

1 **The importance of deadheads in assessing the travel time reliability of buses: Case study of**
2 **Brisbane, Australia**

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26

1 **ABSTRACT**

2 Travel time reliability is crucial for transport operators as it directly impacts traveler behavior and public
3 transport patronage. This study investigates public transport reliability focusing on the underexamined
4 metric "pull-out deadhead" of bus services, which is the travel time from the depot to the first stop of a
5 route. Road traffic congestion affects this journey, thus potentially impacting route-level reliability. To
6 investigate the influence of pullout deadheads, three months of bus scheduling and performance data
7 across 23 first stops were analyzed concerning a case study in Brisbane, Australia. The results of the
8 aggregate analysis revealed that there is a positive correlation between deadhead reliability and on-time
9 running reliability, indicating that the more reliable a pull-out deadhead customers receive a more reliable
10 service. Further disaggregate deadhead time distribution analysis of the first stops was undertaken to
11 provide potential recommendations to improve deadhead reliability. Strategies that could improve
12 reliability included the application of a pre-service bus signal priority and scheduling greater travel time
13 budgets for trips between the depot and first stop. However, it should be noted that the services analyzed
14 generally had on-time running percentages that exceeded 80%, suggesting a relatively reliable service.
15 Ultimately, the results of this study can help transport operators enhance their services, mitigate the
16 effects of congestion, and improve the overall travel experience for public transport users. Future studies
17 in different locations and deadhead modeling will enhance comprehension of the impact of deadheads on
18 bus travel time reliability.

19
20 **Keywords:** Public Transport, Travel Time Reliability, Pull-out deadhead, Performance measures

1 INTRODUCTION

2 Population growth and increasing economic exchanges are intensifying the strain on the
3 relationship between transport supply and demand. Public transport plays a critical role in managing this
4 relationship and it is important that it remains an attractive service for passengers. Travel time reliability
5 has long been identified as an issue for both travelers and operators. Taylor (1) suggests that travel
6 behaviour and system performance assessment are the two broad foci for travel time reliability research.
7 In terms of system performance assessment, public transport operators are interested in understanding
8 factors that affect the efficiency and predictability of their operations. Factors affecting the reliability of
9 public transport services include traffic congestion, vehicle maintenance, scheduling accuracy, weather
10 conditions, and operational efficiency. An aspect of the operational efficiency in the context of bus
11 services, is the deadhead. This study investigates the relationship between the deadhead and travel time
12 reliability of the bus service.

13 The deadhead refers to the period when a bus is out of service and operating without carrying or
14 accepting passengers. This occurs as a bus departs or returns to a depot, travels to the first stop from a
15 different route or travels to a break spot. For transport operators, the accurate estimation of deadheads
16 forms an important part of scheduling services (2) as well as producing bids that are both competitive and
17 achievable for the tender of bus service contracts (3). In producing competitive bids, one of the main
18 considerations is operating costs. Reduction in fuel costs, maintenance costs and non-productive bus
19 driver hours can be realized through the minimization of deadheads. The importance of managing
20 deadheads is also heightened by the transition to electric bus fleets that will occur over the coming
21 decades (4). Whilst being competitive, bids must also be achievable. When awarded a contract, operators
22 are evaluated based on the ability of services to run as timetabled (5). In particular, the first stop is often
23 used as a key performance indicator with the scheduled departure time compared to the actual departure
24 time (6). The first stop of a trip is always preceded by a deadhead and thus its performance is influenced
25 by deadhead reliability. An unreliable deadhead may result in downstream compounding deterioration of
26 in-service reliability, posing a concern to transport operators. Transport operators are challenged in
27 arriving at accurate estimates of dead heads when competing for contracts in areas that are unknown to
28 them as well as when designing new routes in contracted areas (7).

29 Hence, the objective of this research was to gain quantitative insights regarding the presence of a
30 correlation between deadhead travel times and the travel times of buses in-service. Specifically, this study
31 analyzed the pull-out deadhead which refers to when a bus departs the depot and travels to its first stop.
32 This was achieved by empirically analyzing three months of bus scheduling and performance data across
33 23 first stops of a case study in Brisbane, Australia. The outcomes of the study could be used to develop
34 further optimization solutions in pre-service conditions (during the deadhead), thus minimizing the
35 impacts on patrons of public transport services. The remainder of the paper presents a brief review of
36 literature, details the data acquisition, selection and analysis and discusses the results and
37 recommendations arising from the empirical assessment.

38 Background Literature

39 Research investigating deadheads in the context of public transport performance is limited. During the
40 1980s, Furth (8) analyzed the impacts of “alternating deadheading” for the optimization of bus route
41 performance. Alternate deadheading is an operating strategy applied to bus routes that have a directional
42 imbalance in passenger demand. This strategy involves some of the vehicles operating on a route
43 returning with no passengers (deadhead) in the reverse direction while others (alternate service) provide a
44 service on return. The research presented a formula for the application of the strategy and highlighted the
45 operational benefits, Eberlain et al., (2) conducted a similar study focused on “stop-skipping” services in
46 disrupted or congested network scenarios and referred to this concept as the “real-time deadheading
47 problem”. However, neither of these efforts focused on pull-out deadheads or the influence on travel time
48 reliability.

