Planning for Transit System Reliability Using Productive Performance and Risk Assessment

Corresponding Author:
Assoc. Prof. Jonathan Bunker
Civil Engineering and Built Environment School
Science and Engineering Faculty
Queensland University of Technology
Phone No: +61 7 31385086
Fax No: +61 7 31381170
Email: j.bunker@qut.edu.au

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ABSTRACT

Urban transit system performance may be quantified and assessed using transit capacity and productive capacity for planning, design and operational management. Bunker (4) defines important productive performance measures of an individual transit service and transit line. Transit work (p-km) captures transit task performed over distance. Transit productiveness (p-km/h) captures transit work performed over time. This paper applies productive performance with risk assessment to quantify transit system reliability. Theory is developed to monetize transit segment reliability risk on the basis of demonstration Annual Reliability Event rates by transit facility type, segment productiveness, and unit-event severity. A comparative example of peak hour performance of a transit sub-system containing bus-on-street, busway, and rail components in Brisbane, Australia demonstrates through practical application the importance of valuing reliability. Comparison reveals the highest risk segments to be long, highly productive on street bus segments followed by busway (BRT) segments and then rail segments. A transit reliability risk reduction treatment example demonstrates that benefits can be significant and should be incorporated into project evaluation in addition to those of regular travel time savings, reduced emissions and safety improvements. Reliability can be used to identify high risk components of the transit system and draw comparisons between modes both in planning and operations settings, and value improvement scenarios in a project evaluation setting. The methodology can also be applied to inform daily transit system operational management.

INTRODUCTION

Transit system reliability is vital in urban areas where it can be seriously undermined by congestion and other incident events. Commuters ought to be able to rely upon consistent transit service to attract and retain them from less efficient modes such as the private car. The Transit Capacity and Quality of Service Manual (1) and Vuchic (2, 3) theoretically underpin deterministic transit capacity performance analysis which is important in planning, design and operational management of urban transit systems. Measures describing productive performance of an individual transit service or a whole line, offered or utilized, are very useful to the operator as they quantify their resources’ capabilities and passenger quality of service. Bunker (4) defines a number of useful productive performance measures including transit line productiveness. Johnston et al (5) present a risk analysis for prioritising Intelligent Transport Systems options in an urban road network. This paper follows this work by applying productive performance with risk assessment to quantify transit system reliability using a case study of the Brisbane Inner South transit Sub-system in Australia.

Common Definitions

Transit service defines an individual transit vehicle that traverses a line or route such as a bus, ferry, or train. A line includes a train line, Bus Rapid Transit (BRT) corridor, bus route or similar. A segment is a section of line between two discrete stops. A stop includes a train station, bus stop, ferry terminal or similar. A sub-system is a portion of a transit system in an urban area.

Passenger flow expresses transit passenger travel demand on a segment over time (p/h) and can be computed when the pattern of boarding and alighting passengers along the entire line is known (2). The maximum load segment (MLS) incurs the highest passenger flow along the line. Maximum scheduled load (MSL) represents a repeatable, safe working maximum vehicle passenger carrying capacity with all seats and available standing spaces occupied (1).

Vuchic (3) defines transit work (p-km) as the product of number of transported objects and distance over which they are carried. Bunker (4) defines transit productiveness as transit work delivered over time by one or more services traversing a line (p-km/h). This quantity of utilization is appealing to the operator in describing how productive a service or line is over a time period of interest from an aggregate perspective. Bunker (4) expanded on the concepts of an individual service’s and whole of line’s utilized productive performance using transit productiveness.
TRANSIT RELIABILITY OVERVIEW

Vuchic (2) defines reliability as the additive inverse of the probability of failure. Carrasco (6) argues that in transit systems failure is complex and hard to define, and can relate to different system elements and be of different types. According to Abkowitz and Engelstein (7) reliability is usually measured by its consequences and its causes are often due to the dynamic nature of the operating environment. On this basis Carrasco (6) defines travel time reliability as the consistency or dependability in travel times measured from day to day for the same trip. He notes from the literature that transit service reliability can be understood in different ways, and that providing a reliable service is understood as keeping buses on schedule, maintaining regular headways, and minimizing waiting time variability for passengers. Further, transit users experience reliability mostly through punctuality and travel time.

