Quasi-Couplet: Preserving Mobility While Freeing Urban Street Space

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ABSTRACT
A quasi-couplet is an alternative street design that has promise in some locations to preserve vehicle mobility while freeing space for bicycles. A quasi-couplet is possible in an urban corridor with parallel four-lane streets. A one-way pair was a traditional way to maximize mobility in such a corridor, but that treatment is no longer popular. Operating each street as a conventional two-way street usually means both operate poorly with little chance for two-way progression. Inefficient travel on the conventional two-way streets also means there is no room to spare for bicycle lanes.

A quasi-couplet is a potential solution is such a corridor. It consists of maintaining at least two through lanes in one direction on one street, and at least two through lanes in the opposite direction on the other street. Progression priority is given to the dominant direction on each street. One through lane is maintained in the non-dominant directions on each street, which allows local access and overcomes the objections raised to a one-way pair. Maintaining good mobility in three lanes on each street frees the fourth lane on each street for bicycle use.

The paper reviews the history of the quasi-couplet concept and the theory behind it. The paper then presents a proposed application in Asheville, North Carolina. Capacity and bandwidth calculations demonstrate that the concept could provide substantial mobility benefits while freeing a lane for bicycle use. The case study reveals some limits of the concept, which the authors extend into guidelines on future applications.

INTRODUCTION

Downtown and near-downtown neighborhoods that are economically healthy and growing mean more demands on the street. Many urban street corridors lack the capacity to move all of the vehicles, pedestrians, and bicycles that would like to move on them, particularly during peak hours. Widening urban streets is usually next to impossible due to dense development. The lack of capacity means poor mobility through the corridor and poor access to properties within the corridor.

Creating a one-way pair was a traditional answer to creating capacity in urban street corridors with available parallel streets. One-way pairs reduce signal phases and allow for efficient signal progression, which in turn means good speed control is possible. However, one-way pairs create out-of-direction travel, can inhibit access to adjacent properties, can confuse drivers, and can lead to wrong-way movements. In many places, one-way pairs have been removed due to these difficulties. Certainly, it is rare to get the opportunity to install a one-way pair these days.

The quasi-couplet concept, is also known as an “imbalanced lane couplet” or an “unbalanced flow couplet,” has been developed through the years as an attempt to provide the extra capacity and efficiency of a one-way pair without the out-of-direction travel and confusion. A quasi-couplet uses two parallel streets just like a one-way pair. Instead of converting each street to one-way flow, though, a quasi-couplet keeps two-way travel on both streets and emphasizes one direction of flow on one street and the other direction of flow on the other street through restriping and signal progression. A quasi-couplet should not increase travel on the cross streets like a one-way pair likely would.

Figure 1 shows an example of a quasi-couplet in Springfield, Illinois. The corridor is an important one heading west out of downtown Springfield. West Washington Street and West Monroe Street are both two-way streets. West Washington is intended to carry most of the westbound traffic, and West Monroe is intended to carry most of the eastbound traffic. Signals on West Washington are set to progress traffic westbound at a steady speed (with eastbound traffic on West Washington experiencing poor progression as a result), and signals on West Monroe do the same to help eastbound traffic. West Washington has two through lanes westbound and one through lane eastbound, while West Monroe has two through lanes eastbound and one through lane westbound.

The quasi-couplet concept goes back several decades. In the 1960s Redwood City, California tested the concept, along with several others, in an attempt to improve corridor operational performance and concluded that not only did it provide the desired improvements, it was also the least objectionable to businesses and the public (1). The City of Springfield, Missouri, installed a quasi-couplet on South Jefferson and South Campbell between Grand and Sunshine prior to 1975. Subsequent to Springfield, Illinois' adoption of the concept in 1992, the concept has been adopted or examined by the City of Portland, Oregon (2), the Oregon Department of Transportation (3), the Utah Department of Transportation (4), the Las Vegas metropolitan area (5), and San Francisco (6). However, the quasi-couplet is still quite rare and is unknown in many states.