49 Much of the deadhead literature is concerned with the selection of a suitable site for a bus facility,
50 bus-garage allocation decisions, garage capacities and depot management. Shelton et al., (9) used a
51

1 sketch-level methodology to estimate bus deadhead costs associated with the relocation of a bus
2 maintenance facility. Todd et al., (10) presented a tool that runs on open-source software to determine the
3 minimum deadhead time for potential bus facility locations. In addition, the concept of deadhead has been
4 discussed for use as a key performance indicator for transport operators (11, 12). Godachevich and
5 Tirachini (11) investigated a measure related to deadhead, the headway variability of dispatching buses
6 from a depot, which is affected by the distance to the first stop and the operating speed, thus suggesting
7 that deadhead could be used as a performance measure. Further, Moosavi et al., (12) explained the lack of
8 reliability metrics that consider both passenger and operator perspectives and proposed a number of
9 metrics that account for this gap. Two of the metrics are headway regularity index at stops and bunching
10 percentage which may be impacted by the magnitude of the deadhead and the reliability of the deadhead.
11 In 2013, Nasibov et al., investigated the relationship between deadheads and fuel economy of buses in
12 Izmir Turkey (13). The study developed mathematical models to reduce deadhead distance as a means of
13 improving fuel economy and identified optimized stopping scenarios that resulted in 7.8% improvements
14 in deadhead distance. Finally, deadhead research is not restricted to buses. Nair et al., defines a deadhead
15 trip in the context of rideshare as a journey where there are no passengers in the vehicle (14). Research
16 reviewed indicates a gap in empirical studies that focus on measuring the pull-out deadheads and its
17 relationship with travel time reliability.

18 The other dimension of literature that was explored was studies that focused on travel time
19 reliability of bus services. In general bus reliability indicators are derived by using probability-based
20 methods, schedule adherence methods, headway variance, passenger-centric methods and GPS methods
21 (15). This study leverages both schedule adherence methods and GPS methods given the available data
22 was schedule data and realized travel time data of in-service buses. Hassannayebi et al. (15), presents a
23 recent review of the literature and states that there has been limited quantitative research that has
24 investigated bus reliability. Their study establishes a data-driven multi-criteria decision making model to
25 prioritize bus routes considering both operator and consumer objectives (15). The modeling framework is
26 valuable for strategic assessment of route definition and timetabling but does not explicitly focus on
27 deadheads.

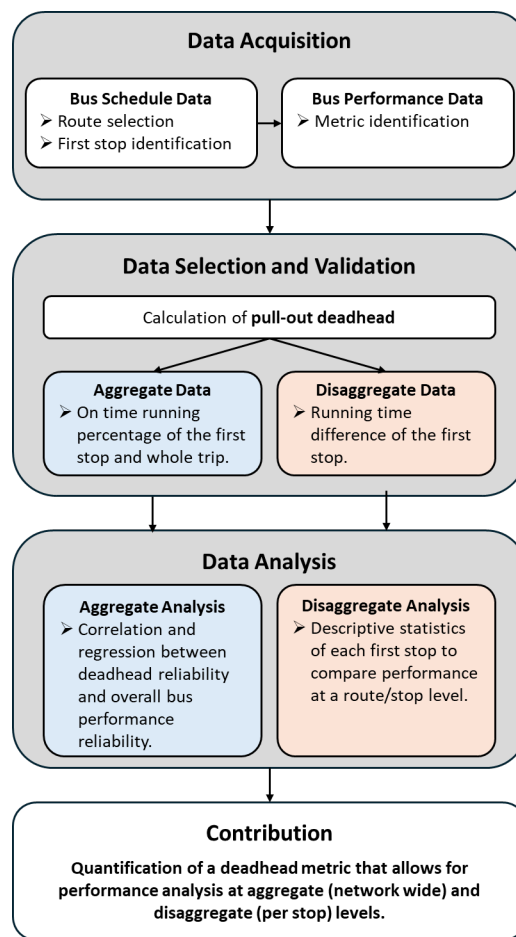
28 Other empirical studies have been conducted across some major urban centers. Low et al., (16)
29 found the variability of bus travel time to be sensitive to both temporal and spatial effects in the Klang
30 Valley in Malaysia. The research considered three major attractors (a school, university and shopping
31 mall) and five operating road environments (CBD, highway, arterial, suburban, residential) and described
32 the differing results across the combinations, highlighting the impact of weekday and weekend travel
33 conditions. Bus section length and traffic signal density impacted the reliability of services. Kaewunruen
34 et al., (17) conducted a similar study of 63 bus routes in Birmingham, United Kingdom again describing
35 that different land uses and traffic signal density have varying impacts on reliability. The reliability of bus
36 services affects the quality of passengers' experience and has financial implications for operators who
37 attempt to abide by their contracts. It causes issues such as bus bunching and gapping which leads to
38 increased wait times and crowding (18). There are many factors that affect the reliability of a bus trip, and
39 these factors can vary depending on whether a bus is in-service or out-of-service. Through a series of
40 regression models, Chioni et al., (19) found that the most significant source of headway irregularity was
41 the dispatch at terminals which is consistent with previous research. Mazloumi et al., (20) investigated the
42 use of traffic flow data in predicting average travel-time variability which had previously been neglected.
43 Finally, there have been many approaches to solving issues of reliability for buses in service. For
44 example, a case study of bus services in Queensland, Australia (21) revealed that reliability would
45 increase by around 15% if onboard top-up for electronic tickets was not offered by the operator.

46 The above literature review has revealed valuable insights concerning the measurement and
47 improvement of bus reliability, but limited attention has been given to the impact of deadhead periods on
48 in-service travel times. Existing studies often focus on operation metrics such as dwell times, route-
49 specific delays, or overall scheduling adherence, without isolating the unique contributions of deadhead
50 performance to service reliability. Additionally, the pull-out deadhead – an essential transitional phase

1 between depot departure and route commencement, remains underexamined in quantitative terms. This
 2 study addresses these gaps by analyzing pull-out deadhead data for a case study in Brisbane, Australia.

