New York City. This study aims to evaluate both new and traditional intersection design treatments and provide recommendations on their design and use.

Overall, this study's findings show that both Mixing Zones and Fully Split Phase intersections have substantial bicycle crash rate reductions following their installation as part of Protected Bike Lane (PBL) projects. The study also found that pilot treatments currently being investigated by NYC DOT show promising results, with high levels of user comfort and low incidence of conflict between bicycle riders and turning drivers. These treatments will continue to be used in NYC bicycle projects while they are refined.

The results of the study include specific design recommendations to modify existing designs, as well as a helpful new matrix to guide in the selection of a new project's intersection treatments. This matrix guides NYC DOT designers in selecting appropriate and consistent treatments for different street contexts and also provide a transparent framework to the public.

EXECUTIVE SUMMARY

This study examines four designs used to manage turning conflicts at intersections with Protected Bike Lanes (PBLs). To achieve a greater understanding of the safety effects, design constraints, behaviors, and bicyclist perceptions for each of these designs, a crash data analysis, video observations, and surveys are employed. **Overall, the findings show that the standard treatments (Mixing Zones and Fully Split Phase) reduced the bicycle crash rate at intersections by 30%** following their installation as part of a PBL project. Other key findings include:

	DESIGN	KEY FINDINGS
	Established Designs for Use with Protected Bicycle Lanes in New York City	
	The **Mixing Zone** is a design where turning vehicles and bicyclists share the same space. This design is intended to reduce the speed of turning vehicles and allow bicyclists to avoid being in the turning path of a motor vehicle.	Mixing zones are a safe (**27% bicycle crash rate reduction**), efficient way for way to allow vehicles to turn across a protected bike lane (PBL), particularly at smaller intersections where they exhibit a similar bicyclist crash rate to the Fully Split Phase design; however, self-reported bicyclist comfort is lower at this type of intersection compared to the Offset Crossing pilot alternative.
	The **Fully Split Phase** signal separates the through-movement of bicyclists and the turning movement of vehicles by giving them each separate green signal phases.	This type of intersection is often requested in place of a mixing zone because bicyclists are fully separated in time and space from turning drivers; however, long delays experienced by bicyclists waiting for a green light can encourage risky behavior (red-light running). **The Fully Split Phase treatment should typically be prioritized at wider intersections and two-way cross-streets.**
	NEW: Pilot Designs	
	The **Delayed Turn** (AKA Split LBI) is a design that builds on the benefits of the Leading Pedestrian Interval (LPI). This design provides a conflict-free head start for bicyclists before turning drivers are allowed to proceed.	This intersection type is similar to the Mixing Zone in terms of bicyclist behaviors and levels of user comfort. Overall the conflict rate between turning vehicles and bicycles is the lowest of the four treatments, but an observed conflict at the start of the Flashing Yellow Arrow phase needs further evaluation.
	The **Offset Crossing** is a design based on Dutch bikeway design principles and is frequently called a Protected Intersection. This design sets the bicycle facility back from the travel lane to improve visibility and slow drivers.	This design is found to have **the highest levels of user comfort** with 93% of bicyclists surveyed feeling safe riding through them (compared to 65% at Mixing Zones). However, bicyclists yield more frequently to turning drivers in this design possibly due to the decreased amount of recognition and reaction time between turning drivers and bicyclists. A modified design to slow turning speeds is recommended.

EXECUTIVE SUMMARY

SUMMARY OF RECOMMENDATIONS

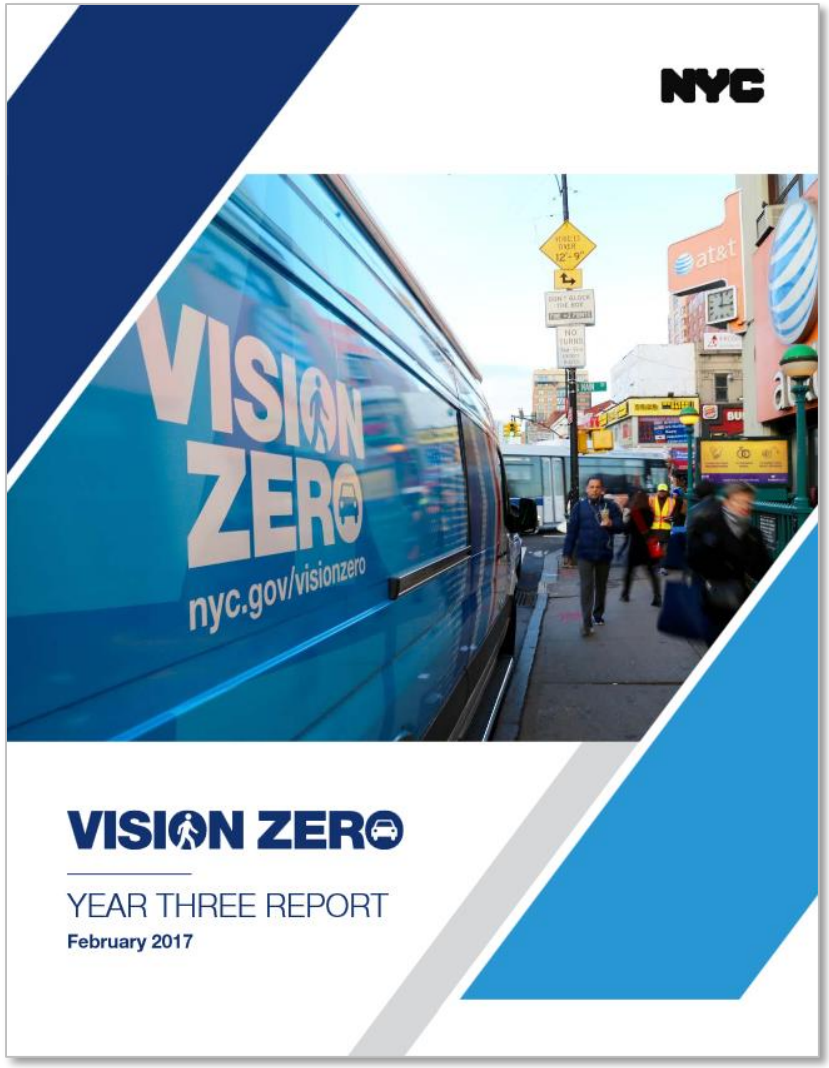
Update designs based on the findings in the study, including:

- Updating first generation mixing zones with a shorter mixing area, as markings are refreshed;
- Use Left-Turn Traffic Calming methods to slow turns at larger intersections;
- Develop strategies to improve signal coordination that reduces bicyclist stopping and delay along corridors with several Fully Split Phase intersections; and
- Install higher visibility markings through conflict zones, such as wider peg-a-track lines or green bars.

Continue to install and evaluate the pilot treatments, including the offset crossing at appropriate locations.

Continue to upgrade 20 key cycling intersections as outlined in the Vision Zero Year Three Report. Upgrades of these 20 intersections as well as all new bicycle projects will be informed by the design matrix developed in this study.

Update educational resources for people bicycling and driving and develop on-street and digital outreach events.



BACKGROUND & PURPOSE

Since 2007, NYC DOT has used Protected Bike Lanes (PBLs) on key corridors of NYC's on-street bike network. By comfortably separating bicyclists from moving traffic using parked cars or other barriers, PBLs provide a proven (1,2) safe bike facility that even those who are less confident riding on city streets can enjoy.

However, these benefits do not affect all parts of the street equally. Since the protection of the bike lane drops at the intersections, where conflicts with other road users are most likely to occur, these locations can be considered the "weakest link" in terms of bicyclist comfort and safety along PBL corridors. This is demonstrated by study findings in NYC where 89% of cyclist fatal or serious injury crashes occur at intersections (of all types, not just locations with bicycle facilities) and the percentage of the total cyclist crashes along a corridor that occur at intersections increases from 86% to 97% after the installation of a PBL (3,2).

While the past corridor evaluations are instructive, *further examination of how different features such as bike facility design, turn volumes, traffic signals and crossing distances affect the safety of bicyclists at intersections is needed.*

1) New York City Department of Transportation. (2014). "Protected Bicycle Lanes in NYC."
2) Rothenberg, H. D. Goodman, C. Sundstrom. Separated Bike Lane Crash Analysis. Presented at 95th Annual Meeting of the Transportation Research Board, Washington, D.C., 2016.
3) Getman, A., L. Gordon-Koven, S. Hostetter, and R. Viola. Safer Cycling: Bicycle Ridership and Safety in New York City, 2017. New York City Department of Transportation.

BACKGROUND & PURPOSE

Providing safe cycling facilities is clearly critical for meeting the City's Vision Zero goal. However facilities need to not only be *objectively* safe but also *subjectively* safe and comfortable to attract the numbers new riders necessary to meet the City's goal of doubling cycling trips citywide and providing a new mobility option to many New Yorkers.

The largest group of New Yorkers (*52%*) in a 2015 survey (3) defined themselves to be "Interested but Concerned" in cycling, a category defined as people who are willing to bicycle if high-quality bicycle infrastructure is provided. This large group represents a majority of New Yorkers and offers a huge opportunity to increase cycling by providing convenient and low stress facilities. PBLs and other cycling investments have clearly been successful at reaching this group as demonstrated by a *156% increase in daily cycling trips* between 2006 and 2016 (4). Additionally, based on the drop in NYC bicycle crashes per cycling trip, there is likely also a "safety in numbers" benefit to encouraging more people to bicycle (5).

Due to the inherent conflict between street users, intersections remain one of the primary design challenges for creating bicycle facilities that are both safe and comfortable for all types of bicyclists while supporting the competing needs for street space and mobility in busy, urban environments. This study aims to evaluate both new and traditional intersection design treatments and provide recommendations on their design and use.

The intent of this study is two-fold:

1. Develop sound findings and insights on the intersection design treatments used at intersections with Protected Bike Lanes; and
2. Create a planning and design resource that identifies the conditions where each treatment is most appropriate.

3) Dill J. and N. McNeil. Revisiting the Four Types of Cyclists: Findings from a National Survey. *Transportation Research Record*. No. 2587, pp. 90-99, 2016.
4) New York City Department of Transportation. (2018). "Cycling in the City: Cycling Trends in NYC."
5) Getman, A., L. Gordon-Koven, S. Hostetter, and R. Viola. Safer Cycling: Bicycle Ridership and Safety in New York City, 2017. New York City Department of Transportation.

PROTECTED BIKE LANE INTERSECTION DESIGNS

PROTECTED BIKE LANE INTERSECTION DESIGNS

Historically, two primary design treatments have been used in NYC to mitigate the conflict at intersections between bicyclists and turning drivers at PBLs:

- The **Mixing Zone** is a design where turning vehicles and bicyclists share the same space. This design is intended to reduce the speed of turning vehicles and allow bicyclists to avoid being on the turning side of a vehicle which could result in a “hook” type crash.
- The **Fully Split Phase Signal** separates the through-movement of bicyclists and the turning movement of vehicles by giving them each separate green signal phases.

