Effects of Bus Stop Consolidation on Transit Speed and Reliability: a Test Case

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This is to certify that I have examined this copy of a master's thesis by

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and have found that it is complete and satisfactory in all respects,
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Abstract

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Bus stop consolidation is the process of evaluating bus stops along an established bus route, and closing or relocating selected stops in order to improve service. This paper first presents a process that was used for a real world bus stop consolidation project in Seattle, WA, and then provides an analysis of the results. Bus stop consolidation was found to have reduced bus travel times and improved schedule reliability on the route, without adverse impacts on ridership. A formula was developed to predict the travel time savings that would be expected on a bus route, given a change in the average bus stop spacing.

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Introduction

The bus is a flexible and versatile mode of public transportation. Unlike fixed-route transit systems, a bus can operate on virtually any public roadway with a multitude of possible routes. Buses can operate with bus stops, as is typical in urban areas, or as a flag service without the use of bus stops, common in rural areas. From a capital-engineering point of view, bus stops are cheap and easy to install. However, an excess of bus stops can result in slow or unreliable bus service and may be an inefficient use of public funds.

On many bus routes in the United States, the existing pattern of stops is the result of a reactive process spanning many decades. New bus stops are commonly installed in response to citizen requests or complaints in a reactive manner without consideration of the corridor-level context. Then, as people become accustomed to established bus stop locations, it can be a painful process to remove existing bus stops, even if the original purpose for a bus stop is no longer an issue. After several decades of reactive process without corridor-level vision, an over-saturation of bus stops can result.

Bus stop consolidation is the process of evaluating the bus stop pattern along an established bus route (or route segment) and developing a new pattern for optimal bus stop placement. Bus stop consolidation involves evaluating each bus stop and identifying critical stops, stops that could be removed or combined, and stops that could be moved for better service. In this case “optimal” bus stop placement is that which results in a good balance of service accessibility, transit vehicle performance/schedule reliability, and investment in public facilities. A good balance will maximize operating efficiency and ridership on bus routes.

This paper will discuss a process used for a bus stop consolidation project in Seattle, WA and will use this real-world example to assess the effects of bus stop consolidation on bus travel time, schedule reliability, and other measures.

Bus Stop Consolidation Overview and Theory

Goals of Bus Stop Consolidation

The basic goal of bus stop consolidation is to provide a smoother and faster ride to customers. Although removal of all stops would provide the smoothest and fastest ride possible, it would obviously not be a balanced approach. Bus stop consolidation should not adversely affect ridership, especially for the riders that depend on transit as their only source of mobility. If managed properly, bus stop consolidation can achieve the goal of a smoother and faster ride with a minimum of adverse impacts. Consolidating bus stops can achieve a number of secondary goals in addition to the improvement of travel time. The primary goals of bus stop consolidation will be described below:

Speed and Travel Time

Removing bus stops should, in theory, result in faster running times for buses as they travel their service routes; in simple terms fewer stops = faster speed = less running time. Improving running times has the benefits of reducing delay for passengers, reducing the cost of operating a particular service route at particular headways, and an overall more efficient use of the transit fleet.

To begin to understand the relationship between bus stops and coach speed, it helps to break down the different sources of delay that a bus might encounter at a bus stop:

- *Deceleration/Acceleration time* is the time that the bus takes to brake to a stop approaching the bus stop and then regain cruising speed after leaving the stop. Simple formulas of dynamics and assumptions about vehicle performance can be used to predict these delay values. However, variations in driver skill, vehicle performance, traffic conditions, roadside conditions, and other unknowns make it difficult to accurately predict this time. The deceleration/acceleration time will be reduced when the number of bus stops is reduced.
- *Dwell time* generally refers to the time taken to load and alight passengers. Dwell time can vary greatly between different bus stops and between times of day, depending on passenger loads, number of lift deployments for disabled passengers, and other factors such as the efficiency of the fare collection system. Bus stop consolidation will not have much impact on total dwell time, assuming no significant changes in ridership. This is because most passengers will simply use a different bus stop and will take a similar amount of time to board/alight. Dwell time can be more effectively reduced through other measures, such as pre-paid boarding or the use of low-floor coaches.

- *Open/Close door time* is defined as the time between when the bus comes to a complete stop and when passengers start to board, plus the time after boarding and before accelerating. This time will also be reduced when bus stops are consolidated.
- *Re-entering traffic delay* is the time that is takes for a bus to merge into the stream of traffic after serving a bus stop. This time is only applicable to out-of-lane bus stops[1], as opposed to in-lane stops. Bus stop consolidation can reduce or eliminate this delay.
- *Traffic signal delay* is not directly associated with the bus stop, but it can share a relationship with the placement of bus stops. In a coordinated signal system, each bus stop located between two coordinated signals has the potential to cause the bus to get out of sync with the coordination timing. Removing bus stops between coordinated signals can reduce signal delay by keeping the bus in favorable progression. This amount of delay and the savings that could be gained through bus stop consolidation are very difficult to quantify. This effect is most pronounced with closely spaced signals. In an area with isolated, uncoordinated signals or where the bus does not follow the signal coordination pattern, the amount of traffic signal delay will be more random and generally will not depend on nearby bus stops.

Reliability

The removal of some bus stops is expected to make buses run more predictably and thus increase adherance to the schedule. Buses usually stop at bus stops only on demand, if there are waiting passengers, or a passenger on board has requested a stop. Removing bus stops should reduce variations in travel times because there are fewer opportunities for delay. Improved reliability allows for a more efficient schedule with less recovery time needed, and reduces passenger waiting time and frustration. Late buses often have to make more stops and take on more passengers, compounding the delay.

An improvement in reliability will also reduce the likelihood of the “bunching” effect. Bunching happens when a bus becomes so late that the next scheduled bus catches up to it, and is a significant problem on long bus routes with frequent service.

Bus Stop Spacing

A number of research efforts have concluded that the optimal bus stop spacing for most transit routes is somewhere between 1000-2000 feet between stops.[2] In most U.S. Cities, the typical bus stop spacing is

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[1] Also known as pullout bus stops.
[2] van Nes, 1999; Furth, 2000; Saka 2001

between 650 and 900 feet, well below the optimal.[3] Many transit agencies have developed guidelines for preferred bus stop spacing in urban environments. Although these guidelines are usually followed when a new route is planned, they are rarely applied to existing bus routes. Bus stop consolidation would be used to bring existing bus routes into agreement with the transit agency's guidelines.

In Seattle, WA, King County Metro's guidelines call for an ideal stop spacing of 4-6 stops per mile in an urban environment, to achieve the proper balance of service coverage and vehicle performance. Tri-Met, in Portland, OR, uses bus stop spacing guidelines of every 3 blocks or 780' in dense areas, and every 4 blocks or 1000' in medium to low density areas.[4] The Public Transport Council in Singapore uses a guideline of 400m - 350m (1312ft – 1148ft) spacing between bus stops.[5]

Pedestrian Safety

Bus stop consolidation can improve pedestrian safety by positioning bus stops near signalized intersections or safer crossing locations. Often the most important bus stops with the highest patronage and transfer activity are already located close to an improved pedestrian crossing, making this goal work in tandem with other goals.

Traffic Safety

Fewer stops mean less vehicle conflict points and thus fewer accidents. In-lane stops create conflicts as other vehicles try to get around a stopped bus, and out-of-lane stops create conflicts as buses merge into traffic. In Washington State, traffic law gives buses the right-of-way when merging into a traffic lane;[6] however, the rate of driver compliance with this law is laughable.

Passenger Facility Investments

Concentrating more passengers at fewer bus stops can make it easier for transit agencies to justify investments in passenger facilities at the bus stops. Passenger facilities could include shelters, benches, lighting, litter receptacles, schedules, real-time bus arrival information, or any other improvements that enhance the passenger-waiting environment.

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[3] Furth, 2000
[4] Tri-Met 2002
[5] PTC 2001
[6] RCW 46.61.220

TSP/Corridor improvements

Bus stop consolidation can prepare the corridor for other improvements to increase bus speed and reliability. For example, Transit Signal Priority performs optimally only when bus stops are not located near the intersection approach[7]. Eliminating or moving near-side stops would prepare a signalized intersection for Transit Signal Priority. Other considerations could be made for future alterations in traffic signal detection, transit queue jump signals, on-street parking, channelization, bus/pedestrian bulbs, or other items.

Attracting Customers

Improving the speed and reliability of bus services helps eliminate one of the primary barriers that impede more people from using the bus[8]. These improvements plus adding passenger waiting amenities will help transit capture more discretionary riders, who are able to choose other modes of transportation.

Review of Bus Stop Spacing Research

Several authors have developed models for determining optimal bus stop spacing, based mainly on social cost and vehicle performance formulas and assumptions.
An article published by Anthony Saka in 2001 proposed a mathematical model for determining optimal bus stop spacing and the effect of bus stop spacing on the fleet size required to serve the route. Saka estimated bus travel time with the following formula:

$$T_{bus} = T_{a,d} + T_S + T_C + T_O + T_M$$

> Where $T_{a,d}$ = total one-way bus travel time during acceleration and deceleration; T_S = total one way delay attributed to solely to bus dwell time at regular bus stops; T_C = total one-way delay attributed solely to traffic control devices; T_O = one-way bus travel time at cruise speed; and T_M = miscellaneous delay.[9]

Saka further develops estimates for each of the travel time components in the model, except for the T_M component. While this model would undoubtedly be useful for planning new bus routes, it would be of limited use for predicting changes on well-established bus routes within a larger transit system. The

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[7] Koonce, 2003
[8] King County 1999
[9] Saka 2001

model groups many sources of delay that are important in the context of bus stop consolidation, into the 'miscellaneous delay' category.

Herbert Levinson published a detailed analysis in 1983 of transit speeds, delays, and dwell times based on surveys of transit agencies across U.S. cities. Among other analyses, Levinson used the survey data to develop formulas to estimate dwell time at bus stops. The formula that provides a reasonable estimate in any community is stated as:

$$T = 2.75n + 5sec$$

> Where T is the total stopped time per bus and n is the number of interchanging passengers per bus.[10]

Given the assumption that bus stop consolidation will have a negligible impact on total route ridership, this formula is useful here only for its constant, which represents the open/close door delay as discussed earlier. Levinson further developed a formula for acceleration and deceleration time per bus stop:

$$T = 23.4 – 1.53X$$

> Where T is the total acceleration and deceleration time per bus stop and X is the number of stops per mile.[11]

Levinson's formulas could be used to estimate the open/close door and acceleration/deceleration components of travel time savings resulting from bus stop consolidation. However, the other components of delay that are expected to be reduced from bus stop consolidation are not considered in these formulas, specifically, re-entering traffic and traffic signal delays.

Peter G. Furth developed a geographic model for optimal bus stop placement. His model uses ridership data, geographic network information, assessor's data, and other inputs to optimize bus stop locations for overall least societal cost. The model was used to analyze a bus route in Boston, MA. The model results concluded that the optimal spacing for that particular route was 4 stops per mile, in contrast to the existing 8 stops per mile along the route. An interesting characteristic of this model is that it prefers larger stop spacing near the center core of the route and smaller spacing near the terminals, the rationale being that there are more passengers on the bus near the core of the route who are delayed by the extra

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[10] Levinson 1983

stops. This model is undergoing further refinement and could be a useful tool for developing a starting point for identifying new bus stop locations on an existing route.

An unpublished study by the San Francisco Municipal Railway showed that after a series of bus stop consolidation projects, bus travel speed increased by 10-15 percent as a result of an approximate 35 percent reduction in the number of bus stops.[12]

This paper builds on the previous research by providing some additional insight into the effects that bus stop consolidation can be expected to have on bus travel times and reliability. Some issues that pertain to a bus stop consolidation will be discussed and a real world example will be described. The results will be used to develop an empirical model that would be useful for future bus stop consolidation projects.

Important Considerations

Selecting a Candidate Corridor

A variety of factors could be relevant in the decision of selecting a transit corridor for bus stop consolidation. Long bus routes with closely spaced bus stops and high service frequency can realize maximum benefit from consolidating bus stops. A bus route with a history of schedule reliability problems could also be a good candidate if the reliability problems can be partly attributed to bus stop locations and spacing. When increases in traffic volumes, increased ridership, or other factors cause a degradation of travel time, and budget constraints do not allow investments into additional service hours, bus stop consolidation can be a desirable alternative to reducing service on the route. Often, bus stop consolidation would be desired before major service investments are made into an existing bus route.

Role of BRT

Many transit agencies worldwide currently have or are considering implementation of Bus Rapid Transit (BRT) service. BRT operates like an express service connecting key activity centers without providing local service. BRT often employs special vehicles, uses special bus stop facilities, and sometimes operates on exclusive rights-of-way. The context of bus stop consolidation in this discussion

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[11] Levinson 1983
[12] Robbins

is for local service. Conversion of local service into express or BRT service would be a more substantial change than consolidation of bus stops on local routes and is outside of the context of this analysis. However the results presented here could be useful in planning or developing a schedule for new BRT service.