3 **METHODOLOGY**

4 The topic was investigated through an empirical case study of bus data associated with 23 first-
 5 stops, made available through Transdev, Australia. Figure 1 presents a flow chart of the methodology
 6 used for the research. Scheduling information and bus performance data were provided; however, the
 7 actual travel time data was not available for the pull-out deadhead. Therefore, the scheduling data was
 8 used to infer pull-out deadhead performance by using differences in running times at first stops of
 9 services and on-time running performance across a trip. An aggregate and disaggregate analysis were
 10 conducted. The aggregate analysis was used to observe the presence of an overarching correlation
 11 between deadhead performance and bus service performance, while the disaggregate analysis allowed for
 12 a more detailed understanding of the performance of each first-stop of the data set. Data was acquired,
 13 cleaned, and analyzed as described in the remaining sections of the Methodology.
 14

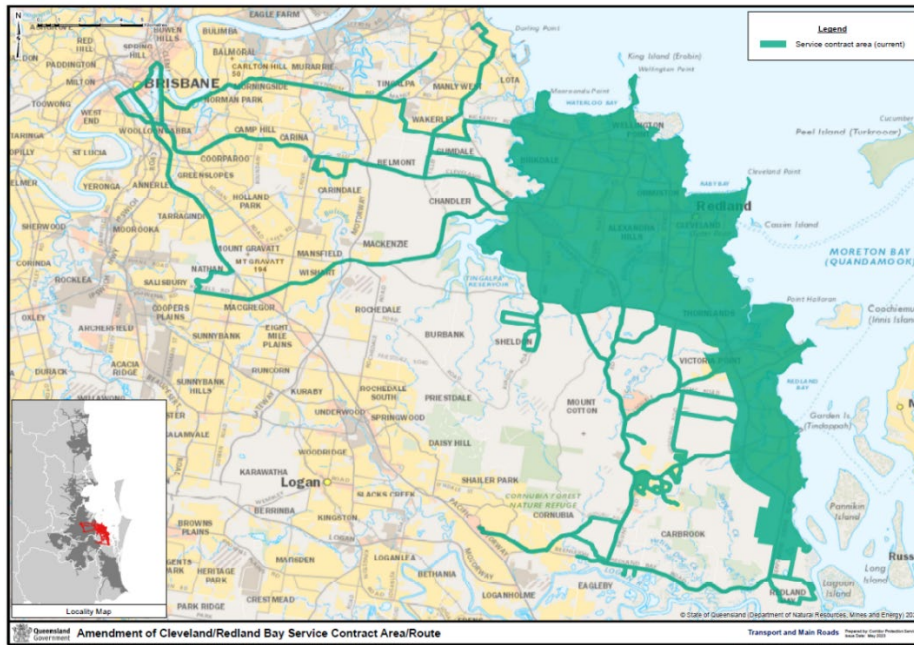


15
 16 **Figure 1 Methodology flow chart**

17
 18 **Data Acquisition**

19 The data used to investigate the reliability of deadheads was acquired through partnership with Transdev.
 20 In Australia, Transdev provides bus, rail, light rail and ferry services with locations in Brisbane, Perth and
 21 Sydney. For this study, three months of bus scheduling and performance data pertaining to operations in
 22 Brisbane, Queensland was gathered. In Queensland, Transdev operates metropolitan bus services that
 23 connect Brisbane, Redlands and greater-Southeast Queensland. Transdev is responsible for the Cleveland/

1 Redland Bay Service Contract Area which can be seen in Figure 2 (22) and will be referred to as the TDQ
2 network for the remainder of the paper. The Redland City local government area (LGA) is located
3 adjacent to Brisbane which is the third largest city in Australia and the capital of Queensland. Bus
4 services within Redland Bay Service Contract Area are considered as a representation of suburb to city
5 connections and thus was used as a case study for this research.
6



7
8 **Figure 2 Bus Service Contract Area (Extracted from (22))**
9

10 Transdev provided two data sources for this study, spanning from June 2023 to August 2023. The
11 first source was detailed scheduling information created using HASTUS software, a commercially
12 available scheduling software platform. The second source was NetBI (commercial data management
13 software), a software used by the Queensland Government Department of Transport and Main Roads,
14 integrating scheduling, ticketing, and real-time systems data. Transdev, under contract with the
15 Department, accesses NetBI to evaluate bus service performance. This study focused on NetBI's
16 scheduled trip analysis category, which incorporates data from the Translink Integrated Scheduling
17 System, Nextfare go card ticketing system, and Nextbus real-time system, along with telematics systems
18 meeting Translink Operations Manual requirements.
19

20 **Data Selection and Analysis**

22 *Aggregate Analysis Methodology*

23 To gain an understanding of the performance of the pull-out deadheads on the TDQ network, it was first
24 necessary to extract data from NetBI at an aggregate level. Of the measures provided in NetBI, on-time
25 running percentage was deemed the most suitable to evaluate the performance of deadheads at an
26 aggregate level. On-time running is a measure of whether a bus has either arrived, departed or passed a
27 stop within a specified range of its scheduled time. For the purposes of this study, on-time running is
28 assumed to be between -60s and 300s (one minute early and five minutes late, inclusive), emulating key
29 performance indicators stipulated by governing transport authorities in Australia (23). Further, on-time
30 running is measured as the departure time difference to schedule, except for the last stop which uses
31 arrival time difference. Therefore, for every stop excluding the last, the following is assumed as true:

- A bus departing from a stop within one minute early (-60s) and five minutes late (300s) inclusive of its scheduled time is reported as on-time.
- A bus departing more than five minutes (300s) after its scheduled time is reported as late.
- A bus departing a stop more than one minute before (-60s) its scheduled time is reported as early.