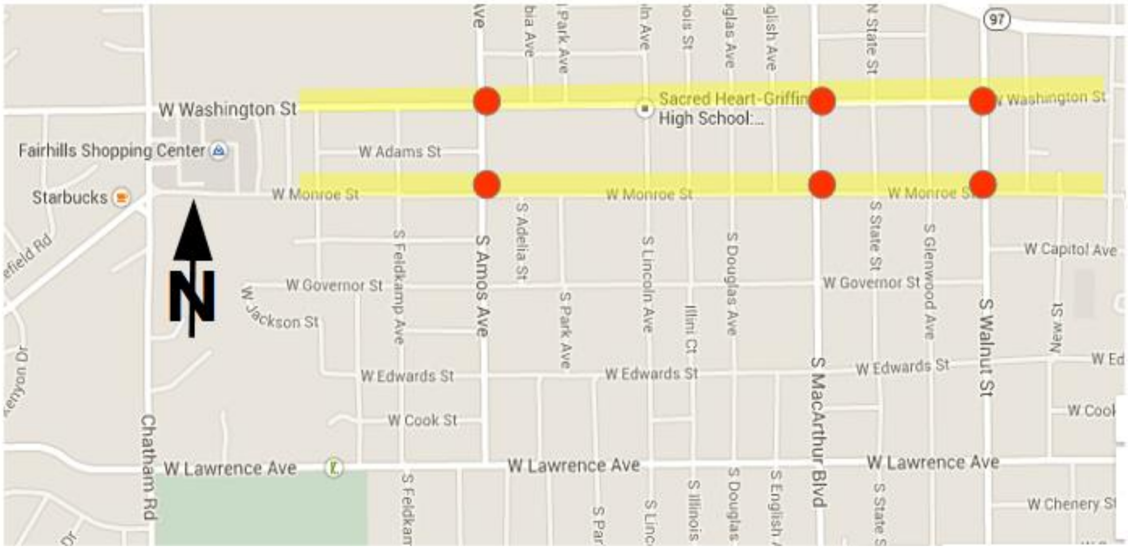

Figure 1. Map of quasi-couplet in Springfield, Illinois (Google).

In North Carolina, a quasi-couplet has been installed in Brevard, a small town in the western part of the state (7). Data on the performance of that quasi-couplet are not yet available, but anecdotal information suggests that it is working well and is generally accepted by the public.

The purpose of this paper is to introduce the quasi-couplet to a larger audience and to present a case study. The case presented here is in Asheville, a medium-sized city in western North Carolina. We studied a quasi-couplet and other alternatives in a dense corridor and arrived at some observations that should help others also considering this idea.

CASE STUDY

Figure 2 shows the corridor that we studied. Biltmore Avenue is a state route. It functions as an urban arterial that connects downtown Asheville, just north of (above) the map in Figure 2 to the Biltmore Village area (a dense shopping area with significant multimodal activity), the Biltmore House (a major tourist attraction) main entrance, and I-40 just south of (below) the map. Biltmore Avenue has four ten-foot wide lanes for the most part, with curb and gutter and sidewalks close to the roadway, as shown in Figure 3. Biltmore Avenue is lined on both sides by fairly dense residential, commercial, and institutional development, including the large hospital shown on the map in Figure 2. The area economy is healthy and local leaders expect growth in the area in the future downtown, in Biltmore Village, and in the corridor between. There are some safety concerns with the four-lane cross-section and with the many driveways and side streets, but the safety situation in the corridor is typical of older urban streets in North Carolina. Likewise, there are a few congested spots along the corridor during the peaks, but nothing that is atypical of such corridors across the state.

