King County

Metropolitan King County Council
Capital Budget Committee

STAFF REPORT

AGENDA ITEM:	5	PREPARED BY:	Arthur Thornbury
MOTION No.:	2007- 0394	DATE:	January 30, 2008

SUBJECT: Legislation that would approve a business case submitted by the Transit Division to upgrade a portion of the trolley system's overhead wire network.

SUMMARY: The Executive has transmitted a justification for the proposed expenditure of $6.5M to ensure uninterrupted operation of electric trolleybuses through the Montlake, University District and Wallingford neighborhoods of Seattle. The 2007 addition of a new articulated trolley fleet has raised concerns that, under certain circumstances, power demands might exceed capacity on that overhead wire segment causing erratic operations or a complete shutdown of service at points. The proposed installation of 100 utility poles and additional wiring would restore the power supply redundancy that existed before the arrival of the new trolley fleet with its higher power requirements.

BACKGROUND:

November 2003 – Breda Trolley Conversion Authorized

With its adoption of the 2004-2009 Transit Capital Improvement Program, the Council authorized a $5.5M project to convert dual-powered tunnel buses into electric trolleys to replace Metro's aging, costly to maintain, articulated, trolley fleet. Rather than purchase new trolleys, the Transit Division chose to create trolleys from the dual-mode buses purchased in 1990 from the Breda Corporation to operate on electric power in the transit tunnel and diesel power elsewhere. Removing the diesel components and refurbishing the Breda coaches allowed the Transit Division to avoid purchasing 59 new trolleys at an estimated cost of $1.3 million each.

November 2005 – Trolleywire Upgrade Proposal

After tests of a converted Breda prototype showed that its power draw was greater than that of the trolley it would replace, a consultant's analysis identified peak-demand circumstances in which overhead wire voltage in a portion of the system would drop below the minimum necessary causing trolleys to slow or stop in service. The Transit Division requested an additional $6.5 million to upgrade a six mile wire segment between the Montlake and Wallingford neighborhoods. While the Council approved the additional $6.5M appropriation,

it prohibited expenditure until the Transit Division provided a clearer picture of the potential for service disruptions and the options for responding:

> *No portion of the funds appropriated for CIP Project A00480, 60 Ft Trolley Buses (Breda Conversion), shall be expended for an upgrade of the electric trolley overhead power system until the executive has submitted and the council approved by motion a business case for the proposed overhead wire upgrade, which shall, at minimum, include,*
>
> *A. Data on the frequency, duration, timing, and cause of unplanned electrical substation shutdowns in the subject wire segment;*
> *B. Analysis correlating substation shutdown information with the periods of potential under voltage identified in the LTK Engineering Services' November 1, 2004, Breda Trolley Bus Traction Simulations Study;*
> *C. Analysis of the range of potential service interruptions attributable to the addition of Breda trolleys, including the number of coaches delayed and the duration of such delays; and*
> *D. Analysis of potential operational preparations for, and responses to, substation shutdowns that could be undertaken to minimize or eliminate the possibility of service disruptions attributable to the addition of Breda trolleys.*
>
> *Ordinance 15329*

The expenditure restriction reflected the Council's uncertainty about the likely frequency trolley power substation failures on which the Transit Division based its estimate that "up to 38 coaches per month could experience service delays due to voltage drops" once the Breda trolleys were put into service. Power is fed to the 70-mile trolley system by 33 substations located at intervals along the overhead wire network. When any one substation is out of service, the two adjacent substations have sufficient output to ensure uninterrupted trolley operations but, under certain circumstances, the higher power demands of the Breda trolleys can exceed the redundancy of the system. The Transit Division's estimate of 38 trolleys delayed per month was based on very general, system-wide substation outage history and the expenditure restriction was intended to give the Transit Division time to gather actual substation performance data and to analyze the feasibility of managing outages to minimize or avoid service delays.

July 2007 – Breda Conversions Completed, Wire Upgrade Project Begun and Business Case Submitted

The Transit Division completed conversion of 59 Breda coaches in mid-2007, at which point Bredas were operating at their maximum frequency throughout the system enabling the Transit Division to observe the actual impacts of the Breda trolleys. In the seven months that the Bredas have been fully operational there have been three low-voltage incidents in that wire segment, all the result of problems with the Montlake substation:

- July 18, 2007 seven trolleys were delayed when the substation shut down unexpectedly
- September 28, 2007 low-voltage due to substation shutdown caused a number of trolleys to slow and shudder in operation
- October 2, 2007 the substation was taken off-line for maintenance during peak demand period causing a number of trolleys to shudder in operation

Beginning in the first quarter of 2007 the Transit Division began to proceed with the trolleywire upgrade project, making expenditures and commitments totaling $470,982 by mid-year. When this came to the Council's attention and concerns over unauthorized expenditures were raised, the Manager of the King County Department of Transportation

suspended all project activity and the Executive forwarded the legislation and business case currently before the committee.