Elderly and Disabled Customers

A major concern with bus stop consolidation is the impact that the bus stop changes might have on mobility impaired customers. Employing a thorough and all-inclusive customer-input process is intended to help transit staff identify these potential impacts and develop mitigating measures. Local social service organizations can help transit agency staff assess the impacts of proposed bus stop changes. If available, paratransit services may be a suitable substitute for individuals who are unable to adapt to new bus stop locations.

Sight-impaired individuals are of special concern because of the visual rider notification methods used by the transit agency, such as bus stop change notices. Also, blind people have difficulty crossing at unsignalized locations, often prefer bus stops that serve a single route, and may not necessarily use the stop closest to their destination. Transit staff need to be especially proactive in reaching out to blind customers.

Pedestrian crossings

The street crossing environment is an important criterion for locating bus stops, particularly when the bus route operates on arterials with four or more lanes. It is desirable to locate bus stops near signalized crosswalks or otherwise protected pedestrian crossings. Unsignalized crosswalks that cross four or more lanes of traffic have been shown to be unsafe and should not be preferred over crossing locations that lack crosswalks.[13] On lower speed streets with three or fewer lanes, locating bus stops near signalized crossings is less crucial. The test case project presented in this paper found opportunities to work with the city to selectively improve pedestrian crossing treatments at several locations.

Transfer/Time points

Identification of the bus stops that patrons use to transfer to/from other transit routes is crucial. Although published bus schedules usually identify locations of official transfer points, some "unofficial" transfer points may be discovered over the course of the project. Transfer points are important to retain, but in some cases they can be moved to a better location. Time points are another

[13] Zegeer, 2001

special type of location along the route. King County Metro prefers to have bus stops at the time points that are listed in the published bus schedule, although this is not an absolute requirement, and other agencies may have different policies.

Security

In urban settings, some areas are commonly perceived to be unsafe locations in which to wait for a bus, particularly at night. If moving or closing a bus stop will require patrons to relocate to a bus stop that has a real or perceived security problem, patrons may find that fact to be a barrier to their continued use of the transit system. A sense of security is subjective, and is often closely related to the “aura” of the place. These qualities can be difficult to quantify, but are nonetheless are important to observe. In some cases, security can be improved with additional lighting, landscaping, murals, or other improvements.

The Route 48 Test Case

The next section will describe a real bus stop consolidation project that was managed by the author. The test case is the route 48 corridor in Seattle, WA, shown in Figure 1. The route is operated by King County Metro and is one of the busiest routes in the Metro system. In the autumn of 2002, a speed and reliability project was launched to help improve running times and schedule adherence of the route. The first task of the project was to evaluate the bus stops along the corridor and consolidate them into fewer stops. After consolidating bus stops, Metro staff planned to evaluate other improvements, such as retiming traffic signals, changing traffic signal phasing, channelization revisions, changes to on-street parking, and Transit Signal Priority (TSP). The results from this test case will be used to draw several conclusions about the effectiveness of bus stop consolidation on travel times, schedule reliability, and ridership.

Description of the Route/Corridor

Route Characteristics

The route 48 is the longest route operated by Metro that is entirely within the City of Seattle. The full route is about 16 miles long and is considered a cross-town route because it does not serve the Seattle CBD. There are four variations of the route:

- Local: Operates from the Loyal Heights terminal in the north to the Rainier Beach terminal in the south and makes all stops.
- Express: Operates from the NE Pacific Place terminal in the University-District to the Loyal Heights terminal, makes no stops from NE 45th St & 15th Ave NE to N 85th St & Wallingford Ave N. There are only 3 express trips per weekday in each peak direction.
- Alternate: Operates from the Loyal Heights terminal in the north to an alternate southern terminal at Columbia City and makes all stops.
- Shuttle: Operates from the Loyal Heights terminal in the north to an alternate southern terminal at Rainier Ave & Walden St and makes all stops. Continuing service is provided by the route 42. This route variant operates only during night and off-peak periods.

The bus stop consolidation analysis that follows uses data only from the local and alternate variants of the route 48.

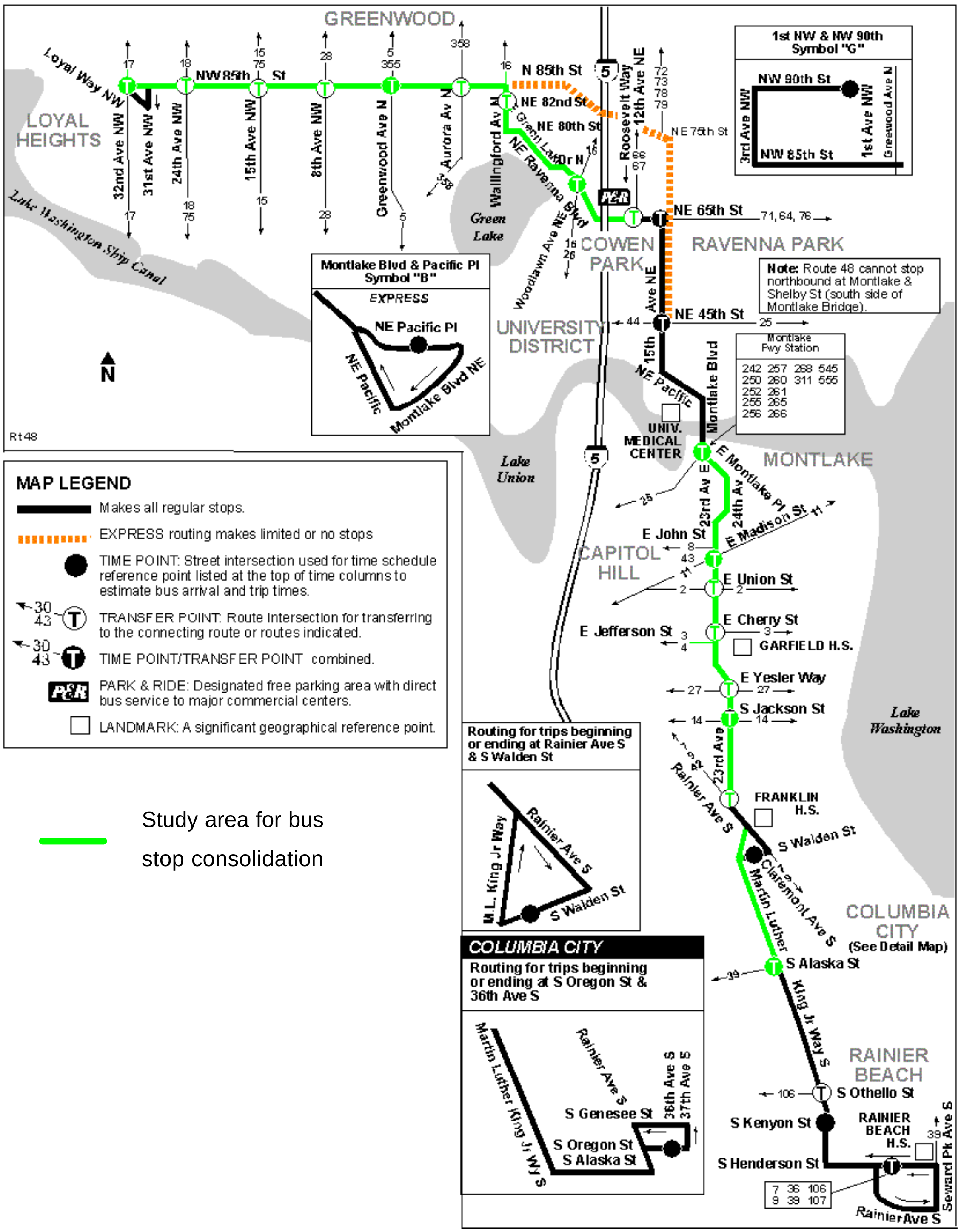

Figure 1: Route 48 timetable map, and bus stop consolidation study area.

The largest ridership generator is the University of Washington, located in the University District near the middle of the route. Coaches heading towards the University District are considered “inbound” and coaches heading towards the terminals are considered “outbound” Thus, the peak flows are inbound towards the University District in the morning and outbound towards residential areas in the evening. As coaches travel through the timepoint located at 15th Ave NE & NE 65th St, just north of the University District, they switch their inbound/outbound designation, although this switch is invisible to the customer.

Bus Stops

Before bus stop consolidation, there were 240 stops along the local route 48 including both directions, of which 198 were within the consolidation area. After bus stop consolidation, the total number of bus stops was reduced to 199, a 17% reduction, or a 26% reduction to 157 total stops within the consolidation area only. See Appendix A for maps showing the exact locations of bus stops, before and after consolidation.

The vast majority of the bus stops along the route 48 are in-lane stops on a 4-lane arterial. This fact is important because <u>in-lane stops do not cause coaches to experience delays related to reentering traffic</u>. A different bus stop consolidation project along a line with many out-of-lane bus stops would likely see greater travel time improvements than those observed this project.

Street System

The route 48 operates almost entirely on four-lane principal arterials without on-street parking. Portions of the route operate on two-lane collector arterials with parking on one or both sides of the street. Smaller portions of the route operate on various other types of streets. Arterials within the City of Seattle have an unposted speed limit of 30 mph. One particular stretch of roadway, Wallingford Ave N between N 80th and N 85th Streets, is a problem to bus operations due to the narrow roadway width and other routes that operate on the roadway; oncoming coaches do not have room to pass, necessitating that operators employ creative and time-consuming passing maneuvers. (e.g. driving over the sidewalk or folding in side-view mirrors)

Fleet

The route 48 uses both 40' standard and 60' articulated diesel coaches. Beginning in October 2003, new low-floor 40' coaches began to be placed into service along the route. These coach types are illustrated in Figure 2.

Figure 2: Coach types used on the route 48. Clockwise from top left: 40´ standard, 40´ low-floor, 60´ articulated

Schedule

During the PM peak, route 48 coaches have about 90 minutes scheduled to travel between the southernmost terminal to the northern terminal. The long length and short service headway of the route causes schedule reliability problems with the route 48, with bunching being a persistent problem. The existing schedule reliability problem was an important reason why this route was targeted for bus stop consolidation.

A significant source of schedule variability is the Montlake Bridge, a drawbridge located near the middle of the route. Bridge openings are frequent and often cause traffic backups in the vicinity that can last up to several hours.

Ridership

The route 48 typically serves over 11,000 riders in an average weekday, according to fall 2002 data. Since the route 48 serves the University of Washington and a number of high schools and middle schools, there are significant seasonal variations in ridership that fluctuate with the school schedules.

Managing the Bus Stop Consolidation Project

The next section will discuss the process that was used for the route 48 bus stop consolidation project. The route 48 project was fairly unique in that the first phase of the project focused solely on bus stop consolidation; often bus stop consolidation is incorporated into larger projects such as roadway improvements, reconstruction, or major service reorganizations.

Making changes to existing transit service is always a controversial process that has tradeoffs. The approach described here proved to be a good balance of community involvement without over-taxing staff resources. These steps represent the method used by the author in the route 48 project; different operating and political environments in other areas may call for different approaches.

Segmentation

Because the route 48 is a long route, it was split into segments for bus stop consolidation purposes. Splitting the route would help prevent staff from becoming overwhelmed with customer inquiries during the public notification phases of the project. Proceeding in segments would also help spread the workload with other elements of a consolidation project, which at times involved parties other than the transit agency. The route 48 was split into four segments, as shown in figure 3, the first segments being shorter than the last to ease the task of establishing processes for customer feedback and response.

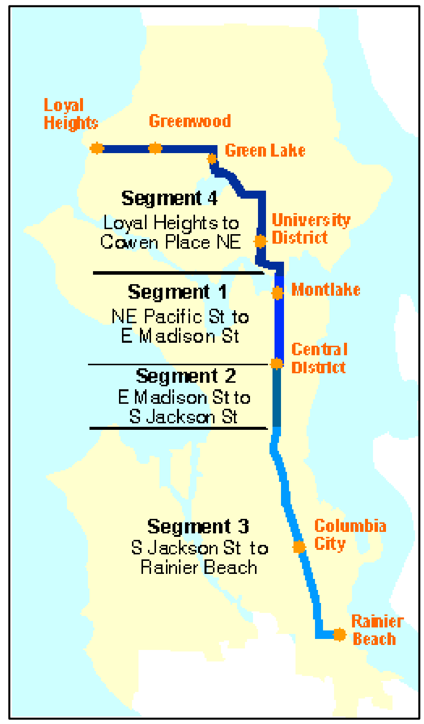

Figure 3: Segmentation of the route.