Camus et al (8) used automated vehicle location data to examine the advantages and limitations of the TCQSM method of estimating route segment reliability level of service (LOS) using its on time arrival (0 to 5 minutes late) percentage measure. They argued that the method does not consider the amount of delay itself, whose magnitude may affect the passenger quite differently between situations. A non-dimensional weighted delay index as a factor of the scheduled headway was proposed taking into consideration the amount of delay as well as early departures. LOS ranges and thresholds were assigned to the index. It is important to note that both of these LOS measures are punctuality based and do not explicitly account for passengers’ travel time.

METHODOLOGY

This research addresses reliability of segments within a transit corridor or system quantitatively on the basis of non-recurrent delay due to incident events. Other incident categories of safety and environmental are not considered. A reliability incident event is defined as that which causes delay to the transit passenger manifested by later than expected punctuality and/or longer than scheduled travel time.

This research uses risk assessment to quantify transit system reliability. Johnston et al (5) and Queensland Department of Infrastructure and Planning (9) define risk as the product of likelihood and consequence. The consequence of a traffic incident can be considered as the collective severity of an event upon those individuals having exposure to the event over its duration and the severity of the impact event upon each individual exposed to it (5). The same model form has been used in other transportation risk assessments as the product of probability, exposure and consequence (10); where probability aligns with likelihood above, exposure is the same, and consequence aligns with severity above.

This paper first develops a theoretical methodology to monetize reliability risk at the transit segment scale. This is important because transit system reliability is affected by all of its segments. High risk segments need to be identifiable for effective decision making in planning and operation activities.

The methodology is then applied to a case study sub-system to illustrate its practical applicability and usefulness to practitioners and researchers through the inferences drawn.

THEORY DEVELOPMENT

In order to quantify a transit corridor or system’s reliability it is appropriate to consider a time period during which conditions are relatively uniform but most vulnerable to unreliability such as the weekday A.M. or P.M. peak hour.

The corridor or system needs to be segmented between consecutive stops and/or points where transit operating conditions change, such as an access point between a BRT facility and an on-street-bus facility, or a junction between a rail branch and rail trunk facility. This segmentation enables both variability in productiveness due to schedule characteristics and segment length and reliability between segments or segment types to be encapsulated.

Passengers On-board Service on a Segment

For reliability analysis the number of passengers on board $P_{OB,h,i}(p)$ a given service $h$ on a given segment $i$ can be determined using the methodology of Bunker (4). This methodology accounts for pass-ups that occur if passengers are left behind at a stop due to the service reaching its MSL.
Scheduled and Actual Service Journey Times

Vuchic (2) defines the basic model of travel time between a transit service’s departures from two adjacent stops, here termed segment time, as the sum of running time and stop standing time.

In the absence of a known schedule scheduled stop standing time for a given transit service can be estimated as dwell time (4). TRB (1) provides methods for estimating dwell time and extensive data for selection of appropriate values by mode. Jaiswal et al (11, 12) provide guidance on estimating dwell time for buses serving a BRT station. TRB (1) provides guidance for including an operating margin on dwell time.

Vuchic (2, 3) provide methodologies for estimating a service’s scheduled running time provided its dynamic operating characteristics are known. TRB (1) specifies methods for various transit modes which account for relevant line effects. Otherwise for an existing line that generally obeys its schedule field trial data may be used, or for a proposed transit provision simulated runs along the line.

Bunker (4) addresses conditions when services experience recurrent high passenger loads and/or recurrent traffic congestion along the line. This actual cumulative journey time reflects recurrent conditions, and not those irregular conditions which affect reliability.