Alternative – Managing Substation Outages

The trolley power system is designed to maintain uninterrupted supply, even when a substation is out of service, but occasionally a power loss caused by a traffic accident or tree branch does stop all trolleys on a portion of the system. The added Breda power demands have increased this exposure to a problem that the Transit Division already must respond to and manage. If the Council removes the expenditure restriction and the project proceeds, the wire upgrade would not be complete until mid-2008, at which point the Transit Division will have already managed the added risk from the Breda trolleys for one year.

Beginning with the 2005 expenditure restriction, the Council has sought more specific information from the Transit Division in order to gauge the magnitude of added risk before making an infrastructure investment that will likely be needed only until the Breda trolleys are replaced in six years. Assessing that risk begins with an understanding of the underlying conditions that might result in a disruption of trolley service:

- The potential for the Breda trolleys to cause service interruptions is limited to times when one of six power substations is off-line. When all substations are in on-line there is no concern over the power demands of the Breda trolleys.

- The risk of service disruptions during a substation outage is limited to weekdays during the morning and afternoon peak periods, approximately six hours a day, five days a week.

- The risk is further narrowed to times during the peak-period when trolleys are bunched and unable to maintain scheduled headways, a relatively common but not constant occurrence.

The other determinant of service disruption risk is the extent to which the Transit Division is able manage service during these infrequent substation outages:

- To a significant degree, periods of potential service interruption could be managed by maintaining trolley spacing using service supervisors who are deployed in vans throughout the system and staff at the Communications Center who are in radio contact with the trolley operators. With regard to trolley spacing, the business case points out that, "if bunched, especially on hills, it will cause them [trolleys] to lurch or to stop in place..." But, during planned substation outages, "in general, Bredas will operate if headways are maintained...if drivers are made aware of the situation they should be able to maintain service..." The business case goes on to warn that "the stress caused by areas of oscillating low voltage will shorten life of the drivetrain" but since the Bredas will be retired in six years it is not clear whether that is significant.

- The Transit Division's 2005 estimate of the potential for "up to **38 coaches delayed** per month" was increased in the 2007 business case to **51 per month** following analysis of actual substation outages and field tests of Breda trolleys. The 51 trolleys-per-month estimate is derived from analysis of ten months of data (May 2005 – February 2006) when there were five unplanned peak-period substation shutdowns. The Breda trolleys were not yet fully deployed at that point but, had they been, the Transit Division estimates that a total of 514 trolleys on the affected wire segments during those events

would have been stopped. But 432 of those "stops" were attributed to a single six-day outage that resulted from the failure of a transformer, an occurrence that the business case terms "rare." Replacing that six-day outage in the business case calculations with a more typical outage event reduces the estimated number of trolleys stopped to approximately **ten per month**.

- The business case estimates of stopped trolleys appears to assume that every trolley in the low-voltage line segment would be stopped and that there would be no ability to manage the situation during an outage. If a substation goes off-line unexpectedly during a peak period there will be a delay in reacting and some disruption would be unavoidable, but extended substation outages, or those that begin in the off-peak period, give the Transit Division the opportunity to prepare for and manage service to minimize disruptions.

- Managing a substation outage would require service supervisors in vans and Communication Center personnel talking to bus operators over the radios to meter the travel of trolleys through the low-voltage wire segment to maintain proper headways. The business case considers this infeasible because it would limit the ability of supervisors and radio personnel to respond to other incidents in the system at the same time.

REASONABLENESS:

- Relying on overhead wires for power, electric trolleys experience service interruptions due to factors beyond the Transit Division's control. This proposed project is a reasonable strategy to completely eliminate the additional element of risk introduced by the deployment of the Breda trolleys.

- Choosing instead to use existing personnel and procedures to manage the added increment of risk in order minimize service disruptions is a reasonable strategy for prioritizing capital expenditures.

ATTACHMENTS:

1. Proposed Motion 2007-0394, with attachment
2. Executive Letter of Transmittal, dated July 18, 2007
3. Trolley System Map

INVITED:

Kevin Desmond, General Manager, Transit Division
Garrett Stronk, Project Manager, Transit Division

ATTACHMENT 1

King County

KING COUNTY

1200 King County Courthouse
516 Third Avenue
Seattle, WA 98104

Signature Report

January 28, 2008

Motion

Proposed No. 2007-0394.1 **Sponsors** Gossett and Phillips

A MOTION approving the Breda Trolley Wire Upgrade Business Case.