The on-time running percentage measures the overall percentage of stops where the bus was on-time. For a selected reporting range, it represents the number of stops reported as on-time as a percentage of the total number of scheduled stops, excluding all stops on any uncompleted trip and any unsighted or untimed stop on a completed trip. To evaluate the performance of pull-out deadheads, the data was filtered in NetBI to include only the first stop of the first trip on all shifts. If a bus travels from the depot and departs the first stop late, this indicates the bus has taken longer than scheduled to complete the pull-out deadhead. Likewise, if a bus travels from the depot and departs the first stop early this indicates a bus has taken shorter than scheduled to complete the pull-out deadhead. Pull-out deadheads that depart late are of a greater concern than those departing early. A bus that departs early from a stop is more symptomatic of a driver's behaviour, as a driver has the option to wait at the first stop if they arrive early and then depart at the scheduled time. From an operational efficiency perspective however, if a bus is consistently arriving early the excess time could be allocated elsewhere in the schedule.

The reporting range for this study was selected to align with the extracted schedule information. The schedule information was extracted from the latest schedule, which was implemented on Monday May 29, 2023. Therefore, data after this date was suitable for extraction. A three-month period from June 1, 2023, to August 31, 2023, was selected for analysis. The extracted schedule information included only weekdays and excluded school and public holidays. The same parameters were applied to the NetBI data. The following measures were extracted alongside on-time running percentage:

- On-time running
- Late running
- Early running
- On-time running numerator
- On-time running denominator

The following schedule information was also extracted from NetBI as a means of identifying the pull-out deadheads:

- Shift number (shift in which pull-out deadhead occurs)
- Minute (the scheduled departure time of the bus at the first stop)
- Route number (the route number following the deadhead)
- Service Type (school, urban or express)
- Direction (inbound, outbound or clockwise)

The performance of the pull-out deadhead was measured as the on-time running percentage of the first stop of the first trip for each shift. For the performance of the whole trip, the on-time running percentage was also used but was applied to a larger number of stops across the trip. The on-time running percentage for the whole trip was extracted for two cases. The first case used all stops on the trip (excluding the first stop) to calculate the on-time running percentage for the whole trip. The second case only considered key stops (excluding the first stop) across the trip. The same parameters used to extract the pull-out deadhead performance measure were applied to extract the two cases mentioned here with the appropriate adjustment made to the stop inclusions/ exclusions. Linear regression was conducted between the deadhead reliability (on-time running percentage to the first stop of the trip) and the bus performance (on-time running percentage of the in-service component of the trip – whole of trip) to determine if there was a correlation between deadheads and bus travel time reliability.

Disaggregate Analysis Methodology

The pull-out deadheads were also analysed at a disaggregate level. Pull-out deadhead routes were identified by applying a pivot table to the aggregate data in a spreadsheet application and grouping the

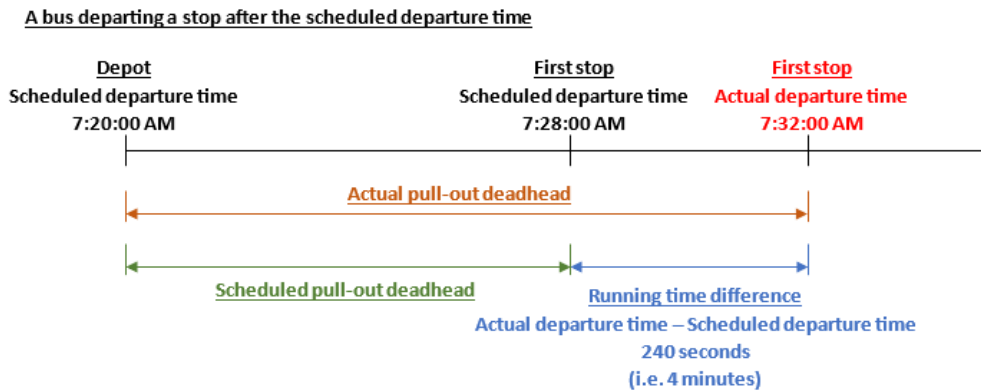
1 pull-out deadhead entries based on their first stop location. For the 74 pull-out deadhead entries, a total of
 2 twenty-three unique first stop locations or pull-out deadhead routes were identified in Table 1. To
 3 understand the contribution of the pull-out deadhead (time from depot to first stop) to the overall running
 4 times (route travel times), scheduled travel time values are also included in Table 1. Travel times were
 5 obtained using the data gathered from Transdev. The second column is an average scheduled running
 6 times of all routes emanating from the originating first stop. The ratio of pull-out deadheads to the
 7 average running time varies between 13% and 61%, with an average ratio of 35% across all 23 stops
 8 studied. Therefore, on average, approximately 25% of the overall travel time (deadhead time plus average
 9 running time) is allocated to the pull-out deadhead, highlighting the importance of managing the
 10 reliability of deadheads within this case study.

11 **Table 1: List of pull-out deadheads by first stop**

First Stop Locations	Scheduled Pull-Out Deadhead (mins)	Average Scheduled Running Time originating from the First Stop (mins)	Ratio of Pull-Out Deadhead relative to Running Time
Alexandra Hills, Burwood Rd	8	61.00	13%
Bunker Rd at High St Stop A	17	56.67	30%
Capalaba Park 'n' Ride, Platform 1	10	39.89	25%
Capalaba Station Stop A	8	29.80	27%
Capalaba Station Stop C	8	41.00	20%
Capalaba Station Stop D	8	39.50	20%
Capalaba, Lyndon Rd	10	69.33	14%
Carindale Interchange Stand J	19	60.80	31%
Cleveland Shopping Centre	17	32.80	52%
Cleveland Station	20	38.00	53%
Cleveland, Sunshine Dr	17	77.00	22%
Eastside Village Shops	20	41.00	49%
Kiwi St near Campbell Rd	13	25.00	52%
Mount Cotton, Papaya St	23	42.00	55%
Ormiston, Rose St	17	75.33	23%
Point O'Halloran Rd near Orana St	24	88.50	27%
Redland Bay Marina	30	51.29	58%
Redland Hospital	18	29.50	61%
Shoreline Ave near Hydrangea Ave	32	97.80	33%
Thornlands, Thornlands Rd	20	81.75	24%
Toondah Harbour	23	76.00	30%
Victoria Point Central Platform 1	22	50.50	44%
Victoria Point Jetty	24	66.17	36%