The challenge on Biltmore Avenue that prompted the case study was a desire by the City of Asheville and the metropolitan planning organization (MPO) to create a dedicated bicycle facility on Biltmore Avenue from its intersection with US-25 (Southside Avenue) toward the top of Figure 2 near downtown to its intersection with US-25 in Biltmore Village toward the bottom of Figure 2, a distance of about 1.7 miles encompassing nine signalized intersections. In particular, the City and MPO wanted to implement a road diet project on

Biltmore Avenue, creating a more "complete street" cross section with one through lane in each direction, a two-way left turn lane, and a bicycle lane on each side. Asheville already has a healthy bicycle culture and decent bicycle usage, and the City and MPO wanted to promote that by linking some major destinations with dedicated bicycle facilities.

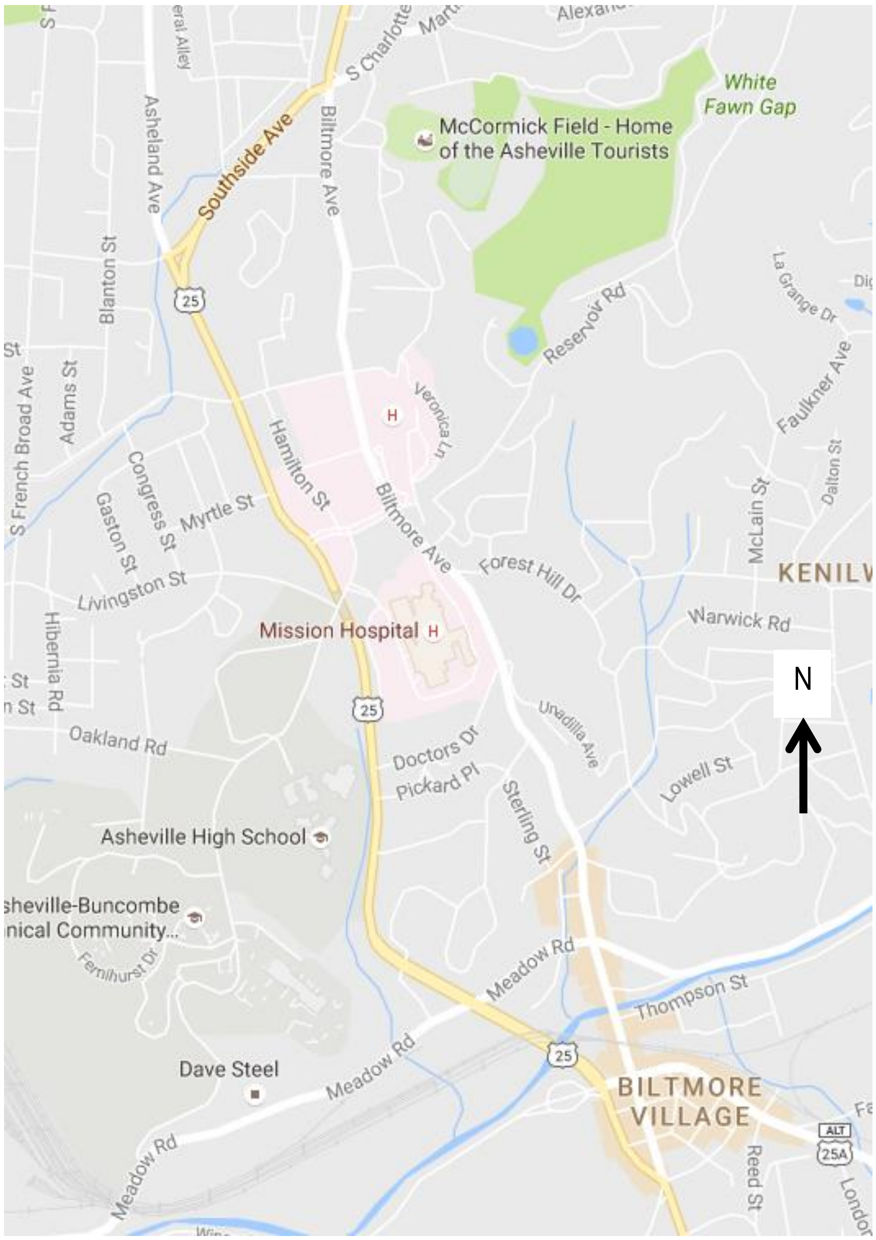

Figure 2. Map of Biltmore Avenue corridor in Asheville, NC (Google).