WHEREAS, the King County executive has submitted a business case, as requested in Ordinance 15083, supporting an upgrade to the electric trolley wire system in the city of Seattle, and

WHEREAS, the King County council has reviewed the business case;

NOW, THEREFORE, BE IT MOVED BY the Council of King County:

The Breda Trolley Wire Upgrade Business Case, Attachment A to this ordinance, is hereby approved.

KING COUNTY COUNCIL
KING COUNTY, WASHINGTON

ATTEST:

Attachments A. Breda Trolley Wire Upgrade Business Case

Breda Trolley Wire Upgrade
Business Case

Project Title: Breda Conversion project
Department/ Agency: Transportation/Transit
Project Number: A00480
Submittal Date: July 17, 2007

Business Need/ Problem Statement

Since 2000, Transit has been planning to replace the aging fleet of articulated electric trolleys by rebuilding dual powered buses (Bredas) that had been operating in electric trolley mode when traveling through the Downtown Seattle Transit Tunnel. The trolley propulsion systems on these vehicles were determined to be sufficient to support normal street operation. Rebuilding the vehicles was a cost effective way to update the age of the articulated trolley fleet and also provide an opportunity to expand the size of the fleet. Cost for new vehicles was estimated to be more than $1-$1.2 million per vehicle, while the rebuild could be completed for $90,000.

Rebuild activities began in 2005 when the Downtown Seattle Transit Tunnel was closed and the Breda coaches were taken out of service. As rebuilt vehicles were put into service, an issue developed with the amount of power being drawn by the vehicles and the effect that would have on the operation of the system. While a number of steps were taken to reduce the power being drawn by the coaches, a number of simulations indicated that power issues would remain on the northern end of the trolley line unless additional power could be delivered to the system.

Background/ Overview

The Transit Division's Capital Improvement Program (CIP) includes a project to convert up to 60 of the retired Bredas to operate solely in electric trolley mode.

The articulated electric trolleys are used on Routes 43, 44, 7 and 49 operating from Ballard through the University District and Capitol Hill to Downtown Seattle and south through the Rainier Valley.

This project was first included in the CIP in 2003 as a cost effective opportunity to replace Metro's aging, high maintenance articulated trolley coaches. A key consideration at the time was that the estimated cost for new articulated trolley buses was approximately $1-$1.2 million per vehicle. Metro Transit staff had just successfully completed a remanufacturing process for the standard trolley coaches that resulted in substantial cost savings compared to the cost of purchasing new vehicles.

The first step in the process, completed in 2003, was to determine the feasibility of converting the Bredas to electric-only mode. Metro Transit's Vehicle Maintenance group completed an engineering assessment and developed a prototype vehicle. Even though many of the diesel

drive train components were worn out, the electric drives were still in good operating condition. Initial testing of the prototype showed that the conversion would work. Additional appropriation authority was obtained in 2004 and 2005 to convert the vehicles at an average cost of approximately $90,000 per vehicle. This effort would also enable Metro Transit to slightly expand the size of the articulated trolley fleet to accommodate service growth.

Following the testing of the prototype vehicle, electrical tests were undertaken to evaluate the impact that this change in fleet would have on the trolley overhead power system.

Converted Bredas were tested to identify their electrical power requirements. The prototype Breda bus has different electrical power and performance characteristics than the 20-year old articulated electric trolleys that were in operation. As part of the conversion process, the diesel engine and fuel tanks were removed and changes were made to the brakes and heaters to reduce power consumption. Despite these changes, testing showed that the electric power consumption was still higher than the existing coaches when pulling away from bus stops, particularly on hills.

To determine the effect that increased power consumption would have on the trolley overhead system, the Transit Division worked with electric systems consultant LTK Engineering to develop a model of the trolley power network. The model network included details of the fleet's power demands, updated route information, bus zone locations, street grades and frequencies of the trolley service. The model testing demonstrated that the likelihood of service disruptions would increase in areas of the University District, Montlake, and along NE 45th Street to Ballard under certain conditions. The testing also concluded that when all substations were on-line, no service disruptions should be experienced. Six of the system's thirty-three substations are located in the corridor of concern. Similarly, testing demonstrated that service disruptions were not likely to occur at night and on the weekends when fewer coaches are in service.

