SmartBRT: A New Simulation Tool to Assess Bus Rapid Transit Systems

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ABSTRACT

We report results of a two-year project to develop a bus rapid transit (BRT) operation and infrastructure concept computer simulation, evaluation and visualization tool, *SmartBRT*. *SmartBRT* was developed to aid in planning and evaluating new or existing infrastructure and operation concepts, deployment stages of BRT and in communicating these concepts or stages through visualization. We present the goals and scope of the tool, its architecture, and details of its three building blocks – simulation, user interface for input and output evaluation, and visualization. While this paper focuses on the *SmartBRT* tool, we also present the results of our preliminary analysis of our case study site in order to show the usefulness and capabilities of the tool. The preliminary analyses represent the capabilities of *SmartBRT* and the type of analyses it performs.

Keywords:
Bus Rapid Transit, simulation, evaluation, visualization, *SmartBRT*, Paramics,
GOAL OF SMARTBRT

*SmartBRT* is a simulation and evaluation tool developed specifically to capture the characteristics of Bus Rapid Transit (BRT) infrastructure and operation concepts and the interaction between BRT and the rest of the transportation system. It was developed to aid in:

- planning new BRT systems
- evaluating new or existing infrastructure and operation concepts for BRT,
- planning and evaluating deployment stages of BRT systems, and
- communicating these concepts or stages through visualization.

Bus Rapid Transit (BRT) cannot be strictly and succinctly defined, but there are a number of features that bound BRT. Bus Rapid Transit systems are too complex for analytical representation. The system’s complexities are best captured through simulation. *SmartBRT* aids in understanding the interactions and tradeoffs within the rapid transit system and between the rapid transit system and the rest of the transportation system. It quickly performs “what if” studies allowing for exploration of possibilities. It is also an ideal tool for simulating and visualizing the effects of implementing intelligent transportation system (ITS) technologies in rapid transit operation minimizing the need for expensive field tests.

SCOPE OF SMARTBRT

*SmartBRT* was developed for transit planners and operators. It can work with either very detailed data or minimum amount of information, depending on the user’s purpose. *SmartBRT*’s inputs and simulation core are sufficiently detailed for transit planning purposes. A transit planner may chose to input detailed geometrics of the roadway and detailed BRT operation parameters to design infrastructure layout and BRT operation. At the other end of the spectrum, no such detailed input is needed if, for example, a transit operator quickly wants to display what a certain infrastructure concept would look like.

*SmartBRT* is developed specifically to deal with the details of BRT operation. Therefore, inputs include variables such as

- **Bus**
  - Physical characteristics (for example, capacity – both seated and standee; floor height; and the number and width of doors)
  - Door operating policy (for example, use of back door for alighting and or boarding)
  - ITS technologies (for example, precision docking or lane assistance / guidance)
- **Bus route**
  - Number of lanes
  - Lane access
    - Location (curb side or median)
    - Restriction (mixed, diamond lane, dedicated lane)
  - Queue jump lane
  - Circular vs. directional route
  - Release policy (headway vs. schedule based)
Bus overtaking policy (whether faster buses can overtake slower buses)
- Speed limit
- Connection to feeder routes through transfers

- Bus stop
  - Configuration (number of bus bays at stop, platform height)
  - Location (near-, far side, mid block)
  - On line vs. off line
  - Amenities

- Signal
  - Per lane timing (for queue jump)
  - Signal priority. SmartBRT allows turning on and off signal priority along the entire corridor at once or by individual intersections. The length of the priority hold (the maximum time in second by which the bus green cycle is lengthened) can be chosen by the user and set to any value for the entire corridor at once or by individual intersections.

- Passengers
  - Demand (arrival rate at stops)
  - Characteristics (mobility, origin / destination, fare payment type)

The Transit Capacity and Quality of Service (TCQoS) Manual (1) served as a foundation for determining some of the input and default operation parameters.

The raw data output of the simulation is prepared for evaluation. Bus movement data is translated into bus run time\(^1\), dwell time; automobile movement is translated into delay on cross streets; and passenger movement data is translated into waiting and passenger travel time\(^2\), seat availability onboard buses or overcrowding information. SmartBRT outputs include:

- Bus
  - Run time per direction
  - Running speed between each stop
  - Time spent at bus stops per run
  - Time spent at red light per run
  - Number of passenger on board per stop
  - Number of standees per stop
  - Number of empty seats per stop
  - Empty seat mile
  - Load factor per stop

- Passenger
  - Travel time
  - On-board travel time
  - Waiting time

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\(^1\) Run time is the time it takes the bus to travel from one end of the route to the other end in one direction. It is an operational parameter, not related to passengers. In the simulation world, it is the time it takes the bus to travel from its source to its sink.