Transit Segment Vehicle and Passenger Flows

For a transit corridor or sub-system the flow of vehicles \( V_{i,Z} \) (veh/h) providing service on segment \( i \) for all services \( k \) equals 1 to \( m \) that complete that segment over a defined time window \( Z \) can be determined according to the published schedule.

Transit passenger flow \( P_{OB,i,Z} \) (p/h) on segment \( i \) for all services \( k \) equals 1 to \( m \) that complete that segment over a defined time window \( Z \) is given by:

\[
P_{OB,i,Z} = \sum_{k=1}^{m} P_{OB,k,i}
\]

Equation 1

Transit Segment Passenger Work and Productiveness

Transit passenger work (p-km) performed by an individual transit service \( h \) along segment \( i \) was quantified by Bunker (4) as:

\[
W_{h,i} = P_{OB,h,i} \cdot s_i
\]

Equation 2

Where:

\( s_i = \) length of segment \( i \) (km)

This measure does not reflect passenger flow, purely passenger numbers.

Segment passenger productiveness is the total work performed by all services \( k \) equals 1 to \( m \) that complete that segment over a defined time window \( Z \) and is given by (p-km/h):

\[
\Pi_{i,Z} = \frac{60}{T_{i,Z}} \cdot s_i \sum_{k=1}^{m} P_{OB,k,i}
\]

Equation 3

Transit Segment Monetized Reliability Risk

The likelihood of an incident event is equal to the number of times an event occurs divided by the total sample size, for instance the total number of significant days in a year (5). Likelihood for a transit
segment \( i \) may be defined as the expected number of reliability incident events per analysis period \( Z \) per year reflecting that segment’s event history. Likelihood of such an event on a homogeneous transit segment is contended to be relatively proportional to its length. For planning purposes it is reasonable to assign segment \( i \) a strategic measure of its incident event likelihood as its Annual Reliability Event rate \( \text{ARE}_{i,Z} \) (events/km-yr for analysis period \( Z \)). A unit reliability incident event may be defined as 10 min \((0.1667\text{h})\) of delay to the passenger. An actual event may be shorter or longer, therefore either a fraction or a multiple of this unit event.

For operational analysis or detailed short range planning analysis each segment’s \( \text{ARE} \) for the analysis period under consideration \( Z \) such as the A.M. peak hour should be determined from data over the most recent reporting period. Both automatic fare collection and automatic vehicle location systems are now ubiquitous in urban transit systems and many facilitate data mining to both the passenger and transit vehicle trip levels \((9, 13, 14)\) such that reliability impact events may be identified for determining \( \text{AREs} \).

For more general planning purposes strategic \( \text{ARE} \) values may be estimated for a limited range of transit facility types in relative proportion to each other. Ideally, values should reflect system wide conditions. A general planning case study is presented later including a demonstration range of strategic \( \text{ARE} \) values for various transit facilities.

The exposure of transit segment \( i \) may be expressed by the quantum of passengers exposed to the risk of reliability delay. The segment’s transit passenger productiveness according to Eq 5 is a direct measure of such exposure.

Reliability incident event severity may be monetized econometrically \((5)\). Unit-event severity \( C_{i,Z} \) ($/p-event) for transit segment \( i \) is attributed to delay experienced by passengers due to non-recurrent incident events. This value may be monetized as the product of duration per event, in this case the unit 0.1667h/event, and passenger delay cost ($/p-h).

Reliability risk score ($/yr for analysis period \( Z \)) for a transit segment \( i \) is given by:

\[
R_{i,Z} = \text{ARE}_{i,Z} \Pi_{i,Z} C_{i,Z}
\]

\text{Equation 4}

TRANSIT RELIABILITY CASE STUDY

Background
This background illustrates the diversity of the case study transit sub-system, in doing so highlighting its usefulness in demonstrating the methodology described above.