Having one or more substations off-line is a relatively common condition for the trolley system. Maintenance activities result in each substation on the line being down for four to five days once a year. Unplanned substation shutdowns due to events like power disruptions or traffic accidents currently average three to four per month for the entire system. Given current power consumption, the trolley system is usually able to operate during these events, although unplanned shutdowns can result in service disruptions. With the increased power consumption of the reconditioned Breda coaches, the model testing determined that up to thirty eight coaches per month could experience service delays due to voltage drops unless changes were made to lower the power demand or increase the supply.

In response to questions raised by councilmembers and staff, Transit undertook additional testing of the system to validate the assumptions generated by the simulations. To refine the study, actual substation outage data replaced the assumptions used in the simulation. In addition, to verify how the reconditioned Bredas operate during substation outages, the coaches were field tested using various outage conditions.

The use of actual data demonstrates that substations do fail unpredictably for a number of reasons beyond Metro Transit's control and the reconditioned coaches cannot operate under these low-voltage conditions. The randomness and duration of outages highlight the fact that the

situation is beyond Transit's ability to respond with replacement buses or expediently restore service after a low-voltage incident. The low voltage situations were most likely to occur during the peak period when the most passengers would be impacted. Exhibit A shows the results of the tests.

The reconditioned coaches were field tested in November of 2006 to log their electric characteristics after the conversion and to monitor the effect of low voltage/substation outage conditions. The test replicated peak hour conditions over 6 miles of trolley route. The results are presented below. A summary of the test is included as Exhibit B.

The test ran four reconditioned Bredas over outage areas to represent the typical headways used on route 43, 44, and 49. The instrumentation and observations results closely matched the simulation predictions and support the following conclusions.

1. **All substations operational in the north end:** Bredas operate normally.

2. **Planned substation outage (maintenance):** In general, Bredas will operate if headways are maintained; if bunched, especially on hills, it will cause them to lurch or to stop in place if the batteries don't recharge. If drivers are made aware of the situation, they should be able to maintain service through the outage condition. However during the outage, the stress caused by areas of oscillating low voltage will shorten the life of the drive train.

3. **Unplanned substation outage:** Voltage "holes" will develop and cause sporadic trolley service disruptions or stoppages until Power & Faculties responds to jump the feeders. Bredas will stop due to steep inclines, bunching, or because the batteries failed to recharge. In areas of marginal voltage, the trolleys will begin to lurch and may or may not be able to continue service. For example during the test, all Bredas stopped eastbound on N 46th Street and eastbound on NE Pacific Street equating to a full halt in trolley service.

Description and Causes of System Outages:

The possible causes of substation outages can be attributed to a variety of circumstances. The most common occurrences are trolley poles coming loose, cross-connecting the overhead trolley wires, and causing a short. A falling tree branch or other objects that contact the overhead wires can also cause a short. These shorts are transient conditions that clear themselves but still require a service call to reset the substation. A traffic accident, construction activity or a break in the wire can also cause the wire to fall to the ground. The substation will then shut down the electrified wire for safety reasons. The electrical supply side, Seattle City Light, can cause a substation shutdown when there is a power surge or a planned or unplanned loss in their power. In some substations, the age of the equipment extends beyond 20 years and can fail without warning. Equipment failures are rare but can produce the biggest impact because of the extended time required to find and install replacement breakers, switches, rectifiers, or transformers.

The most significant outage event during the observation period was the failure of a transformer in the Ballard area on May 26, 2005. The substation was off line twice for 3 continuous days as

repairs were made. The trolley system did however operate normally during the transformer replacement, but if the Bredas were in service, this would not have been possible. With the planned surplus of articulated MAN coaches, Metro Transit does not have a sufficient number of spare trolleys or diesel coaches to substitute for Bredas. Service would be curtailed/reduced for the life of the outage. In this recent case, that would mean 6 days of limited service around Seattle as buses are shuffled between routes. Metro Transit would have limited success with substituting diesel for trolley buses, using 40-foot buses for articulated buses, increasing overtime, and decreasing route frequencies around the county to free up buses to use in the heavy ridership areas served by the trolleys.

Today, and in the future, following completion of the project, the trolley system will continue to be susceptible to wires breaking, trolley poles coming off the wire and other daily occurrences that disrupt trolley service.