\(^2\) Travel time is the time between when the passenger gets to the stop and when he/she alights. It is the sum of waiting time and on-board travel time. Lack of passenger origin-destination data prevented us to estimate door-to-door travel time for passengers and forced us to make assumptions for origin-destination stops. Travel time is estimated for every passenger individually.
The evaluation of the simulated BRT systems are based on performance measures. Since transit systems are unique, the user defines what performance measures are important and in what priority and evaluate the system according to these local performance requirements. SmartBRT can show the tradeoff between these performance measures as simulation inputs change.

In addition to the attention devoted to capturing the details of BRT systems, SmartBRT includes traffic simulation as well through its link to Paramics. Certain BRT systems may operate in mixed traffic or on diamond lanes. Such scenarios require simulating the interaction between the BRT system and the rest of the traffic system. Therefore, SmartBRT was developed to simulate this interaction and evaluate the effect of transit on the rest of the transportation system, both on the BRT corridor and on cross streets.

SMARTBRT, THE TOOL

Architecture

SmartBRT consists of four main building blocks Figure 1:

1. Extended user interface (yellow or solid)
2. Extended Paramics simulation core (green or vertical strips)
3. Post processing of output (blue or upward sloping stripes)
4. Visualization (orange or downward stripes)

SmartBRT’s architecture is shown on Figure 1. In Figure 1, square boxes represent processes, while boxes with a soft bottom line represent data files.

Simulation

The core of the SmartBRT software is the simulation, which runs the specified BRT system for a given length of time and collects output data. The simulation is based on Paramics, with extensions using the Paramics API (Application Program Interface). Paramics is a widely used program for modeling large-scale traffic networks. However, Paramics itself cannot represent all the BRT elements we wish to study. Therefore, we extended Paramics by models of bus stops (passenger and bus arrival), passenger motion (boarding, alighting, seating, transferring), and bus motion (release from terminal, lane selection, behavior when approaching signals and stops) in the context of BRT technologies and policies (signal priority, headway, payment mechanisms, door usage). These extensions are implemented as a library of C functions known as a Paramics ‘plug-in’.
Input: BRT Corridor and Network Specification

Just as the SmartBRT simulation plug-in supplements the models provided by Paramics, the SmartBRT input mechanism (Custom Graphical User Interface or GUI, in Figure 1) supplements Paramics input mechanism (Modeller GUI in Figure 1) by accepting a wider variety of settings and configurations to cover the added models. During the “Network generation” step, this information is translated into input files for both the SmartBRT plug-in and Paramics itself.

Furthermore, the SmartBRT user can describe a network at a higher level of abstraction (such as a BRT corridor, a jurisdiction, or a neighborhood) than allowed by Paramics. The Paramics input interface, whether via the text files describing the network and traffic, or via the Modeller Graphical User Interface (GUI), operates at the level of individual links, nodes, traffic signals, and so on. The SmartBRT input mechanism allows the user to define larger scale structures, such as a BRT corridor, a jurisdiction, and intersection, or a neighborhood. In the network generation step (“Network generation” in Figure 1), SmartBRT translates each high level structure into a set of low level Paramics entities (links, nodes, signals, etc.) for both the SmartBRT plug-in and Paramics input files. SmartBRT's GUI simplifies the input specification for users because they can use terms they are familiar with (such as corridor, or jurisdiction or intersection) and data in a format they are likely to have. It also allows changes to, for example, the lane usage policies within a jurisdiction to be made in just one place rather than at each affected node, link or signal, etc.

After the “Network generation” process generates the input files, the extended Paramics simulation is run. Paramics calls on the plug-in functions in certain situations (when a bus crosses a link, for example) or at every time step (for deciding whether to generate a passenger at a stop, for example).