14
 15 The measure used to evaluate the performance of pull-out deadheads at the disaggregate level was
 16 running time difference. In NetBI, running time difference reports the number of seconds early or late a
 17 bus has departed a stop by comparing the schedule and ticketing data. The running time difference at the

1 first stop was used to evaluate the deadhead performance. As shown in Figure 3, running time difference
 2 is calculated by subtracting the scheduled departure time from the actual departure time, as recorded by
 3 an approved source. Therefore, a bus that departs a stop early will be represented by a negative number of
 4 seconds while a bus that departs late will be represented by a positive number of seconds. Where there are
 5 multiple approved sources of departure times for a stop, NetBI selects the time nearest to the schedule to
 6 calculate running time difference. Further, NetBI prioritizes those times that fall within the on-time
 7 running boundaries which have been specified in this study as -60s and 300s. For example, a recorded
 8 departure time of 120 seconds late will be selected in favor of 70 seconds early and 150 seconds late as it
 9 is the nearest time to the schedule within the on-time range.
 10



11
 12
 13 **Figure 3 Illustrated example of running time difference calculation**
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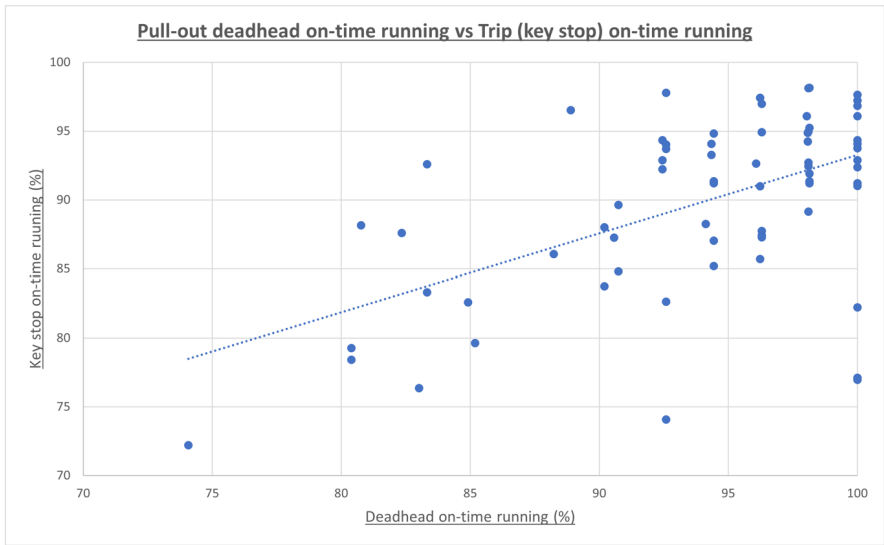
15 For each of the twenty-three pull-out deadhead routes, the running time difference at the first stop
 16 was extracted for every pull-out deadhead that occurred over the observation period from 1 June 2023 to
 17 31 August 2023. The same parameters were applied to include only those pull-out deadheads occurring
 18 during the school term and on weekdays. To extract the pull-out deadheads associated with each pull-out
 19 deadhead route from NetBI, the shift number was used. The number of observations for each pull-out
 20 deadhead route varied depending on the number of shifts associated with the pull-out deadhead route. To
 21 match the conditions used to calculate the on-time running percentage, a filter was applied to exclude all
 22 stops on any uncompleted trip and any unsighted or untimed stops on a completed trip. Descriptive
 23 statistical analysis of the running time difference observations for each deadhead location was completed.
 24 The on-time running percentage for each deadhead location was also calculated so that an assessment of
 25 the descriptive statistics in relation to the deadhead performance could be made.

26 **RESULTS AND DISCUSSION**

27
 28 **Aggregate Analysis**

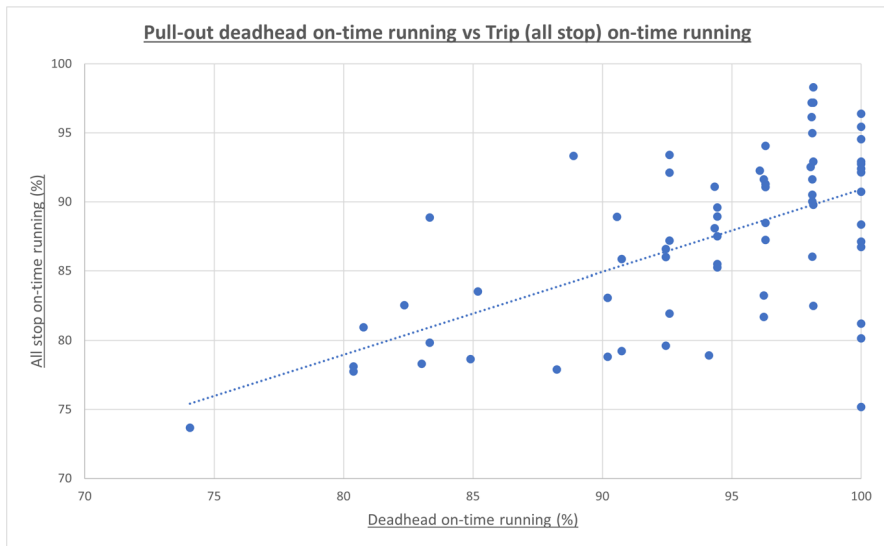
29 The results of the linear regression models are presented in Figure 4. There is a positive correlation
 30 between the pull-out deadhead on-time running percentage and the on-time running percentage of the
 31 subsequent trip emerging from the first stop. As described earlier, two models were developed comparing
 32 pull-out deadhead reliability against trip reliability for key stops (Figure 4 (a)) and for all stops (Figure 4
 33 (b)). Both models have R-squared values that are less than 0.4, which suggests that further data is required
 34 to define a statistically significant model to predict on time running reliability from collecting pull-out
 35 deadhead data. The “all-stop” model has a marginally higher R-squared value, most likely associated with
 36 the greater number of observations used to generate the model. It is also important to note the dispersion
 37 of data across the vertical axis (for a corresponding deadhead on-time running percentage) is associated
 38 with a single first stop being a common origin for multiple routes.