Operational Response to System Outages:

King County Metro Transit has limited ability to rapidly respond to stranded trolley buses and customers, especially during peak-hours. The type of response would vary based on the severity of the outage. Options for response are discussed below:

> Replacement Vehicles: During peak service hours there are few, if any, diesel vehicles available to dispatch to the scene of a delay. An additional constraint to using replacement vehicles is the ability to get the vehicle to the stranded coach with the traffic congestion that could result from a trolley being stopped in the street. The use of diesel buses to replace trolleys would be an option to consider for outages that are of longer duration or are planned.
>
> Manual intervention on street: There are currently 3 service supervisors covering the entire north end during peak service hours. If there was an outage of the trolley system, these supervisors would need to be moved from locations throughout the county to Downtown Seattle. This could result in service disruptions in other areas of the system, in the event of accidents. Depending on the location and availability of the service supervisors it could take 30 minutes or more for multiple staff to arrive on the scene. With typical disruptions lasting a few minutes, the response would be to push the stranded trolley or trolleys clear of traffic until power could be resolved.
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> Manual intervention from communication center: Currently, the trolley system operators communicate with the Communication Center using one of the 4 radio channels. As a result, there is frequently a queue of operators waiting to talk to the Communication Center. Operators talk to the Communications Center for a number of reasons including accidents, passenger incidents, and service disruptions.

Project Objectives and Outcomes, Benefits

Based on the confirmation obtained from field tests on the trolley system, this project would provide funding to accommodate changes in the electric trolley overhead power system to maintain schedule reliability of the trolley system. This project will upgrade the conductors and

overhead wire system along a 6-mile stretch of the existing trolley system. Despite this increase, the total conversion cost of $12 million is significantly lower than the $60-$70 million cost that would have been required to purchase up to 60 new articulated trolley buses.

Constraints, Criteria, Dependencies

A key performance measure for the Transit system is on-time performance. This is a measure of system reliability. Transit's 2007 target for on-time performance is 80%. Through the first quarter of 2007, on-time performance was 75%. Transit has been focusing efforts on improving this important measure. Based on evidence from the testing and simulations, on-time performance of the articulated trolley fleet would be adversely impacted if this project were not undertaken, as trolley service would be disrupted.

Average weekday boardings on the articulated trolley fleet were 28,900 for the Spring 2007 service change based on data from the automated passenger counters. This number excludes rides taken in the ride free area of Downtown Seattle, as well as customers on standard size trolleys that would be impacted by a service disruption. These passengers rely on the bus system to predictably get them to their destinations based on published schedules. Transit does not believe that it is acceptable to knowingly subject these passengers to service disruptions.

Maintaining or improving schedule reliability is a cornerstone of the transit program. Over the years Transit has made a number of capital investments that were designed to improve schedule reliability. These improvements include the ongoing maintenance of the system infrastructure to minimize the risk of system failures, replacing aging fleets and speed and reliability investments designed to improve travel times.

There are no impacts to other county agencies from this request, although reduced schedule reliability could generate more customer complaints to councilmembers and the Executive.

Risks

The electric trolley coaches operate on overhead wire that is strung along the trolley routes. In the event that sufficient power is not available to a trolley anywhere along its route, the coach stops and cannot be moved unless power is restored, or the vehicle is physically pushed to a different location. The electric trolley routes are some of the busiest in the transit system and they operate in highly congested areas of Seattle. The disruption to passengers and vehicles in the vicinity of a coach that has lost power is significant to the individuals involved. Passengers must wait until either power can be restored or a diesel bus can be dispatched. Under these circumstances, riders are delayed and connections are missed. Other traffic must maneuver around the stalled coach, if possible. Similarly, any trolley coaches operating in either direction along the same stretch of the system would also stop, congesting traffic in both directions.

The lurching caused by a sudden loss of power to the reconditioned Breda's could cause additional problems to drivers, passengers and equipment. Drivers could become distracted and passengers jostled by the unexpected changes in bus speed. The voltage/ acceleration fluctuations will damage the bus drive trains.

A schedule risk also exists since, optimally, the wire upgrade project needs to be completed in conjunction with coaches being rebuilt and available for service. If the wire upgrade project cannot be completed coincident with rebuilt coaches going into operation, there could be problems.

Work Plan

The schedule for the project is dependent upon two elements: timely acquisition of poles and permits from the City of Seattle. Actual construction should be completed within 6-8 months following contract award.

Approach

The project will be managed internally, with consultant support for design and construction. Permits are required from the City of Seattle for the work.

Cost

The cost of the project is estimated at $6.5 million.
Cost details, in thousands of dollars, are listed below:

Internal Staff Labor, Design and Construction	$ 550
Internal Staff Labor, Power and Facilities	471
Consultant (LTK)	220
Permit and City inspection during construction	39
Steel Poles	320
Construction, includes 15% contingency *	3,700
Contingency*	1,200

*This is a relatively high contingency amount, supported by the Office of Management and Budget, to reflect the uncertainty about whether some of the overhead wires will need to be placed underground. A significant effort will be undertaken to expend less than the budgeted $6.5 million.