The Brisbane Statistical District in Queensland, Australia has a land area of 5,950 km\(^2\) (2,300 sq mi) and population of 2.043 million at 2010 \((15)\). This transit reliability case study incorporates the Brisbane Inner South transit Sub-system (BISS), which includes trunk segments that carry bus and rail services between the south side of Brisbane and the Central Business District (CBD) on Brisbane’s inner north side, in total serving up to one half of its transit demand. For brevity ferry services that contribute less than 2 percent of sub-system capacity have been excluded.

Contained within BISS is the Inner Eastern Transit Corridor (IETC). This study estimates that IETC itself serves a population of 75,000. IETC includes the Cleveland urban heavy rail line and Old Cleveland Road four lane urban arterial road, which carries on-street-bus (OSB) into the Eastern Busway (BRT) corridor and parallel OSB segments. Both connect the satellite city of Redlands to the CBD via middle and inner urban suburbs of eastern Brisbane.

BISS is illustrated in Figure 1, which contains IETC from Coorparoo to CBD via Stones Corner, Buranda, Woolloongabba, South Bank and South Brisbane, along with access points onto the trunk busway and trunk rail corridors from the south side to the CBD. All transit schedule data was obtained from TransLink Division \((16)\). Table 1 list within BISS each segment’s transit mode, transit facility classification, and length.
IETC carries five bus service categories during the A.M. peak hour; high frequency limited-stops routes 200 and 222, all-stops routes 203 and 204, peak express routes 206, 207 and 217, cross-country limited-stops route 209, which are all contained within Brisbane City, along with regional routes 250 and series 2xx from Redland City. IETC carries all-stops rail services CLA and express rail services CLE.

Figure 2 illustrates the number of IETC services offered on each BISS segment during the 7:15 to 8:15 weekday A.M. peak hour. Between Coorparoo and the CBD, IETC bus routes disperse onto six paths while train routes take one path. Other services that join the trunk corridors from other branch corridors besides IETC are included since they contribute to productiveness. The rail segments carry far fewer services, therefore at much lower frequencies, than their counterpart OSB/busway segments.
TABLE 1 BISS Segments' Transit Mode, Transit Facility Classification, and Length

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<tr>
<th>Segment Name</th>
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<th>Classification</th>
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<td>Major Arterial</td>
<td>1.05</td>
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<td>Rail</td>
<td>Branch</td>
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<td>Branch</td>
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<td>On Street Bus</td>
<td>Major Arterial</td>
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<td>Gold Coast Rail</td>
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<td>Rail</td>
<td>Core</td>
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This case study is based on existing BISS characteristics. Some data has been synthesised to demonstrate the methodology. Weekday A.M. peak hour Load Factor (LF = P/PMsl) profiles shown in Figure 3 have been synthesised based on field inspections to establish passenger loads on-board services for estimating productiveness using Eq 3. $P_{MSL}$ of buses deployed on routes 200, 203, 204, 206, 207 and 217 is 65p. Higher capacity buses of 75p are deployed on route 222. Coaches and buses with all passengers seated are predominantly used on regional bus routes 250 and series 2xx having $P_{MSL}$ of 55p. Trains on both CLA and CLE have typical $P_{MSL}$ of 750p. An average $P_{MSL}$ of 65p has been used for other bus services on trunk segments and 750p for other rail services on trunk segments.
FIGURE 2 BISS Services Offered by Segment during Weekday A.M. Peak Hour

IETC limited-stop bus routes generally approach MSL by the time they join Eastern Busway (segment 32) or parallel Deshon Street (segment 30) while IETC all-stops routes approach MSL by the time they join Woolloongabba Busway branch (segment 40). \( LF \) declines slightly by the time buses reach South East Busway’s Victoria Bridge Brisbane River crossing (segment 70). IETC peak express bus routes approach MSL as they cross Brisbane River via Riverside Expressway (segment 71). IETC regional bus routes reach IETC at Coorparoo approaching MSL, with a very slight decline in \( LF \) as they service Buranda station (segment 42) before continuing via Riverside Expressway.