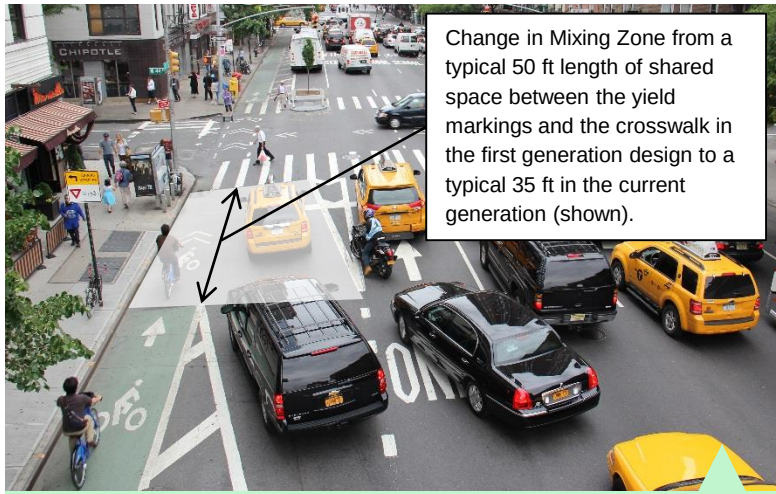
With all design decisions, trade-offs must be made. For example, Fully Split Phase intersections provide a complete separation between bicyclists and turning vehicles but also create time delays for bicyclists riding through the corridor. The Mixing Zone design reduces bicyclist delay and preserves more on-street parking and loading, but allows for more conflict due to the green phase being shared between bicyclists and turning vehicles.

Both designs have a long, proven history. Fully Split Phased intersections were first installed on 8th and 9th Avenues in 2007 and Mixing Zones on Grand Street in 2008. Over time, NYC DOT has modified the Mixing Zone design to reduce the length of the shared zone, which resulted in improved safety.

NYC DOT is also developing two additional designs that are still in a pilot phase:

- A design that builds on the benefits of the Leading Pedestrian Interval (LPI), named a **Delayed Turn** in this study; and
- A design based on Dutch design principles, frequently called a Protected Intersection, and named an **Offset Crossing** in this study.

This study evaluates the preliminary results of these pilot designs and identifies design modifications and other recommendations for their use.



Change in Mixing Zone from a typical 50 ft length of shared space between the yield markings and the crosswalk in the first generation design to a typical 35 ft in the current generation (shown).

Example of a Mixing Zone intersection

Bicycle signals are installed at Fully Split Phase Signal intersections

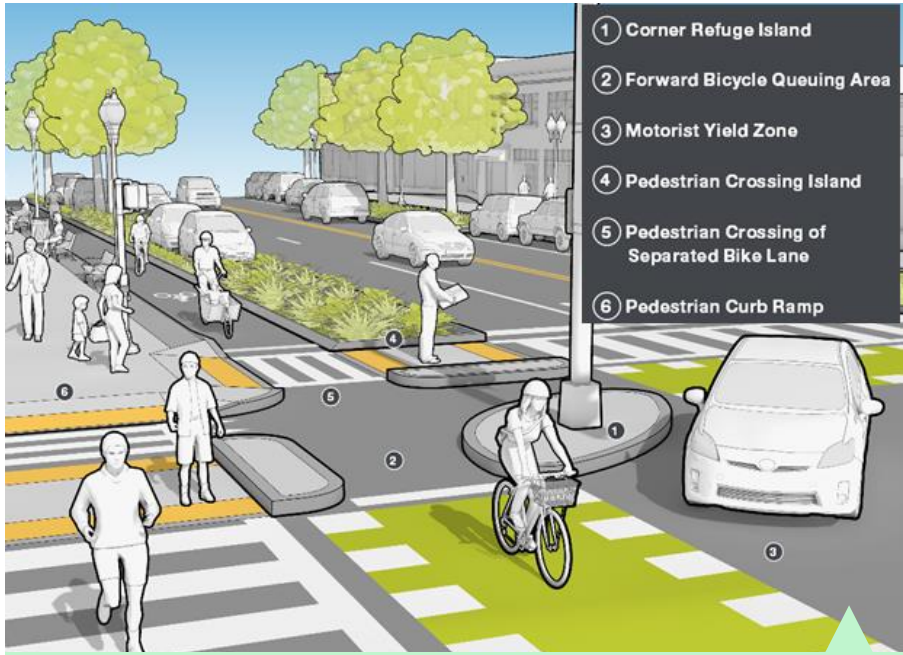
DEVELOPMENT OF THE OFFSET CROSSING DESIGN

As part of this study the “Offset Crossing” intersection treatment was developed and installed in two pilot locations. Also known as a “protected intersection” design, it is based on Dutch bikeway design principles and rapidly gaining popularity in North American cities.

This graphic presents many of the key design elements of this design including the corner refuge island to slow turns and yielding space for drivers to recognize and stop for bicyclists. Protected intersections are designed to create clear and predictable travel behaviors, reduce crossing distances, and increase comfort.

Compared to other intersection designs, these design elements likely provide a less stressful crossing for bicyclists by limiting their interaction with turning vehicles to a single point. Other benefits with this design include an additional pedestrian island and a lower reduction of parking and loading space. These benefits make the design particularly appealing.

While these benefits are appealing, particularly at Protected Bike Lanes (PBLs) where less confident or experienced bicyclists are expected, the design needs to be proven both safe and feasible in terms of design and operations. While there is limited experience with this type of design in North America, the safety research from urban environments in Europe provides a strong safety performance record. This study aims to clarify how the design performs on NYC streets, recommend a refined geometry, and identify suitable conditions for use.



Elements of protected intersections (Source: MassDOT Separated Bike Lane Planning & Design Guide 2015)

A protected intersection in Chicago (Source: CDOT)

DEVELOPMENT OF THE OFFSET CROSSING DESIGN

To develop a type of protected intersection design that can be retrofitted to typical NYC streets, NYC DOT designers conducted a review of US and international safety literature and referenced recent design guides* from FHWA, state and local agencies, NACTO, and the Netherlands.

The result is a design that features a 15 ft. offset to the bike lane, painted corner islands with vertical delineators to slow turns, and an advanced stop bar to improve bicyclist visibility when stopped at a red light.

The pilot locations of Columbus Avenue & W 70th Street and Amsterdam Avenue & W 85th Street were selected as suitable test sites due the existing Mixing Zone geometry that is typical of Manhattan avenues and turning vehicles volumes below 120 in the peak hour.

NYC DOT has also begun experimenting with this design at other locations including both on and crossing two-way streets. The results of these installations will be studied as part of the addendum study.

Pilot Offset Crossing treatment at Columbus Avenue & W 70th Street

*A partial list of the design guides featuring protected intersections and similar features include: FHWA (2015) *Separated Bike Lane Planning and Design Guide;* FHWA (2016) *Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts;* NACTO (2017) *Global Street Design Guide;* Seattle DOT (2017) *Right-of-Way Improvements Manual; MassDOT* (2015) *Separated Bike Lane Planning & Design Guide;* CalTrans (2018) *Design Information Bulletin 89-01 Class IV Bikeway Guidance;* CROW (2016) *Design Manual for Bicycle Traffic (*The Netherlands)

SUMMARY OF PROTECTED BIKE LANES INTERSECTION DESIGNS

	Mixing Zone **Primary treatment**	Fully Split Phase **Primary treatment**	Delayed Turn (AKA Split LBI) **Pilot treatment**, not in widespread use	Offset Crossing **Pilot treatment**, not in widespread use
Description	Parking is removed on the approach to the intersection to create visibility between bicyclists and turning motorists. Motorists are provided yield signs and markings while the bicycle lane converts to a shared area where motorists and bicyclists negotiate their movements.	Provides a dedicated turn lane adjacent the bicycle lane. Turning movements across the bike lane happen in a dedicated phase with a green turn arrow during which bicyclists are held with a red bicycle signal.	Bicycles receive a conflict free head start (10 sec. min.) with a green bicycle signal. Following this head start, turning drivers receive a Flashing Yellow Arrow (FYA) and may turn after yielding to people walking and bicycling.	Dutch style treatment within the intersection that features a tight corner radius to slow vehicle turns and a modest deflection of the bike lane to allow for reaction time and queuing space. The conflict between cyclists and motorists is constrained to middle of intersections.
Benefits	Bicyclists receive all of the through phase green time, reducing their delay. Removes the turning vehicle from the through lane allowing the driver to focus on bicycle and pedestrian traffic.	Complete separation in time and space between through bicyclists and turning vehicles. Removes turning vehicles from through lanes improving traffic capacity.	Bicyclists proceed with no conflict for part of through phase. Allows for the installation of Leading Pedestrian Intervals with no capacity impacts for through vehicles.	Slowed turn with a short conflict zone between bicyclists and turning vehicles. A continuous bike lane enhances the sense of security and creates more predictable movements.
Parking loss	Medium	High	High	Low
Challenges	The shared space in advance of intersection can increase bicyclist stress levels. The design creates unpredictable bicycle movements.	Little green time for bicyclists (1 of 3 phases) creates delay and can result in frequent non-compliance by bicyclists. High loss of parking and typically a reduced turning vehicle capacity.	Driver comprehension of the FYA may be low. The placement of the bike lane between the curb and turning path of vehicles places bicyclists in a potentially unexpected and less visible location. High parking loss.	A new, unfamiliar design where drivers may recognize bicyclists late in turn. Requires an amount of street space that may not always be available and turning vehicles may block the through lanes.
Typical use	One-lane cross streets where a Leading Pedestrian Interval (LPI) is not needed.	Multi-lane cross-streets; higher speed roadways; locations with no gap in pedestrian traffic; in conjunction with a LPI.	Where a LPI is needed but some curbside use needs to be retained compared to Fully Split; moderate pedestrian and turning volumes.	Cross streets with a low turning volume and sufficient roadway width for design.
				

STUDY DESIGN

STUDY METHODOLOGY

This study builds on the success of NYC's protected bike lanes through improving the understanding and impacts of different intersection designs. Specifically, to better understand safety, geometric and operational constraints, behaviors and preferences, several different data sources and research methods are combined. These different approaches are summarized into the following categories:

SAFETY

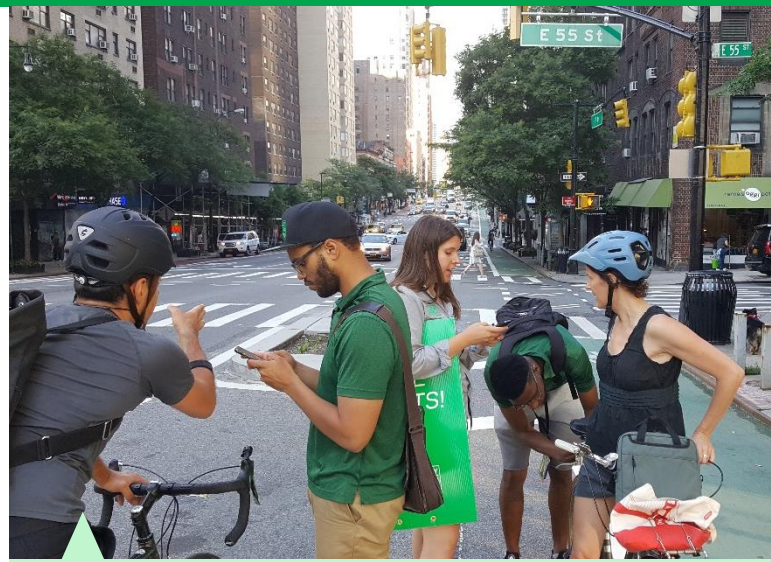
An evaluation of **bicyclist-involved injury crashes** at intersections with Protected Bike Lanes (PBLs);

CONFLICTS

An **observational study** using video to evaluate behaviors and conflicts between people on bikes and turning drivers; and

COMFORT

An **intercept survey** to assess bicyclists' comfort and understanding of different types of PBL intersections.



