Stantec

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# COULD CONSTRUCTION CAUSE CONSTERNATION? UTILIZING VISSIM TO ASSESS CONSTRUCTION IMPACTS

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## ABSTRACT

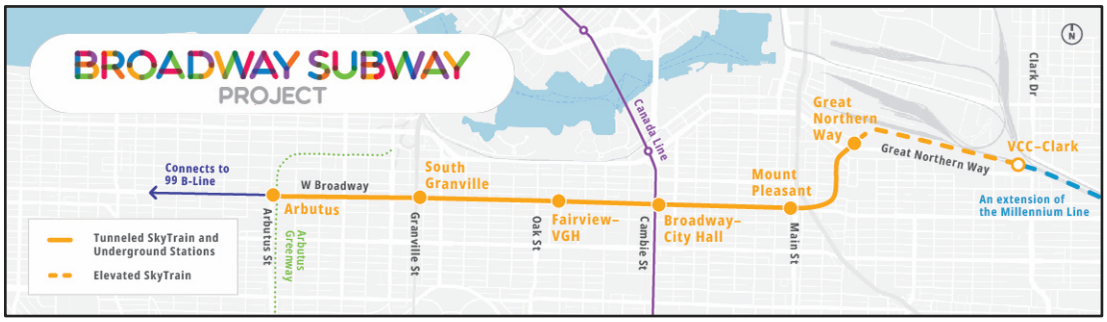
When transportation engineers consider the impact that a proposed project might have on future operations, it is equally important to focus on not only the ultimate state, but also the construction phase of the project. Stantec recently served on the owner's engineering team for a project that will construct a new subway line with five stations underneath a busy six-lane arterial in Vancouver, British Columbia. During station construction, disruption to traffic along the arterial is expected, so Stantec was tasked with preparing a microsimulation model of the corridor to quantify the anticipated level of disturbance. A variety of adjustments to geometry and traffic operations during construction were condensed into two scenarios to be modeled: one long-term "steady state" and one worst-case "interim" scenario. Each scenario considered the impacts of reducing the number of through lanes from six to four around the station construction areas. Of particular importance to this project was the operation of the two shoulder lanes, which alternate as general-purpose, bus-only, or on-street parking throughout various parts of the day. The analysis included consideration of the effects on bus operations because this is one of the busiest bus corridors in North America. Evaluation of the construction layouts focused on the impacts to both bus and vehicle travel times, as well as congestion hot spots. The results of the microsimulation analysis successfully informed the client about how their construction staging over the next few years will affect the corridor and the thousands of users who travel it each day.

## INTRODUCTION

The Broadway Subway Project (BSP) is an ongoing project to extend the existing Millennium Line, a key link in the transportation network of Vancouver, British Columbia. The majority of the 5.7-kilometer extension will run underneath Broadway, a major east-west arterial south of downtown. In particular, the new subway line is intended to replace the busiest segment of Route 99, an express bus route that is currently one of the busiest transit routes in Vancouver and carries over 55,000 passengers per day.

However, in order to construct the five new stations that will be located along the underground portion of the BSP, temporary disruption to the traffic operations along Broadway will be necessary. The project stakeholders, including the Province of British Columbia, the City of Vancouver, and TransLink, the transit agency for Metro Vancouver, were especially concerned with the potential impacts to the already busy Route 99. In coordination with these stakeholders, Stantec worked to quantify the potential level of disturbance that travelers along Broadway may experience during the station construction period.

**Figure 1: Broadway Subway Project Overview Map**




*This map shows the full extent of the BSP, from the existing VCC-Clark Station to the proposed Arbutus Station. The eastern end of the extension will be elevated, while the remainder will be underground.*

*Source: https://engage.gov.bc.ca/broadwaysubway/*

Stantec achieved this task by building a microsimulation model of the Broadway corridor in VISSIM. The use of microsimulation allowed for the detailed modeling of multi-modal traffic, such as personal vehicles, trucks, buses, and pedestrians, including interactions between all the different modes.

The model only encompassed the segment of Broadway that will be affected by the BSP station construction. Approximately 4.7 kilometers of Broadway were modeled, from Vine St on the west end to Prince Edward St on the east end. The intersection at Kingsway/Main St/7th Ave, just north of Broadway, was also modeled. In total, 29 intersections were included in the scope of this task. The scope focused solely on the Broadway corridor, without including any parallel or perpendicular routes, to simplify the modeling process and shorten the project duration.