CLA and CLE rail services generally approach MSL by the time they depart Buranda station (segment 48). \( LF \) declines slightly by the time they reach Merivale Bridge Brisbane River crossing (segment 78).
Segment Passenger Flow Comparison

Figure 4 illustrates passenger flow on segments for the weekday A.M. peak hour study period to appreciate relativities of throughput between segments. For ease of investigation all IETC routes are consolidated from here on. Key observations are as follow:

- Comparison between segments 10 and 18 shows that Old Cleveland Road carries 40 percent of combined IETC flow compared to 60 percent by Cleveland rail line, highlighting the significant role of OSB within this corridor.

- Comparison between segments 70 and 71 show that Riverside Expressway carries 60 percent of the bus river crossing passenger flow compared to 40 percent by the South East Busway. Alone the busway could not cope with the total peak hour flow due to operational constraints at the core stations, particularly Cultural Centre on the south side of the Victoria Bridge.

- Comparison between the totals of bus segments 70 and 71 against Gold Coast rail segment 78 shows that the two bus crossings carry 70 percent of the combined river crossing passenger flow highlighting bus’ important role within BISS.

- In a general sense, Figure 4 highlights that both OSB and BRT can play a pivotal role in carrying passengers in a multi-modal urban transit setting. Understanding their infrastructure reliability is therefore necessary.
Figure 5 illustrates passenger productiveness by segment within BISS for the weekday A.M. peak hour study period. Key observations are as follow:

- The most productive segments are long trunk segments including South East Busway trunk segment 42 and Riverside Expressway segment 71. Gold Coast rail trunk segments 58 and river crossing 78 are also highly productive but less than 42 and 71 due to their marginally lower passenger flows.

- While passenger flows are very similar, South East Busway river crossing segment 70 is less productive than Gold Coast rail river crossing segment 78 due to its shorter length but despite it being more direct. This highlights the importance of network topology in reliability analysis.

- All branch OSB segments 10, 20, 23, 30, 33 and 34 along with branch busway segments 22, 32 and 40 are noticeably less productive than trunk busway segments 42, 50, 60 and 70 because they carry significantly fewer services. Such a network appreciation is important in reliability analysis.

- Despite Old Cleveland Road segment 10 being a four lane arterial road with no bus priority it is twice as productive as Eastern Busway segment 22 due to a combination of its greater length and its concentration of all IETC bus services. This is important in understanding their relative reliabilities.
Strategic Annual Reliability Event Rates

In order to demonstrate the methodology, strategic annual reliability event rates have been synthesised for estimating segment non-reliability risk by Eq 4. Figure 6 presents, for the 10 min unit reliability incident event, demonstration strategic ARE values for each segment classification of Table 1.

Important here is the relativity between strategic ARE values by segment classification. Nine classifications are included; three by OSB facility, three by busway facility, and three by rail facility. The relativities by length for OSB facilities reflect from observation that within BISS minor arterial roads bear about half of the reliability impact events of major arterial roads and expressways bear slightly more events than major arterial roads. The relativities by length for busway facilities reflect observation that branch segments bear about half of the events than mainline segments while core segments bear about twice those of mainline segments. The relativities by length for rail facilities reflect that branch segments bear about half of the events than mainline segments while core segments bear about half as many again than mainline segments. Overall rail bears fewer events than busway, which in turn bears fewer events than OSB facilities. While these rates are for demonstration purposes, this methodology will benefit from further research on calibrating ARE values across a range of localities, using historic data where available and/or Delphi technique for collecting and synthesizing network knowledge from local agency experts.