Alternatives

Transit staff and the consultant (LTK) evaluated alternatives to mitigate the impact of the increased power requirements on system reliability. These alternatives and the results of the evaluation included:

1) Modifying the power consumption of the vehicles (heaters, lighting, etc.). Changes were incorporated in the conversion process, but the changes were not sufficient to fully mitigate the problem.
2) Installing additional power substations in affected neighborhoods. Additional substations can be difficult to site and expensive to purchase and install, as a result, this alternative was deemed unfeasible and more costly and was not pursued further.

3) Upgrading the conductors and overhead wire to improve the voltage that could be carried on the line. Through the consultants work, this was determined to be the most feasible and lowest cost alternative to maintain system reliability.

Policy Links

This project supports the ongoing operation of the electric trolley system in Downtown Seattle. Maintaining system reliability supports increased system ridership.

EXHIBIT A

Results of Substation Outage Testing

The table represents the impact to passengers if Bredas were in service during an outage and the effect the wire upgrade would have on service reliability. The historical substation outage data was collected between May 2005 and February 2006. Without the wire upgrade, the outage results demonstrate that trolley service would be impacted if the full complement of 59 Bredas were in service. With the wire upgrade, the study confirms substation disruptions would not affect the operation of the trolley fleet and passengers during these same occurrences, as it is today.

Actual Substation Outage Data Applied Against Planned Breda Trolley Service
May 2005 through February 2006
(Peak-Times Only and does not include maintenance outages)

Event (Substation Outage Time)	Location (Substation Name) (Impacted Routes)	Outage Duration	Cause	Number of Trolleys that would STOP mid-service	Number of Trolleys that STOP mid-service if the Wire Upgrades were Installed
5/7/05 7:50am to 8:56am	**U-District** (Bob Sharp Sub) (70, 49, 44, 43)	**66 min**	**Unknown** (Electrical short cleared when breaker reset)	**45 Trolleys**	**0 Trolleys**
5/26/05 Outages over 12 peak periods	**Ballard** (W. Woodland Sub) (44/43)	**2 - 3 day peak-hour outages**	**Transformer failure** (Down time for replacement work)	**432 Trolleys**	**0 Trolleys**
6/10/05 5:45pm to 7:40pm	**Ballard** (W. Woodland Sub) (44/43)	**115 min**	**Unknown** (Electrical short cleared when breaker reset)	**18 Trolleys**	**0 Trolleys**
11/24/05 7:36am to 8:41am	**U-District** (Sharp/Jones Sub) (70, 49, 44, 43)	**65 min**	**Downed Guy wire**	**7 Trolleys**	**0 Trolleys**
12/13/05 8:30am to 9:01am	**Capital Hill** (Capital Sub) (43, 44)	**31 min**	**Unknown** (Electrical short cleared when breaker reset)	**12 Trolleys**	**0 Trolleys**

Rider Impact only during Peak Hours

51 Trolleys would Stop/Month (Under full service conditions) *(Original Prediction - 38 Trolleys)*	**-0- Trolleys would Stop/Month** *(if the Trolley Wire Upgrade Work were Completed)*

EXHIBIT B
Breda Low Voltage Field Testing Results
(Substation Outage Impact on Northern Trolley Routes)

Summary:

The project team performed a field test to substantiate the analytical concerns over the traction power grid supporting Breda traffic. The field test on November 19th mirrored peak hour conditions over 6 miles of trolley route during planned and unplanned substation outages. The Breda's performance was confirmed as unacceptable for passenger service during these outage conditions. The team observed at least one and sometimes all four test Bredas stopping dead in the street, or within the marginal voltage areas the Bredas began to lurch.

Aside from verifying the analytical predictions, the "run to failure test" identified the effects to passengers, equipment, and service. The Breda's sudden loss of power or the lurching cause by too little power leads to:

- Drivers becoming distracted.
- Passengers jostled by the fluctuating changes in acceleration.
- The voltage/acceleration fluctuations damaging the drive trains.
- Breda batteries not charging at low voltages causing the trolley to stop in place.
- Not being able to maintain headway or worse case, leaving trolleys stopped in the street.

Operating Conditions:

The test ran four Bredas over outage areas to represent the typical headways used on route 43, 44, and 49. The instrumentation and observations results closely matched the simulation predictions and support the following conclusions.

1. **All substations operational in the north end:** Bredas operate normally.