Some parts of the route were omitted from the bus stop consolidation project. Parts of the route in the University District and NE 65th St, and the portion south of S Alaska Street were omitted, due to other projects underway in those areas. The route map in Figure 1 shows the portions of the route that were included for bus stop consolidation.

Bus stop consolidation work proceeded through the segments according to the schedule shown in Table 1. The comment period indicates the time span during which customers were provided an opportunity to comment on bus stop consolidation proposals. Table 1 also indicates other Metro routes that share one or more of the bus stops that were consolidated.

Table 1: Schedule for bus stop consolidation public process and implementation.

Seg-ment	From	To	Comment Period	Implementation Date	Routes Sharing Stops
1	NE Pacific St	E Madison St	12/4/02 - 1/24/03	February 2003	43
2	E Madison St	S Jackson St	12/23/02 - 3/24/03	June 2003	4
3	S Jackson St	Rainier Beach	1/17/03 - 3/24/03	June 2003	4, 42
4	Loyal Heights	Cowen Pl NE	5/7/03 - 6/2/03	September 2003	16, 18, 64, 71, 72, 73, 75, 78, 76, 355

Data collection, field observations

Figure 4: A bus stop with unique characteristics.

Shortly after the launch of the bus stop consolidation effort, the project manager first became familiar with the bus route and the area that it serves. Each bus stop was evaluated and an idea for new bus stop placement was sketched out. Then, the bus stops that would be closed or moved were carefully evaluated in order to assess the impacts of the proposed changes. Important features that were noted included passenger amenities, condition of the sidewalks, presence of curb ramps, pedestrian crossing treatments, evidence of hide-and-ride[14] usage, nearby schools, community centers, facilities for the elderly or disabled, and other important or unique characteristics. The author found it helpful to keep a notebook of maps, photographs, field notes, ridership data, and other information, sorted geographically for quick reference.

Operator input

Bus operators provided valuable information for the bus stop consolidation effort. Bus operators are obviously very familiar with the day-to-day usage of bus stops, although operators' opinions about specific bus stop changes will often vary widely. Operators' comments were useful for identifying stops with high numbers of elderly and disabled riders, and also for identifying stops that cause specific

[14] "Hide-and-ride" is the practice of parking one's car on-street in a neighborhood with good transit service, and using transit for the final leg of the journey.

problems or delays to bus operations. Operator input was collected through informal interviews and with comment sheets posted at the transit bases.

Review of coverage area

Generally, a quarter-mile walk is considered to be a reasonable distance that customers will walk to a bus stop. With a detailed neighborhood map, the quarter-mile coverage area was sketched out by tracing all of the possible walking paths, following only legal walkable paths (usually streets, but sometimes also sidewalks, public paths, stairs, etc). Areas that would lose quarter-mile access to a bus stop as a result of a bus stop closure or relocation were scrutinized carefully; if high-ridership generators such as schools or multifamily dwellings existed within the lost coverage area, then alternative bus stop placement scenarios were evaluated. In areas with a regular grid street system and existing bus stop spacing of less than 1000´, the lost coverage area from revising the bus stop spacing to 1000-1200´ is typically small. However, irregular streets and gaps in the grid may make the lost coverage much larger. Figure 5 shows an example of a sketch of the coverage area.

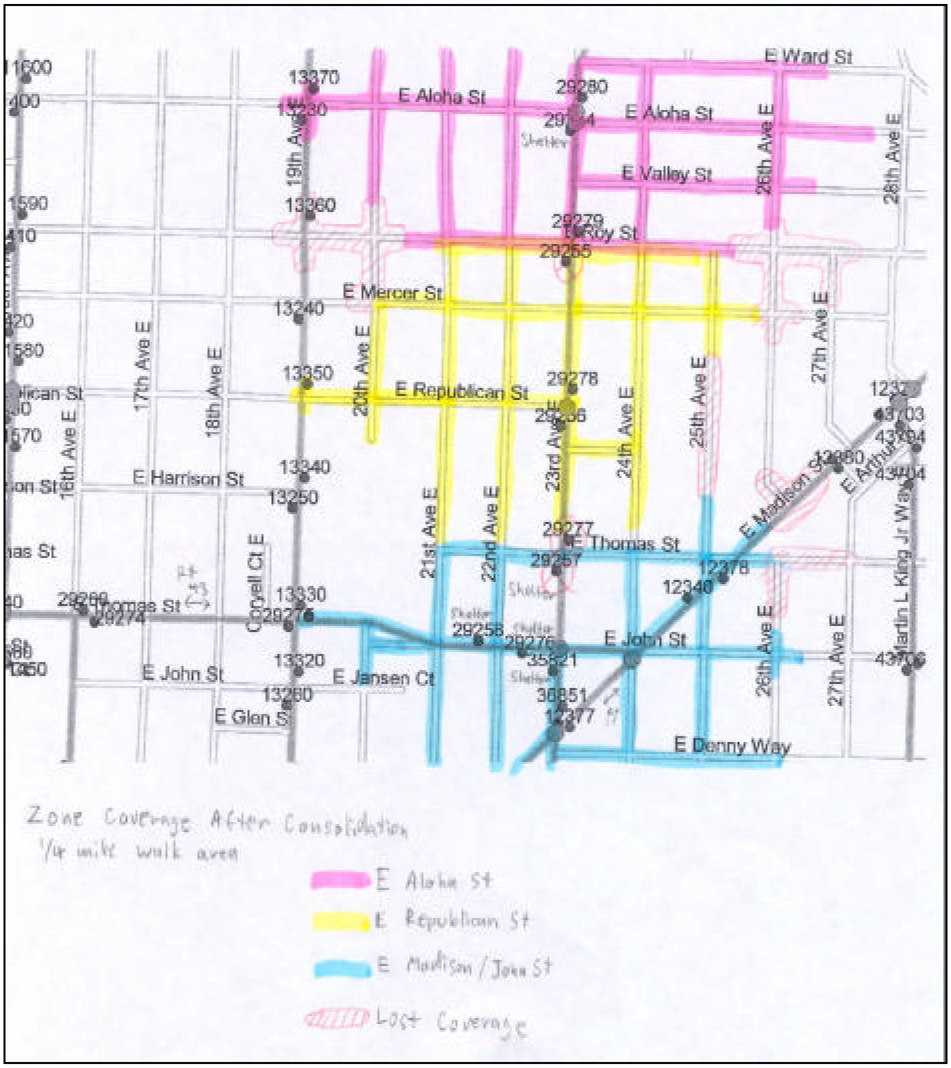

Figure 5: Example of a bus stop coverage sketch, superimposed on a GIS-generated street network map. Small circles are bus stops, with bus zone ID number shown, larger circles are traffic signals. The three highlight colors represent the coverage area from the three pairs of bus stops that would remain. The red crosshatch shows the area that would no longer be within a ¼ mile walk of a bus stop, if the two pairs of bus stops, circled in red, were removed. (Note that neither of these bus stops were actually closed, due to customer opposition)

Review committee

Once a draft bus stop consolidation plan was developed by the project manager, it was reviewed by other staff within the transit agency before being released to the public. It was especially important to gather input from people with knowledge of historical issues and experience with day-to-day operations. Once the bus stop consolidation plan was reviewed and approved by transit staff, it was released for public comment.

Rolling Out the Proposal

At this point the bus stop consolidation proposal was released to the public and a comment period of at least three weeks was established. Three primary forms of communication were employed to solicit feedback from transit riders and other interested parties:

Bus stop notices: Informative signs were posted at any bus stop that would be closed or moved under the bus stop consolidation proposal. The signs invited riders to submit their comments via telephone, postal mail, or email. In addition, selected bus stops were stocked with project brochures describing the purposes of the bus stop consolidation and the other improvements that were planned to follow. For one segment of the route 48, bus stop notices were posted at all bus stops within the segment, to alert riders to expect some changes to bus stops in the area. The hope was to generate additional feedback from riders who would be positively affected by the bus stop changes; however, this approach only resulted in confusion about which bus stops were proposed to change.

Figure 6: Bus stop notice and literature holder placed at a bus stop proposed for closure. (Also note the bus stop facility improvement generously donated by a local community member.)

Project website: A website was created on Metro Online specifically for the project. The website contained background information, maps and other detailed information about the bus stop consolidation proposal, and was continually updated with project updates as the project progressed. This website can be viewed on Metro's archives at http://transit.metrokc.gov/up/archives/nov02/rt48-improvements.html

Contacts to community organizations: Metro staff identified and contacted community organizations in the affected areas. Neighborhood associations, local services for the elderly or disabled, local business organizations and schools were all contacted about the proposal. In the case of some groups with regularly scheduled meetings, Metro staff attended one of their meetings and gave a short presentation about the proposed changes.

Finalizing Bus Stop Locations

After the comment period had closed, all of the feedback received was scrutinized and summarized. In outstanding circumstances, Metro staff made additional contacts to individuals to ascertain their situations and negotiate mitigating measures.

In all, a total of 191 customers submitted feedback about proposed plans for bus stop consolidation. Table 2 summarizes this feedback.

Table 2: Customer feedback received during the route 48 project.

	Number of Comments Received			
Segment	Positive	Negative	Total	"Hot" Issue
1	18	83	101	Preserve "unofficial" transfer points
2	5	22	27	Security of other stops
3	3	11	14	Blind customers
4	9	40	49	Elderly/Disabled customers

Most of the comments received were negative comments, which is not surprising, given that the negative impacts are clearly apparent to a few people, while the positive impacts are less obvious among a greater number of people. Negative comments were generally directed at a specific bus stop location, while positive comments were directed at the project as a whole.

Final Notification

After a final decision was made for the new bus stop locations, riders were notified of the decision by these methods:

Rider Alerts: A rider alert message was posted at each bus stop to be changed, at least two weeks before in advance of implementation.

Website Updates: The project website was updated with maps and descriptive text about the final bus stop locations.

Written Responses: A message was sent out to all persons who had submitted written comments about the bus stop consolidation proposal, or who had been contacted directly by Metro staff. The message informed them that a decision had been reached and thanked them for their comments.

Schedule Adjustments

A significant challenge with this project was determining how to translate bus stop consolidation into adjustments of the schedule. Anticipating travel time savings in a scheduled route always must take into account this paradox: if no adjustments were made, then drivers would continue to adhere to the old schedule, absorbing the potential travel time savings into deliberate delays in order to maintain the schedule. Conversely, if too much time is taken out of the schedule, then problems with reliability, recovery times, and bunching could result in poor performance.

A rough estimate was used to anticipate the travel time savings for the purpose of adjusting the schedule, using the following rule of thumb: 20 seconds saved per stop, factored by the percentage of buses observed stopping at each stop. The analysis in the next section will help provide a basis for determining schedule adjustments more accurately for future bus stop consolidation projects.

Implementation of Changes

The actual implementation of the bus stop changes was handled through a well-established work order process between the city and transit agency. Field crews were sent out to remove bus stop signs and curb paint. New bus stops were installed where needed. Bus stop facility improvements such as shelters and benches followed a longer process of implementation.

Analysis of Results

The route 48 bus stop consolidation project provides a unique opportunity to measure directly the effects that bus stop consolidations have on transit speed and reliability. What follows is a description of a before and after study that attempts to measure the effectiveness that a change in bus stop spacing will have on transit vehicle travel time and schedule performance. The results of this analysis would be useful for future bus stop consolidation projects, specifically for the purpose of determining appropriate adjustments to be made to the schedule after bus stop consolidation is implemented. These results could also prove useful for purposes of planning potential bus stop consolidation projects-for example, by predicting savings in service hours that could be realized from such projects.

Data Collection

Special data collection efforts were not needed for the purposes of this evaluation, thanks to the systems already built in on Metro buses.

All coaches in Metro's fleet are equipped with an Automatic Vehicle Location (AVL) system. The AVL system uses signpost and dead-reckoning methods to track progress of vehicles along pre-programmed routes. AVL information is transmitted back to a central server over a trunk radio system. Among other functions, the central AVL server keeps a database of all coach travel times between every timepoint, rounded to the nearest minute. For the bus stop consolidation evaluation, travel times within this database were simply queried for specific time periods before and after the bus stop consolidation was fully implemented.

In addition to the AVL system, a selected number of Metro coaches are equipped with the Automated Passenger Count (APC) system. Coaches equipped with APC use pressure-sensitive pads near the doors to record where passengers get on and off the coach. APC-equipped coaches are selectively assigned to trips in order to get adequate sampling of all trips for all routes throughout the system. The APC data was used in two ways for this project: to determine activity at specific bus stops in order to develop a plan for bus stop consolidation, and to measure the effects of bus stop consolidation on overall route ridership.