Figure 3. Photo of typical cross section on Biltmore Avenue (Google).

The road diet proposal was met with skepticism by traffic engineers at the NCDOT responsible for traffic operation and safety on Biltmore Avenue. While generally supportive of the concept of bicycle facilities linking downtown Asheville to destinations to the south, the engineers were concerned about the impacts of the road diet on vehicles. Annual average daily traffic (AADT) volumes were estimated in 2014 on Biltmore Avenue to range from 18,000 to 24,000 vehicles per day (vpd). The experience in NC has been that three-lane cross-sections in urban areas typically struggle in operations and safety above about 13,000 vpd.

Faced with this challenge, the authors embarked upon a search for alternatives that could provide the bicycle facility the City and MPO wanted while still moving traffic along Biltmore Avenue in a reasonable fashion. The idea for a one-way pair was raised but quickly discarded due to the concerns mentioned above. Two other alternatives were raised and did not have obvious flaws so they were brought forward into an analysis. One idea was the quasi-couplet. Figure 2 shows that US-25 runs parallel and to the west of Biltmore Avenue from downtown to Biltmore Village, covering about 2.0 miles and moving through ten signalized intersections. US-25 is similar to Biltmore Avenue in cross-section, surrounding land uses, and traffic volume. A quasi-couplet could be formed with US-25 carrying two through lanes southbound and one through lane northbound, with its signal providing generous green bands for southbound travelers. Meanwhile, Biltmore Avenue could carry two through lanes northbound and one through lane southbound, with its signal providing generous green bands for northbound travelers. A quasi-couplet would free a through lane on both Biltmore Avenue and US-25, allowing bicycle lanes to be striped in both directions on both routes.

The other alternative analyzed was to drop a northbound lane on US-25. This was feasible because Asheville is a community with many tourists and retirees, and relatively few 9-to-5 commuters. Thus the AM peak is not that heavy on US-25, and the need for northbound capacity headed toward downtown on that route was not that great. In this alternative US-25 would have two southbound through lanes and one northbound through lane, and a bicycle lane could be striped on both sides of US-25. While not exactly meeting the wishes of the City and MPO, this option still would provide a bicycle facility between downtown and Biltmore Village.

ANALYSIS

To analyze traffic operations for the existing geometry and three alternatives (quasi-couplet, road diet on Biltmore, and northbound lane reduction on US-25) in the corridor the authors employed Synchro (8). Synchro is a popular macroscopic analysis tool that also optimizes signal timing, which was a needed feature for this work.

The authors obtained turning movement counts from 2015 or 2016 at all signalized intersections on both Biltmore Avenue and US-25. We assumed no growth to bring the 2015 counts into 2016, based on published AADT values in the corridor, and performed our analyses on 2016 volumes. Some balancing was necessary to make the counts from different days mesh into one corridor analysis. The authors made no changes in the existing signal phasing. The existing condition results generally conformed with the authors' experiences driving in the corridor.

One major factor in the analysis of the alternatives is the magnitude of traffic that will shift from its current route to the route favored by geometry and signal timing. We should expect some diversion of northbound traffic currently using US-25 to Biltmore Avenue with the quasi-couplet in place, for example, because northbound traffic on US-25 will lose a through lane and will have poor progression. However, the authors did not have detailed origin-destination data or a forecasting model available with enough precision to estimate such a diversion. Since the total through volume in the peak direction in the peak hour on each route is about 1,000 vph, a diversion of 500 vph represents about half of the total and would be proportional to the number of through lanes carried on the route. If the quasi-couplet, road diet, or US-25 lane drop alternatives are built, the actual diversion will likely be somewhere between the zero and 500 vph extreme. We therefore made an assumption that one-third of vehicles on each movement in the network with the opportunity to divert from the penalized to the rewarded route would do so, which meant about 350 vehicles per hour (vph) would divert in each direction. Two Synchro runs were performed for each alternative, one run with no diversion and one run in which about 350 vehicles per hour (vph) per direction divert.