An intercept survey of people on bikes is conducted at a Delayed Turn intersection

Video screenshot: Offset Crossing at Columbus Avenue & W 70th Street

METHODOLOGY: SAFETY

Crash Analysis*

The low number of bicyclist-involved crashes is one of the biggest barriers to conducing safety evaluations of cycling treatments. To conduct an evaluation that yields meaningful results requires a large set of locations and years after installation. For this study, the intersections from one-way Protected Bike Lanes (PBLs) installed between 2007-2014 are evaluated (184 intersections). Due to the requirement of several years of post-installation data, **only the Mixing Zones and Fully Split Phase signals are evaluated with this method.**

Because not all of the treatment types were installed at the same time and cycling volumes changed dramatically over time, the comparative crash analysis between treatments uses crashes from 2014-2016.

Bicycle volumes for all sites are estimated using known volumes along the study corridors and adjusted for seasonal and annual variations with data from permanent bicycle counters and the annual bicycle count program.

A summary of the methodology, data, and results are provided in this report. For further details refer to the **Appendix**.

Example of a current generation Mixing Zone

*Crash data source: NYPD Crash Database

METHODOLOGY: CONFLICTS

Observational Study

As a complementary approach to the crash analysis study, an observational study provides a method to evaluate more recent intersection designs that do not have sufficient crash data. This technique analyzes conflicts and interactions between turning vehicles and bicyclists to identify whether the designs are functioning safely and as intended. An additional benefit to using video is that observations can be made on other interactions and road user behaviors. This can help inform design modifications that incorporate bicyclist comfort and better guide people into safer behaviors.

This study viewed **9 intersections** in total using approximately 12 hours of peak travel period (morning and evening) footage.

Video screenshot: Columbus Avenue & W 70th Street

METHODOLOGY: COMFORT

Intercept Survey

To get a better understanding of bicyclists' comfort and understanding of different types of Protected Bike Lane (PBL) intersections, an intercept survey was conducted by the NYC DOT Street Ambassadors team. The Ambassadors surveyed 515 bicyclists at **Mixing Zone, Delayed Turn, and Offset Crossing** intersections and asked them questions relating to their perceptions of safety, clarity of the intersection designs, and general demographic and cycling frequency questions.

This survey focused on questions relating to conflicts with turning vehicles and thus **Fully Split Phase intersections are not included**.

KEY FINDINGS

KEY FINDINGS: SAFETY

The following table provides a summary of bicycle crash rates by treatment for before and after Protected Bike Lane (PBL) projects. A key result is the overall reduction in intersection bicycle crashes per bicyclist by 30% after installing protected bike lanes.

It is also interesting to compare the rates between different treatments. **For example, the crash rate at Current Generation Mixing Zones is lower than that of Fully Split Phase locations (1.4 and 2.0, respectively).**

Crash risk factors including traffic volumes and geometry are included in the design decision to install a particular treatment type. This is demonstrated in the table below where the Fully Split Phase, typically used at wider and higher volume intersections, have higher *before* crash rates than the overall Mixing Zone locations (4.3 and 1.9, respectively), and thus a higher reduction in crash rates when compared to the Mixing Zone, is expected. **Before-after comparisons between the full set of Mixing Zone and Fully Split Phase locations should not be considered an "apples-to-apples" comparison.**

Change in Intersection Injury Bicycle Crashes per Million Bicyclists from *before* PBL installation[1]

Treatment	Study Sites	Before	After	Crash Rate Change
Current Generation Mixing Zone[2]	71	1.9	1.4	-27%
First Generation Mixing Zone[2]	55	2.1	1.7	-21%
Fully Split Phase	53	4.3	2.0	-54%
All Study Intersections[3] (Mixing Zones and Fully Split Phase)	184	2.5	1.7	-30%

1) Calculated from 2000-2017 bicycle crashes and volumes
2) The first generation mixing zones are designed with a longer shared lane between cyclists and turning vehicles
3) Includes 5 non-Mixing Zone or Fully Split Phase intersections

↓30%

Overall reduction in intersection crashes per bicyclist following PBL installations

1.4

Intersection injury bicycle crashes per million bicyclists for **Mixing Zones** (current design)

2.0

Intersection injury bicycle crashes per million bicyclists for **Fully Split Phase** signal locations

KEY FINDINGS: CONFLICTS

Classification of Bicycle-Motor Vehicle Interactions*

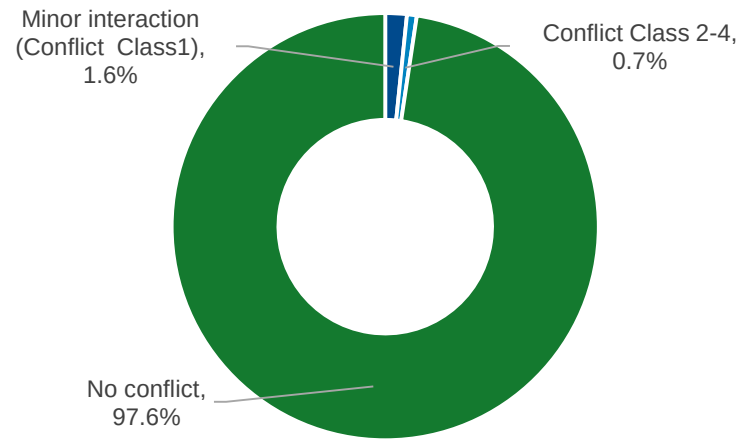
Class (Severity)	**Definition**
-	Normal traffic interaction
1	Precautionary braking or direction change with a *low probability of collision*
2	*Controlled* braking or direction change with little maneuvering time
3	*Strong* braking and/or rapid swerving, near-crash
4	*Emergency* braking or swerving, near or slight crash
5	Crash

*Conflict categorization adapted from the Dutch Objective Conflict Technique for Operation and Research (DOCTOR) method

All of the interactions between people on bicycles and turning drivers are classified based on the above criteria. Any unusual interaction above a normal traffic interaction is assigned a score based on ascending severity.

As shown in the figure below, unusual interactions with conflicts between bicyclists and turning vehicles are relatively rare events occurring to less than 2.3% of bicyclists traveling through any given intersection. Over half of these are simply precautionary moves with a low chance of collision that are more related to bicyclist comfort.

Percentage of people bicycling through an intersection that are involved in a conflict with a turning vehicle (all study sites)



Rare events

As presented in the table below, very few “serious” conflicts were observed. **No Class 5 (actual crashes) were observed**. Only 2 Class 4 conflicts (1 at a Mixing Zone and 1 at a Delayed Turn) and 12 Class 3 conflicts were observed.

The predominate type of conflict identified, Class 1, are unlikely to result in a crash and are more related to bicyclist stress and comfort.

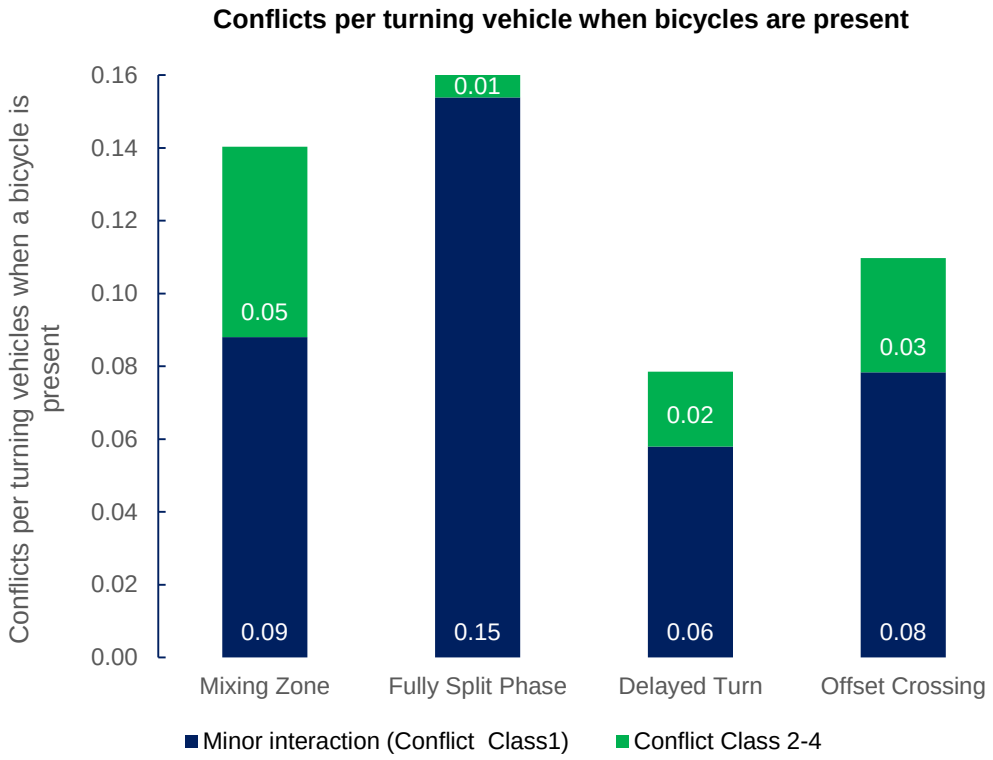
	Class	**For all observed conflicts, % occurring in each class**
Increasing conflict severity ↓	1	69%
	2	28%
	3	3%
	4	1%
	5	0%
		100%

KEY FINDINGS: CONFLICTS

To understand how frequently conflicts between bicyclists and turning vehicles occur, conflict rates are calculated based on the observed conflicts and the total number of vehicles turning while people are bicycling near or through the intersection.

Separate rates are calculated for the Class 1 (minor interaction) conflicts and the more serious Class 2-4 conflicts. These rates provide helpful insights into how an intersection performs on the key measures of comfort and safety. As an example, 9% of the time that a vehicle is turning at a Mixing Zone while a bicyclist is also present, the result is a minor interaction.