Analysis Methodology

Data sets queried from the AVL database were used to compare bus travel times before and after the bus stop consolidations were implemented. A six-week period of weekday bus travel times in year 2002, between 11/11/02 and 12/19/02, was compared with a similar six-week period in year 2003, between 11/10/03 and 12/18/03. The before and after data was chosen this way because of the seasonal variations in ridership inherent with the route 48, and also due to the fact that the bus stop consolidation was implemented incrementally in segments within a span of about 7 months.

For an analysis of the effectiveness of this particular project, one could simply compare the travel times measured across the entire route as a whole and draw some conclusions about the net benefits from bus stop consolidation. However, breaking the data down further can yield some more general conclusions about these effects. For this reason, data was queried and compared separately by TPI (Time Point Interval: a segment of the route between two time points), direction, and time period.

The route 48 is split up into 12 TPIs; 9 TPIs were used in the analysis, with 3 not used because of construction or other irregularities. Each TPI and direction received a different treatment in terms of the change in bus stop spacing; a few TPIs had no changes in the bus stop spacing. Each trip within each TPI was grouped into one of the following time periods, depending on the time of day the trip was scheduled to enter the TPI:

AM	6:00AM – 9:00AM
MD	9:01AM – 3:15PM
PM	3:16PM – 6:15PM
EV/LN	6:16PM – 5:59AM (Not used)

The breakdown and grouping of the travel time data resulted in 108 subsets of travel times to be analyzed (9TPIs x 3TODs x 2DIRs x 2 years) Each of these subsets was analyzed for average travel time and reliability factors, as will be described in further detail later. The number of observations per subset ranged from 139 to 692, due to time period groupings and the fact that some trip variants do not travel the entire length of the route.

Dependent Variables

These are the measures of effectiveness that were calculated from the subsets and used as dependent variables in the formulation of various models. Variable abbreviations are indicated in the parenthesis as they are referenced in the findings. The complete data set with these variables is provided in Appendix B.

Travel Time Change (ttchg)

A key measure of effectiveness is the difference of travel times before and after bus stop consolidation. From each of the data subsets, an average travel time was calculated. Each TPI/DIR/TOD combination in 2002 (before) was compared with its corresponding set in 2003 (after). Calculating the difference of the before and after averages created another data set of analysis points, with 54 observations. Before making this comparison, the outlying 10% of the travel times from each data set were removed from the travel time analysis. Outlying data often is caused by unusual circumstances, like major traffic accidents, which are not pertinent to this investigation, yet can have significant effects on the calculated average if not removed.

Travel Time Change Per Mile (ttchgpm)

Since TPIs are not of a consistent length, it is logical to normalize the travel time differences by mile of travel. Use of this dependent variable would lead to more general conclusions about travel time savings applicable to future projects.

Lateness (%late, %verylate)

Reliability of transit service is another measure of effectiveness directly related to the goals of bus stop consolidation. To transit operations, reliability means not being late. Transit operators are strictly instructed not to run ahead of schedule; therefore, early operation should, in theory, not be observed within the data. However, if coaches become late within one particular TPI, they may recover time in a subsequent TPI, showing a travel time less than the scheduled time in the AVL data. Late operation, however, is a common occurrence and undesirable. Thusly, lateness is the important measure of reliability. Lateness was measured by two simple measures: the percentage of trips observed to take more than 1 minute above the scheduled run time (% late), and the percentage of trips observed to take more than 3 minutes above the scheduled run time (% verylate).[15] By analyzing reliability in this fashion for each TPI along the route, sources of lateness can be pinpointed and related to bus stop

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[15] Three minutes late may not seem to be "very late" to an average rider, but consider that each data point represents a travel time along one of 12 route segments.

spacing. As with the travel time analysis, the change in %late and %verylate was measured before and after bus stop consolidation and compared with the change in bus stop spacing for each TPI, direction and time.

Independent Variables

Change in Bus Stop Spacing (spacechg)

The main treatment variable that was changed between the before and after conditions is the average bus stop spacing. The average bus stop spacing is calculated by taking the length of the TPI divided by the number of bus stops within the TPI, calculated separately for each direction. The change in bus stop spacing is simply the difference in average spacing before and after bus stop consolidation. The positive number represents the increase in average bus stop spacing.

Displaced Riders (disrider)

Another variable that could be significant, related to the change in bus stop spacing, is the number of riders that had to relocate to another bus stop. In theory, closing a busier stop should result in a greater travel time savings than closing an infrequently used stop. On the other hand, use of this variable could simply add more random effects for a looser correlation from the treatment variable. This variable was measured by summing the ons and offs observed within each TPI/TOD/DIR at the closed bus stops prior to their closure.

Peak/Non-Peak (pk_ind)

An indicator variable was used for trips that are considered to be within the peak flow, peak flow being inbound during the AM and outbound during the PM. It was hypothesized that peak flow trips would realize a greater benefit from bus stop consolidation than non-peak flow trips; the peak indicator variable was used to test this hypothesis.

Schedule Adjustments (schedchg)

As mentioned earlier, the factor of the schedule poses a cause-and-effect paradox that can make travel time comparisons difficult. Minor schedule adjustments are made periodically during each of the three annual service changes in the King County Metro system. These schedule changes are made to fine tune the schedule performance as well as other critical parts of the operation of the transit system, such as layover space allocation and coordination of transfers. Some of these adjustments were made in anticipation of travel time savings due to bus stop consolidation. Schedule adjustments are made on a per-trip basis and not necessarily with any specific time period grouping. So, for each subset of travel time data, a scheduled time value was calculated based on the average scheduled time for all of the trips within the subset. Average scheduled time was compared before and after for each analysis point to obtain a parameter of change of average scheduled time for each of the 54 observations.

Findings

With this data set, some interesting trends can be observed resulting from bus stop consolidation. High variability is an inherent quality of transit vehicle travel time data; it is hoped that the large data set will wash out random factors from the data (wheelchair loadings, bridge openings, etc.) and the fact that the data is derived from before-after comparisons will cancel out recurring factors (traffic congestion, roadway characteristics, demographic effects, driver variability, etc.). Of concern, however, are recurring factors that changed over time from 2002 to 2003, which could cause false effects to be observed in the data. Some possible sources of this kind of error are discussed later.

Travel Times

To begin to understand the effects of bus stop consolidation on bus travel time, some general comparisons of the data subsets are made. Figure 7 is a chart of the scheduled and running times by each scheduled trip across the entire north part of the route, in the inbound direction. Each point in this figure represents the six-week average travel time for each individual trip, across a whole weekday.

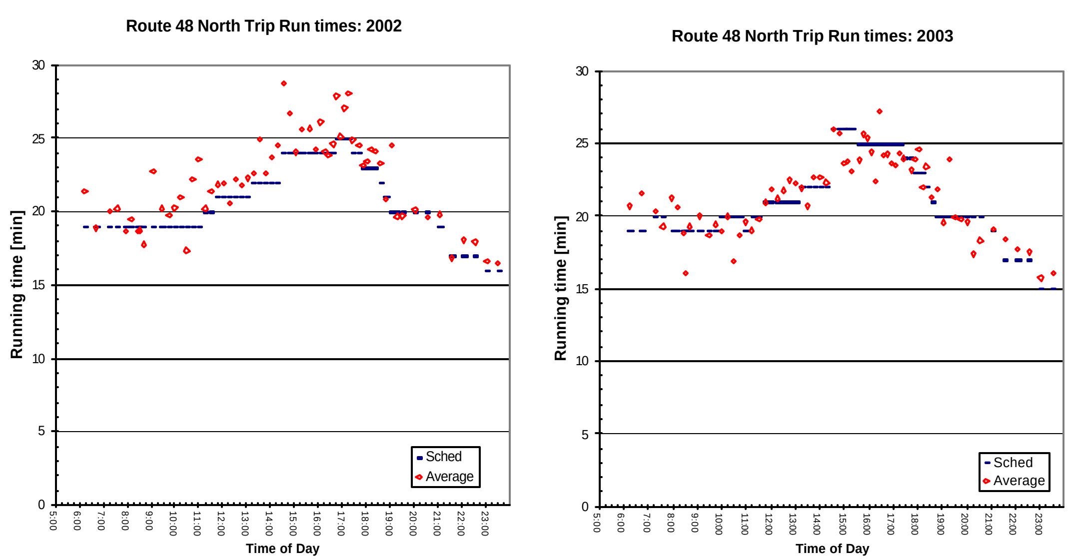


Figure 7: 6-week average and scheduled running times for all outbound trips on the route 48, north part.

Although this comparison provides detailed information about time-of-day effects and variability, it suffers from a significant source of error when making before and after comparisons. Each trip is generally operated by the same driver across the entire 6-week period; however, drivers change route assignments during the three annual shakeups. Due to variations in driver technique, before and after comparisons at the trip level may be misleading. Grouping the trips by time of day avoids this error.

Figure 8 is a comparison of the 2002 travel times and 2003 travel times for each TPI and direction, with the 2002 and 2003 average scheduled times included for comparison. For simplicity, the PM peak period is shown only.

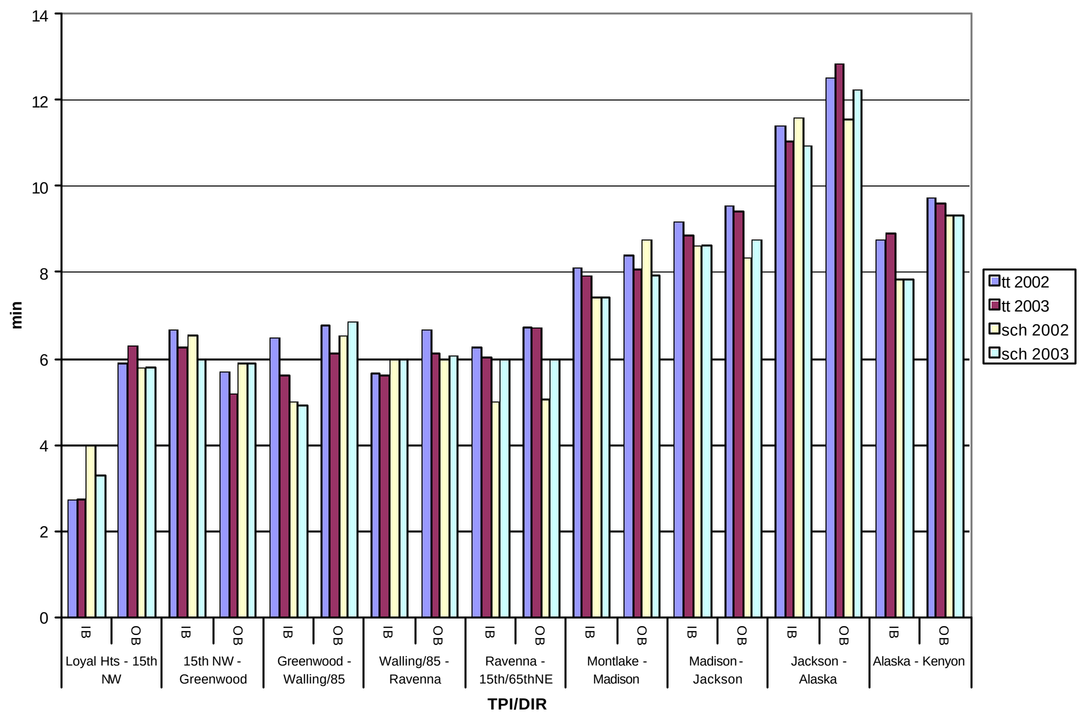


Figure 8: PM Peak comparison of travel and schedule times by TPI/DIR.

Figure 8 shows that, overall, travel times decreased from 2002 to 2003 after bus stop consolidation was implemented. To help understand the effect of the schedule, Figure 9 below compares the average schedule adjustments with the average actual travel time change for each TPI/DIR.

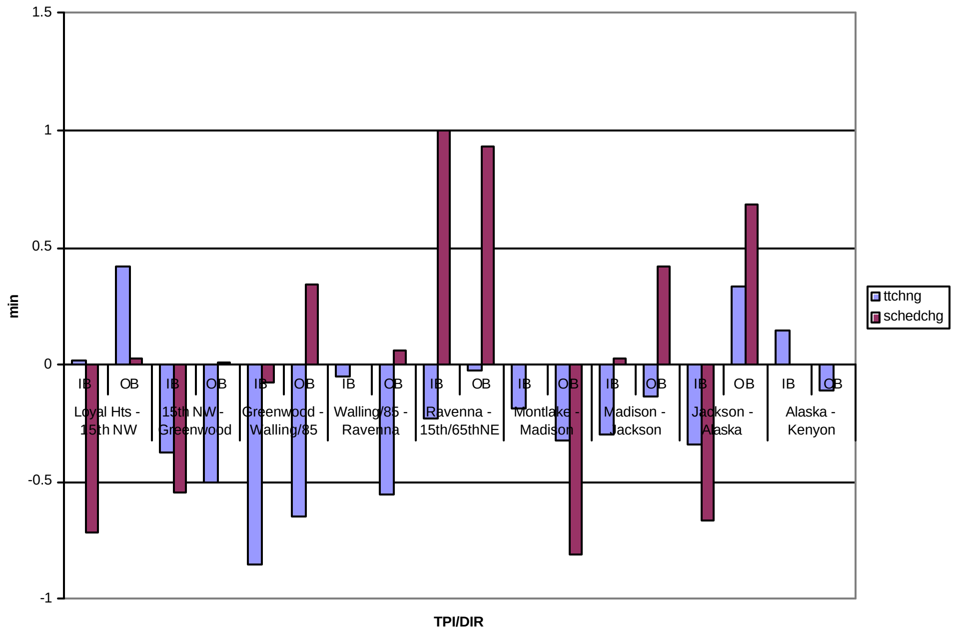


Figure 9: Change in PM peak travel time and schedule adjustment by TPI/DIR.