Quantitative Output

The output of the SmartBRT simulation is detailed bus, traffic, and passenger data. The data points represent measurements taken when events happen (e.g., boarding) and at time intervals (bus position every second). The Synthesis step of the SmartBRT tool processes this raw output data into a more useful form (customized output text files), depending on the user’s selections. The user can specify what these customized output files should contain, for example, the user may want to know average bus travel speed of the vehicle between each pair of stops along the corridor, or performance measures such as average run time, number of overcrowding occasions, etc. over the length of the corridor for one given run.

The output of the SmartBRT simulation (bus, traffic, and passenger data) is then imported into a spreadsheet where the user can generate statistical results and plots / graphs. In addition, cost calculations can be performed using the cost specification in the BRT input.

In addition to working with results of individual runs, SmartBRT allows the user to compare results of different runs. For example, the user creates a dedicated lane scenario and runs the simulation with different demand and/or different bus frequency. SmartBRT records data for
each run. The results of each run contain for example the average bus speed over the corridor. SmartBRT allows comparison of this variable over several simulation runs. For example, the user could examine the average bus speed for this dedicated lane scenario under different demand and/or with different bus frequencies.

Visualization

SmartBRT produces output for visualization as well. The goal of the SmartBRT visualization is to enhance communication of results both to technical and to lay communities. SmartBRT presents the simulated concepts in 3D video-like images, and it communicates operation and traffic movement in 2D plan view.

We accomplish visualization by running Paramics’s original 2D visualization simultaneously with the SmartBRT simulation, and by running our 3D visualization sequentially. 3D visualization uses trajectory data files (text files) generated by Paramics and selected and sorted by the “Synthesis” process.

Paramics outputs relatively low fidelity models of vehicle dynamics. Hence, for visualization, the vehicle data is post-processed to smooth the trajectories generated by Paramics. SmartBRT interpolates (fills in between points on the vehicle movement trajectory) to smooth the movement of the bus for the 3D visualization. In addition to trajectory data, the 3D visualization receives other data from the simulation, for example trajectory for other vehicles or traffic signal data. Roadway geometry input data comes from the “Unified input data file” (yellow or solid, in Figure 1). Furthermore, our 3D visualization receives input from SmartBRT’s visual editor.

The objective of our visual editor tool, dubbed SWEditor, is to create, what we term, mid-level photo-realistic 3D images of roadway networks, buildings, traffic signs, and transit amenities with simple commands that do not require a visualization expert. SWEditor works with mouse clicks or programming scripts, depending on the user’s skill and preference. In addition to the built in library of images, this editor is able to load 3ds objects (a popular 3D object format) (7), thus allowing for endless possibilities in creating visual images or scenery. Figure 2 shows an example of images created by the SWEditor.

Conceptually, there are two different object categories in SWEditor: traffic entities and environmental elements. Traffic entities are the objects that are related to traffic and transit and are active elements of the simulation. Roadways, junctions, traffic lights, road signs, and barriers are in this category. Environmental elements are not associated with traffic and they are not elements of the simulation. These are, for example, buildings, sidewalks, houses, trees and miscellaneous objects.

The editor provides four types of viewing windows for top, front, side and perspective views. Among these four viewing windows the side, and top view windows are used as editing windows. Before creating an object, an editing window has to be activated and the desired object type has to be selected. Properties of an object, which are shown in a dialog box, can be modified before or after the object is created. For example, the properties of a roadway object include number of lanes, lane width, ramp, merge, roadside entities, etc. Users are allowed to define
most of these properties such that a real-world scene can be created. Each object’s dialog box has a viewing window that allows users to preview the object. To make the editing process easier and less time-consuming, a friendly GUI (Graphics User Interface) consisting of buttons, dialogs, and viewing windows is provided in this editor.

INITIAL ANALYSES

While our emphasis in this paper is on the description of SmartBRT, the tool, we also present our preliminary analyses in order to show the usefulness and capabilities of SmartBRT in planning and evaluation of new or existing BRT systems.

Case Study Site: the Metro Rapid Bus on the Wilshire –Whittier Corridor in Los Angeles, CA

The Wilshire-Whittier (W-W) corridor (approximately 27 miles long) was serviced by local and express bus routes. LACMTA’s survey showed that its passengers want:

- Fast service
- Reliable service (not yet evaluated)
- No overcrowding (3)

Before implementing Metro Rapid Bus, LACMTA studied the causes of delays:

- 25% of total bus run time was spent at bus stop loading and unloading passengers
- 20% waiting at red light (4).

