Modeling Transit Engineering Infrastructure: Synchro Can Do That?

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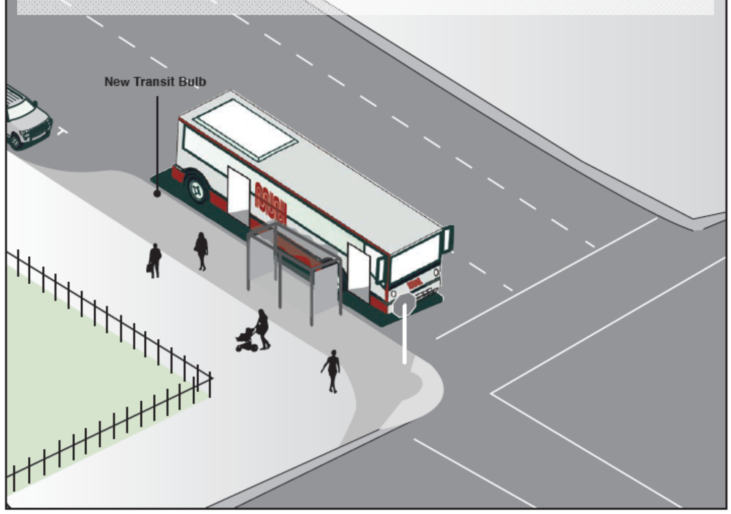
ABSTRACT

Synchro software is widely used to analyze vehicle delay at a macroscopic level. Despite this, it is our experience that it is rarely used to analyze the effects of transit-beneficial engineering improvements on intersection delay. In order to analyze these effects as part of the San Francisco Municipal Transportation Agency's (SFMTA) Transit Effectiveness Project (TEP) environmental review process it was necessary, for legacy reasons, to use Synchro.

Through collaboration with the SFMTA and San Francisco Planning Department, we developed a methodology for coding the transit-beneficial infrastructure (a.k.a. toolkit elements). We determined the relative effect of each toolkit element (e.g. transit-only lanes, bus bulbs, transit queue jump phases, etc.) by conducting a separate sensitivity test for each. Each toolkit element was applied discretely to a representative study intersection, and its effect quantified by examining the change in weekday PM peak hour intersection and approach delay from the "No Project" scenario. These discrete applications consisted of adjusting Synchro settings such as the number of bus blockages by approach, green time, signal phasing, and intersection geometries. Despite the fact that effects will vary somewhat from location to location due to intersection characteristics, our results have been able to convey the general magnitude of change in intersection delay.

INTRODUCTION

Figure 1 - Conceptual illustration of a transit bulb



Note: The above conceptual figure is not to scale and is for illustrative purposes only.

The City of San Francisco launched the *Transit Effectiveness Project* (TEP) in 2005 as a vehicle for evaluating and implementing a comprehensive catalog of service- and engineering-based improvement measures to bus and light rail transit, that in consort would transform convenience, reliability and attractiveness of service. The TEP is jointly directed by two city agencies:

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the San Francisco Municipal Transportation Agency (SFMTA), which operates bus and light rail service in the city; and the Office of the Controller, a division of city government responsible for financial oversight. The major engineering–based component of the TEP, the *Travel Time Reduction Proposals* (TTRP), consists of corridors wherein 16 different roadway engineering measures (such as bus bulbs, transit-only lanes, turn restrictions, etc.) that are known to be beneficial to transit are deployed. Each individual improvement is also known as a *Transit Preferential Streets* (TPS) "*toolkit element"*. An example toolkit element, the humble bus bulb, is illustrated in Error! Reference source not found..

As part of the TEP's on-going environmental review process under the California Environmental Quality Act (CEQA), a number of representative study intersections throughout the city were analyzed to determine the difference in automobile delay resulting from a variety of applied TEP scenarios. The innovative nature of the transit engineering improvements proposed within the TEP preclude them from being analyzed using the typical environmental review methodology. By necessity, innovative approaches to modeling their effects within the frame of the macrosimulation model were developed. By virtue of their responsibility for the proper application of CEQA environmental review regulations within planning studies, the San Francisco Planning Department collaborated during the development of these original procedures.