The Figure 9 comparison shows that the minor schedule adjustments made to various parts of the route 48 had little corresponding impact on actual travel times.

Analyzing Trends in Travel Times

Now, some more generalized trends in the complete data subset are analyzed, including all time periods. First a comparison is made between the change in bus stop spacing and the change in travel time, including all 54 TPI/DIR/TOD combinations. Figure 10 shows a plot of these data points, with a linear model calculated and shown in the plot.

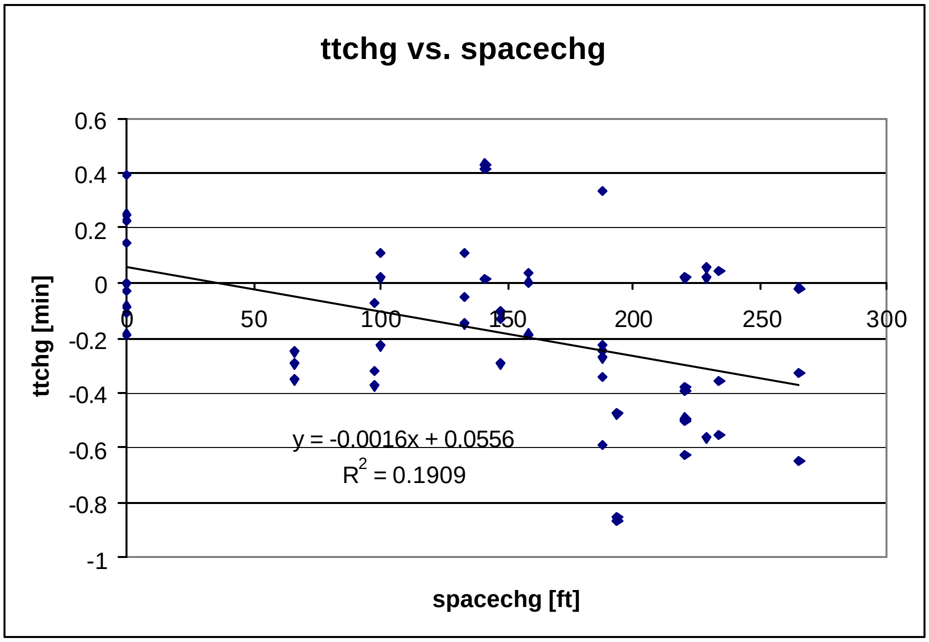


Figure 10: Change in travel time vs. change in bus stop spacing.

Although the correlation of the linear model is poor, the downward slope indicates a clear improvement in travel time after bus stop consolidation. The positive constant suggests that travel times would have increased slightly on average if the bus stops were not changed between 2002 and 2003; this is a typical assumption due to increased traffic, ridership, and area growth. A paired t-test of the 54 pairs of before and after data returned a value of 9.5×10^{-5}.

Since the TPIs are not of a consistent length, it is useful to chart the change in travel time changes per mile of travel. Figure 11 is a similar to Figure 10, but with the travel time change normalized by TPI length.

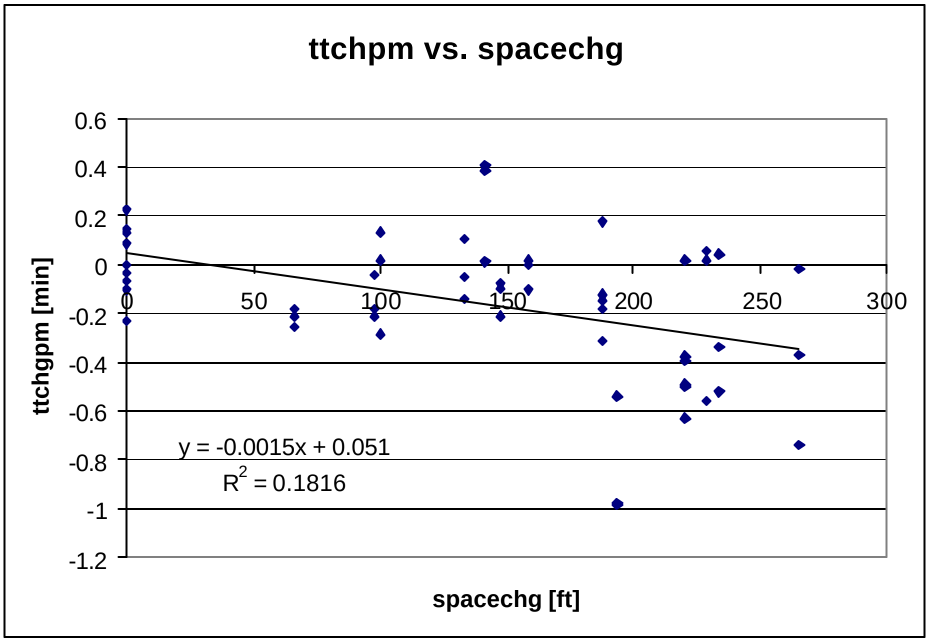


Figure 11: Change in travel time, per mile vs. change in bus stop spacing.

These results are similar to those in Figure 10 in this case because most of the TPIs are close to a mile in length.

To further understand how the schedule adjustments might have affected travel times in this investigation, these two variables were plotted against each other. Figure 12 is a plot of the change in travel time versus the change of scheduled time

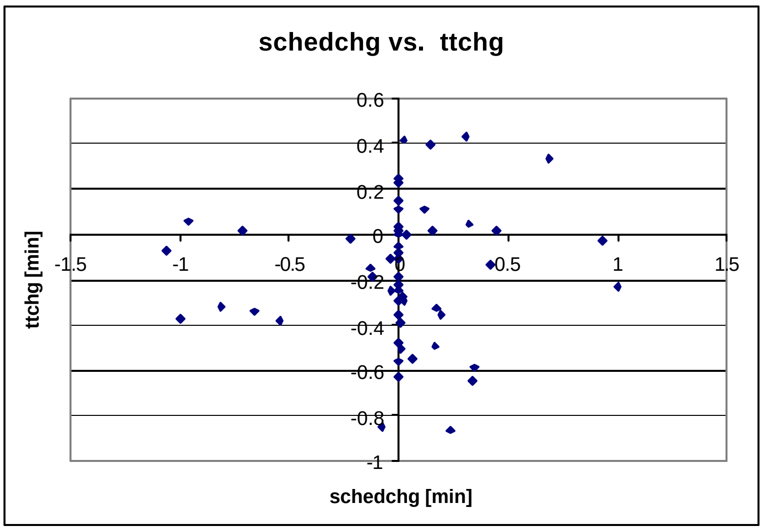


Figure 12: Change in travel time vs. Change in average scheduled time.

There is no clear correlation between these two variables, which further suggests that the schedule adjustments did not have a significant effect in travel times in this case.

To see how the number of displaced passengers relates to the change in bus stop spacing, these two variables were plotted against each other, as shown in Figure 13.

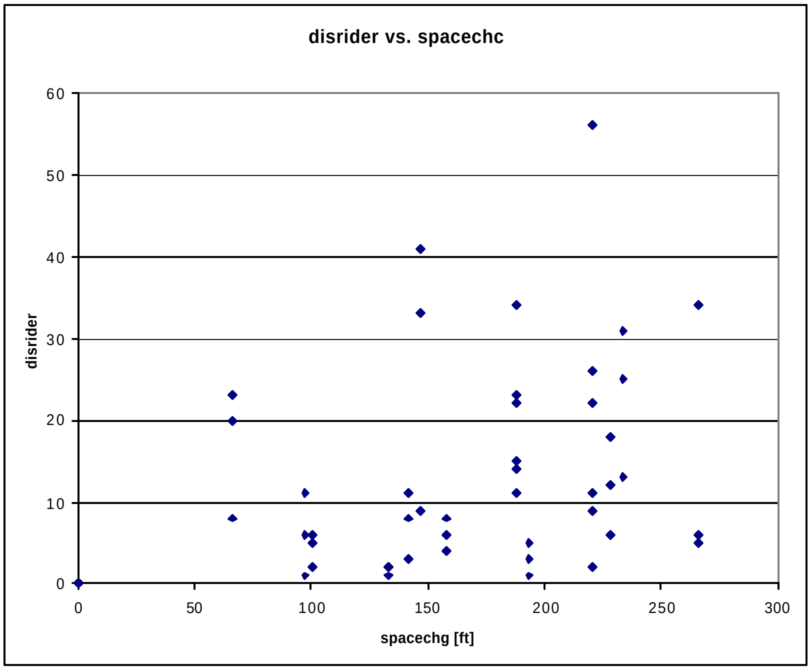


Figure 13: Displaced riders vs. change in bus stop spacing.

Figure 14 shows a partial correlation between these two variables. A small bus stop spacing change did not displace many riders, but large bus stop spacing changes resulted in a wide range of the number of displaced riders

Regression Analysis

To explore the effects of the other independent variables, a general linear model was formulated and tested using SPSS software. The dependent variable used was travel time change per mile; the peak indicator was set as a fixed factor, and the variables of stop spacing change and schedule change were set as covariates. The resulting analysis of variance table is shown in Table 3.

Table 3: Univariate analysis of variance for the generalized linear model.

Tests of Between-Subjects Effects

Dependent Variable: TTCHGPM

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.865[a]	3	.288	4.019	.012
Intercept	2.101E-02	1	2.101E-02	.293	.591
SCHCHG	1.509E-03	1	1.509E-03	.021	.885
SPACECHG	.810	1	.810	11.289	.001
PK_IND	4.896E-02	1	4.896E-02	.682	.413
Error	3.588	50	7.176E-02		
Total	5.897	54			
Corrected Total	4.453	53			

a. R Squared = .194 (Adjusted R Squared = .146)

Only the factor of SPACECHG was found to have significance. The schedule effect was not significant, as expected from the previous plots presented, and peak/non-peak flow was surprisingly not a significant factor.

Based on these findings, the relationship between changes in bus stop spacing and changes in travel time can be expressed as a linear formula. For a rough estimate of travel time savings resulting from a change in the bus stop spacing, the following formula can be used:

$$\Delta tt = -(0.0015\Delta ss + gc)d$$

Where:

Δtt = Change in average travel time (in minutes)

Δss = Change in bus stop spacing (in feet)

gc = Growth constant (baseline travel time increase, per mile of travel)

d = Length of project segment (miles)

If a baseline condition is assumed where the growth constant is negligible or not relevant, the formula simplifies to:

$$\Delta tt = -0.0015\Delta ss * d$$

Additional travel time savings are likely to be possible when bus stops are located out-of-lane or in pullouts. The formula represents an average for both peak and non-peak periods. This formula would be useful for predicting travel time savings for the purpose of determining appropriate schedule adjustments after consolidating bus stops, as in the following example:

Example

Consider a 5-mile segment of a bus route with an existing average bus stop spacing of 650'. What is the expected one-way travel time savings that would result from consolidating stops to a new average spacing of 1000', assuming no other changes in travel time?

Answer:

Δss = 1000' – 650' = 350'

Δtt = -0.0015 * 350' * 5mi = -2.6 min.

A savings of approximately two and one-half minutes would be expected.