## EXISTING CONDITIONS MODELS

The first step in any microsimulation modeling project is to build and calibrate a base model to match existing field conditions. For this project, three times of day were identified by the stakeholders to be modeled: weekday morning (AM), midday (MD), and evening (PM) peaks. Each peak period model included a half-hour seeding period and two hours for analysis.

VISSIM models for each time of day (TOD) were built based on a combination of aerial imagery and field observations. Of particular importance to this project was the operation of the shoulder lane along eastbound and westbound Broadway, which alternates as a general-purpose lane, a bus-only lane, or on-street parking throughout the day. Settings were changed within each TOD model to identify the appropriate segments of the shoulder lanes as being for buses only or being open to all vehicles; for times when the curb lanes are designated as on-street parking, they were removed from the model.

The 29 intersections in the model scope featured a mix of full traffic signals, pedestrian crossing signals with accompanying stop control on the side streets, and unsignalized two-way stop control. All signal timing and traffic control settings were coded into the VISSIM models using the most up-to-date data available.

A variety of traffic counts were compiled for this study, including some that were newly collected for this project and some that were provided to Stantec from previous studies. The turning

movement counts (TMCs) were first balanced between intersections to resolve any discrepancies between the varied data sources. Then, the balanced turning movement volumes were used to develop origin-destination matrices for each TOD. Volumes were assigned to paths throughout the network from each entry point to each destination point using Dynamic Traffic Assignment (DTA). Although the use of static routing is more typical for linear models such as this, it was determined by the project team that DTA was the preferred methodology for this model because it would more realistically reflect field-observed driver behaviors along this corridor.

As one of the primary objectives of this modeling project was to identify the effect of the BSP station construction on the existing bus operations, it was critical to ensure that the bus routes were modeled correctly from the beginning. Extensive transit data was provided by TransLink for each of the five bus routes that travel on this segment of Broadway, including departure times, stop dwell times, and travel times. Even details such as the precise location of each bus stop and the type of bus used for each route were verified in the model to provide the most accurate representation of the existing bus operations.

**Figure 2a: VISSIM Model Limits (West)**

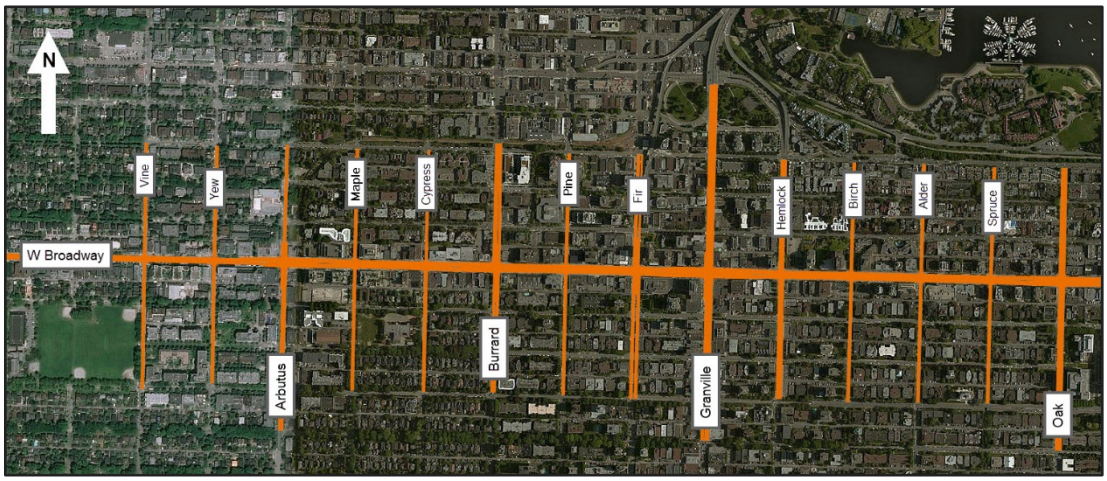
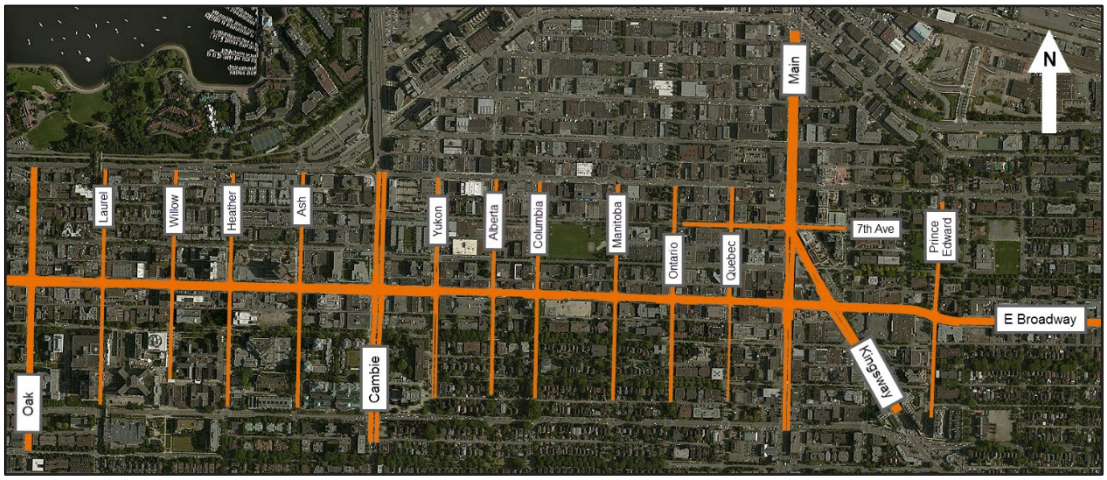