2. **Planned substation outage (maintenance):** In general, Bredas will operate if headways are maintained; if bunched, especially on hills, it will cause them to lurch or to stop in place if the batteries don't recharge. If drivers are made aware of the situation, they should be able to maintain service through the outage condition. However during the outage, the stress caused by areas of oscillating low voltage will shorten the life of the drive train, which is already a problem due to a limited supply of spare parts.

3. **Unplanned substation outage:** Voltage "holes" will develop and cause sporadic trolley service disruptions or stoppages until Power & Faculties responds to jump the feeders. Bredas will stop due to steep inclines, bunching, or because the batteries failed to recharge. In areas of marginal voltage, the trolleys will begin to lurch and may or may not be able to continue service. For example, during the test all Bredas stopped eastbound on N 46th Street and eastbound on NE Pacific Street equating to a full halt in trolley service.

Recommendation:

The team recommends the Wire Upgrade Project in the north end be approved. The analytical study and field-testing confirm the weakness in the existing system and the risk to Metro Transit's performance, equipment, and public perception. The appropriation is in place to fund the project and the work could be done in phases to help mitigate the problem over the next year, 2007.

ATTACHMENT 2

July 18, 2007

The Honorable Larry Gossett
Chair, King County Council
Room 1200
COURTHOUSE

Dear Councilmember Gossett:

The 2005 Adopted Budget Ordinance (15083) was amended to include an expenditure restriction related to a supplemental budget request for the Metro Transit trolley wire system. The request was made to add funding for an upgrade of the system, necessary to maintain system reliability on our popular electric trolley system. Specifically, Ordinance 15083 was amended to include:

> *ER 5 Expenditure Restriction:*
> *No portion of the funds appropriated for CIP Project A00480, 60 Ft Trolley Buses (Breda Conversion), shall be expended for an upgrade of the electric trolley overhead power system until the executive has submitted and the council approved by motion a business case for the proposed overhead wire upgrade, which shall, at minimum, include,*
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> *A. Data on the frequency, duration, timing, and cause of unplanned electrical substation shutdowns in the subject wire segment;*
> *B. Analysis correlating substation shutdown information with the periods of potential under voltage identified in the LTK Engineering Services' November 1, 2004, Breda Trolley Bus Traction Simulations Study;*
> *C. Analysis of the range of potential service interruptions attributable to the addition of Breda trolleys, including the number of coaches delayed and the duration of such delays; and*
> *D. Analysis of potential operational preparations for, and responses to, substation shutdowns that could be undertaken to minimize or eliminate the possibility of service disruptions attributable to the addition of Breda trolleys.*

Transit staff has completed additional system testing and I am pleased to submit for your consideration a business case for the Trolley Wire Upgrade project and a motion to approve the business case. This project will enable Transit to move ahead with the necessary trolley wire upgrade and assure the ongoing reliability of the system.

Background

The Transit Division's Capital Improvement Program (CIP) includes a project to convert up to 60 of the retired Dual-Powered Breda Coaches (Bredas) to operate solely in electric trolley mode.

The articulated electric trolleys are used on Routes 7, 43, 44, and 49 operating from Ballard through the University District and Capitol Hill to Downtown and south through the Rainier Valley.

This project was first included in the CIP in 2003 as a cost effective opportunity to replace Metro's aging, high maintenance, articulated trolley fleet. A key consideration at the time was the estimated cost for new articulated trolley buses, approximately $1.2 million per vehicle. Metro Transit staff had just successfully completed a remanufacturing process for the standard trolley coaches resulting in more than $30 million in cost savings compared to the cost of purchasing new vehicles.

The first step in the process, completed in 2003, was to determine the feasibility of converting the Bredas to electric-only mode. Metro Transit's Vehicle Maintenance group completed an engineering assessment and developed a prototype vehicle. Even though many of the diesel drive-train components were worn out, the electric drives were still in good operational order. Initial testing of the prototype showed that the conversion would work. Additional appropriation authority was obtained in 2004 and 2005 to convert the vehicles at an average cost of approximately $90,000 per vehicle. This effort would also enable Metro Transit to slightly expand the size of the articulated trolley fleet to accommodate service growth. Transit was able to expand the fleet by 13 coaches at a cost of slightly more than $1 million compared to the more than $15 million cost of purchasing new vehicles.

Following the testing of the prototype vehicle, electrical tests were undertaken to evaluate the impact this change in fleet would have on the trolley overhead power system.

