

Safety Implications of Conversions to Flashing Yellow Arrow Indications

Richard A. Perez, P.E.
City Traffic Engineer
City of Federal Way

13 September 2010

Introduction

This report analyzes the before-and-after collision history of Flashing Yellow Arrow (FYA) traffic signal indications in the City of Federal Way.

Flashing Yellow Arrows were allowed by FHWA by Interim Approval and have since been adopted in the 2009 MUTCD. Federal Way took advantage of WSDOT's statewide Interim Approval to implement a pilot project in 2006. An evaluation of the first six months of operation resulted in City Council approval of FYA's for all new protected/permitted installations and established criteria for a retrofit program to be funded with project savings from the pilot project. This funding has been supplemented with developer mitigation and small works capital funding. FYA's have now been installed at eight of the City's seventy-six signalized intersections in Federal Way, with funding for one more retrofit in 2010, and proposed capital funding of four more retrofits in 2011, and four new installations in 2011 and five more in 2012.

Public education consisted of press releases and a web page. The initial press release resulted in a front page article in the *Tacoma News Tribune* on a Sunday. Press releases have been issued for each subsequent turn-on. Most public comments have been positive, frequently including requests to consider implementation at other intersections. Negative comments have dwindled since initial implementation.

One issue that arose with the implementation of FYA was a complaint that the FYA indication was confusing given the City's use of night flash operations and the lack of explicit language in state law and the Driver's Manual. To address the first issue, night flash operations were halted at all locations where FYA was implemented. The second was the installation of 24" x 42" instructional signing at FYA installations beginning on December 3, 2008, pictured below:



The Driver's Manual has since been revised to include discussion of FYA.

Locations Installed

Each of the intersections where FYA has been implemented is described below:

9th Avenue S at S 336th Street:

At this location, adjacent land uses are primarily office parks. 9th Avenue S is a 3-lane principal collector, with a posted speed limit of 30 mph on the south leg and 25 mph on the north leg, and the ADT is about 5,000. S 336th Street is a 4-lane divided principal arterial with left-turn lanes at the intersection, a posted speed limit of 35 mph, and the ADT is about 19,000. Previous phasing was protected only on S 336th Street and permitted only on 9th Avenue S. All approaches have FYA. The protected phases are lagging only. Auxiliary left-turn heads were also installed on the far left corner of all approaches. On 9th Avenue S, the inside through heads were replaced with left-turn heads, and a second through head was installed pole-mounted on the far right corner of the intersection.



SR 99 at S 312th Street:

This intersection is located in a commercial retail area. SR 99 is a 6-lane divided principal arterial with left-turn lanes and a southbound right-turn lane, a speed limit of 40 mph and ADT about 35,000. S 312th Street is a 5-lane minor arterial with left-turn lanes, a speed limit of 35 mph, and ADT about 20,000. Previous phasing was protected on all approaches and a southbound right-turn overlap. Only S 312th Street approaches were converted to FYA. The coordination plans were not revised, so this runs lead/lag much of the day, and lag/lag in free operation. Auxiliary left-turn heads were already installed on the far left corners of the revised approaches.



Military Road S at S 288th Street:

Both roads are principal arterials in a commercial retail node surrounded by single- and multi-family residential development. Military Road S at this location has 3 lanes with right-turn lanes on each approach, 40 mph speed limit, ADT about 15,000 on the south leg and 20,000 on the north. These approaches were converted from protected only to lagging protected/permitted. The southbound right also has a "No Turn on Red" restriction due to a sight distance restriction. As part of the conversion, a southbound right-turn overlap was also added. S 288th St. has a 4-lane section with left-turn lanes at the intersection, speed limit of 35 mph, and ADT about 15,000 on both the east and west legs. S 288th Street remains with protected phasing due to sight distance restrictions. The FYA phases lag. No auxiliary left-turn heads were installed due to limited conduit capacity. One mast-arm mounted signal head was moved from each mast arm to the mast arm pole on subject approaches to avoid increasing windload.