Reliability

Schedule reliability is summarized in Figure 14 in terms of the percentage of trips that were observed to take more than 1 minute above the scheduled run time (%late) or greater than 3 minutes above the schedule time (%verylate)

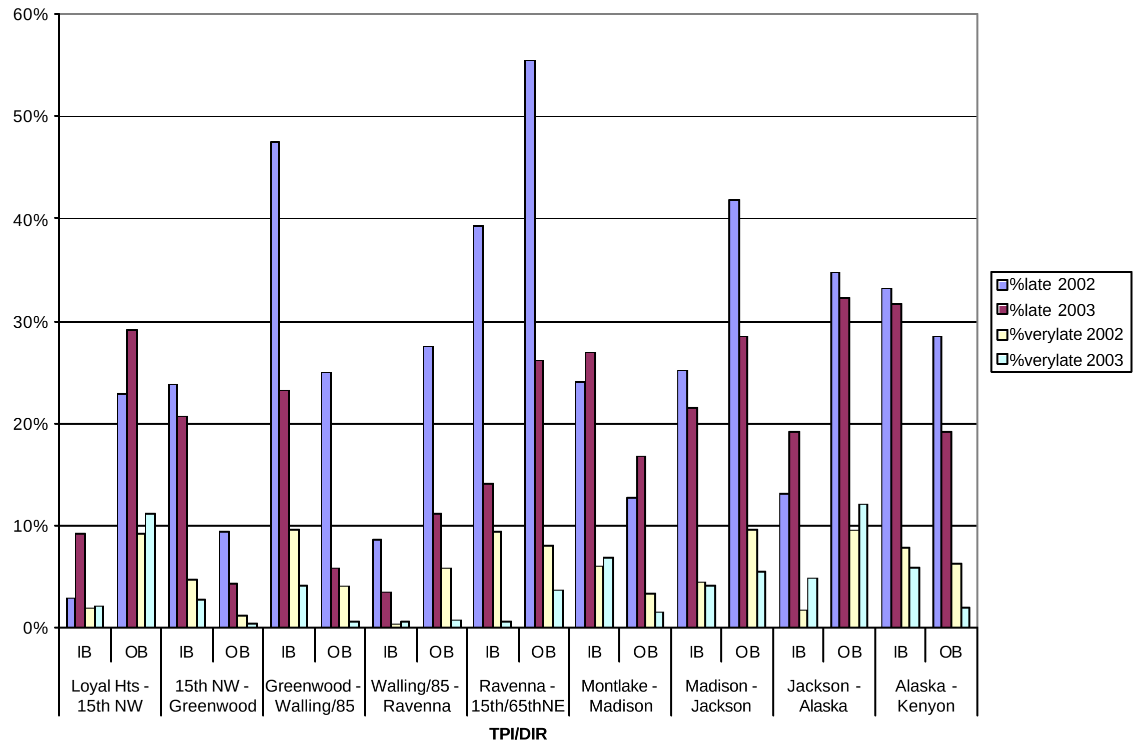


Figure 14: PM Schedule Reliability by TPI/DIR.

Figure 14 shows a clear improvement in schedule performance after bus stop consolidation in most of the TPIs. Figure 15 presents a generalized plot of the reliability factors.

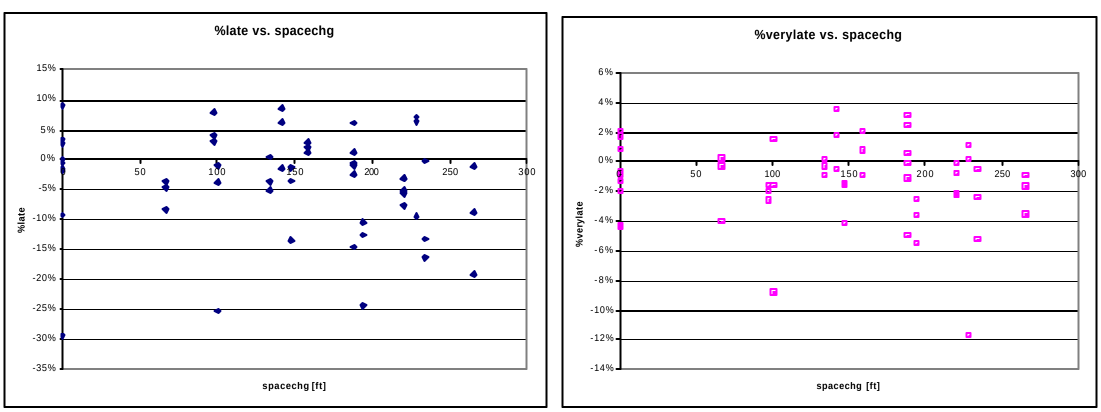
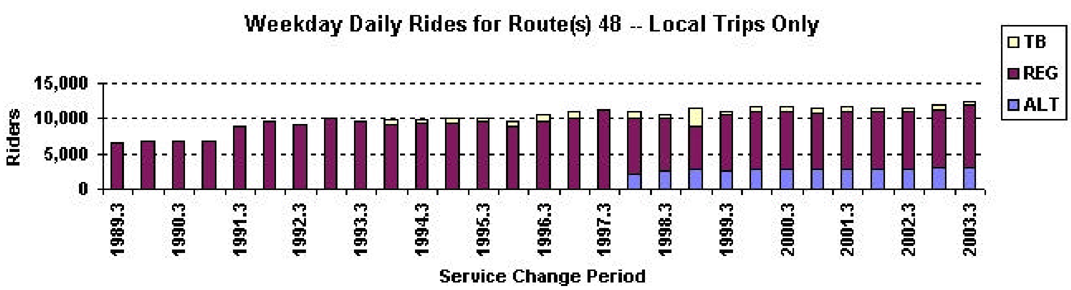


Figure 15: Change in %late & %verylate vs. change in bus stop spacing.

Although the majority of the data points are below the zero axis, indicating an overall improvement in reliability the correlation of lateness change with bus stop spacing change is not clear. Paired t-tests of the before and after lateness factors retuned values of 0.0016 and 0.001 for %late and %verylate respectively.

Ridership Analysis

Total route ridership increased slightly after the bus stop consolidation. In the fall of 2002, the route 48 served an average of 11,590 daily rides, and in fall of 2003, this number increased to 12,430 (not including the express variant). This represents a 7% ridership increase, at a time when many of Metro's other inner-city bus routes saw a slight decrease in ridership. However, it should be noted that some additional service, approximately 8 trips both directions, mostly in the late evening period, were added to the route between 2002 and 2003. This additional service may account for some portion of the ridership increase. Figure 16 illustrates the 15-year ridership history of the route.



TB = Late night shuttle route
REG = Regular local route
ALT = Alternate route to Columbia City

Figure 16: Ridership history of the route 48. *year*.3 indicates the service change period in the fall of *year*.

These ridership trends are encouraging not only because they show that bus stop consolidation did not likely harm ridership, but also because they demonstrate that travel time savings were realized even with the addition of passengers. Conclusions about the effect of bus stop consolidation on total route ridership can be made more certainly as future ridership data becomes available.

Possible Confounding Issues

Bus stop spacing was the main treatment variable that was changed in the before and after condition. However, other changes that occurred between 2002 and 2003 could be factors affecting the results of the analysis.

Construction and Lane Closures

During the "before" time period in 2002, University Way NE in the University District was closed for construction. Other bus routes were diverted from University Way onto 15th Ave NE, on which the route 48 operates. In addition, some of the general traffic that normally uses University Way was also diverted onto 15th Ave NE. For this reason, the portion of the route in the University District was excluded from the analysis; however, residual effects of congestion in the University District might be observed in other portions of the route. Smaller construction projects were underway near the vicinity of E Union St and 3rd Ave NW during the study periods, but it is uncertain how these may have affected route 48 operations.

Fleet changes

During the fall of 2003, new low-floor coaches were beginning to be used on selected trips on the route 48. This fact could have contributed to a portion of the travel time savings observed from the before and after conditions, since the low-floor design is expected to reduce dwell times.

Random Traffic Effects

As is typical with most real-world transportation studies, variations in traffic volumes can be a factor affecting results of the study. A traffic study conducted by the Seattle Department of Transportation found a 6.9% to 3.5% increase in traffic volumes between April 2003 and December 2003 in the southbound direction of 23rd Ave/24th Ave, on which a portion of the route 48 operates. The northbound direction showed a 4.2% decrease at the north end of the arterial near Montlake Bridge, but also showed a 6.6% increase in traffic at the south end of the arterial near S Massachusetts St.[16] The study also attempted to compare floating-car travel times across the same time period, but this study was befuddled by several accidents that occurred on a nearby interstate. The effect of traffic variation is unknown in this analysis, but it is hoped that using such a large span of time for the analysis, six weeks, will minimize the effect of this variation.

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[16] SDOT 2003

Conclusions

Based on an analysis of a real-world bus stop consolidation case, in which average bus stop spacing was varied and the before and after travel times were measured, bus stop consolidation has proven to be an effective tool for improving the speed and reliability of bus service. Bus stop consolidation has been shown to improve schedule reliability by reducing the number of late trips. However, the relationship between bus stop spacing and reliability remains elusive. Bus stop consolidation was shown to have no adverse impacts in ridership, and may have in fact improved ridership on the route.

Based on the trends observed in the route 48 data, a linear formula was developed to help predict the travel time savings that bus stop consolidation can generate. It is hoped that this information will be useful to transit agencies planning similar bus stop consolidation projects.

Further Research

Additional analysis of data related to bus stop consolidation could further refine the ability to predict the effects of bus stop consolidation. This analysis focused on only one route in one city. The inclusion of data from similar projects on different routes would further improve the predictability of travel time and reliability measures. Specifically, the analysis of a route where more out-of-lane stops were removed would be useful. It is hypothesized that this factor of in-lane vs. out-of lane would prove significant, due to the effect of merging delay. King County Metro is currently undergoing a bus stop consolidation project on its route 5 corridor; this route has many out-of-lane stops and it would be interesting to perform a similar analysis of this corridor when the bus stop consolidation is complete.

Based on field observations, it was expected that there would be a significant difference in the effects of bus stop consolidation for peak and non-peak flows. With more samples, this factor might be found to be significant, and separate formulas could be developed for predicting peak and non-peak travel time savings. Analysis of a route that serves a CBD would be more likely to reveal this significance than the cross-town route 48.

A more rigorous statistical analysis of the data set used in this analysis could yield additional conclusions. Some additional data could be added and tested for significant effects. Some other independent variables that could play a role in the effects of bus stop consolidation on transit speed and reliability include: hourly traffic flow (vphpl), number of traffic signals, average traffic signal cycle length, average approach g/c ratio[17], service headway, coach type, fare payment policy, and others. A more rigorous statistical evaluation might also reveal some combined interactions with two or more of these variables.

The author offers the data set used in this analysis, in electronic format, to any interested parties. Contact owen@kehoe.org.

[17] Green/cycle ratio for the signal phases that serve the movements used by the bus,

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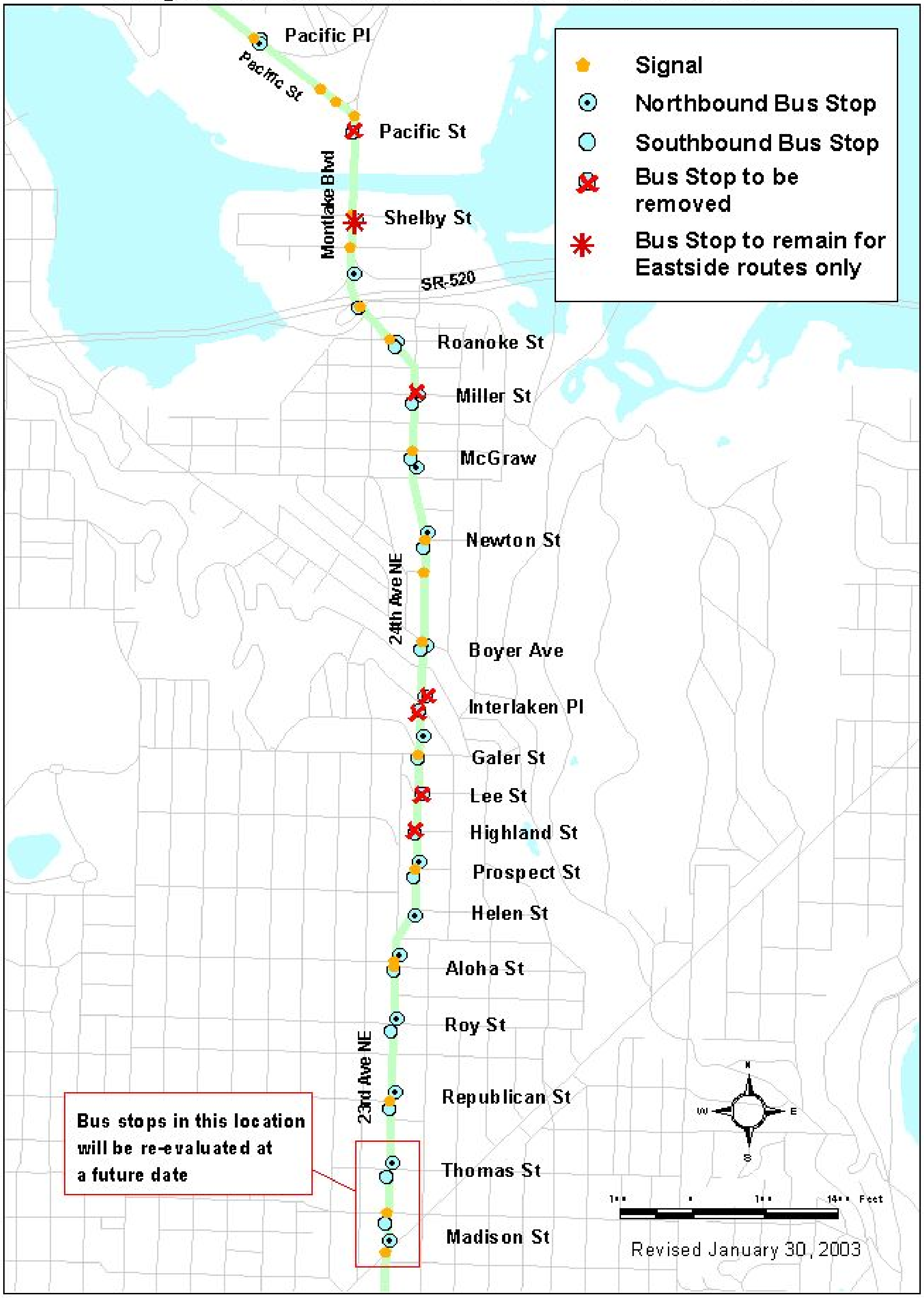
Appendix A: Detailed Maps of Bus Stop Consolidation Area