1 The correlation coefficients of both models are above 0.5 and each had p-values considerably less
 2 than 0.05, indicating that with at least 95% confidence there is a positive correlation between the
 3 independent and dependent variables. Therefore, the reliability of the trip following the pull-out deadhead
 4 was impacted by the reliability of the pull-out deadhead for the case study data considered. Consequently,
 5 by improving pre-trip reliability, the reliability of the whole trip can be improved. This concept can be
 6 further illustrated by removing all pull-out deadhead on-time running observations that fell below 90% in
 7 Figure 4. By doing so no correlation between on-time running percentage of the deadhead and the on-time
 8 running percentage of the whole trip would exist.
 9



Statistic	Value
R-squared	0.296
Correlation Coefficient	0.544
P-Value	<0.001
Constant	36.275

(a)



Statistic	Value
R-squared	0.356
Correlation Coefficient	0.597
P-Value	<0.001
Constant	31.224

(b)

10 **Figure 4: Linear regression results relating pull-out deadhead on-time running percentage and (a)**
 11 **trip on-time running percentage considering key stops as well as (b) trip on-time running**
 12 **percentage considering all-stops.**
 13
 14

1 However, a key limitation of this study is the lack of access to additional operational data that
 2 could better explain the variation in trip reliability, particularly as deadhead on-time running approaches
 3 100%. Factors such as intersection delays, boarding and alighting times, dwell time variability were not
 4 captured in the data acquisition but are likely to contribute to the observed dispersion in on-time running
 5 percentages. Future research should incorporate more detailed operational variables and explore non-
 6 linear or multi-variable models to offer a deeper understanding of the relationship with pull-out
 7 deadheads.

8 Despite these limitations, the correlation analysis provides valuable insights into the relationship
 9 between pull-out deadhead reliability and subsequent trip reliability, highlighting an important operational
 10 consideration for improving service performance. However, while the findings suggest that improving
 11 pre-trip reliability can enhance trip reliability, further research is needed to determine its causal impact
 12 relative to other factors.

13 **Disaggregate Analysis**

14 On-time running is determined using running time difference for each “first stop” in the data set.
 15 Therefore, a descriptive statistical analysis of running time difference was conducted to understand
 16 context-based performance at a disaggregate level, as summarized in Table 2.
 17
 18

19 **Table 2 Descriptive statistical analysis for running time difference observations at each first stop**
 20 **location.**

First Stop Location	Total observations	On-time running (%)	Earliest departure (seconds)	Latest departure (seconds)	Range (seconds)	Median (seconds)	Mean (seconds)	Standard deviation (seconds)	Kurtosis	Skewness
Alexandra Hills, Burwood Rd	159	91.8	-39	805	844	82	122	132	5.83	1.99
Bunker Rd at High St, Stop A	107	95.3	-6	508	514	79	93	98	5.82	2.12
Capalaba Park 'n' Ride, Platform 1	105	93.3	-5	811	816	70	111	117	12.06	2.78
Capalaba station Stop A	320	98.4	-60	661	721	22	45	80	17.65	3.56
Capalaba station Stop C	101	97.0	-145	435	580	14	37	71	13.82	2.99
Capalaba station Stop D	54	85.2	-11	693	704	75	115	149	3.67	1.92
Capalaba, Lyndon Rd	108	99.1	-20	319	339	63	84	72	0.57	1.02
Carindale Interchange, Stop J	424	95.5	-31	745	776	59	90	101	10.87	2.82
Cleveland Shopping Centre	269	87.0	-30	887	917	74	136	160	5.26	2.14
Cleveland Station	108	98.2	-254	308	562	43	52	69	4.65	0.39
Cleveland, Sunshine Dr	103	91.4	-17	623	640	51	91	123	6.62	2.54

First Stop Location	Total observations	On-time running (%)	Earliest departure (seconds)	Latest departure (seconds)	Range (seconds)	Median (seconds)	Mean (seconds)	Standard deviation (seconds)	Kurtosis	Skewness
Eastside Village Shops	54	100.0	4	170	166	29	49	44	0.13	1.16
Kiwi St near Campbell Rd	106	97.2	-592	391	983	16	27	85	30.06	-2.39
Mount Cotton, Papaya St	53	98.1	-4	387	391	35	58	63	14.69	3.37
Ormiston, Rose St	157	94.3	-48	754	802	55	95	120	9.17	2.70
Point O'Halloran Rd near Orana St	156	85.3	-291	716	1007	54	85	151	5.31	1.74
Redland Bay Marina	470	96.6	-53	737	790	63	90	99	12.35	2.87
Redland Hospital	105	90.5	-52	758	810	87	127	134	4.68	1.87
Shoreline Ave near Hydrangea Ave	266	98.1	-53	676	729	41	62	83	22.32	3.79
Thorncroft, Thorncroft Rd	212	93.9	-203	575	778	70	98	103	3.71	1.66
Toondah Harbour	54	94.4	2	394	392	35	68	83	6.25	2.47
Victoria Point Central Platform 1	105	97.1	-28	367	395	30	61	77	4.04	2.00
Victoria Point Jetty	318	91.8	-4	870	874	89	128	141	8.11	2.58

1
2 Total observations measured the number of instances, in line with the conditions set out in the
3 method, that the pull-deadhead occurred over the data collection period. Each pull-out deadhead
4 comprised of a different number of shifts and therefore produced a different number of observations. It is
5 important to note that in addition to the conditions set out in the method that excluded invalid
6 observations, outliers were also removed during the analysis process. Outliers were defined as those
7 instances where running time difference exceeded 15 minutes following the scheduled departure time.