Monetizing Unit-incident Severity

Average Weekly Earnings in the State of Queensland for the last quarter of 2011 were sourced from Australian Bureau of Statistics (17) to be AU$1,032.80. Average hours worked in Queensland is 36.25 h/week. Canada’s Victoria Transport Policy Institute (18) provides guidance on monetizing commuter transit passengers’ delay under uncomfortable conditions, which is estimated to be 50 percent of the prevailing wage rate. For a 10 minute reliability incident unit-event severity \( C_{i,z} \) is therefore valued at AU$2.38/p-event.
FIGURE 6 Demonstration Strategic Annual Reliability Event Rates for Weekday A.M. Peak Hour by Segment Classification

Segment Reliability Risk Comparison

Eq 4 has been applied to all segments for the weekday A.M. peak hour using the segment demonstration strategic ARE values of Figure 6, segment passenger productiveness values of Figure 5, and unit-event severity calculated above.

Figure 7 illustrates for demonstration purposes the reliability risk score (AUS/yr for A.M. peak hour) by segment within BISS for the weekday A.M. peak hour. Key observations are as follow:

- The highest risk segments are long, highly productive bus segments of Riverside Expressway river crossing 71 followed by South East Busway trunk 42. Despite segment 42 being approximately 40 percent more productive than segment 71, its reliability risk is estimated to be under half that of 71, highlighting that a busway corridor may have a significant benefit over a general traffic expressway in mitigating reliability risk. In a daily system management context, it also highlights the need to detect, respond to and clear incidents quickly on an expressway that carries significant bus traffic.

- South East Busway trunk segment 42 bears approximately twice the risk of core segments 60 and 70. This is mainly attributed to segment 42 being over four times as productive as the core segments which are considerably shorter and each carry fewer services. Notwithstanding, in a daily system management context this highlights the critical role of segment 42 on this busway network and the need to detect, respond to and clear incidents quickly.

- Inner busway segment 50 is almost as productive as segment 60. However, its estimated risk is significantly lower than segment 60 due to the lower ARE assigned to segment 50, which unlike...
segment 60 has no signalized access points or erratic queue spillback from the downstream station.

- Eastern Busway branch segments 22 and 32, and Woolloongabba Busway segment 50 have very low risk scores relative to all other busway segments due to a combination of lower productiveness and lower AREs on these more lightly trafficked segments.
- Despite being of similar productiveness to branch Woolloongabba Busway segment 40, OSB segments 10 and 33 are estimated to be of notably higher risk. In a daily system management context, this highlights the need to detect, respond to and clear incidents quickly on arterial roads that carry significant bus traffic.
- Despite Gold Coast rail river crossing segment 78 being 2.4 times as productive as South East Busway river crossing segment 70 its risk is 1.6 times due to higher inherent rail system controls. However lower risk might generally be expected of rail. The ARE assigned to the rail segments reflect that Brisbane’s inner rail system is operating close to its slot capacity during peak periods and highlights the importance of daily incident detection, response and management.
- Cleveland rail segment 18 is highly productive, however carries very low risk especially compared to less productive OSB segments such as 10 and 33. The inherent rail controls along with lower frequencies than inner and core rail segments are reflected in a significantly lower assigned ARE.

FIGURE 7 BISS Reliability Risk Score by Segment during Weekday A.M. Peak Hour

This case study demonstrates the usefulness of quantifying reliability risk scores by segment within a given urban transit system. In a planning setting it can be used to inform decision making on deployment of treatments and delivery of infrastructure aimed at improving transit reliability. In an
operational setting it can be used to target elements in a transit system for incident detection and to develop the most effective response and mitigation protocols.

Reliability Risk Reduction Treatment Evaluation Example
This hypothetical case study adaptation demonstrates the applicability of transit reliability risk assessment to risk reduction treatment evaluation. Consider a proposal to improve transit reliability within the IETC sub-system by deploying transit lane priority on Old Cleveland Road OSB segment 10 for a Net Present Cost (NPC) of AU$40.0 million. The presumed reliability impact derived is a weekday A.M. peak hour projected reduction in ARE from 30 events/km/yr to 15 events/km/yr for an annual saving of $119,000. Other impacts derived would include transit passenger travel time saving, reduced emissions, and improved passenger safety. However, for clarity this evaluation only addresses the reliability improvement impact.