Per the requirement of the Planning Department, the macrosimulation program *Trafficware Synchro 7* was used to model the intersection level of service (LOS) and delay for the Existing and Existing Plus Project scenarios. Calculations were carried out in accordance with the Transportation Research Board's 2000 *Highway Capacity Manual* (HCM). The study area model was coded with PM peak hour volumes, posted speed limit, vehicle mix, signal timings, and other inherent intersection characteristics (such as turn pocket lengths, pedestrian volumes, etc.) that reflected observed conditions. Current signal timing and phasing parameters were obtained from the SFMTA.

While the HCM and Synchro exhaustively model the intricacies of the typical automobile-centric road network, they bestow only a cursory glance upon characteristics particular to transit service. In fact, the sole parameter describing transit service is "bus blockages per hour", which is a rudimentary measure of the number of buses that block automobile traffic at intersections by virtue of stopping to pick up and drop off passengers. Synchro simply lacks the desired transit-related intersection approach parameters such as "presence of bus bulb", "presence of transit boarding island", or "presence of transit-only lane". Thus, techniques were developed to cunningly deceive it into showing the effects of transit engineering improvements through tweaking of parameters built into the software.

PLOTTING THE DECEPTION OF SYNCHRO

The development of a unique methodology to represent each of the 16 toolkit elements was an iterative process involving experimentation within the constraints of the limited number of input parameters within Synchro. After discussions with traffic operations experts within Fehr & Peers, appropriate modifications to inputs were chosen that accurately represent the expected changes to intersection operations upon implementation of each particular toolkit element. These inputs include:

- lane width and intersection geometry,
- crosswalk length and pedestrian crossing time,

- bus blockage regularity,
- parking lane presence and use,
- volume of regular and heavy vehicle types, and
- signal phasing and timing.

To take one toolkit element as an example, the insertion of a transit bulb (see **Figure 1**) cannot be directly modeled in Synchro because there is not a “transit bulb” toggle button, or any equivalent parameter or combination of parameters. The primary effects of a transit bulb are the reduction of dwell time through shortened transit boarding and alighting time, the elimination of bus re-entry delay, and the shortening of pedestrian crossing distance at the bulbout. In this case, the first two of these improvements would have a negligible impact on automobile delay and nevertheless cannot be modeled, not even indirectly, in Synchro. The third measure can be modeled through reducing the pedestrian crossing phase duration by the ensuing amount. Through re-allocation of the available green time, a higher proportion of the cycle length can thus be assigned to either the critical automobile movement to reduce overall delay, or to the transit-approach to further speed transit, depending on the primary concern.

DETERMINING THE SENSITIVITY OF EACH MEASURE

The relative effect of each toolkit element on automobile delay was determined via sensitivity testing, which involved the discrete application of each toolkit element separately to a representative intersection. The effect of a particular toolkit element was recorded by measuring the change in weekday PM peak hour intersection and/or approach delay against Existing Conditions (i.e. No Project Conditions) at a representative intersection. The toolkit elements, how they were each modeled, and the effects to automobile delay are listed in **Table 1 to 5**.

By studying the effect of each toolkit element at a single representative intersection, these results should be interpreted to convey merely the *approximate* effect of implementing each particular toolkit element. The effects are expected to vary from location-to-location by virtue of different intersection characteristics (i.e., intersection traffic volumes, geometry, and control type).

Notably, neither the 2000 HCM or 2010 HCM explicitly captures the effect each toolkit element has on transit travel time. The expected travel time reductions for each element have been separately estimated by SFMTA staff based on industry research.

RESULTS

Based on the nature of the Synchro input(s) modified to represent each engineering improvement, the toolkit elements were sorted into the following five categories:

1. Signal and phasing modifications
2. Geometry modifications
3. Bus blockage modifications
4. Volume modifications
5. No modifications available

The information presented identifies, for each toolkit element, the Synchro setting or settings to be adjusted, the proposed adjustment for each element, and the resulting change to intersection and approach delay at a representative intersection.

Signal & Phasing Modifications

The five toolkit elements shown in below have all been modeled in Synchro using adjustments to the signal timing and phasing. A sample toolkit element, the transit queue jump, is shown in **Figure 2**.