**Figure 2b: VISSIM Model Limits (East)**

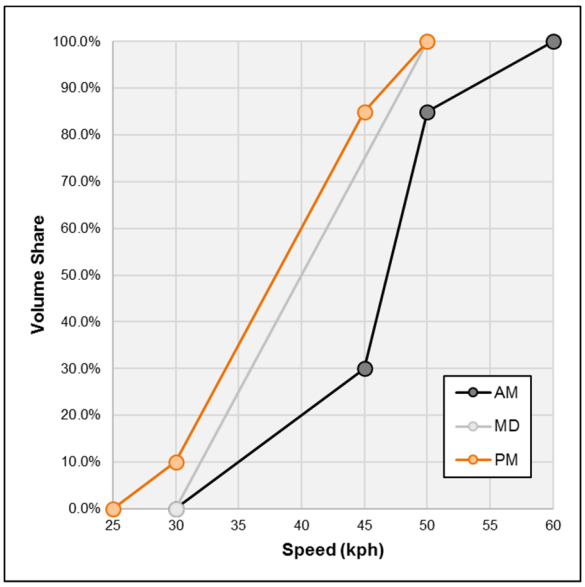



*These figures illustrate the exact limits of the VISSIM model. Broadway & Alberta St was the only unsignalized intersection in the project scope. All other intersections were either full traffic signals or signalized pedestrian crossings with stop control on the northbound and southbound approaches. The intersection at Kingsway/Main St/7th Ave, north of Broadway, was included in order to properly model the relation between Main St and Kingsway.*

A thorough model calibration process was completed based on traffic volumes, travel times, and visual validation. This included travel times of both personal vehicles and buses to ensure that all modes were being modeled accurately.

One of the main model parameters that was altered over the course of calibration was the default speed profile applied to vehicles traveling on Broadway. Typically, speeds are coded into microsimulation models as a range fairly evenly distributed around the posted speed limit for each roadway. While the posted speed on Broadway is 50 kph at all times, field observations and feedback from the stakeholders indicated that drivers do not travel at that speed at all times of day. In order to meet the calibration criteria for travel times and visually validate the congestion observed in the model, the 50-kph speed profile in each TOD model was adjusted independently. The AM model ended up with the fastest speed profile, reflecting the reduced demand for on-street parking during the time period when parking is prohibited in the shoulder lanes. The PM model had the slowest speed profile due to higher volumes and increased friction between commuters and drivers utilizing the on-street parking.