Route 48, 43: Final Bus Stop Consolidation Plan

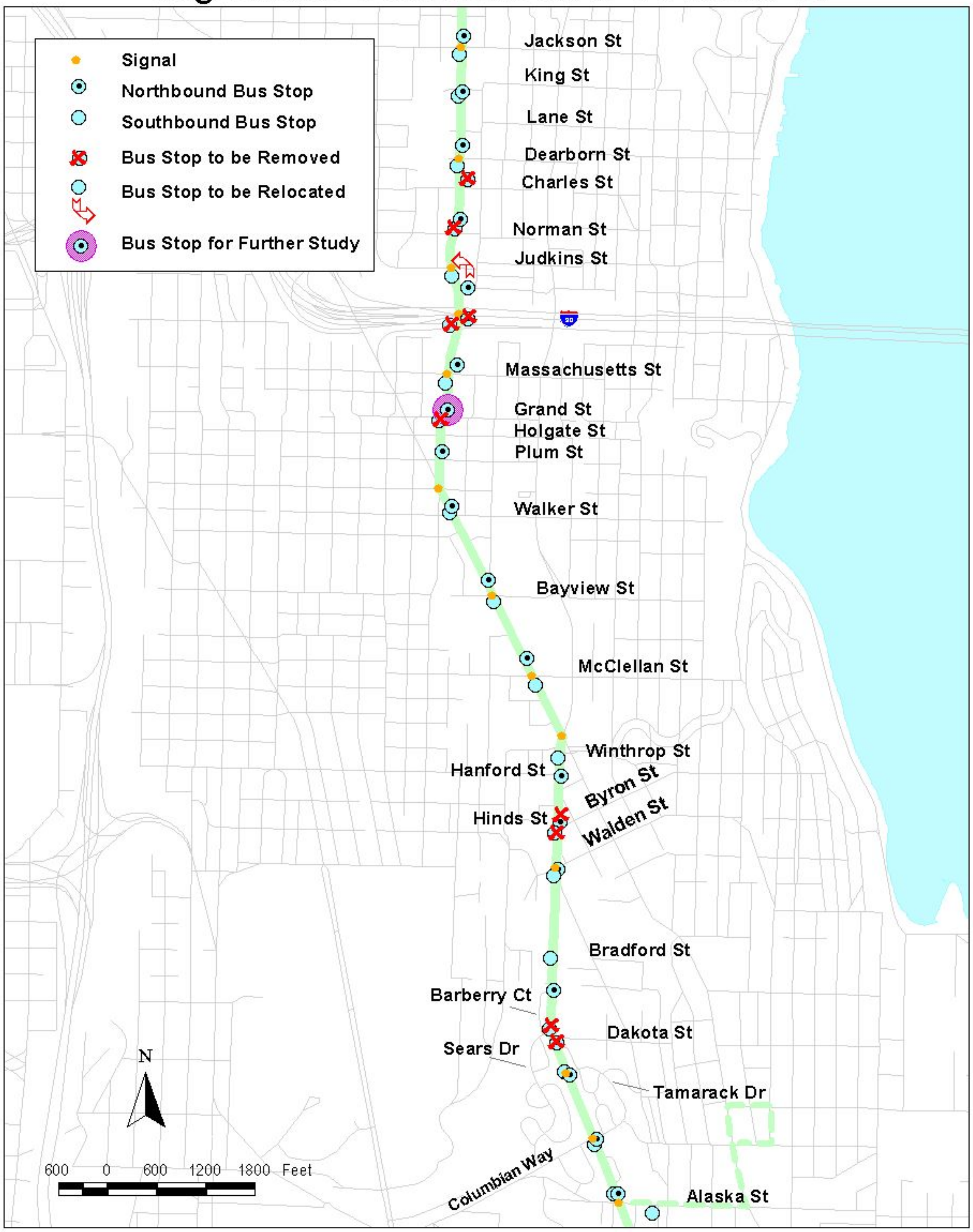
Segment 1: Pacific Place to Madison St



Route 48 Final Bus Stop Consolidation Plan
Segment 2: E Madison St to S Jackson St

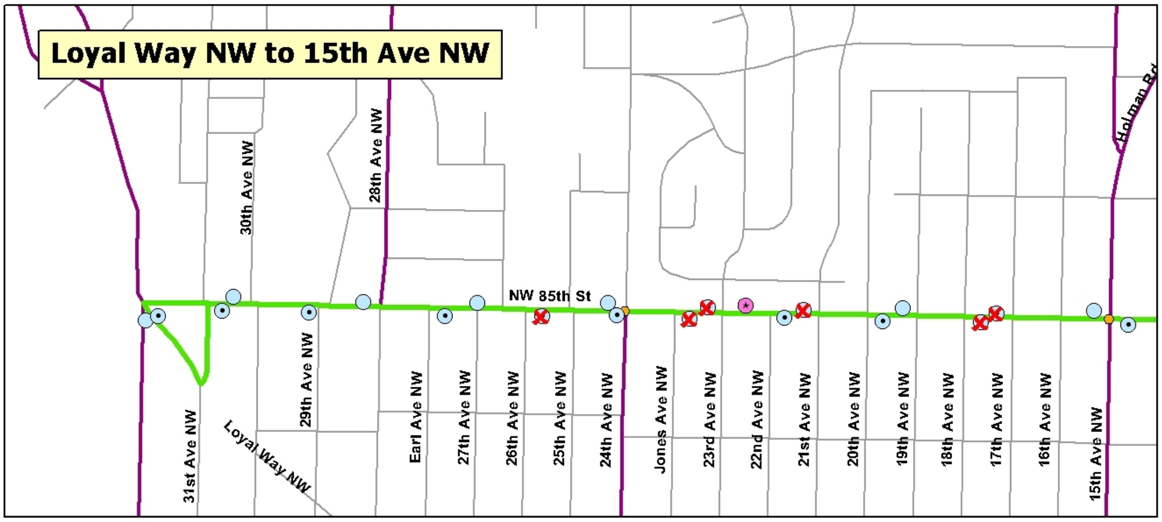
Route 48 Final Bus Stop Consolidation Plan