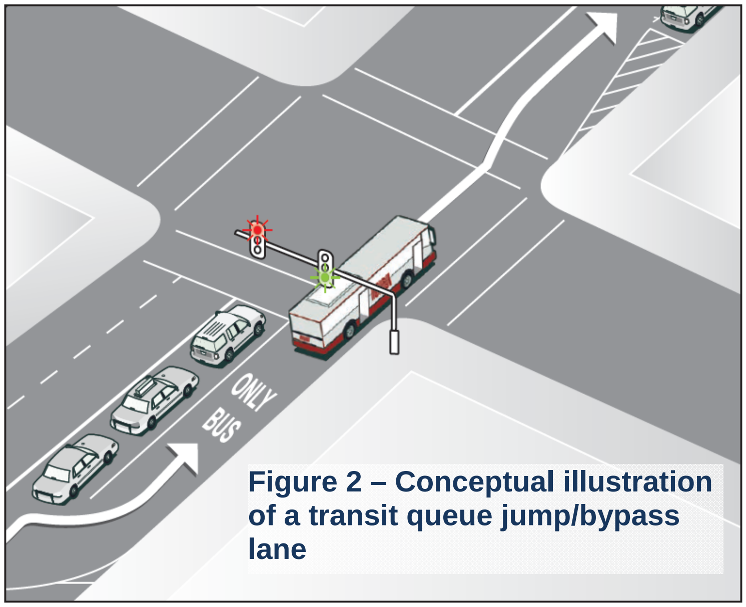

Figure 2 – Conceptual illustration of a transit queue jump/bypass lane

Note: The above conceptual figure is not to scale and is for illustrative purposes only.

Table 1 - Signal and Phasing Modifications

Toolkit Element	Default Settings	Adjustment	General Results
Install Transit Bulbs	Pedestrian clearance time = Minimum green for crossing movement	Minimum cross street green time reduced due to shorter pedestrian crossing distance. Resulting second of extra green time given to transit approach movement	Decrease in intersection delay; decrease in approach delay (tested at the north- and southbound approaches of Mission/16th)
Create Transit Queue Jump / Bypass Lanes	Existing signal timing and phasing plan	Create new independent phase by taking green time from other movements at the intersection (e.g., protected left-turn phase)	Slight increase in intersection delay; decrease in approach delay; (tested at the northbound approach of Mission/16th).
Replace STOP Signs with Traffic Signals	Existing all-way stop control	Convert control to actuated traffic signal with cycle length, phasing, and green time splits reflective of the corridor	Decrease in intersection delay; decrease in approach delay (tested at Geneva/Cayuga) roughly proportional to the traffic volumes of the intersection.
Install Pedestrian Sidewalk Bulbs	Pedestrian clearance time = Signal timing for cross/vehicle movement	Minimum pedestrian/green time reduced due to shorter crossing distance and given to transit approach movement (one second of green time added)	Decrease in intersection delay; decrease in approach delay (tested at the east- and westbound approaches of Mission/16th). The resultant changes in delay are highly influenced by the approach chosen to receive extra green time.
Widen Sidewalks	Pedestrian clearance time = Signal timing for cross/vehicle movement	Minimum pedestrian/green time reduced due to shorter crossing distance and given to transit approach movement (one second of green time added)	Decrease in intersection delay; decrease in approach delay (tested at the east- and westbound approaches of Mission/16th). The resultant changes in delay are highly influenced by the approach chosen to receive extra green time.

Geometry Modifications

The four toolkit elements shown in below have all been modeled in Synchro using adjustments to the lane geometry. A sample toolkit element from this category, the widening of travel lanes from parking lane reductions, is shown in **Figure 3**.