RESULTS

Table 1 shows average intersection control delay results, in seconds per vehicle, from Synchro for the current conditions and the three alternatives at each signalized intersection in the corridor. In Table 1 a lightly-colored cell indicates an average delay of 55 to 80 seconds per vehicle, which corresponds to a level of service (LOS) E in the 2016 Highway Capacity Manual (9), while a dark-colored cell indicates an average delay of over 80 seconds per vehicle which corresponds to a LOS F.

Table 1. Delay results.

		Average delay at intersection (seconds/vehicle)						
North/south street name	East/west street name	Existing	Quasi-couplet no diversion	Quasi-couplet with diversion	Road diet no diversion	Road diet with diversion	One lane NB US-25 no diversion	One lane NB US-25 with diversion
Biltmore	Southside/ Charlotte	18	28	22	30	22	27	24
Biltmore	Short Coxe	4	3	5	7	10	5	3
Biltmore	Choctaw/ Florence	12	27	18	20	20	17	17
Biltmore	Hospital	19	42	22	32	22	20	20
Biltmore	Rose Chapman	12	17	11	14	18	11	8
Biltmore	Unadilla/ Doctors	3	10	5	10	5	5	5
Biltmore	Bryson/ Meadow	45	107	57	78	63	55	53
Biltmore	Brook/ Lodge	26	141	426	268	129	24	28
Biltmore	All Souls	50	124	142	114	118	51	54
US-25	Lodge	32	107	93	37	34	43	45
US-25	St Dunstans	12	20	16	17	15	13	13
US-25	High School Exit	8	27	14	9	9	21	11
US-25	Anna Woodfin	9	30	12	14	7	16	12
US-25	Hospital	10	20	13	13	13	9	13
US-25	Choctaw	13	23	14	20	15	23	22
US-25	Southside/ Asheland	15	25	19	18	17	28	29
US-25	Coxe/ Short Coxe	14	16	18	15	14	18	19

As expected, all three alternatives make traffic flow worse. None of the existing intersections had a LOS of E or F. However, there were four intersections at LOS E or F for the quasi-couplet, three intersections at LOS E or F for the road diet, and one intersection at LOS E for the one northbound lane option with no diverted traffic.

Table 1 shows that the quasi-couplet leads to highest delays, as it should since it had the most lane reductions and provided the best bicycle facilities. The four problem intersections in the quasi-couplet design were all in the Biltmore Village area at the southern end of the corridor, which is a dense shopping and tourist area with narrow streets, short block lengths, and high demands. The worst intersection with the quasi-couplet is Biltmore Avenue at Brook and Lodge, because that is an intersection with a large demand and only three lanes would be available on Biltmore for traffic movement. Traffic will struggle at that intersection without a left turn lane. The results show that the quasi-couplet would work well everywhere outside Biltmore Village. Thirteen intersections analyzed with the quasi-couplet in place would operate at LOS D or better in the peak period.

From Table 1 we can see that diverting demand from the less-favored to the more-favored route of the quasi-couplet helps significantly at one intersection, changing the LOS from F to E, but three intersections remain at LOS F. Biltmore Village, where the LOS F intersections are located, is where Biltmore Avenue and US-25 come back together, so diversion should not matter much there. At intersections operating at LOS D or better diversion would reduce delay at eleven intersections and increase delay at two intersections.

Table 1 shows that the road diet alternative provided somewhat better traffic flow than the quasi-couplet, as it should since the road diet only has bicycle lanes on one route. With the road diet, two intersections at LOS F and one is at LOS E. All three problem intersections are again in Biltmore Village where there is significant pedestrian, bicycle, and transit traffic. As with the quasi-couplet, traffic will struggle at the intersection of Biltmore Avenue at Brook and Lodge because that is an intersection with a large demand and only three lanes would be available for traffic movement. Traffic will struggle at that intersection with only one through lane in each direction on Biltmore. Diversion does not make much of a difference with the road diet option.