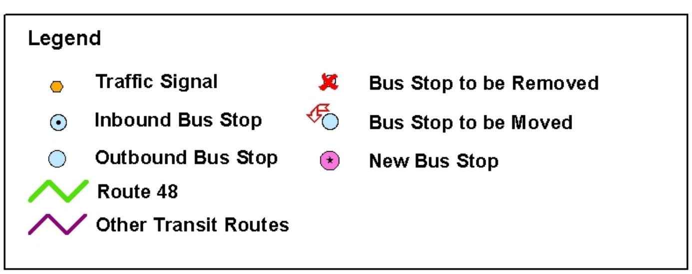
Segment 3: S Jackson St to S Alaska St

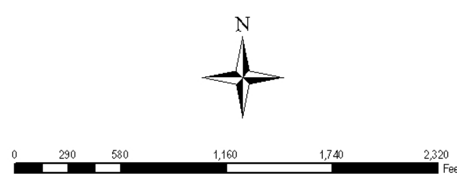


Route 48 Final Bus Stop Consolidation

Segment 4A: Loyal Way NW to Greenwood Ave N







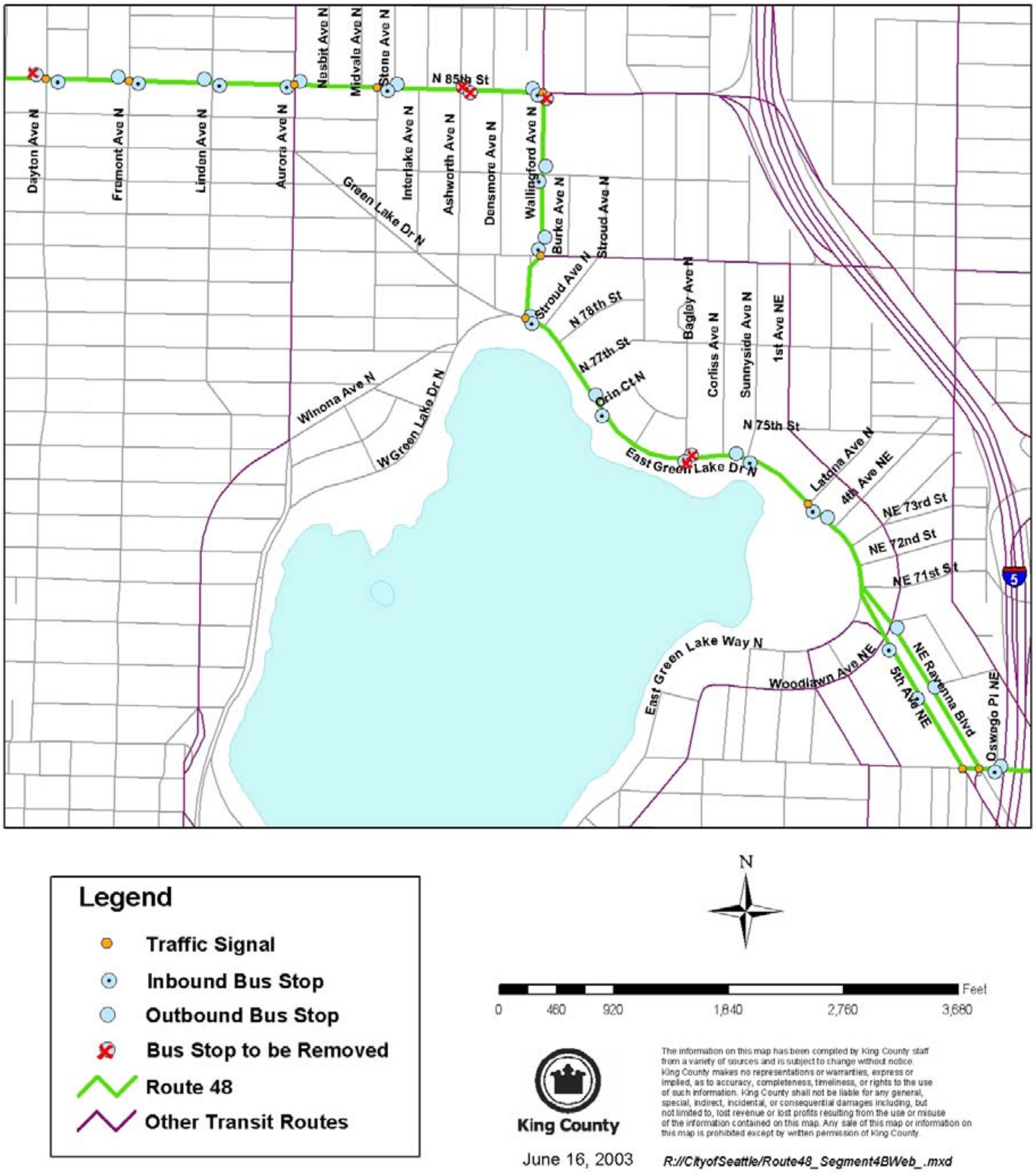
King County

June 16, 2003

R://CityofSeattle/Route48_Segment4A_Web.mxd

Route 48 Final Bus Stop Consolidation

Segment 4B: Greenwood Ave N to Oswego Pl NE



Appendix B: Data Set Used for Analysis

Time Period	Segment	Dir	Parameters: TPI Length	Bus stops in segment: Before	After	Removed	ons/offs: TPI Total	displaced	Calc. Parameters: Stop spacing Before	After	Change	Results: Average trip time (10% trim) Before	After	Change	Change mile	Pk_ind	Scheduled time (avg.) Before	After	Change	% Late (<1 min) Before	After	Change	% Late (<3 min) Before	After	Change
AM	Loyal Hts - 15th NW	IB	5330	10	7	3	49	12	533	761	228	4.33333	3.77027	-0.5631	-0.5578	1	4	4	0	0.19	0.10	(0.09)	0.17	0.05	(0.12)
6:00		OB	5670	10	8	2	38	3	567	709	142	5.2359	5.6699	0.43401	0.40415	0	5	5.3043	0.3043	0.26	0.34	0.09	0.06	0.10	0.04
to	15th NW - Greenwood	IB	5290	8	6	2	116	26	661	882	220	5.8915	5.26075	-0.6307	-0.6296	1	6	6	0	0.10	0.07	(0.03)	0.00	0.00	(0.00)
9:00		OB	5290	8	6	2	54	2	661	882	220	4.42929	4.44601	0.01672	0.01668	0	4	4.4444	0.4444	0.15	0.09	(0.06)	0.04	0.03	(0.01)
	Greenwood - Walling/85	IB	4650	8	6	2	163	3	581.25	775	193.75	6.12445	5.26075	-0.8637	-0.9807	1	4.7619	5	0.2381	0.46	0.35	(0.10)	0.06	0.03	(0.02)
		OB	4650	7	5	2	42	6	664.29	930	265.714	4.38119	4.36279	-0.0184	-0.0209	0	5	4.7778	-0.2222	0.05	0.04	(0.01)	0.01	-	(0.01)
	Walling/85 - Ravenna	IB	5610	7	6	1	74	2	801.43	935	133.571	5.22251	5.32973	0.10722	0.10091	1	5.5294	5.5294	0	0.06	0.07	0.00	0.01	0.01	(0.00)
		OB	5610	8	6	2	38	13	701.25	935	233.75	4.94949	4.99535	0.04585	0.04316	0	5	5.32	0.32	0.10	0.10	(0.00)	0.00	-	(0.00)
	Ravenna - 15th/65thNE	IB	4210	7	6	1	162	6	601.43	701.667	100.238	6.00969	6.11749	0.10781	0.13521	1	5	5.1176	0.1176	0.34	0.33	(0.01)	0.02	0.04	0.02
		OB	4170	6	6	0	83	0	695	695	0	4.83105	4.74786	-0.0832	-0.1053	0	4.2	4.2	0	0.17	0.17	0.00	0.01	-	(0.01)
	Montlake - Madison	IB	9500	15	12	3	197	6	633.33	791.667	158.333	8.4708	8.50512	0.03432	0.01907	1	7.8462	7.8462	0	0.26	0.28	0.02	0.08	0.07	(0.01)
		OB	9500	15	13	2	104	1	633.33	730.769	97.4359	7.21037	7.13611	-0.0743	-0.0413	0	8	6.9375	-1.0625	0.08	0.16	0.08	0.03	0.01	(0.03)
	Madison - Jackson	IB	7300	11	10	1	341	23	663.64	730	66.3636	8.91909	8.5646	-0.3545	-0.2564	1	8	8	0	0.30	0.22	(0.08)	0.06	0.02	(0.04)
		OB	7300	11	9	2	198	9	663.64	811.111	147.475	8.1165	7.82405	-0.2925	-0.2115	0	7	7	0	0.36	0.33	(0.04)	0.05	0.03	(0.02)
	Jackson - Alaska	IB	10000	19	14	5	311	15	526.32	714.286	187.97	11.9219	11.6484	-0.2735	-0.1444	1	12.267	12.286	0.019	0.10	0.09	(0.01)	0.01	0.02	0.01
		OB	10000	19	14	5	111	14	526.32	714.286	187.97	9.84969	9.62428	-0.2254	-0.119	0	9.8667	9.8667	0	0.09	0.11	0.01	0.01	0.01	(0.00)
	Alaska - Kenyon	IB	9150	16	16	0	202	0	571.88	571.875	0	8.7378	8.96407	0.22627	0.13057	1	8	8	0	0.30	0.33	0.03	0.02	0.04	0.02
		OB	9150	16	16	0	47	0	571.88	571.875	0	6.98425	7.37748	0.39323	0.22691	0	7.2857	7.4286	0.1429	0.09	0.11	0.03	-	0.02	0.02
MD	Loyal Hts - 15th NW	IB	5330	10	7	3	70	18	533	761	228	2.94821	3.00375	0.05555	0.05502	0	4	3.0385	-0.9615	0.02	0.09	0.07	0.01	0.02	0.01
9:01		OB	5670	10	8	2	139	11	567	709	142	5.46863	5.48184	0.01321	0.0123	0	5.3043	5.3043	0	0.23	0.22	(0.01)	0.07	0.07	(0.00)
to	15th NW - Greenwood	IB	5290	8	6	2	231	56	661	882	220	6.18163	5.78947	-0.3922	-0.3914	0	5.84	5.8462	0.0062	0.18	0.14	(0.03)	0.03	0.01	(0.02)
15:15		OB	5290	8	6	2	256	11	661	882	220	5.13197	4.63899	-0.493	-0.492	0	4.7083	4.875	0.1667	0.17	0.10	(0.08)	0.04	0.01	(0.02)
	Greenwood - Walling/85	IB	4650	8	6	2	348	5	581.25	775	193.75	5.89425	5.41848	-0.4758	-0.5402	0	5	5	0	0.30	0.17	(0.12)	0.05	0.01	(0.04)
		OB	4650	7	5	2	179	34	664.29	930	265.714	5.81919	5.49479	-0.3244	-0.3683	0	5.6667	5.84	0.1733	0.17	0.08	(0.09)	0.03	0.01	(0.02)
	Walling/85 - Ravenna	IB	5610	7	6	1	125	2	801.43	935	133.571	5.08118	4.93103	-0.1501	-0.1413	0	5.32	5.1923	-0.1277	0.09	0.06	(0.04)	0.02	0.01	(0.01)
		OB	5610	8	6	2	127	31	701.25	935	233.75	5.51136	5.1513	-0.3601	-0.3389	0	5.125	5.32	0.195	0.19	0.06	(0.13)	0.03	0.01	(0.02)
	Ravenna - 15th/65thNE	IB	4210	7	6	1	262	5	601.43	701.667	100.238	5.68132	5.69707	0.01576	0.01976	0	5	5.1538	0.1538	0.24	0.21	(0.04)	0.03	0.02	(0.01)
		OB	4170	6	6	0	280	0	695	695	0	5.58382	5.39965	-0.1842	-0.2332	0	5.125	5	-0.125	0.21	0.19	(0.02)	0.04	0.03	(0.01)
	Montlake - Madison	IB	9500	15	12	3	283	8	633.33	791.667	158.333	7.31964	7.32253	0.00288	0.0016	0	7.0769	7.0769	0	0.17	0.19	0.01	0.02	0.04	0.02
		OB	9500	15	13	2	254	11	633.33	730.769	97.4359	7.43363	7.05714	-0.3765	-0.2092	0	8.1538	7.1538	-1	0.06	0.09	0.03	0.02	0.00	(0.02)
	Madison - Jackson	IB	7300	11	10	1	597	20	663.64	730	66.3636	8.81661	8.5646	-0.252	-0.1823	0	8.1923	8.16	-0.0323	0.27	0.22	(0.05)	0.07	0.07	0.00
		OB	7300	11	9	2	590	33	663.64	811.111	147.475	8.63299	8.52724	-0.1057	-0.0765	0	7.5926	7.5556	-0.037	0.36	0.35	(0.01)	0.09	0.08	(0.01)
	Jackson - Alaska	IB	10000	19	14	5	523	23	526.32	714.286	187.97	11.3923	11.1468	-0.2455	-0.1296	0	11.346	11.346	0	0.16	0.15	(0.01)	0.04	0.03	(0.01)
		OB	10000	19	14	5	508	34	526.32	714.286	187.97	11.4453	10.8522	-0.5931	-0.3132	0	10.654	11	0.3462	0.32	0.18	(0.15)	0.08	0.03	(0.05)
	Alaska - Kenyon	IB	9150	16	16	0	268	0	571.88	571.875	0	8.59862	8.84775	0.24913	0.14376	0	8.0769	8.0769	0	0.19	0.28	0.09	0.02	0.03	0.01
		OB	9150	16	16	0	276	0	571.88	571.875	0	8.49175	8.49007	-0.0017	-0.001	0	8.4286	8.4615	0.033	0.17	0.16	(0.01)	0.02	0.01	(0.01)
PM	Loyal Hts - 15th NW	IB	5330	10	7	3	25	6	533	761	228	2.70526	2.72441	0.01915	0.01897	0	4	3.2857	-0.7143	0.03	0.09	0.06	0.02	0.02	0.00
15:15		OB	5670	10	8	2	84	8	567	709	142	5.88491	6.30155	0.41664	0.38798	1	5.7778	5.8	0.0222	0.23	0.29	0.06	0.09	0.11	0.02
to	15th NW - Greenwood	IB	5290	8	6	2	96	22	661	882	220	6.65072	6.27155	-0.3792	-0.3784	0	6.5455	6	-0.5455	0.24	0.21	(0.03)	0.05	0.03	(0.02)
18:15		OB	5290	8	6	2	174	9	661	882	220	5.68101	5.17532	-0.5057	-0.5047	1	5.8889	5.9	0.0111	0.09	0.04	(0.05)	0.01	0.00	(0.01)
	Greenwood - Walling/85	IB	4650	8	6	2	154	1	581.25	775	193.75	6.47788	5.62069	-0.8572	-0.9733	0	5	4.9231	-0.0769	0.48	0.23	(0.24)	0.10	0.04	(0.05)
		OB	4650	7	5	2	147	5	664.29	930	265.714	6.78343	6.13158	-0.6518	-0.7402	1	6.5185	6.8571	0.3386	0.25	0.06	(0.19)	0.04	0.01	(0.03)
	Walling/85 - Ravenna	IB	5610	7	6	1	40	1	801.43	935	133.571	5.66403	5.61111	-0.0529	-0.0498	0	6	6	0	0.09	0.03	(0.05)	0.00	0.01	0.00
		OB	5610	8	6	2	113	25	701.25	935	233.75	6.66972	6.11869	-0.551	-0.5186	1	6	6.0588	0.0588	0.28	0.11	(0.16)	0.06	0.01	(0.05)
	Ravenna - 15th/65thNE	IB	4210	7	6	1	102	2	601.43	701.667	100.238	6.27092	6.04364	-0.2273	-0.285	0	5	6	1	0.39	0.14	(0.25)	0.09	0.01	(0.09)
		OB	4170	6	6	0	241	0	695	695	0	6.73591	6.70732	-0.0286	-0.0362	1	5.0667	6	0.9333	0.55	0.26	(0.29)	0.08	0.04	(0.04)
	Montlake - Madison	IB	9500	15	12	3	153	4	633.33	791.667	158.333	8.11047	7.92135	-0.1891	-0.1051	0	7.4375	7.4375	0	0.24	0.27	0.03	0.06	0.07	0.01
		OB	9500	15	13	2	217	6	633.33	730.769	97.4359	8.40625	8.08451	-0.3217	-0.1788	1	8.75	7.9375	-0.8125	0.13	0.17	0.04	0.03	0.02	(0.02)
	Madison - Jackson	IB	7300	11	10	1	389	8	663.64	730	66.3636	9.17529	8.87949	-0.2958	-0.2139	0	8.625	8.6471	0.0221	0.25	0.22	(0.04)	0.04	0.04	(0.00)
		OB	7300	11	9	2	432	41	663.64	811.111	147.475	9.55629	9.4234	-0.1329	-0.0961	1	8.3333	8.75	0.4167	0.42	0.28	(0.13)	0.10	0.06	(0.04)
	Jackson - Alaska	IB	10000	19	14	5	244	11	526.32	714.286	187.97	11.3963	11.054	-0.3423	-0.1807	0	11.6	10.938	-0.6625	0.13	0.19	0.06	0.02	0.05	0.03
		OB	10000	19	14	5	320	22	526.32	714.286	187.97	12.5165	12.8528	0.33626	0.17755	1	11.563	12.25	0.6875	0.35	0.32	(0.02)	0.09	0.12	0.03
	Alaska - Kenyon	IB	9150	16	16	0	141	0	571.88	571.875	0	8.75333	8.9026	0.14926	0.08613	0	7.8571	7.8571	0	0.33	0.32	(0.01)	0.08	0.06	(0.02)
		OB	9150	16	16	0	141	0	571.88	571.875	0	9.73077	9.62044	-0.1103	-0.0637	1	9.3333	9.3333	0	0.28	0.19	(0.09)	0.06	0.02	(0.04)
												T-stat:	9.5E-05							T-stat:	0.0016		T-stat:	0.001	