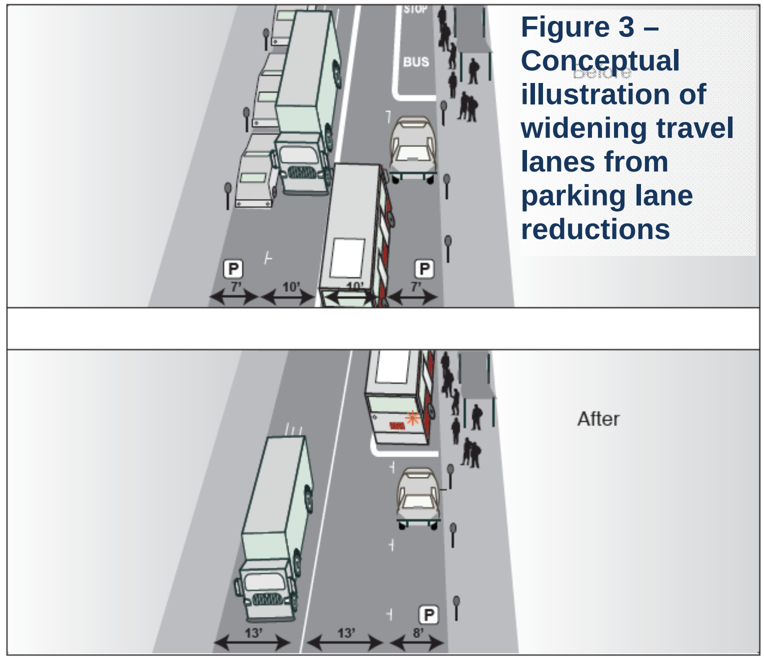

Figure 3 – Conceptual illustration of widening travel lanes from parking lane reductions

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Table 2 **- Geometry Modifications**

Toolkit Element	Default Settings	Adjustment	General Results
Create Turn Lanes / Pockets	Existing intersection geometry	New intersection geometry	Slight decrease in intersection delay; slight decrease (averaged) in approach delay (tested at the north- and southbound approaches of Mission/16th)
Widen Travel Lanes from Parking Lane Reductions	Existing intersection geometry; Parking maneuvers by approach (with parking) = 10 per hour in downtown; 5 otherwise; 0 peak period tow-away zone	Reallocate width of parking lane to remaining travel lanes to reduce transit friction; Parking maneuvers by approach (with change) = 0 per hour	Slight decrease in intersection delay; slight decrease in approach delays (tested at the north- and southbound approaches of Mission/16th)
Widen Travel Lanes from Peak Period Parking Restrictions	Existing intersection geometry; Parking maneuvers by approach (with parking) = 10 per hour in downtown; 5 otherwise; 0 peak period tow-away zone	Reallocate width of parking lane to remaining travel lanes to reduce transit friction; Parking maneuvers by approach (with change) = 0 per hour; lane widths adjusted	Slight decrease in intersection delay; slight decrease in approach delay (tested at the north- and southbound approaches of Mission/16th)
Replace STOP Signs with Other Measures	Existing all-way stop control and geometry	This toolkit element encompasses a variety of different measures. The scenario tested was removal of stop control from transit approaches in conjunction with pedestrian corner bulbs	Decrease in intersection delay; decrease in approach delay (tested at McAllister/Central)

Bus Blockage Modifications

The two toolkit elements shown in below have been modeled in Synchro using adjustments to the bus blockages per hour setting. The second element, create transit-only lanes, also includes a change to lane geometry. A sample toolkit element from this category, the creation of transit-only lanes, is shown in **Figure 4**.

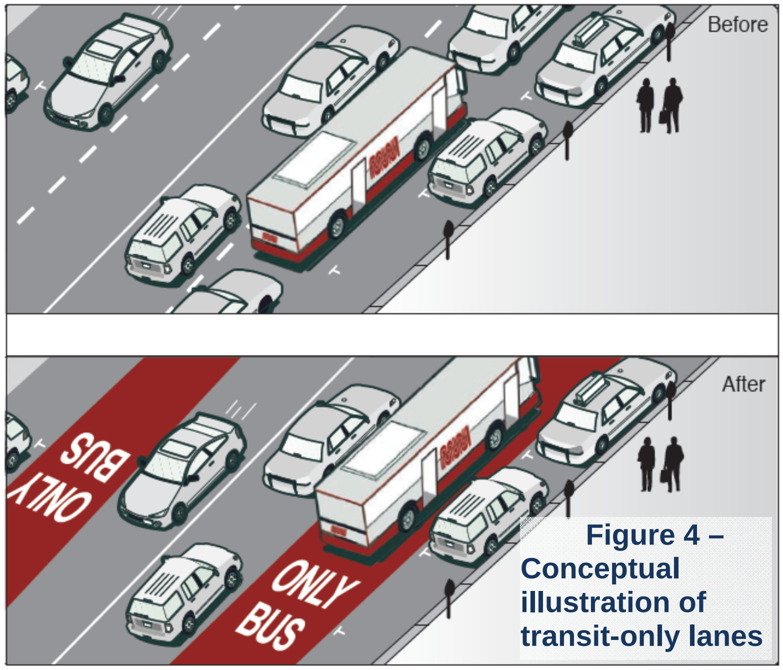

Figure 4 – Conceptual illustration of transit-only lanes

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Table 3 - Bus Blockage Modifications