8 The on-time running percentage for each pull-out deadhead was calculated using the running time
9 difference observations. The number of running time difference observations within the on-time bounds
10 were counted and divided by the total numbers of observations to get the on-time running percentage.
11 Capalaba Station Stop D had the worst on-time running percentage at 85.19%. The best on-time running
12 percentage was 100% for Eastside Village Shops. Approximately half of the deadheads had on-time
13 running percentages greater than 95%. Overall, the pull-out deadheads for each stop could be considered
14 reliable as the on-time running percentages exceed 85%.

15

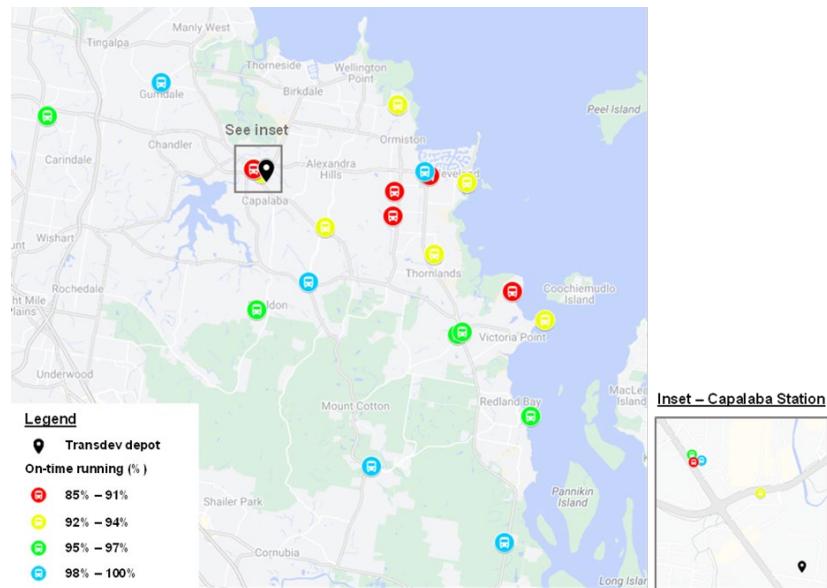


Figure 5 Spatial representation of the first stop location and the corresponding on-time running percentage.

Figure 5 presents the locations of each first stop relative to the Transdev depot. Each stop is coloured based on the on-time running performance. This spatial visualization was used to identify if any geographic features could explain differences in performance. Road hierarchy, land use and whether certain roads were influencing deadhead reliability were all considered, however little similarity between deadhead performance and these features was found. Those stops located further away from the depot were generally more reliable than those closer to the depot. This could be attributed to schedulers assigning additional travel time to those stops, as greater variability is expected over longer distances. Although there was a tendency for those stops further away to be more reliable than those closer to the depot, a large degree of variability still existed. This was exhibited for the three stops located at Capalaba Station. Capalaba Station Stop D was the worst performing deadhead of all 23 deadheads but was located within 50m radius of Capalaba Station Stop A and C which had on-time running percentages of 98.44% and 97.03% respectively.

The earliest departure and latest departure, shown in Table 2 reported the largest running time differences occurring before the scheduled time and after the scheduled time respectively. The range presents the difference between the earliest and latest departure time. Intuitively, the pull-out deadheads with larger ranges tended to have lower on-time running percentages and those with smaller ranges mostly had higher on-time running percentages.

The mean, median, standard deviation, skewness and kurtosis metrics are consistent with the on-time running performance of each first stop. In general, the distributions were positively skewed, suggesting that when a bus was not on-time, the service was late rather than early. Table 3 presents a comparison between on-time running percentage and standard deviation of the running time differences at each first stop. Lower standard deviations indicate more consistent pull-out deadhead travel times and consequently higher percentages of on-time running at the first stop. This outcome is consistent with existing travel time reliability literature and practice that use standard deviation of travel time as a measure of reliability (1), validating the process of the assessment.

Like the limitations discussed previously, future research is necessary to compare the first-stop performance against the prevailing traffic conditions, which can be completed by collected corresponding travel time and delay data for the routes and stops considered. This analysis could provide greater insights regarding the reliability trends and patterns identified at the first stop locations.

1 **Table 3 Ordered comparison of on-time running percentage and standard deviation for all first**
 2 **stop locations**

First stop Location	On-time running (%)	Standard Deviation (seconds)
Eastside Village Shops	100.00%	44
Capalaba, Lyndon Rd	99.07%	72
Capalaba Station, Stop A	98.44%	80
Cleveland Station	98.15%	69
Shoreline Ave near Hydrangea Ave	98.12%	83
Mount Cotton, Papaya St	98.11%	63
Kiwi St near Campbell Rd	97.17%	85
Victoria Point Central Platform 1	97.14%	77
Capalaba Station, Stop C	97.03%	71
Redland Bay Marina	96.60%	99
Carindale Interchange, J	95.52%	101
Bunker Rd at High St Stop A	95.33%	98
Toondah Harbour	94.44%	83
Ormiston, Rose St	94.27%	120
Thornlands, Thornlands Rd	93.87%	103
Capalaba Park 'n' Ride, Platform 1	93.33%	117
Alexandra Hills, Burwood Rd	91.82%	132
Victoria Point Jetty	91.82%	141
Cleveland, Sunshine Dr	91.35%	123
Redland Hospital	90.48%	134
Cleveland Shopping Centre	86.99%	160
Point O'Halloran Rd near Orana St	85.26%	151
Capalaba station, Stop D	85.19%	149