**Figure 3: Existing Conditions Speed Profiles (50 kph Posted Speed)**




*Each speed profile illustrates the percentage of all vehicles that will travel at a certain speed when driving along a roadway with a posted speed of 50 kph. For example, for the AM distribution, the slowest 30% of drivers will go between 30 kph and 45 kph while in a 50-kph zone. The fastest 15% of drivers will go between 50 kph and 60 kph while in a 50-kph zone.*

The adjustments made to the speed profiles, combined with some additional changes to driver behavior parameters, led to the successful calibration of the base models. Existing conditions results such as intersection delay and level of service were extracted from the finalized models to compare against the proposed construction scenarios.

## CONSTRUCTION CONSIDERATIONS

During construction of the BSP, a variety of changes to roadway geometry and traffic operations will accommodate the construction activity on Broadway. There are several permutations of geometric and traffic operation changes being considered for use as the stations are constructed, but the potential changes were condensed into two construction scenarios for modeling purposes:

- **Steady State:** This layout will be in place long-term during the majority of the station construction period. The Steady State model reflects one of the potential "steady state" construction periods.
- **Interim:** There will be numerous interim construction scenarios before the Steady State is reached. The Interim construction scenario modeled in this project represents a "worst-case" scenario of turn restrictions at the five most major intersections along the corridor.

There will be a total of five station construction zones along this segment of Broadway. For modeling purposes, each was referred to using the name of the closest major north-south street: Main, Cambie, Oak, Granville, and Arbutus. Adjacent to each station construction zone, the existing shoulder lanes–including the bus-only lane–are expected to be eliminated as the available cross-section shifts and narrows. The preliminary laning plans developed by Stantec in conjunction with the stakeholders attempted to preserve a minimum of two lanes in each direction through each of the five construction zones. To alleviate some of the delays that buses might experience along the reduced cross-sections, the remaining shoulder lanes between the construction zones are designated to be bus-only at least during the peak hours, with parking in the shoulder lanes prohibited.

After the existing conditions models were developed, the PM peak period was identified as the most critical TOD to model for the proposed construction scenarios, because it saw higher volumes and worse existing conditions operations compared to the AM peak. Both PM Steady State and PM Interim models were developed in tandem. Once results from the two PM models were reviewed, the stakeholders determined that the analysis for the AM period only needed to focus on the Interim construction scenario. A total of three construction scenario models were completed: PM Steady State, PM Interim, and AM Interim.

In addition to straightforward modifications to the roadway geometry around each construction zone, a variety of adjustments were made in the construction scenario models to create a reasonably realistic representation of the expected operations.

One such change was the speed applied to vehicles driving through the construction zones. The design team had previously determined that the posted speed limit in each station construction zone should be 30 kph, with drivers allowed to return to a posted speed of 50 kph along the segments in between. The default speed profile used for 30 kph zones in the existing conditions model actually ranged from 25 kph to 40 kph. After discussion with the stakeholders, Stantec determined that drivers would not likely travel 10 kph over the posted speed limit in a construction zone, especially considering how narrow some of the proposed lane widths were. A specific Construction Zone speed profile was created with speeds ranging from 25 kph to 35 kph. Utilizing a slower speed profile through each of the construction zones was one way to more realistically represent drivers' increased caution around BSP station construction.