1st Avenue S at S/SW 312th Street:

Both roads are minor arterials with 35-mph posted speeds, located in a small retail node surrounded by single- and multi-family residential development. All approaches have single lanes for each movement. ADT's are about 20,000 on east and south legs, 15,000 on north and west legs. All approaches were protected only. A northbound right-turn overlap was added with the conversion. All left-turn phases lag. A through signal head was relocated from the mast arm to the mast arm pole on the far right corner of each approach, and an auxiliary left-turn signal head was added on the far left corner of each approach.



1st Way S at S 336th Street:

The west leg is local access street, and the other three legs are 4-lane divided arterials with 35-mph posted speeds. The eastbound approach has left and through lanes, westbound has left, left+through, and 2 right-turn lanes with split phasing and a westbound right-turn overlap. Northbound and southbound approaches have left and two through lanes and is on a mild curve with 4% superelevation. ADT's are about 20,000 on the north and east legs, 15,000 on the south leg, and 5,000 on the west leg. Surrounding land uses are office buildings. The north and south approaches were converted from protected to protected/permitted in 2006, and then converted to FYA on 12/29/2008. FYA phases run lagging most of the day. A through signal head was relocated from the mast arm to the mast arm pole on each modified approach. No auxiliary left-turn signal heads were installed due to limited conduit capacity.



21st Avenue SW at SW 336th Street/SW Campus Drive:

Both roads are principal arterials with 35-mph posted speeds and 5-lane cross-sections in a commercial retail node surrounded by residential development. Previous phasing was protected/permitted with cluster heads on all approaches. This intersection had a high collision rate, with lots of left-turn collisions. The intersection was over capacity during evening peaks and weekend midday peaks. Volumes are about 30,000 ADT on the east and west legs, and about 20,000 ADT on the north and south legs. Conversion to FYA allowed use of lead/lag phasing by time of day to improve progression. A through signal head was relocated from the mast arm to the far right corner mast arm pole on each approach. No auxiliary left-turn signal heads were added due to limited conduit capacity.



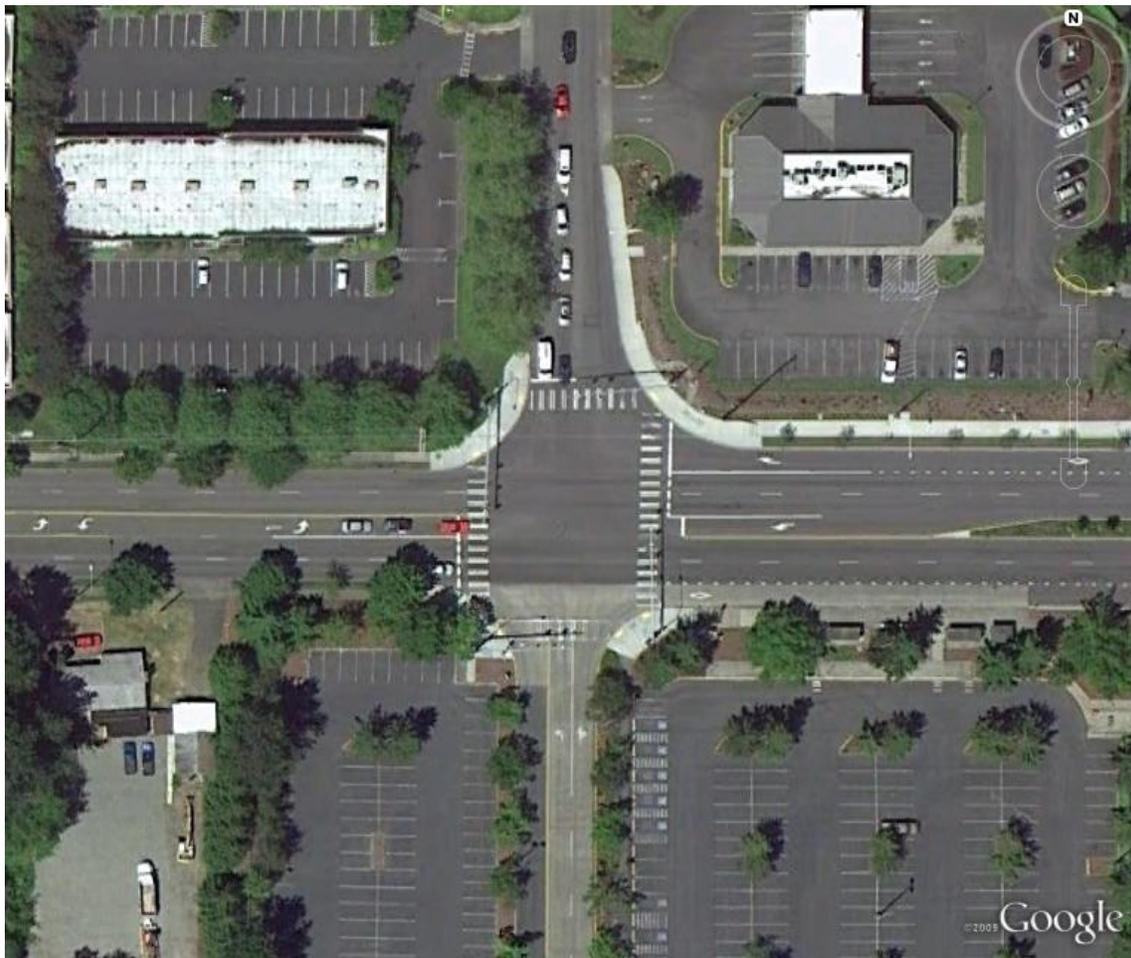
16th Avenue S at S 344th Street:

16th Avenue S is a 5-lane principal arterial with a 35-mph posted speed and over 20,000 ADT. S 344th Street is a 2-lane minor collector with left-turn pockets and with 1000 ADT and a 25-mph posted speed. This signal was initially installed to serve a new Wal-Mart, and had permitted left-turns. Following the store opening, left-turn volumes from 16th Avenue S were higher than forecast, particularly on weekends, so FYA was added for northbound and southbound. Each mast arm on the modified approaches already had pole-mounted signal heads for through phases. Auxiliary left-turn heads were added on the far-left corner of each modified approach.



9th Avenue S at S 348th Street:

S 348th Street is a 5-lane principal arterial with a 35-mph posted speed and 35,000 ADT. 9th Avenue S is a 3-lane principal collector with 7000 ADT and a 30-mph posted speed. The south leg is the main entrance to a 600-stall park-and-ride lot. S 348th Street used to have protected/permitted lefts, but the signal was rebuilt with protected lefts when the east leg was widened to 7 lanes in 2008. This generated several complaints about increased delays, however, the number of gaps is very limited in peak hours. We are implementing switching between protected only and protected/permitted by time-of-day. The rebuilt signal included pole-mounted through phase signal heads on the far right corner of each approach and auxiliary left-turn signal heads on the far left corner of each approach with a left-turn phase.



Collision Data

This analysis is based on reported collisions from three years prior to the conversion to FYA to up to 3 years following collision or to the end of June 2009, whichever is less. As a result, there is no data for the last conversion. Where data is available for only part of a year, the number of collisions is annualized.

Collision data has been stratified by number of years before and after the conversion, collision severity, and type of collision. Collision rate (collisions per million entering vehicles) and severity rate (societal cost per million entering vehicles) were also calculated. Societal cost is calculated using TIB values of \$5000 for a property damage only collision and \$27,500 for an injury collision. No fatalities were reported.

The data is also summarized by all 6 intersections, and by type of conversion (protected phasing to FYA, and protected/permitted phasing to FYA). Since the intersection of 9th Avenue S at S 336th Street involved both conversion from protected and permitted to FYA, this intersection was deleted from the latter calculations.

Intersection Highlights:

9th Avenue S at S 336th Street:

This intersection was selected for the pilot project because it needed left-turn phasing on the north and south approaches, which had permitted lefts, and it had a queue storage problem for the westbound left-turn phase, which had protected lefts. A signal modification project was funded in the CIP for \$100,000. The total cost of the conversion was just under \$30,000. The initial 6-month evaluation showed only one reported collision (a 47% reduction in collisions) and, although it involved a left turn movement, was determined to be not the result of driver misunderstanding of the FYA display. It was on this basis that the City Council approved additional FYA installations.