Therefore, LACMTA targeted the first two causes in converting the express transit on W-W into Bus Rapid Transit, called Metro Rapid Bus. Phase I implementation (REF) achieved

- 28% reduction in run time from limited transit’s run time
- 25% increase in ridership (4).

Since the Metro Rapid Bus system is still capacity constrained (5) LACMTA plans to further improve the system. In the following section we demonstrate through two preliminary analyses how SmartBRT can assist LACMTA to refine their BRT system.

General Description of Simulation Model in SmartBRT v.1

Based on the actual Metro Rapid transit operation on the W-W Corridor we built the following model for SmartBRT, on which the hypothetical scenarios analyzed are based:

1. Running way
   Assumed dedicated lane operation in peak period, therefore interaction with traffic is none to minimal.
2. Stops
   There are 135 local stops and 30 Metro Rapid Bus stops.
3. Headway
   Tested are 5 minutes vs. 3 minutes headway operation in peak period. While in reality local bus operation is schedule-based, we assume a 5-minute headway operation.
4. Demand: number of passengers per stop per hour
   Due to the lack of data, passenger demand is modeled such that: passengers arrive at
   each stop at the same rate with a negative-exponentially distributed inter-arrival times;
   the destination for passengers starting from any stop is uniformly distributed along all
   stops ahead in the bus line; and passenger demand ranges between a minimum 30 and a
   maximum of 100 passenger per hour per BRT stop. We assumed that 4 percent of all
   passengers have bicycles and 2 percent use wheelchairs.

5. Vehicle
   We assumed: a low floor vehicle with two single doors, with 2-second door opening-
   closing time; only the front door is used for both boarding and alighting; exact change
   fares are paid at boarding; and standees are not permitted. Based on these characteristics,
   for dwell time calculation we used default values based on those given by the TCQoS
   Manual (1). As default, bus capacity was assumed to be 40 seats per vehicle. Bus
   movement characteristics (e.g., bus speed, acceleration and deceleration rate, and door
   opening-closing time) are held constant.

6. Signal priority
   We implemented our model of an actuated signal priority system. If the light is about to
   turn red as the bus approaches the intersection, the priority system will delay the red
   signal by up to 9 seconds. The total signal cycle time is 90 sec. It takes two cycles (3
   min) for the signal to recover after giving priority.

Initial Analysis of Bus Run Time

The objective of our first analysis is to demonstrate how SmartBRT can assist decision-making
on system operation. Our first analysis is predicated on one goal for the Wilshire-Whittier
corridor: to lower run time (3). Strategies that LACMAT could employ are:
   • Invest in
     Low floor buses
     Signal priority
   • Change operation practices:
     Increase frequency
     Reduce number of stops
   • Implement any combination of these

In actuality, LACMTA employed many BRT elements as once (4), where as we examined
incremental implementation.

Therefore, we tested how run time changes as a function of the following variables:

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3 Due to lack of passenger demand data at the time of these initial analyses, we had to make assumptions about the
    number of passengers per stop for each stop and about the origin-destination of each passenger. Passengers’ travel
time savings’ sensitivity to passenger boardings and trip distribution is being tested at the time of writing.

4 This 9-second (10% of signal cycle) signal hold was chosen by LACMTA in an experimental manner. It is not
    related to bus frequency.
Number of stops: from 135 local to 30 BRT
Headway: 5 and 3 minutes
Demand: 30, 50, 75, 100 passenger per hour per stop
Bus type (conventional vs. low floor): different set of boarding and alighting times
Application of signal priority: (1) turned on vs. off; (2) if on: length of priority hold: 5 or 9 sec maximum.

Each scenario as defined by a unique combination of variables, was simulated during 3-hour peak period. We calculated the average of bus run times within each run in order to draw distinctions between scenarios/runs.

Initial Results and Observations from Run Time Analysis

Local transit operation:
- Higher demand, naturally, results in longer run time (Figure 3).
- Adding signal priority to local operation lowers run time (Figure 3). However, the trend in marginal change is not clear, requiring further investigation (Figure 4).
- Interestingly, the effect of the length of priority hold seems insignificant and is not clear. For example, changing priority hold from max 5 sec to max 9 sec resulted, at 30 pass/hr/stop, run time increased by 44.86 sec (or 0.83%), while at 50 pass/hr/stop, run time decreased by 55.25 sec (or 0.98%).