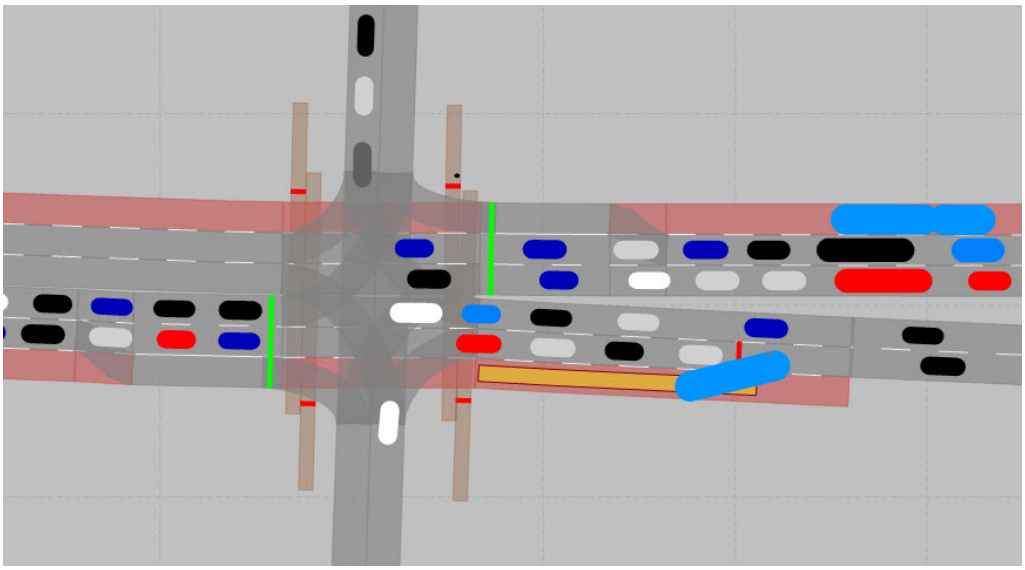
With the need to temporarily eliminate the shoulder lanes around each station, the project stakeholders were concerned about the impacts to buses that are normally able to travel in the shoulder lanes. The decision was made to divert three of the five bus routes to parallel corridors, so they would only need to cross Broadway, rather than travel along it. However, this solution

would not be possible for Route 99 or its local counterpart, Route 9. Adjustments were made to move and/or delete a few of the existing bus stops so buses would not be stopping in the narrower cross-section near each BSP station.

One complication that arose after moving some of the bus stops was the impact to pedestrians. At the intersection of Broadway & Cambie, there is an existing subway station for the Canada Line, which connects to downtown Vancouver. Under existing conditions, Route 99 Eastbound has a stop immediately adjacent to the subway entrance so thousands of passengers can easily transfer between bus and train. The lane alignments around the Cambie construction zone, however, necessitated the bus stop be moved upstream, across Cambie St. Thousands of pedestrians who previously had direct access to the subway entrance are expected to cross Cambie St parallel to Broadway during the construction. Modifications were made to the models to account for this, including restricting the eastbound right turn from Broadway to Cambie to remove potential conflict points and improve safety.

Upstream of each construction zone, at the locations where the shoulder lanes drop, the stakeholders indicated that "Yield to Bus" (YTB) zones would be implemented through a combination of signing, marking, and enforcement. Per the British Columbia Motor Vehicle Act, vehicles in the general-purpose lanes would be required to yield to buses merging from the shoulder lane. However, to make the model more realistic, the stakeholders requested that Stantec incorporate only a 75% rate of compliance with the YTB zones in the VISSIM model. After extensive testing of multiple methods of coding YTB zones, virtual traffic signals were determined to have the most consistent operations and could be specified to have a 75% compliance rate. The virtual traffic signal at each YTB zone activated with the presence of a merging bus to temporarily stop vehicles in the adjacent general-purpose lane.

**Figure 4: Yield to Bus Operations in VISSIM**



*A "Yield to Bus" zone west of the Oak station construction in the PM Steady State model. The eastbound Route 9 bus, shown in light blue, has just completed its dwell time at the bus stop. It pulls forward slightly, indicates its intent to merge using a turn signal, and activates the virtual traffic signal. The traffic signal shows a red indication to vehicles in the adjacent general-purpose lane until the bus completes its merge maneuver. Vehicles in the inside general-purpose lane are allowed to move freely.*

Traffic volumes were not forecasted to a future year for modeling of the construction scenarios. However, many turning movements along the corridor were designated to be temporarily prohibited during one or both of the representative construction scenarios. The existing turning movement volumes were manually redistributed throughout the network as needed to accommodate the BSP construction. Extensive discussions with the stakeholders helped to determine the most logical alternate routes for drivers to use in place of the prohibited movements. In some cases, left turns were planned to be added at intersections where they are currently prohibited in order to accommodate the removal of left turns at other locations during construction.

Additionally, an overall diversion of traffic off of Broadway was applied to the network as a whole. This was done at the request of the stakeholders to reflect the general public avoiding the construction zone completely by detouring around the network. It was assumed that the overall diversion would reduce all turning movement volumes by a specific percentage. After testing multiple percentages for this diversion, the entire project team determined that 10% was an appropriate assumption, neither too optimistic nor too conservative.