Toolkit Element	Default Settings	Adjustment	General Results
Consolidate Bus Stops	Bus blockages by approach = Where a bus stop is present; six bus blockages per hour	Bus blockages by approach reduced to zero (i.e., new number of bus blockages per hour)	Slight decrease in intersection delay; decrease (averaged) in approach delay (tested at the east- and westbound approaches of Mission/16th)
Create Transit-Only Lanes	Number of mixed-flow travel lanes at intersection approach	Bus blockages by approach zeroed (i.e., buses stop in transit-only lane and therefore don't affect traffic flow); Remove one through lane and convert curbside lane to a right-turn only lane	Increase in intersection delay; increase in approach delay; (tested at the north- and southbound approaches of Mission/16th). The resultant changes in delay from implementation of this element are directly correlated with the magnitude of traffic diversions (informed by the post-processing of travel demand model runs) and location.

Volume Modifications

The toolkit element shown in **Table 4** below has been modeled in Synchro using adjustments to the traffic volumes.

Table 4 - Volume Modifications

Toolkit Element	Default Settings	Adjustment	General Results
Implement Turn Restrictions	Existing intersection geometry and volumes	Applicable turning movement volume zeroed and added to through movement	Decrease in intersection delay; decrease (averaged) in approach delay (tested at Potrero/16th). Note that this analysis is simplified for this exercise to conservatively assume no auto traffic would divert to other facilities as a result of proposed turning restrictions. The resultant changes in delay from implementation of this element are directly correlated with the magnitude of the left-turn volumes being diverted to the through movement, traffic diversions (informed by the post-processing of SF CHAMP model runs), and may vary by location.

No Modifications Available

The three remaining TPS toolkit elements are those where no modifications are available in Synchro. Explanations for why they could not be represented in Synchro are shown in **Table 5** below.

Table 5 - No Modifications Available

Toolkit Element	Default Settings	Adjustment	General Results
Optimize Transit Zone Locations and Length (i.e., Convert nearside to farside stop)	Bus blockages by approach = Where a bus stop is present; six bus blockages per hour	Because bus blockages by approach are not assigned to a particular location, i.e., nearside or farside, the change due to the element cannot be represented in Synchro, and the element is not expected to materially affect intersection operations.	No change.
Install Transit Boarding Islands	Bus blockages by approach = Where a bus stop is present; six bus blockages per hour	This element will change which lane the bus blockage occurs in, not the frequency of blockages. Since blockages by lane, rather than approach, cannot be represented in Synchro and the element is not expected to materially affect intersection operations, no change was made.	No change.
Convert Flag Stops to Bus Zones (i.e., new red curbed bus zone)	Bus blockages by approach = Where a bus stop is present; six bus blockages per hour	This element will change the type of stop (e.g. from curbside to parking lane), not the frequency. Since blockages by lane cannot be represented in Synchro, no change was made.	No change.

CONCLUSION

A new methodology to evaluate specific transit-related engineering improvements within the Synchro platform was developed. The computed effect of the toolkit elements on automobile delay, as determined through sensitivity testing using Synchro, was in general accordance with expected results. Therefore, Synchro had been successfully "tricked" to model some of the effects of targeted transit-related engineering measures. The results have been accepted by the collaborating agencies (SFMTA and the Planning Department) and thus enter the record as a demonstration of the environmental effect of transit engineering improvements specifically pertaining to automobile delay, as required by CEQA for a project of this type. In summary, these methodologies present the user with a new tool to determine the impact of transit improvements on automobile operations at intersections, which can prove valuable during the environmental review of a range of transit infrastructure projects.

AUTHOR INFORMATION

Andy Kosinski is a Transportation Engineer/Planner with Fehr & Peers and has worked as a transportation engineer and planner in both Chicago and the San Francisco Bay Area. Andy has had a key role in the successful completion of a number of transportation-related projects, ranging from traffic impact analyses to planning the prioritization of millions of dollars of transit improvements. His project experience includes alternatives analysis, travel demand modeling, transit planning and design, carbon emissions reductions, transit-oriented development, and streetscape design. Andy has also performed research in the areas of transit effectiveness metrics, the environmental impact of high-speed rail, and geospatial navigation. Contact: A.kosinski@fehrandpeers.com; (415) 348-0300

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