While additional data is needed to more fully understand the relationship, the conflict rate likely relates to both likelihood of a collision and bicycling stress levels, particularly for the higher class of conflicts. Examining the difference in rates may also explain some of the disparity between the findings of the crash analysis and the bicyclist-reported comfort. In the following section, the differences between treatments are discussed in further detail.

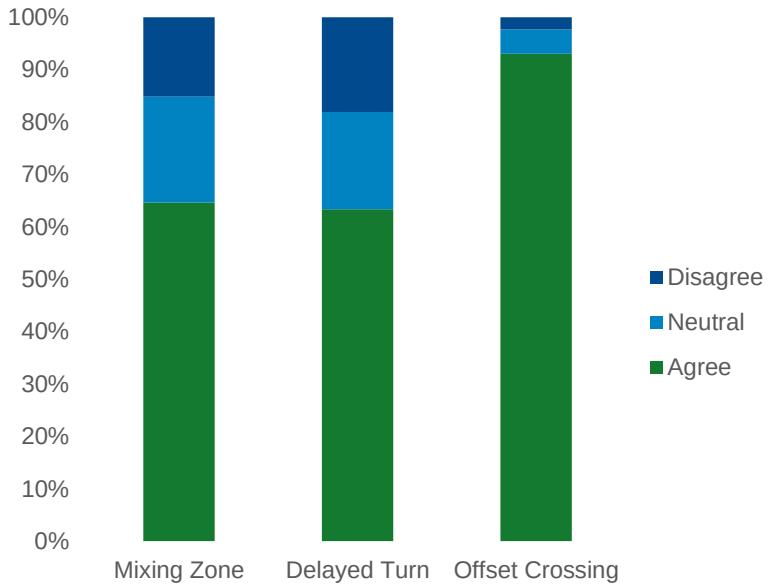


KEY FINDINGS: COMFORT

Some of the key survey results relating to bicyclist comfort levels at intersections include:

- Most bicyclists (65% of those surveyed) report feeling safe riding through Mixing Zones with similar results at the Delayed Turn locations.
- Of the three treatments evaluated where conflicting vehicle turns are allowed, the Offset Crossing is found to have the highest levels of user comfort with 93% of bicyclists surveyed feeling safe riding through them.
- Because the survey focused on the understanding of intersection designs where bicyclists and turning drivers must interact, no locations of the Fully Split Phase design, with the two movements completely separated in time, are included in the survey. However, based on the frequent community requests for Fully Split Phase intersections in place of Mixing Zones and the separation of the bicycle phase and the turning vehicle phase, it is expected that this intersection design has a high level of cyclist comfort.

Response to bicyclist intercept survey question: "I feel safe cycling through this intersection"



Note: This survey focused on questions relating to conflicts with turning vehicles and thus **Fully Split Phase intersections** are not included.




KEY FINDINGS: BY TREATMENT

KEY FINDINGS: MIXING ZONE

Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

SAFETY

Evaluation Methods: Crash ✓ | Video ✓ | Survey ✓

Intersection Bicycle Crashes per Million Biyclists[1]

Category	Current Generation Mixing Zone[2] Sites[4]	Current Generation Mixing Zone[2]	First Generation Mixing Zone[2] Sites[4]	First Generation Mixing Zone[2]	Fully Split Phase Sites	Fully Split Phase
All Study Intersections	71	1.4	55	1.6	53	2.0
Low Vehicle Turning Vol.[3]	10	1.5	5	2.1	12	2.0
High Vehicle Turning Vol.[3]	10	1.3	8	1.6	34	2.2
1 Lane Cross-Streets	63	1.2	43	1.3	21	0.9
2 Lane Cross-Streets	7	2.7	8	2.3	9	0.6
2+ Lane Cross-Streets	8	2.7	12	2.7	32	2.8

1) Calculated from 2014-2016 bicycle crashes and volumes
2) The first generation mixing zones are designed with a longer shared lane between bicyclists and turning vehicles
3) The low turning vehicle volume subset is approximately <120 turning vehicles in the peak hour
4) The 5 Mixing Zone intersections with 3+ cross-street lanes are not included in this table due to the low sample size

The crash rates presented here best assess for the individual risk of a person bicycling. They can be used to compare the safety of the intersection design treatments under different street and traffic contexts. Key findings for Mixing Zones include:

- **Overall, the current, shorter Mixing Zone has a lower crash rate when compared to the first generation design.** This result is consistent even under different conditions.
- **The crash rate is similar for Mixing Zones at both high and low turning vehicle volume locations**. This suggests that from a safety perspective (though perhaps not an operational or comfort perspective) Mixing Zones are a reasonable treatment at higher turn volume locations.
- **The crash rates are considerably higher at intersections with wide cross-streets.** This reinforces the findings from the NYC DOT Left Turn study that higher turn speeds and greater exposure distances contribute to a higher crash risk at wide streets.

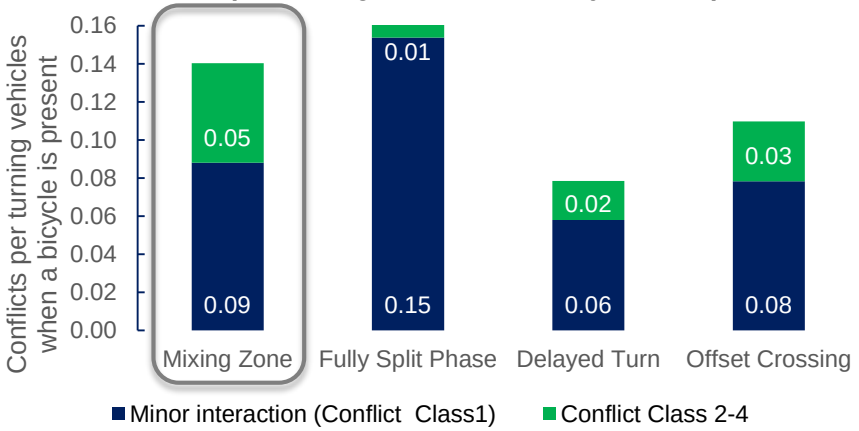
KEY FINDINGS: MIXING ZONE

Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

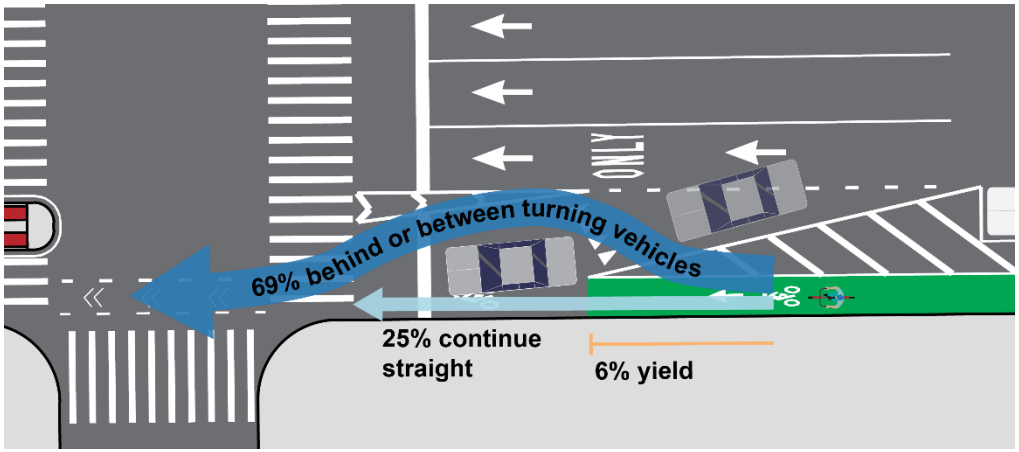
CONFLICTS

Evaluation Methods: Crash ✓ | Video ✓ | Survey ✓

Conflicts per turning vehicle when bicycles are present



Cyclist behavior through an intersection *when a turning vehicle is present*



While safety is the primary concern, bicyclist comfort, mobility, and predictable movements by all street users are important considerations in intersection design.

The observational study provides details on how frequently unusual interactions between people on bicycles and drivers turning occur. It also examines behaviors such as path choice through the intersection, red light running, and yielding to determine how people are actually using the facility. Key findings for Mixing Zones include:

- **There is little consistency in whether bicyclists go in front or behind of turning vehicles**, but bicyclists appear to prefer going behind the path of the turning vehicle. The intent of the Mixing Zone design is to allow for freedom of movements to negotiate the space between turning drivers and bicyclists, this includes bicyclists riding behind turning vehicles. Not all bicyclists may be aware that this is a permitted maneuver which can make behaviors at Mixing Zone intersections less predictable and may add to the stress of people bicycling.
- **While still a rare event, Mixing Zones have higher rates of the more concerning conflicts between bicyclists and turning vehicles (conflict scores 2-4) than the other intersection treatments.** These conflicts may not necessarily lead to crashes but these interactions may explain some of the disparity between the findings of the crash analysis and the bicyclist-reported comfort.

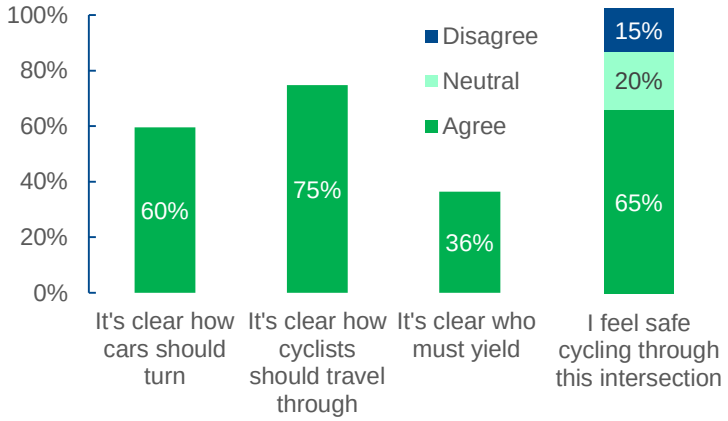
KEY FINDINGS: MIXING ZONE

Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

COMFORT

Evaluation Methods: Crash ✓ | Video ✓ | Survey ✓

Intercept survey of 265 bicyclists at Mixing Zones



Video Screenshot: Example of bicyclists in a Mixing Zone weaving through or behind turning vehicles

The intercept survey of people who had just bicycled through the intersection can reveal additional insights into the clarity of an intersection design, the understanding of traffic rules, and the feeling of safety. Key findings from the survey responses at Mixing Zones include:

- **It is evident that clarification is needed on how drivers should use the Mixing Zone and who should yield.** The majority of respondents stated that it is usually not clear who has the right-of-way between turning drivers and people bicycling through the intersection. This lack of clarity may lead to additional traffic conflicts, stress, and assertive driving and bicycling behaviors.
- **At Mixing Zones, 65% of the respondents stated that they feel safe** with another 20% stating that they neither feel safe or unsafe.