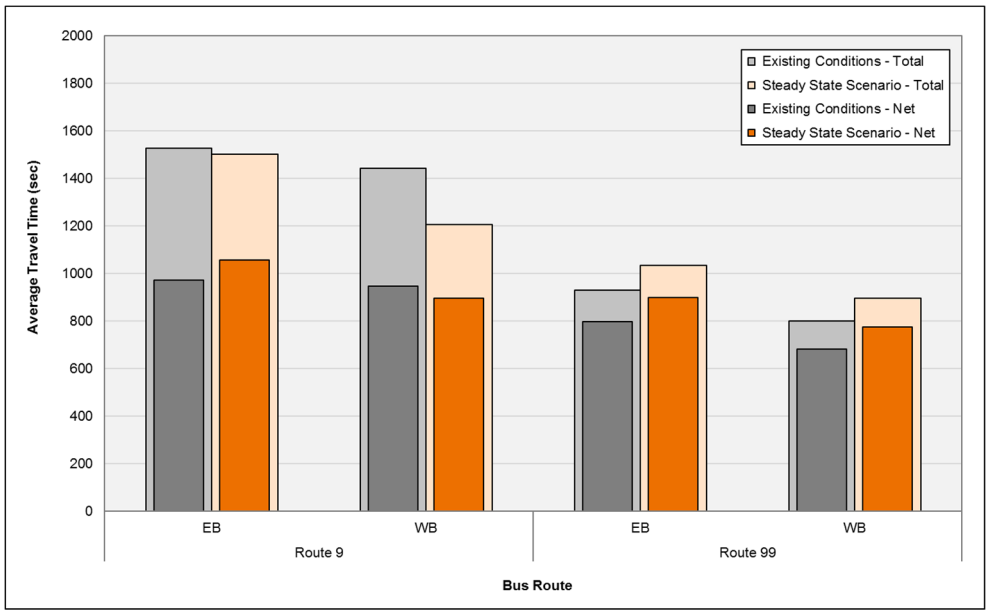
## STUDY RESULTS

Once the stakeholders were confident that the model inputs accurately reflected the specified construction scenarios, Stantec proceeded to extract delay, level of service, and travel time results from the models to compare against the existing conditions.

One of the most interesting findings from the model results was the differences between the Steady State and Interim scenarios. Intersection operations and general vehicle travel times in the Steady State scenario were found to be roughly the same or even improved over the existing conditions. The additional movement and lane restrictions present in the Interim scenario, however, led to an increase in delay and travel times over the existing conditions. These differences were especially evident on the busier east end of the model near Main St and Kingsway. For example, the average delay per vehicle at the intersection of Broadway & Kingsway during the PM peak increased by only 6% from the existing conditions to the steady state scenario, while it increased by 77% between the existing model and the interim scenario.

Upon initial review of the bus travel times from each of the models, it seemed as though some of the bus routes, Route 9 Westbound in particular, were experiencing significantly shorter travel times during construction. However, upon inspection, it was determined that most of the difference was due to the removal of certain stops adjacent to the construction zones, and thus the removal of those stop dwell times from the overall travel time. Rather than using the total travel time, a net travel time was calculated instead by subtracting the sum of the average dwell times at all of the bus stops along that particular route. This allowed for the comparison of just the time that the bus was in transit along each route. For instance, during the PM peak, Route 9 Eastbound showed a slight decrease in the total travel time between the existing conditions and the steady state scenario. But when the total dwell time is removed from each value, the net travel time is actually longer under steady state conditions.

**Figure 5: Bus Travel Times (PM Peak)**




*This graph illustrates the impacts of dwell time on the bus travel times. The removal of certain stops along Route 9 due to the BSP construction created a discrepancy when trying to compare existing and steady state travel times. Route 99, which did not have any stops removed due to the construction, shows a consistent relationship between the total and net travel times.*

## SUMMARY

Overall, the stakeholders were satisfied by the results of this study. The outputs obtained from the models allowed the project team to identify the most critical causes of delay in each construction scenario. Although the exact lane alignments and turning restrictions included in these models may not be the ultimate construction staging implemented in reality, the results from this microsimulation analysis have successfully identified the major congestion hot spots. The stakeholders will be better equipped to anticipate and alleviate any consternation that may arise during the BSP station construction.