Converted Bredas were tested to identify their electrical power requirements. The prototype Breda bus has different electrical power and performance characteristics than the 20-year old articulated electric trolleys Metro currently operates. As part of the conversion process, the diesel engine and fuel tanks are removed and changes are made to the brakes and heaters to reduce power consumption. Despite these changes, testing showed that the electric power consumption was still higher than the existing coaches when pulling away from bus stops, particularly on hills.

To determine the effect that increased power consumption would have on the trolley overhead system, the Transit Division worked with electric systems consultant LTK Engineering to develop a model of the trolley power network. The model network included details of the fleet's power demands, updated route information, bus zone locations, street grades and frequencies of the trolley service. Six of the system's 33 substations are located in the corridor of concern. The testing done with the model demonstrated the likelihood of increased service

disruptions in areas of the University District, Montlake, and along NE 45th Street to Ballard under certain conditions. The testing also concluded that when all substations are on-line, no service disruptions should be experienced. Similarly, testing demonstrated that service disruptions were not likely to occur at night and on the weekends when fewer coaches are in service.

However, having one or more substation off-line is a relatively common condition for the trolley system and the system needs to be able to continue to function during these events. With the increased power consumption of the reconditioned Breda coaches, the model testing determined that up to 38 coaches per month could experience service delays due to voltage drops unless changes were made to lower the power demand or increase the supply.

As a result of this extensive technical review, a supplemental budget ordinance was transmitted to the council on September 29, 2005 requesting an increase of $6,500,000 to the project. During council review a number of questions were raised about the project. Transit and Executive staff worked with council staff to address these concerns. At the end of these discussions, council moved forward by approving the supplemental budget request with the addition of an expenditure restriction to address some specifically identified concerns.

On December 2, 2005, I signed Ordinance 15329 which provided appropriation authority of $6,500,000 to CIP Project #A00480, Breda Conversion to Trolley.

In order to respond to the expenditure restriction, Transit staff and their consultant, LTK Engineering, conducted additional field testing and incorporated actual data on substation outages into the simulations. Testing with actual data as well as the field tests demonstrated that up to 51 vehicles per month could experience service delays due to voltage drops. This is an even larger impact then was documented in the earlier simulations and supports the need to take steps to mitigate these service disruptions. These results have been incorporated into the attached business case.

The terms of the 2007 expenditure restriction was thought at one time to supersede the 2005 expenditure restriction on the same project. While some expenditures have been made against the capital project, those expenditures were made in the belief that the 2005 restriction had been superseded. Through May of this year, approximately $35,000 of staff time and other charges have been recorded against the project. Some commitments have been made, although Transit has not yet made payments on the commitments and could potentially cancel some of this work if council decides they do not want to move forward with this project.

Conclusion

The original computer simulation model and engineering analysis demonstrated a hypothetical problem operating the fleet of up to 60 reconditioned Bredas. The simulations demonstrated that up to 38 vehicles could be impacted. To refine the study, actual substation outage data replaced the original assumptions in the simulation. These results indicated that the problem was potentially greater than originally believed with up to 51 vehicles being impacted by low

power. For further validation of how the reconditioned Bredas would operate during substation outages, field tests using various outage conditions were conducted.

The actual data allowed staff to identify specific information on time, place, and number of trolleys that would experience a low voltage condition and come to a stop in the street. The data demonstrates that substations do fail unpredictably and reconditioned Bredas cannot operate under those low-voltage conditions. The tests also demonstrated that the service reduction resulting from these conditions could not be easily managed by Transit.

Upgrading the trolley wire to alleviate these outage conditions is the most effective approach to maintain today's level of reliable service. There were six outages during the simulation period, and if the reconditioned Breda's had all been in service, an average of 51 trolley buses per month would have stopped in mid-service. The trolley system is heavily used and service disruptions of this magnitude would impact more than 28,900 average weekday daily boardings [per the Spring 2007 service change statistics]. These passengers would experience delays and additional crowding on replacement coaches.

Recommendation

It is my recommendation that council adopt the attached motion approving the business case in support of moving this project forward. It is our responsibility and our passengers' expectation that we minimize avoidable service disruptions to Trolley route passengers, while implementing cost-effective methods to provide continuing service.

Sincerely,

Ron Sims
King County Executive

Enclosures

cc: King County Councilmembers
ATTN: Ross Baker, Chief of Staff
Nancy Glaser, Interim Policy Staff Director
Anne Noris, Clerk of the Council
Bob Cowan, Director, Office of Management and Budget
Sid Bender, Capital Section Supervisor, Office of Management and Budget
Harold S. Taniguchi, Director, Department of Transportation (DOT)
Kevin Desmond, General Manager, Metro Transit Division, DOT