3
 4 **Recommendations**

5 The analysis presented in this paper provides evidence that managing deadheads is integral to providing a
 6 reliable service. From a practical perspective, ensuring reliability for the deadhead would also be easier
 7 for a transport operator as in-service reliability is affected by additional factors associated with passengers
 8 boarding and alighting. There have been several suggestions made throughout literature to improve in-
 9 service reliability such as traffic signal priority as well as enhanced data collection and real-time
 10 monitoring through intelligent transportation systems and route optimization (24-26). It is possible that it
 11 may also be beneficial to extend these strategies to improve the reliability of the pull-out deadhead. The
 12 descriptive analysis presented in Table 2 can guide the prioritization of such improvements. Locations
 13 such as Cleveland Shopping Centre, which exhibits the widest variability, with a range of 917 seconds
 14 and standard deviation of 160 seconds can be identified and used as a point of reference to adjust
 15 schedules and enhance the system.

16 Furthermore, to directly manage deadheads, public transport authorities could place greater
 17 resourcing and operational adjustments on deadhead routes identified as critical to overall service
 18 performance. For example, in the case study presented, the analysis indicated the variable on-time
 19 running performance at Capalaba Station, a key interchange point in the Brisbane network. The 3 stops at
 20 this station have on-time running percentages that vary from above 98% to 85% and standard deviations
 21 of travel time that vary from 80 seconds to 149 seconds (referring to Table 3). Though these stops are

1 located within the same vicinity, the deadhead performance varies significantly which ultimately affects
2 public perceptions of the services provided. Authorities could adjust schedules to ensure deadheads are
3 consistent at different stops of a single location by isolating routes. In addition, operators can explicitly
4 measure deadhead travel times to ensure allocated deadheads are achievable in practice. Once empirical
5 measurements are gathered the timetable could be adjusted, which in turn could improve overall network
6 performance. Further research and investigation are required to quantify the impacts and effectiveness of
7 this type of strategy.

8 Finally, as shown by the lack of literature and attention to the topic, drivers may not be aware of
9 the importance of the deadhead. Thus, future driver education and training programs could include
10 emphasis on the criticality of achieving reliable deadheads and authorities can provide feedback to drivers
11 with performance metrics, such as the ones developed in this research.
12

13 **CONCLUDING REMARKS**

14 Travel time reliability significantly influences commuter behavior, affecting their choice of travel mode,
15 route, and time, which in turn impacts the overall function of the transport network. Authorities have
16 started evaluating transport operators based on travel time reliability, but the reliability of bus deadheads,
17 specifically the pull-out deadhead from depot to first stop, has been overlooked. This study addressed this
18 gap by analyzing bus data from Transdev in Brisbane, Australia, focusing on the reliability of pull-out
19 deadheads across 23 first stops.

20 The importance of improving deadhead reliability was made evident through the aggregate data
21 analysis that indicated a positive correlation between deadhead reliability and trip reliability (correlation
22 coefficient of between +0.54 and +0.59). The disaggregate analysis was also consistent with the aggregate
23 analysis, clearly highlighting the positive correlation. Overall, the pull-out deadheads at each stop
24 demonstrated reliability, with on-time running percentages consistently exceeding 85%. Around half the
25 first stops had routes that had on-time running percentages above 95%. This analysis, however, did not
26 reveal any significant trends or patterns when comparing the deadhead route or surrounding land uses,
27 outside of an overarching trend that first stops located further away from the depot tended to have greater
28 on-time running percentages.

29 Additional data collection could provide greater insights into the research topic. This study used
30 the running time difference at the first stop as the metric for deadhead performance. Instances of early
31 running could be concealed using this measure as drivers may arrive at the stop early and wait before
32 departing on time. While late running was the focus of this study as it is inherently more problematic,
33 early running presents an opportunity to use resources more efficiently and expanding the framework to
34 capture early running would be beneficial for operators. This could be done by recording the deadhead
35 travel times, which would provide a more accurate depiction of deadhead performance. In addition, to
36 define context-based solutions and recommendations it is also key to gain access to detailed data about
37 the route (traffic signal data, traffic flow and speed data) as well as surrounding land uses.

38 However, this case study presents a clear demonstration of the importance of measuring and
39 evaluating deadheads to manage bus operations. In addition, the study adds to the limited research
40 concerning deadheads by developing a methodology to compare deadhead performance with on-time
41 running performance leveraging real-world bus scheduling and performance data. Future research could
42 advance this approach to evaluation of bus performance by completing more detailed travel time data
43 analysis. The methodology developed in the study could potentially be applied to evaluate other public
44 and on-demand modes of transport that are present on road networks, like light rail systems and on-
45 demand bus routes.

46 Finally, the results of the case study suggest that to enhance bus performance, transport operators
47 should develop and refine methods to analyze deadhead reliability. Continuous data collection and
48 analysis will improve deadhead predictions and contribute to a more reliable transport network.

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5

6 **AUTHOR CONTRIBUTIONS**

7 The authors confirm contribution to the paper as follows: study conception and design: Felea, A., Sinclair,
8 J., Wijayaratna, K.P.; data collection: Felea, A., Sinclair, J.; analysis and interpretation of results: Felea,
9 A., Sinclair, J., Wijayaratna, K.P.; draft manuscript preparation: Felea, A., Sinclair, J., Wijayaratna, K.P.
10 All authors reviewed the results and approved the final version of the manuscript.

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