Dropping a northbound lane on US-25 provided the best traffic flow of the alternatives according to Table 1. This alternative decreases the quality of traffic flow through the corridor only marginally compared to existing conditions. Only one intersection would be at LOS E in this alternative without diversion. Diverting traffic from US-25 to Biltmore Avenue did not make much difference in performance for this alternative. The intersection at LOS E without diversion improved marginally to make it into LOS D.

CONCLUSIONS

Based on the results provided above, the authors concluded that a quasi-couplet is a viable option for the Biltmore Avenue corridor and should move on to the next stage of analysis, including estimation of costs, estimation of impacts, and computation of multimodal LOS. The quasi-couplet will add motor vehicle travel time compared to current conditions, but all of the alternatives do that because they all remove motor vehicle lanes in favor of bicycle lanes. The quasi-couplet allows the best bicycle facilities of all options considered, with bicycle lanes in both directions on both Biltmore Avenue and US-25. A quasi-couplet would not work well at the signals in the Biltmore Village area at the southern end of the corridor, but neither would the road diet option. The findings for the quasi-couplet hold in this case regardless of level of diversion from the less-favored to the more-favored route. Although the results show that diversion would help, it makes only a small difference at most intersections and only moves one intersection from LOS F to E status.

The road diet alternative would provide generally similar traffic conditions to the quasi-couplet, making a significant difference compared to the quasi-couplet option at only one intersection. Since the quasi-couplet provides bicycle lanes on both routes in the corridor, while the road diet provides bicycle lanes only on one route the road diet does not seems to be a great choice in this case. Like the quasi-couplet, the road diet alternative would work well enough at all signals north of Biltmore Village. Diversion of traffic from the route with the road diet to the other route seems to help just a little in this case.

One northbound lane on US-25 would provide the best motor vehicle traffic service of three alternatives, with no intersections worse than LOS E regardless of the level of diversion. This option provides bicycle lanes only on US-25, though, which is a longer route than Biltmore Avenue. Considering the results for all three alternatives, the City, the MPO, and the NCDOT have three viable options and a tough decision ahead.

In general, the effort described here indicates that the quasi-couplet concept can be a viable alternative in certain situations. The quasi-couplet seems reasonable to at least investigate where there are two parallel routes, where there is a desire to either add capacity or reduce lanes, and where adding capacity to either route would be costly or have high impacts. Our investigation showed that quasi-couplets are better where there are four travel lanes on each route, so that the cross-section can feature one through lane in one direction, one left turn lane, and two through lanes in the favored direction, because designs with either one through lane in the favored direction or without a left turn lane will struggle. We also saw that a quasi-couplet cannot remove lanes where capacity is needed; better progression only helps if enough basic capacity is provided. Finally, we conclude that quasi-couplets do work better with some amount of traffic diverting from the less-favored to the more-favored route. To achieve traffic diversion the favored route really needs to be better—faster and a shorter distance—and there should not be too many intermediate destinations along the route. That is, a quasi-couplet will likely work better when most of the traffic travels the whole corridor.

There are several promising avenues of research in which to follow up this work. First, data on the safety of quasi-couplets that have been installed would be helpful. At this point, planners and engineers must trust that the individual components of quasi-couplets are standard traffic treatments that will not add crashes, but it would be reassuring to see data on the overall safety performance of the systems. Second, reliable ways to estimate the diversion from one roadway to the other within a quasi-couplet would be helpful. For now, it seems reasonable to believe that there will be some diversion of demand from the less-favored to the more favored route, but the magnitude of such a diversion and the factors on which it depends are just guesswork. Finally, research on the public and political acceptance of quasi-couplets would be productive. The quasi-couplet concept is itself a reaction to the negative public reaction to one-way pairs. It would be a shame if the treatment in a case of negative public reaction also induced a negative public reaction.

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