KEY FINDINGS: FULLY SPLIT PHASE

SAFETY

Evaluation Methods: Crash ✓ | Video ✓ | Survey ✗

Intersection Bicycle Crashes per Million Bicyclists[1]

Category	Current Generation Mixing Zone[2] Sites[4]	Current Generation Mixing Zone[2]	First Generation Mixing Zone[2] Sites[4]	First Generation Mixing Zone[2]	Fully Split Phase Sites	Fully Split Phase
All Study Intersections	71	1.4	55	1.6	53	2.0
Low Vehicle Turning Vol.[3]	10	1.5	5	2.1	12	2.0
High Vehicle Turning Vol.[3]	10	1.3	8	1.6	34	2.2
1 Lane Cross-Streets	63	1.2	43	1.3	21	0.9
2 Lane Cross-Streets	7	2.7	8	2.3	9	0.6
2+ Lane Cross-Streets	8	2.7	12	2.7	32	2.8

1) Calculated from 2014-2016 bicycle crashes and volumes
2) The first generation mixing zones are designed with a longer shared lane between bicyclists and turning vehicles
3) The low turning vehicle volume subset is approximately <120 turning vehicles in the peak hour
4) The 5 Mixing Zone intersections with 3+ cross-street lanes are not included in this table due to the low sample size

The crash rates presented here best assess for the individual risk of a person bicycling. They can be used to compare the safety of the intersection design treatments under different street and traffic contexts. Key findings for Fully Split Phase intersections include:

- **The crash rate at wider cross-streets are considerably higher than single-lane streets**. This is a similar finding to the Mixing Zone intersections.
- **When comparing the treatments by cross-street width, lower crash rates are found at the Fully Split Phase intersections than Mixing Zones.*** The Mixing Zone and Fully Split Phase intersection designs have a similar safety performance at the narrow (1-lane) cross-street locations.
- **In general, the Fully Split Phase design is used at larger intersections, thus a higher overall crash rate compared to Mixing Zones is expected.** In the table, the 'number of sites' column highlights that 60% of the Fully Split Phase sites are at locations with 2+ cross-street lanes (32 locations) compared with 16% of the Mixing Zone locations
- The higher crash rate at Fully Split Phase locations may be partially explained by risky behavioral issues such as red-light running during the cross-street phase are amplified by use of this treatment at higher risk intersection locations.

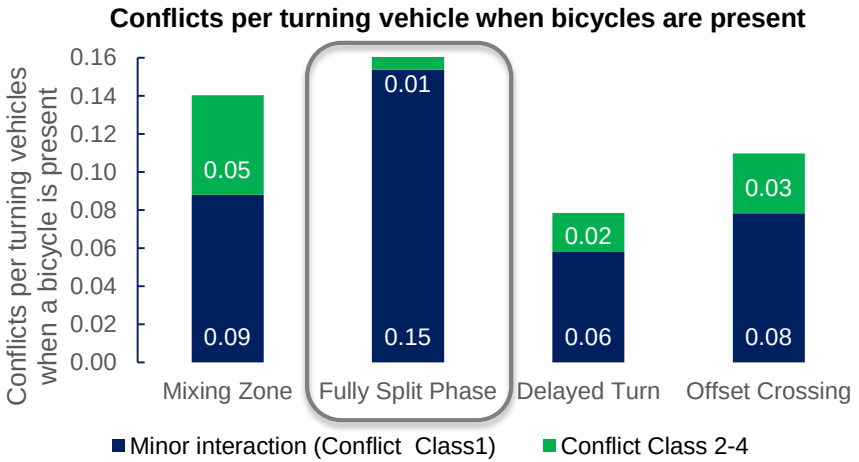
*Note: When the number of study sites becomes low, which occurs when an analysis is conducted on subgroups, the results become less reliable.

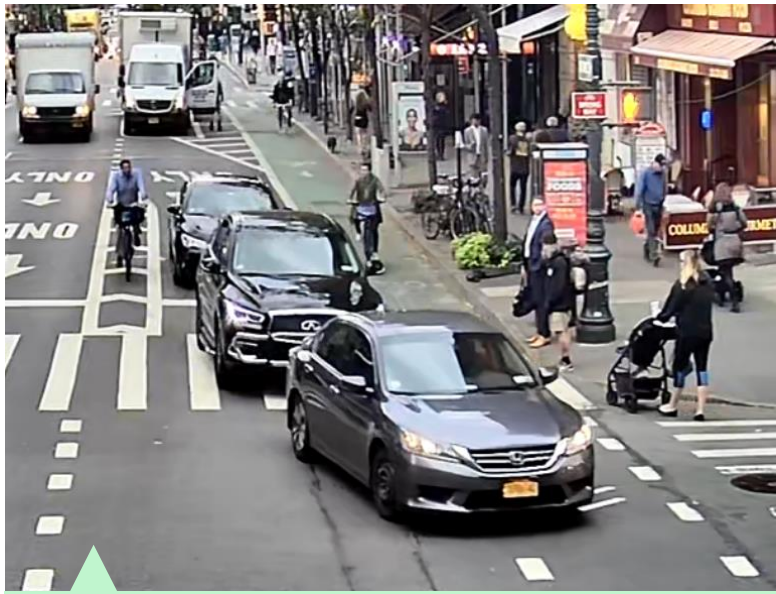
KEY FINDINGS: FULLY SPLIT PHASE

Treatment: Mixing Zone | **Fully Split Phase** | Delayed Turn | Offset Crossing

CONFLICTS

Evaluation Methods: Crash ✓ | Video ✓ | Survey ✗





Video screenshot: Example of different bicyclist routes through the intersection during the turning vehicle phase

While safety is the primary concern, bicyclist comfort, mobility, and predictable movements by all street users are important considerations in intersection design. Key findings for Fully Split Phase intersections include:

- **The Fully Split Phase location has the lowest conflict rate for the higher scoring (conflict scores 2-4) conflicts.** This is likely due to the design providing separate signal phases for bicyclists and turning vehicles
- **The high rate of minor conflicts typically occur during the turning vehicle phase when bicyclists would continue through the intersection** (disregarding the red bicycle signal indication) either by entering into the turn lane upstream of the intersection or merging through cars while in the intersection.

KEY FINDINGS: FULLY SPLIT PHASE

COMFORT

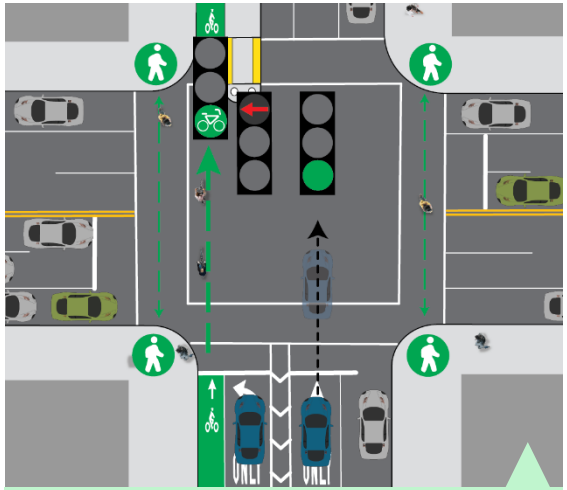
Evaluation Methods:	Crash	Video	Survey
	✓	✓	×

Because the intercept survey of people bicycling focused on questions relating to conflicts with turning vehicles, Fully Split Phase intersection locations, with separate signal phases for bicyclists and turning vehicles, are not included.

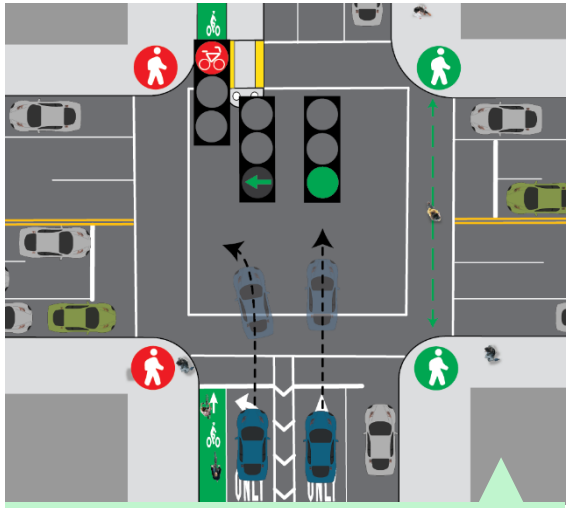
However, based on letters and other comments from the public received by NYC DOT, it is clear that the Fully Split Phase design provides a feeling of safety for many people bicycling or who are interested in bicycling.

While this design is comfortable to many, the frequent use of this treatment along a corridor, particularly at smaller cross-streets, can result in discomfort and stress to some people bicycling due to the increased intersection delay. This added delay can quickly compound along a corridor which may decrease mobility and contribute to impatient bicycling behaviors. Additionally, the implementation challenges that come from the loss of parking and/or loading zones needed for a full turn lane may make a Protected Bike Lane (PBL) project impractical on some corridors.

Therefore, using the results of the crash analysis as guidance, the Fully Split Phase design is most appropriate at larger intersections where this delay is acceptable, at higher speed locations, or where such a low stress design makes a critical PBL or greenway connection possible.



Bicycle and through-vehicle phase



Turning- and through-vehicle phase (bicyclists held on red signal)

KEY FINDINGS: DELAYED TURN

Treatment: Mixing Zone | Fully Split Phase | **Delayed Turn** | Offset Crossing

SAFETY

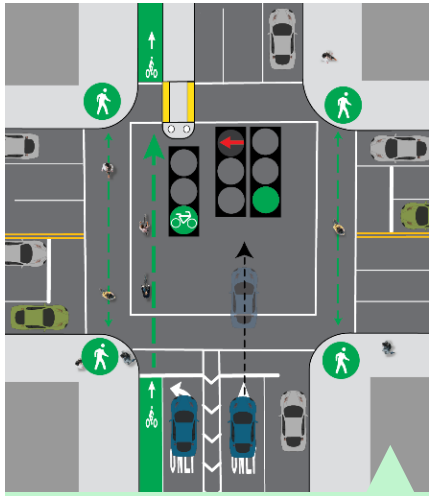
Evaluation Methods: Crash ✗ | Video ✓ | Survey ✓

Because this treatment is a new design, there is with limited 'after' data available to conduct a crash-based evaluation. While a minimum of 3 years of data at several sites are typically necessary for these studies, video observations and surveys can capture valuable interim data to gain an understanding of how the design is functioning.

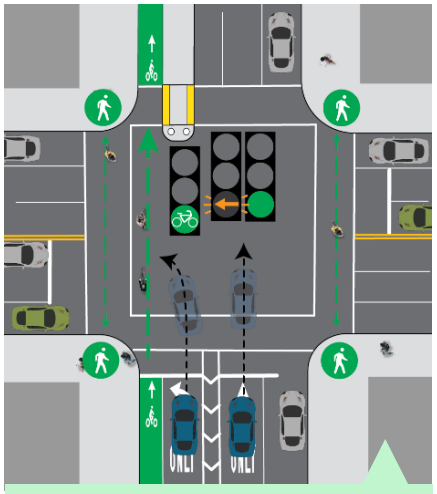
The conflict study (on the following page) indicates that this design can work well, however the video analysis revealed several interesting observations that may affect safety, including:

- **At the start of the Flashing Yellow Arrow phase (from red), several conflicts were observed.** This occurred when people were bicycling adjacent to the turning vehicle at the moment that the drivers' light changed and the drivers entered the bike lane extension without looking.
- **When the vehicle turning queue spilled out beyond the turn lane, drivers were observed to bypass the queue and make a double turn onto the cross-street.** This behavior was also observed at high turn volume Mixing Zone locations and presents a safety concern as the view between the double turning driver and people in the bike lane is blocked by the car in the turn lane.