BRT operation:
- Switching from local to BRT operation saves run time (Figure 3). The higher the demand, the smaller the reduction in run time for any given hourly demand (or for any individual traveler) (Figure 4).
- More frequent BRT service (from 5 min to 3 min headway) results in lower run time. The higher the demand, the higher this reduction in run time. (For example, at 30 pass/hr/stop run time decreased by 155.0 sec (or 3.26%), while at 50 pass/hr/stop run time dropped by 183.99 sec (or 3.73%).)
- Adding signal priority to BRT operation further lowers run time (Figure 3 and 4). Given the same headway and priority-hold period, the higher the demand, the higher this reduction is.
- Furthermore, the length of priority-hold seems to have an insignificant effect on run time and its effect is not clear. For example, changing priority hold from max 5 seconds to max 9 seconds resulted in a 44.86 sec (or 0.83%) increase in run time at 30 pass/hr/stop; while at 50 pass/hr/stop, run time is decreased by 55.25 sec (or 0.89%). Given the fact that at the time of the initial tests the simulation tool was not yet fully functional, such small changes in the run time are considered insignificant. The effects of the length of signal priority hold on transit vehicles’ run time and on cross street delays are under investigation at the time of this writing.
- Adding signal priority to BRT operation saved slightly more time (8-8.81%) than adding signal priority to local operation (6.75-8.3%), at comparable levels of demand and the same headway (Figure 3 and 4).
- Switching from local operation (no signal priority) to BRT saved more time (18-19%) then adding SP to local operation (8%). Adding signal priority to BRT operation further lowered travel time by an additional 8%. The overall travel time gain from
local operation without signal priority to BRT operation with signal priority was 26-27% (Figure 3 and 4).

Interestingly, the effect of the length of priority hold seems insignificant and is not clear.

For example, using series G2, changing priority hold from max 5 sec to max 9 sec resulted, at 30 pass/hr/stop in travel time increase by 44.86 sec (or 0.83%), while at 50 pass/hr/stop in travel time decrease by 55.25 sec (or 0.98%). Further investigation is needed.

Results of SmartBRT are presented to assist in decision-making. Figures 5 gives an idea how the results of the simulation might assist operators in their decision to achieve desired system performance. Given an “existing base” case, the simulation estimated time saving from two investment actions (low floor buses and signal priority) and from an operational change (increasing service frequency) individually and in combination. Figure 5 shows a column for future cost-effectiveness estimation (time saving for every $1000 invested). If two options would result in about the same run time saving but for very different investment, and knowing how much time would be saved per dollar by each action, the operator could chose where to focus his agency’s resources to achieve the desired service quality.

Initial Analysis of Service Quality under Increasing Demand

The objective of the second analysis is to demonstrate the usefulness of SmartBRT in studying complex relationships between operation parameters and performance measures of BRT systems. In our second analysis, we examine how LACMTA could accommodate increasing demand by:

- Investing in bigger buses and/or
- Increasing service frequency.

System performance is measured by overcrowding, load factor and passenger waiting time.

The three input variables are:
- passenger demand level: 30, 40 and 50 passengers per hour per stop
- bus service frequency (headway): 5 or 4 minutes
- capacity of individual vehicle: 40 or 60 passengers per vehicle

For reference:
1. “base” service: 5 minute headway, vehicle capacity of 40 passengers;
2. “increasing capacity” service: 5 minute headway, vehicle capacity of 60 passengers
3. “increasing frequency” service: 4 minute headway, vehicle capacity of 40 passengers
4. “increasing frequency and capacity” service: 4 minute headway, vehicle capacity of 60 passengers

Results are listed in Figure 6. “Waiting time” and “waiting time percentage” are the mean values of each corresponding metric for all passengers within the three-hour peak period. “Waiting time” is passengers’ waiting time at bus stops, in seconds. “Waiting time percentage” is the percentage of each passenger waiting time in his/her total run time (total run time is the sum of waiting time and run time). The data for the last two measures, “bus load factor” and
“overcrowding percentage” are the mean values of averages corresponding to bus stops, over the total number of occasions when a bus docks at a bus-stop within the three hour peak-period. “Bus load factor” is the ratio of the number of passengers onboard and the total seating capacity of the vehicle. “Overcrowding percentage” is the percentage of times that a bus docks at a stop but cannot take all passengers waiting because the bus is full.