Unfortunately, this experience has not been matched since. Although the collision rate is still only 0.64, the number of injuries has doubled, resulting in a 31% increase in collision rate and a 75% increase in severity rate. Strangely, the biggest increase in collision type is a 500% increase in rear-end collisions, even though the modification reduced delay on all approaches. The second-biggest increase was in approach turn collisions, with three collisions on the eastbound approach. This may be due to a slight curve on the east leg, which would obstruct the eastbound left-turning driver's view of oncoming traffic if there is a large vehicle in the westbound left-turn lane. However, none of the approaches comes near the City's threshold of 5 left-turn collisions per year to warrant protected left-turn phasing.

SR 99 at S 312th Street:

This intersection was selected due to queuing issues on the eastbound left-turn lane, and was the City's first implementation of FYA with coordination and using lead/lag phasing. The eastbound and westbound left-turn phases were converted from protected to FYA.

Collision rates increased 22%, injuries increased 35%, PDO's increased 16%, and severity rate increased 30%. Approach turn collisions increased 226%, with a near equal split between approaches. Pedestrian collisions went from 0 to less than 1 per year. Rear-ends dropped 12%, and backing collisions were eliminated.

Although the collision data shows a significant increase in most measures, the vast majority of this increase occurs in the first year of implementation. After the first year, which coincided with the installation of explanatory signing, these measures reduced below the "before" levels. It was initially unclear whether it was this signing or driver conditioning drove this change in collision experience. After the first year, collisions dropped 19%, injuries dropped 67%, PDO's dropped 8%, and the severity rate dropped 51%. Although approach turn collisions predictably increased 38% and pedestrian collisions increased to over 1 per year, all other collision types dropped: rear-ends by 66%, right angles by 11%.

Military Road S at S 288th Street:

This intersection was selected to defer a pending concurrency issue, and also to allow the installation of a southbound right-turn overlap, which was needed to improve compliance with a "No Right Turn on Red" restriction due to limited sight distance on the east leg.

Collisions dropped by 11% and severity rates dropped 17%. Injuries dropped by 16% and PDO's dropped 19%. Fixed object collisions increased 189%, pedestrian collisions went from 0 to over 1 per year, and approach turns and sideswipes both increased by 44%. However, rear-ends dropped by 48% and right angles dropped by 28%, presumably from reduced delay.

The "first-year learning curve" effect noted at SR 99 and S 312th Street was not realized at this location. In fact, most measures were less favorable in the second year, although still generally positive.

1st Avenue S at S 312th Street:

This intersection was selected for potential delay reduction, as it had protected left-turn phases on all approaches, even though sight distance was good and there is a limited number of opposing lanes. This project also provided the opportunity to upgrade a controller cabinet and add a northbound right-turn overlap.

However, the collision rate increased 48% and severity rate increased 198%. This was primarily due to approach turn collisions increasing from 0 to over 6 per year, although these are distributed around the intersection such that no approach has more than 5 per year, which is the warrant for going back to protected left-turn phasing. However, right angle, backing, head-on, and sideswipe collisions were eliminated and rear-end collisions were reduced by 66%.

Eliminating the first year shows a 6% increase in collisions and a 42% increase in severity rate. Injuries increased 67% and PDO's dropped 23%. Approach turn collisions averaged 5 per year, and pedestrian collisions over 1 per year.

1st Way S at S 336th Street:

This intersection was selected for the potential to reintroduce lead/lag phasing on 1st Way S, which capability was eliminated when the intersection was converted from protected to protected/permitted in conjunction with a project that added a second westbound right-turn lane.

The conversion resulted in a 32% reduction in collision rate and a 52% reduction in severity rate. Approach turn collisions were reduced 80%. Rear ends increased 284%. Sideswipes increased 48%, although all of these were associated with the westbound dual right-turn lanes. Fixed object collisions went from 0 to 1 in the first year.