Example of a driver bypassing the turning queue and making a double turn at a Delayed Turn location



Leading Bicycle Interval Phase: 10+ s



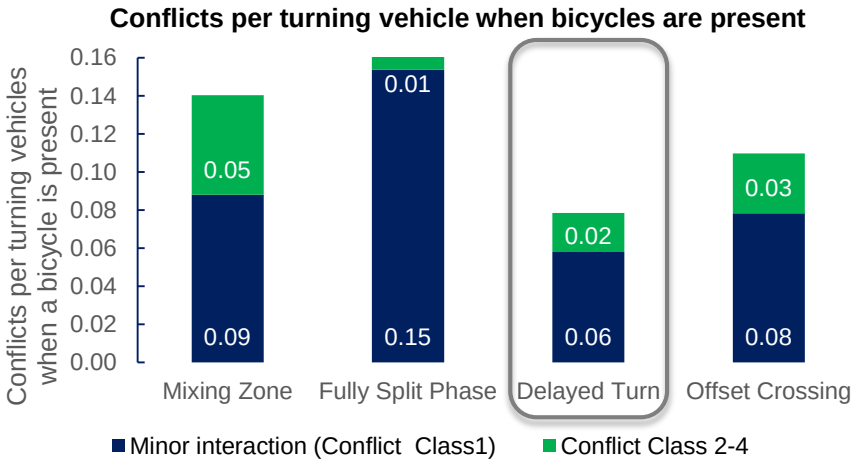
Flashing Yellow Turn Phase

KEY FINDINGS: DELAYED TURN

Treatment: Mixing Zone | Fully Split Phase | **Delayed Turn** | Offset Crossing

CONFLICTS

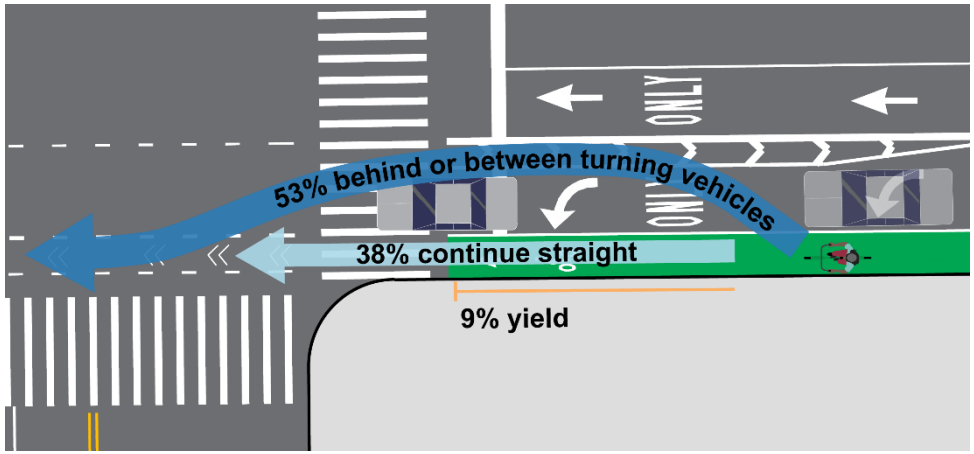
Evaluation Methods: Crash ✗ | Video ✓ | Survey ✓



The video analysis revealed several interesting observations on the operation of the Delayed Turn intersection including:

- **53% of bicyclists were observed to leave the bike lane to go behind a turning vehicle**, treating it similar to a Mixing Zone with a preference to go behind the path of the turning vehicle.
- **The Delayed Turn locations have the lowest total rate of interactions between bicyclists and turning vehicles.** However, the conflict at the start of the Flashing Yellow Arrow should be addressed.

Cyclist behavior through an intersection *when a turning vehicle is present*



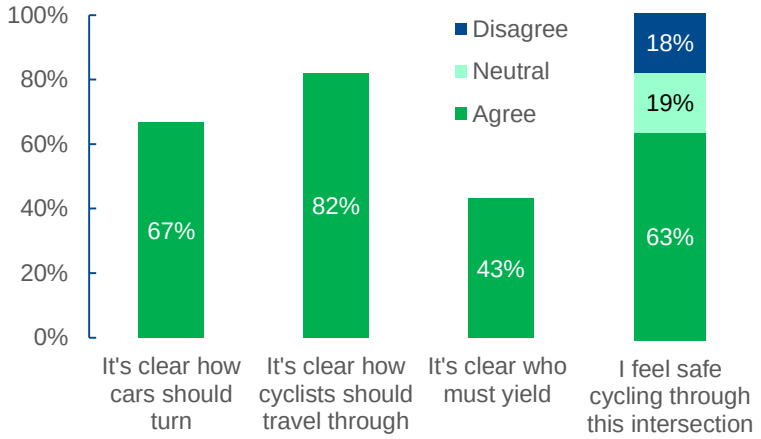
KEY FINDINGS: DELAYED TURN

Treatment: Mixing Zone | Fully Split Phase | **Delayed Turn** | Offset Crossing

COMFORT

Evaluation Methods: Crash ✗ | Video ✓ | Survey ✓

Intercept survey of 222 cyclists at Delayed Turn intersections



Example of different bicyclist routes through the intersection when a turning vehicle is present

The intercept survey of people who had just bicycled through the intersection can reveal additional insights into the clarity of an intersection design, the understanding of traffic rules, and the feeling of safety. This is information is particularly helpful when evaluating the understanding and effectiveness of new designs. Key findings from the survey responses at Delayed Turn intersections include:

- **There is slightly higher bicyclist reported rate of understanding on how users should navigate the intersection** when compared to the Mixing Zone.
- **Similar to the Mixing Zones, the majority of bicyclists stated that it is not clear who is to yield at the intersection**.
- **At Delayed Turn intersections, 63% of the respondents stated that they feel safe**, thus reporting a similar feeling of comfort as the Mixing Zone locations.

KEY FINDINGS: OFFSET CROSSING

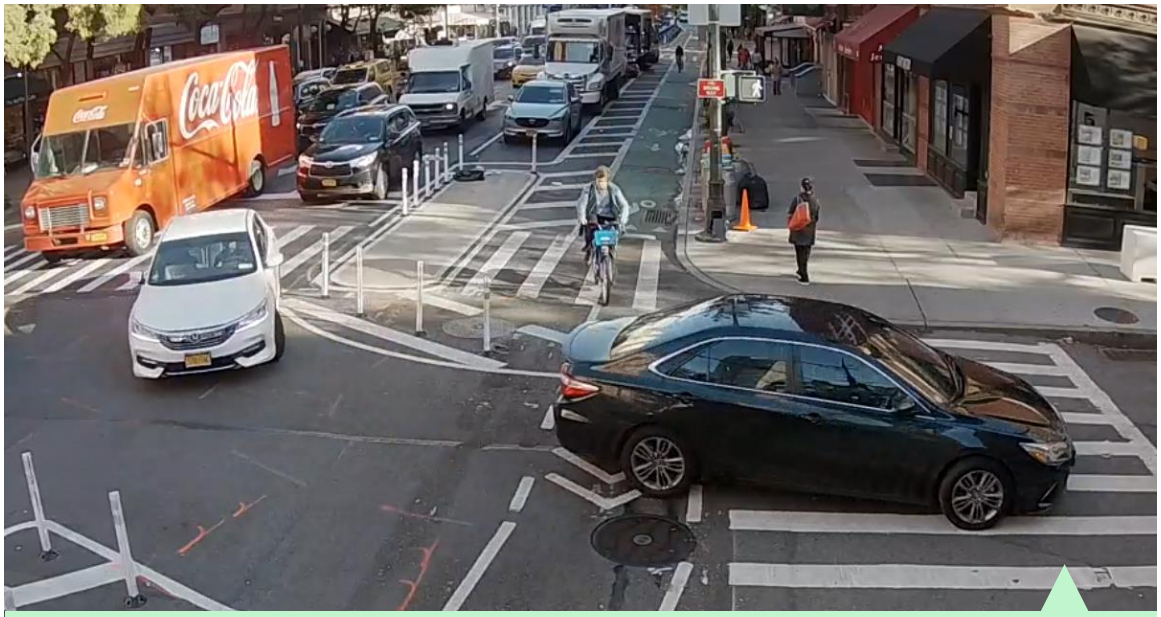
Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

SAFETY

Evaluation Methods: Crash ✗ | Video ✓ | Survey ✓

Because this treatment is a new design, there is with limited 'after' data available to conduct a crash-based evaluation. However, video observations and surveys can capture valuable interim data to gain an understanding of how the design is functioning. The conflict study (on the following page) indicates that this design can work well, however the video analysis revealed several interesting observations that may affect safety, including:

- **Drivers are turning faster than preferred.** Utilizing a design with a tighter radius will likely slow the speeds at which drivers turn allowing for more reaction time and a greater opportunity to yield.
- **The 15' offset between the motor vehicle travel lane and bike lane provides sufficient space for a typical vehicle to turn and yield to people walking and biking without blocking the bike and travel lanes.**



Cyclists and drivers interacting at the Columbus Avenue & W 70 Street Offset Crossing