Initial Results and Observations from Service Quality Analysis

It would be very hard, if not impossible, to develop a single mathematical formula that would capture the relationship between these performance measures, passenger arrival rate and bus service indices. But SmartBRT’s output allows us to study such relationship without analytical representation.

- Improved performance measures shows that increasing passenger demand was indeed accommodated by increasing frequency and/or increasing vehicle capacity. The marginal performance changes are not clear and require further investigation.

- Not all performance measures change with the same trend. For example, comparing the “increasing capacity” service to the “increasing frequency” service for the arrival rate of 30 passengers per hour (Scenario 2 and 3 in Figure 6), “increasing frequency” service has better “waiting time”, “waiting time percentage”, and “maximum waiting time”, while “increasing capacity” service has better “load factor” and “percentage of bus skipping”. Therefore, it is important to recognize the trade-offs within the system and to focus resources to improve those performance measures that are valued highest by passengers.

- Increasing bus capacity can significantly improve the system performance (Figure 7). The higher passenger demand, the larger benefit can be obtained from increasing bus capacity.

SUMMARY

We have developed a simulation and evaluation tool specifically for bus rapid transit, SmartBRT. It captures

- BRT infrastructure characteristics within a transportation network;
- microscopic details of transit vehicles that affect the operation performance of the transit system;
- microscopic details of BRT operation, for example, fare collection and door use policies that affect system performance;
- passenger demand; and
- individual passenger characteristics (such as mobility and fare payment type) that has effect on boarding and alighting time and that are needed to estimate waiting and travel time for passengers on individual bases.

We developed SmartBRT for transit operators and transit planners. It can aid them in:

- planning future BRT systems,
• planning future deployment phases for future or existing BRT systems,
• evaluating existing BRT systems by user defined performance measures, and
• communication of BRT system concepts in visualization and the results of analyses in graphs to the public or to decision makers.

SmartBRT can perform the following type of analyses:
• Performance measure evaluation
  o For example, what effects reliability the most?
• “What if” studies
  o For example, what if we add signal priority in some jurisdictions but cannot in others?
• Cost-effectiveness analysis
  o For example, is it worth the effort to push through signal priority in those remaining jurisdictions? Which is more cost-effective: regular 40-foot buses at higher frequency or articulated buses at lower frequency?
• Trade-off analysis
  o For example, trade-offs within the BRT system, running articulated buses at lower frequency will improve load factor but will increase waiting time.
  o For example, trade-offs between the BRT system and the rest of the transportation system, what effect does transit signal priority have on cross traffic?
• Threshold analysis
  o For example, when should we switch from mixed traffic to dedicated lane?
• ITS technology evaluation
  o For example, what is the effect of precision docking on travel time?

Detailed information on SmartBRT can be found at http://path.berkeley.edu/SMARTBRT/

Our initial analyses of transit run time and service quality under increasing demand showed the capabilities of SmartBRT.

ACKNOWLEDGEMENT

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REFERENCES

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Figure 1  SmartBRT Architecture
Figure 2   Visualization
Run time [sec] as a function of demand (given 5 min headway, if signal priority is enabled, priority-hold is 9 sec)

Figure 3
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<thead>
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<th>Run time reduction</th>
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<td></td>
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**Figure 4** Effect of signal priority: Run time reduction in local and rapid transit operation due to signal priority implementation at four demand levels.
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<th>Scenario</th>
<th>Cost-effectiveness</th>
<th>Run time [sec]</th>
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<td>Investing in low floor bus and signal priority, Reducing headway</td>
<td>Future work</td>
<td>Rapid, low floor bus, SP-9, 3 min</td>
<td>4151.11 \text{ sec} – 15.8%</td>
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</tbody>
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**Figure 5** Preliminary example of SmartBRT supporting decision-making with future cost-effectiveness capability indicated
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**Figure 6** Preliminary analysis of tradeoff study
Figure 7 Reduction in “Waiting time” and “overcrowding percentage” due to increasing bus capacity, at 50 passengers per hour per stop

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<th>Service Change</th>
<th>“waiting time” reduction</th>
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<td>From “increasing frequency” service to “increasing capacity and frequency” service</td>
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