21st Avenue SW at SW 336th Street/SW Campus Drive:

This intersection was selected to address a high collision location, where developer mitigation had been dedicated to address a problem with the number of left-turn collisions, and was planned to be converted from protected/permitted to protected phasing. However, this conversion was going to create a capacity problem, as this intersection was operating near capacity much of the day. With the developer's permission, we installed FYA to try to address the safety issue without reducing intersection capacity.

The results were gratifying, with a 41% reduction in collision rate and a 67% reduction in severity rate. Although fixed object collisions increased 135%, and a 37% increase in rear end collisions, this was more than offset by a 76% reduction in approach turn collisions, and 77% reduction in right angle collisions, a 61% reduction in pedestrian collisions, 22% reduction in sideswipes, and elimination of head-on collisions.

16th Avenue S at S 344th Street:

This intersection was originally constructed to support a new development, and it was built with permitted phasing. Southbound left-turn volumes were higher than anticipated, so FYA was added northbound and southbound. Thus, this was the City's first intersection implementing FYA under the policy dictating that new protected/permitted left-turn phasing be implemented using FYA displays.

As would be expected when adding a warranted left-turn phase, all collision measures were positively impacted by this addition. Collisions were reduced 45%, and severity rates reduced by 30%. Approach turn collisions were reduced 50%, rear-ends by 29%, and right-angles and sideswipes were eliminated.

Summary

Out of the seven intersections analyzed, we had a 9% reduction in collision rates, and an 8% reduction in severity rates. Although samples are limited, it appears that FYA increased fixed object, approach turn, and pedestrian collisions, but reduced rear-end and right angle, and backing collisions, and eliminated head on collisions.

Stratifying by the type of phasing before conversion results in more meaningful comparisons. Converting from protected phasing to FYA at three intersections resulted in a 15% increase in collision rates and 41% increase in severity rates. This was primarily in a 341% increase in approach turn collisions, an increase from 0 to almost 3 pedestrian collisions, and a 189% increase in fixed object collisions. On the positive side, there was a 37% reduction in rear ends, and a 24% reduction in right angle collisions, and elimination of backing and head-on collisions. Most of these changes would be expected with the elimination of protected phasing, although the increase in fixed object collisions isn't so intuitive. Review of the collision reports for the fixed object collisions did not reveal any pattern that could be attributed to this increase. However, it is noted that only the intersections that did not have auxiliary left-turn signal heads on the far left corners of the approaches with FYA experienced this increase in fixed-object collisions. Why this correlation would exist is unclear.

However, regarding the protected phasing conversions in general, these data are heavily influenced by the first year's experience. Comparing the three years before to after, but eliminating the first year after conversion, resulted in a net positive experience, with a 8% reduction in collisions and 22% reduction in severity rate. Although approach turns increased 161%, pedestrian collisions increased from 0 to almost 6 per year, and fixed object collisions increased 179%, this was more than offset by a 73% reduction in rear end collisions, 17% reduction in right angle collisions, and elimination of backing and head-on collisions.

The conversion from traditional protected/permitted phasing at the two intersections is more encouraging, with a 39% reduction in collision rates and a 64% reduction in severity rates. Fixed object collisions, again, increased 233%, and rear-ends increased 56%. These were more than offset by a 77% reduction in approach turn collisions, a 68% reduction in right angle collisions, 61% reduction in pedestrian collisions, and elimination of head-on collisions.

Conclusions

Although limited in sample size, it appears that the conversion from protected/permitted to FYA has a significant safety benefit. The conversion from protected phasing to FYA should be reviewed closely, because, at least in the short term, collisions can be expected to increase. However, it appears that this may be a learning curve issue, and eventually results in better safety performance. Evidence is mixed as to whether the explanatory signing helps drivers on the learning curve with FYA, given that the large increase in collision rates occurred only at protected phasing conversions and occurred regardless of when the signing was installed in relation to the conversion. It also appears that installation of auxiliary left-turn signal heads on the far left corner of a subject approach tends to avoid an increase in fixed object collisions, although why this would be so is unclear.

These data suggest that prioritization of FYA installations should consider potential safety improvements in addition to reduction in queuing, delay, vehicle emissions, and improvement in signal coordination.