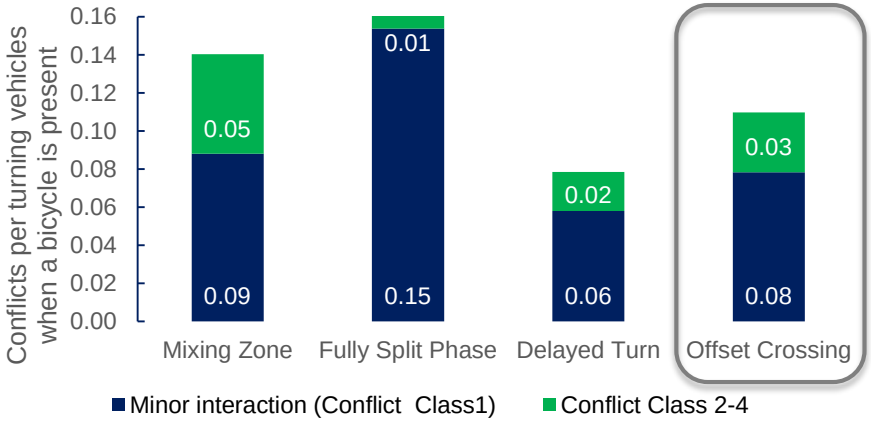
KEY FINDINGS: OFFSET CROSSING

Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

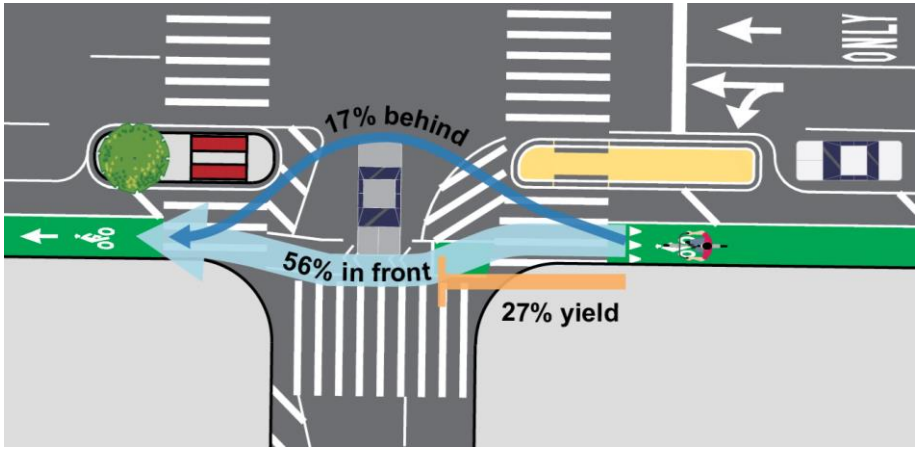
CONFLICTS

Evaluation Methods: Crash × | Video ✓ | Survey ✓

Conflicts per turning vehicle when bicycles are present`



Cyclist behavior through an intersection *when a turning vehicle is present*



Because the Offset Crossing is a new pilot treatment a crash analysis can not be conducted. Instead, the observational study provides an initial understanding on whether people are using this intersection type as designed and the type and frequency of interactions that occur between bicyclists and turning vehicles. Key findings include:

- **Drivers are turning at a higher speed than preferred** leading to short reaction times and more potential crashes than if the speeds were slower.
- **Bicyclists are much more likely to yield to turning vehicles (27% of the time) than at the other intersection designs.** This is likely related to the short reaction time, where bicyclists are unsure whether a driver will yield to them and thus make a cautionary stop. It is also not designed to allow for bicyclists to go behind the turning vehicle, the typical movement at Mixing Zones, likely increasing the number of bicyclists stopping for turning traffic.
- **The conflict rate can likely be reduced** through changes in the geometry that slow turning speeds and increase the visibility of the bicycle facility.

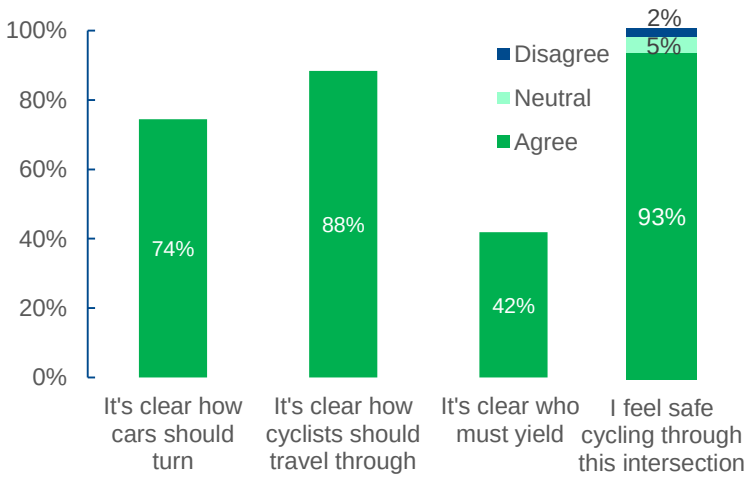
KEY FINDINGS: OFFSET CROSSING

Treatment: Mixing Zone | Fully Split Phase | Delayed Turn | Offset Crossing

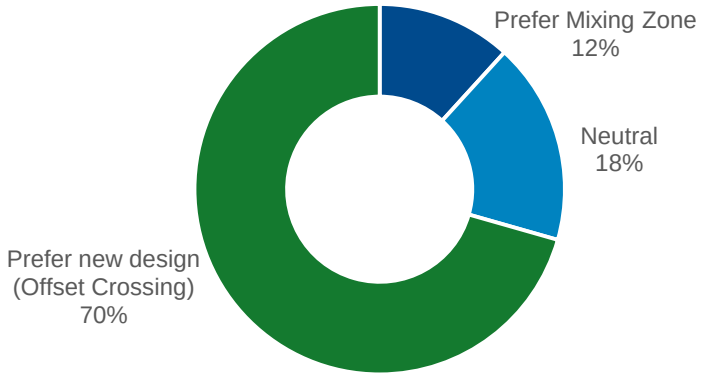
COMFORT

Evaluation Methods: Crash ✗ | Video ✓ | Survey ✓

Intercept survey of 43 cyclists at Offset Crossings



The NYC DOT recently changed the design of this intersection, if you noticed a difference, which intersection design do you prefer? (43 responses)



At Columbus Avenue & W 70th Street, the Mixing Zone was converted into a pilot Offset Crossing location. This afforded the opportunity of conducting an intercept survey for both treatments at the same location. This intercept survey of bicyclists at the pilot Offset Crossing found:

- **The design is effective in creating a comfortable intersection for bicyclists.** Where the pilot Offset Crossing replaced a Mixing Zone, 70% of the bicyclists stated that they preferred the new (Offset Crossing) design and 18% were neutral.
- **93% of the respondents stated that they feel safe** riding through the Offset Crossing intersection. *However, that feeling of safety must also translate into actual safety for this to be an effective design.*
- **The Offset Crossing had the highest stated understanding of how bicyclists and drivers should use the design.**
- **The clarity of who must yield at Offset Crossings is low.** This is a similar finding compared to the other intersection designs.

RECOMMENDATIONS AND NEXT STEPS

INTERSECTION DESIGN MATRIX FOR ONE-WAY PROTECTED BIKE LANES

This study identified the effects, perceptions, and understanding of the different design treatments used for Protected Bike Lanes at intersections. Overall, the findings show that both Mixing Zones and Fully Split Phase intersections have substantial reductions in the rate of bicyclist crashes following their installation as part of a PBL project.

The two pilot treatments evaluated in this study show potential to be valuable additions to the intersection design toolbox. When appropriate, these treatments will continue to be used in NYC bikeway projects while they are continued to be studied and refined.

Based on results of this study, NYC DOT's current design practices, and a review other research and guidance, this report developed interim design recommendations for selecting PBL intersection treatments under different conditions.

These recommendations include a range of different street conditions and presents the applicability of each of the designs under those conditions taking into account both safety, comfort, and feasibility. Note that these recommendations are suggestions as a starting point for designers but that site- and project-specific conditions may require a different approach. This is particularly the case for the turning vehicle volumes where the recommendations are primarily based on operational rather than safety constraints. As the knowledge base is always evolving, the design matrix will be updated periodically to reflect new information and best practices.

This design matrix will help guide NYC DOT designers in selecting appropriate and consistent designs for different street contexts and are intended to provide a transparent decision making framework to the public.

Progression of bicycle facilities on 2nd Avenue (none, buffered bike lane, PBL with Mixing Zone)

INTERSECTION DESIGN MATRIX FOR ONE-WAY PBLS

Application Considerations[1]		Mixing Zone	Fully Split Phase	Delayed Turn (AKA Split LBI) Continue with limited use under specific conditions	Offset Crossing
Along a one-way street with cross-street lanes:	**1**	Preferred for higher turn volumes	Preferred when a gap in ped traffic is required to process traffic	Possible for turn volumes <150/hr where a LPI is needed	Preferred for turn volumes <120/hr
	2+	Possible with turn volumes <60/hr	Preferred	Possible with turn volumes <60/hr where a LPI is needed	Possible with turn volumes <60/hr
Cross-street is two-way		Possible with turn volumes <80/hr and LTTC	Preferred	Possible with turn volumes <150/hr and LTTC	Possible with turn volumes <80/hr and Left Turn Traffic Calming (LTTC)
PBL is along a two-way street[2]		Consider when left turns <50/hr[3]	Consider when left turns >50/hr	Consider when left turns <50/hr[3]	Consider when left turns <50/hr[3]
Leading Pedestrian Interval		Possible with sign: 'Bikes May Use Ped Signal'	Possible	Possible	Possible with bike signal or sign: 'Bikes May Use Ped Signal'
Curb space needed (parking/loading loss)		Typically 90 ft	Typically 130 ft - Based on 85th percentile queue	Typically 110 ft	Typically 25 ft on mainline and 20 ft on narrow cross-streets
Speed limit ≥30mph		Not recommended	Preferred	Not recommended	Not recommended
Other considerations		• The current, shorter design should be used • If used at multilane cross-streets, traffic calming and visibility measures should be included • Consider context (e.g. schools, paths, etc.) where more comfortable designs with the tradeoffs such as higher delay may be desirable	• Turn lane/bay is req'd, of a length that can store all turning vehicles • Consider where a lower stress connection is preferable • Where multiple turn lanes/turning movements cross the impacted crosswalk/bike facility • No gap for turning vehicles due to high pedestrian and bike volumes • If several split phases are used along a corridor, a progression speed for bicyclists should be considered	• **Continue with limited use when a LPI without delaying through traffic is needed – must meet conditions in this table** • **Preferred installation is at a two-way cross-street w/ LTTC due to additional maneuvering space before conflict** • **Not recommended at downhill locations where cyclist speed may be higher** • Moderate turning volumes, but minimal storage space for turning lane/bay • High through volumes that would be delayed by a standard LPI • A turn lane or bay is required	• A 15 ft offset requires approximately 17 ft from curb to edge of travel lane • If used at multilane cross-streets, traffic calming and visibility measures should be included (i.e. high visibility markings, LTTC) • If a turn lane is provided, the full 15 ft offset may be reduced • Operationally not recommended on streets with >300 through veh/lane/hour • Truck and bus routes require additional care • Requires 40 ft of clear distance on approach to the Point of Curvature

1. This table provides planning guidance for typical intersection conditions, site specific conditions may require different design approaches
2. This threshold may be increased if there is only one opposing lane
3. On a two-way street, the right turn treatment should be selected separately
NOTE: As the knowledge base is always evolving, the design matrix will be updated periodically to reflect new information and best practices.

ACTIONS: COMFORT

Under some conditions, the intersection design matrix allows for the discretion of the street designer to select the most appropriate treatment based on the project context. This makes understanding the substantive safety of a bicycle facility and the amount traffic stress that it presents to bicyclists critical to designing a bikeway network that is safe, convenient, and attractive to bicyclists of all abilities.

Lower-stress designs can increase safety by contributing to the "safety in numbers" effect that comes from an increase in bicyclists. But due to a number of factors that include predictability and tolerance for delay, not all designs that are comfortable are safe or practical in all situations.