This evaluation incorporates a 4.0 percent uniform annual passenger growth assumption which would be accommodated progressively using greater proportions of high capacity buses. Identical reliability improvement impacts are projected to be derived during the weekday P.M. peak hour, weekday A.M. two-hour shoulder peak period, and weekday P.M. two-hour shoulder peak period. Therefore total daily reliability improvement impacts are estimated to be four times that of the A.M. peak hour for an annual saving of $476,000.

For this evaluation two key econometric assumptions must be made; Discount Rate and Discount Period. Queensland Department of Infrastructure and Planning (8) provides some guidance on nominal discounting and discount period stating that “while in theory, long run benefits should be included in the analysis, it can be problematic and in most cases impractical to estimate them”. A Discount Rate is not specified in (8) however a long range value of 6 percent has been widely adopted, and discounting periods upwards of 20 years adopted depending on project scale. New South Wales (NSW) Treasury (19) is more prescriptive specifying a consistency project life of 20 years and a Discount Rate of 7 percent with sensitivity rates of 4 percent and 10 percent.

For these assumptions the resulting Net Present Value of reliability savings vary between AU$5.7 million, AU$6.5 million, and AU$8.6 million depending on Discount Rate adopted, or between 14% and 21% of NPC. This order of cost impact over and above those of regular travel time savings, reduced emissions and safety improvements for this hypothetical case is significant. This example demonstrates that it would be worthwhile incorporating reliability improvements into transit project evaluation to guide decision making.

CONCLUSION
This paper extended on previous work (1, 2, 3, 4) by applying transit productiveness and risk assessment (5) to quantify transit system reliability. Theory was developed to monetize transit segment reliability risk on the basis of Annual Reliability Event rates by transit facility type, segment productiveness, and unit-event severity.

Using the Brisbane Inner South transit Sub-system in Queensland, Australia an A.M. peak hour reliability case study was presented to illustrate the practical applicability of the methodology and its usefulness to practitioners and researchers through the inferences drawn. The sub-system serves up to half of the Central Business District’s commuter transit demand and includes branch and trunk line for heavy rail, busway (Bus Rapid Transit), and on street bus (OSB) modes.

A segment comparison of passenger flow found that the combined bus-on-expressway and busway river crossings carry 70% of the total river crossing flow while the rail river crossing carries the remaining 10,000p/h, highlighting the crucial role of bus in serving a multi-modal urban transit system’s commuter task. A segment comparison of passenger productiveness found that long trunk segments are most productive, particularly a long, high speed trunk busway segment approaching the CBD and the bus-on-expressway river crossing, followed closely by two long, trunk rail segments approaching the CBD.
A reliability risk comparison for the case study sub-system using demonstration Annual Reliability Event rates revealed the highest risk segments to be long, highly productive bus segments, although the significant benefit of a busway corridor over a general traffic expressway or an arterial road in mitigating reliability risk was apparent. In daily system management this analysis highlights the need to detect, respond to and clear incidents quickly on highly utilized OSB segments.

The rail trunk and branch segments proved to have substantially less risk than both their bus-on-street and busway segment counterparts due to rail system inherent controls. A core trunk rail segment did reveal to be of relatively high risk attributed both to its length and the intensity of operation of Brisbane’s inner urban rail system during peak periods.

A hypothetical reliability risk reduction evaluation example was presented for a transit priority treatment on the highest flow and highest risk OSB branch segment. The Net Present Value range demonstrated that reliability improvements can be significant and that it would be worthwhile incorporating them into transit project evaluation.

The methodology which combines transit productiveness with risk assessment was demonstrated to be extremely useful in a transit system planning and project evaluation setting. Its features can also be applied to inform daily transit system operational management.

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REFERENCES