Facility design can provide both the highest level of safety as well as comfort and convenience. In practice however, trade-offs are often necessary based on balancing other street users, curbside and adjacent uses, and transportation network needs. When selecting intersection treatments, it's critical to understand the conditions where each design may be used safely and the effect on bicyclist comfort and delay.

Comparing the Fully Split Phase and the Mixing Zone designs provides a good example. While the Fully Split Phase often has a lower stress level for bicyclists, it also creates higher bicyclist and pedestrian delay, particularly if used frequently along a corridor. In addition, factors such as the greater infrastructure needs and an increased loss of curbside loading zones and parking may make the Mixing Zone a better choice at many locations.

To help with the decisions at individual intersections, a review of the crash analysis indicates a marginally higher safety performance from the Fully Split Phase over the Mixing Zone with minimal differences at low volume, narrow cross-street locations. Therefore, **the application of the Fully Split Phase treatment should be prioritized to where it is most beneficial such as at wider intersections** or where a low-stress cycling connection is needed.

ACTIONS: DESIGN

Mixing Zone

Design Recommendations

- The longer (older generation) Mixing Zones should be replaced with the shorter, current design as markings are refreshed.
- Pursue modifications to the placement of sharrows and intersection markings and the addition of elements in the channelized intersection approach to maintain the clear zone free from parking.
- Intersection crossings should be shortened to reduce the possibility of double turns at locations where the turning queue frequently spills back into the travel lane.
- Include traffic calming measures at multilane cross-streets to reduce turning speeds and cyclist exposure to turning vehicles.

ACTIONS: DESIGN

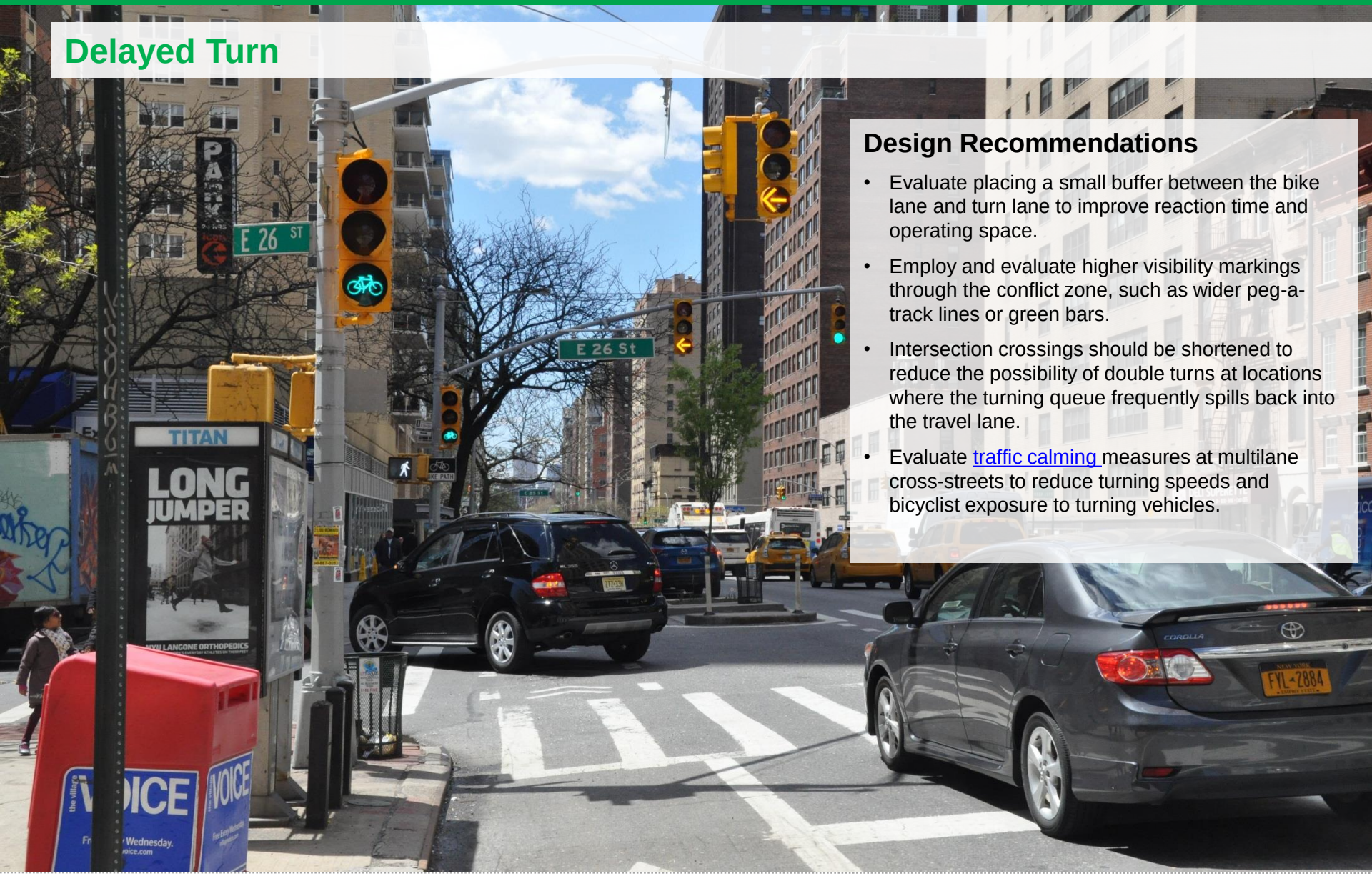
Fully Split Phase

Design Recommendations

- At locations with a high crash potential, evaluate vertical elements between the bike lane and turn lane. Note that increased maintenance is necessary for such a design, including snow plowing.
- Develop strategies to improve signal coordination that reduces bicyclist stopping and delay along corridors with several Fully Split Phase intersections.

ACTIONS: DESIGN

Delayed Turn



Design Recommendations

- Evaluate placing a small buffer between the bike lane and turn lane to improve reaction time and operating space.
- Employ and evaluate higher visibility markings through the conflict zone, such as wider peg-a-track lines or green bars.
- Intersection crossings should be shortened to reduce the possibility of double turns at locations where the turning queue frequently spills back into the travel lane.
- Evaluate traffic calming measures at multilane cross-streets to reduce turning speeds and bicyclist exposure to turning vehicles.

ACTIONS: DESIGN

Offset Crossing

Design Recommendations

- Evaluate a reduced corner radius to 12 ft for turning passenger vehicles along with larger radius for small trucks with traffic calming to slow their speeds and discourage the use of the larger radius by passenger vehicles.
- Extend the far side channelization to visually narrow the cross-street for turning drivers.
- Evaluate narrower offset options (<15 ft) for low speed, low turning volume locations to allow for this design on streets with more constrained widths.
- Install and evaluate higher visibility markings through the conflict zone, such as wider peg-a-track lines or green bars.
- Investigate a raised crossing concept for a future toolkit addition. A raised lane should not be used if the cross-street is a bus or truck route.
- Review the pilot installations placed on two-way streets.
- Study the traffic impact on traffic due to the absence of a turn lane with this design.

ACTIONS: EDUCATION & ENFORCEMENT

EDUCATION

- Update the Bike Smart Cycling Guide to highlight risky behaviors and clarify how to interact with drivers at different intersection types.
- Create handouts for cyclists and drivers to clarify when and where one must yield and how to safely share the road at intersections.
- Develop an on-street activation event (e.g. ‘Dusk and Darkness’) to engage with drivers and cyclists citywide to promote safe intersection behaviors.
- Conduct digital outreach to share highlights from this report, provide context for bicycle project updates on social media channels, and feature the different intersection types in NYC DOT newsletters.

ENFORCEMENT

- Continue to work with NYPD to develop actions based on the locations and behaviors found to be the most likely to result in crashes. Tailored enforcement will focus on locations with higher traffic speeds, volumes, and crossing distances where the cyclist risk of injury is higher.

ACTIONS: KEY INTERSECTION UPGRADES

The **Vision Zero** Year Three Report (NYC Mayor's Office of Operations, February 2017) included a new initiative for Vision Zero Year 4: **Make upgrades to at least 20 key cycling intersections within the bike network**. In 2017, NYC DOT upgraded 8 intersections. The remaining 12 intersections will be completed in 2018. The results of this report are being used to inform upgrades to Protected Bike Lane intersections.

NYC DOT is committed to improving cycling safety. Intersection upgrades will be selected based on crash history and the high potential for crashes based on known contributing factors such as street design, turning traffic volumes and crossing distances.

2017 upgrades included a bike lane to Protected Bike Lane conversion on 5th Avenue in Manhattan, featuring both Mixing Zones and Fully Split Phase (shown) intersections

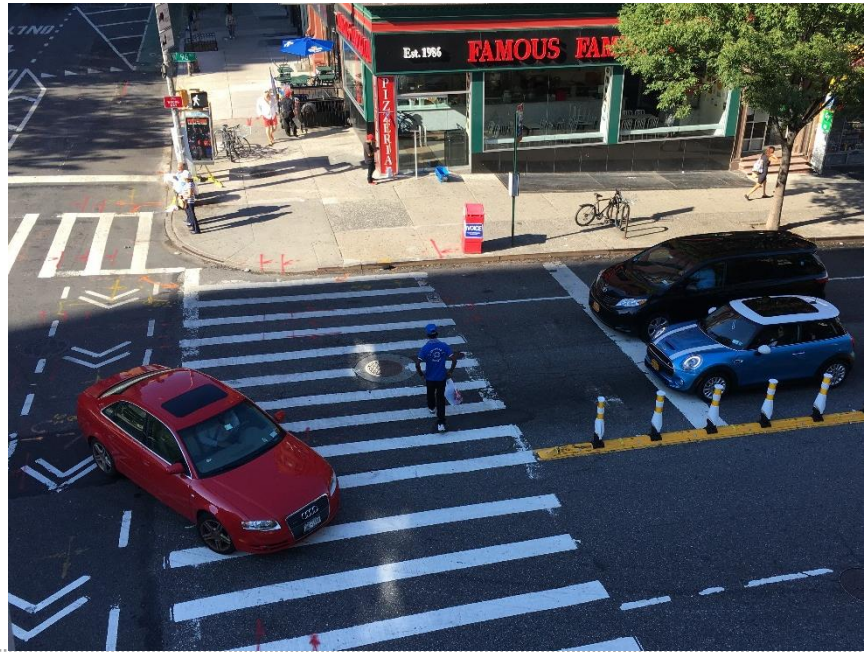
NEXT STEPS

This report lays out recommendations for design modifications and other actions for all four of the intersection design types that may further improve their safety, comfort, and operation.

We will update our current standards to reflect these recommendations into all future bicycle projects.

An addendum to this study will be developed to follow up on these recommendations, including:

- A summary of intersection design modification trials and evaluation results;
- Review the Offset Intersections designs installed at locations on two-way streets and two-way cross streets;
- Updates to the key intersection improvements; and
- Final design recommendations.



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All photos NYC DOT unless noted

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