Analysing Bus Transit On-Time Performance at the Stop Level Using AVL Data

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Abstract: Throughout the world the reliability of public transport systems is constantly under review. Questions of reliability are particularly applicable to bus services where they share road space with other vehicles. This study used graphical and statistical approaches to assess the reliability of services composing two key route groups in Adelaide. Geographic Information System (GIS) methods were used to locate the service information along the corridor. Using Automated Vehicle Location (AVL) data in conjunction with the published timetables, bus reliability measures were developed. It was found that the majority of services departed within the required tolerances of between 1 minute early and 5 minutes late; however there are significant departures from this trend. Finally, the analysis suggests that the passenger's boardings and traffic congestion are the key factors that are contributing to the variations in on-time performance of buses at the stop level.

Keywords: Bus Service Reliability, AVL data, Adelaide, GIS, Public transport

1. INTRODUCTION

The aim of this study is to investigate the performance of busses as they travel along two key corridors defined by the South Australian Government Department of Transport. This will be undertaken through analysis of the busses location with time compared to that idealized in the timetable. The primary objective of this research was to demonstrate the usefulness of Automatic Vehicle location (AVL) data in understanding and measuring reliability of bus services at the stop level.

Throughout the world the reliability of public transport systems is constantly under review. In recent years the widespread prevalence of privately owned motor vehicles and people's quickening pace of life is increasing the importance of public transport service reliability and on time performance. This is potentially of concern for bus services where they are sharing road space with increasing numbers of other vehicles. The Public Transport System in Adelaide has been plagued with unreliable services for years.

The Department of Planning, Transport and Infrastructure (DPTI) is South Australia's main transport body. Adelaide Metro is the body that manages Adelaide's public transport system, run by the Public Transport Services (PTS) Division of DPTI. PTS's routes across Adelaide are run by a variety of vehicles; Buses, Trams and Trains. The bus routes particularly are prone to the effects of congestion across city links and near-CBD suburban arterial and connector roads.

The South Australian community is encouraged to use public transport, especially for regular trips such as the daily commute. However the South Australian public sector has found that many commuters are boycotting public bus services, reducing the total number of commuters using public transport (Kelton, 2012). The initial boardings in South Australia for metropolitan public transport have risen incrementally each year from 2000 to 2009 up to 52.4 million in the 2009-2010 financial year (DPTI, 2011). However, the DPTI Annual Report for 2010-11 (DPTI, 2011) states that in 2010-11 initial boardings are reduced by 2.2 percent to 51.25 million. One cause of this is the perceived unreliability of these services. Buses often do not meet the advertised service times, with many services running a quarter or even half an hour later than advertised, or in some cases, not arriving at all (Kelton, 2012).

Public transport in South Australia is far from reaching its full potential. As measured by the Australian Bureau of Statistics (ABS, 2009) only 14.4% of adults were using public transport for their usual trip to work or study in 2006. The use of public transport between 1996 and 2006 only increased by 18% in Adelaide, dwarfed by increases of 35% and 22% in Melbourne and Brisbane respectively (Statistics, 2009).

According to the Adelaide Metro website (Adelaide Metro, 2012), the quality of South Australian public transport could do with some improvement. The Department of Planning, Transport and Infrastructure (DPTI) monitors the performance of the bus contractors to make sure that the quality of service (on-time running and reliability) meets community needs and demands. DPTI defines service as ‘on-time’ and ‘reliable’ if the bus departs no more than 59 seconds before and no more than 4 minutes and 59 seconds after the time published in the timetable (Adelaide Metro, 2012). Even with 6 minutes flexibility, on an average only 67% of bus drivers were able to provide ‘on-time running’ performance from January to March 2012. This lack of reliability for public transport services is a big concern for both Government and Community.

Several approaches have been made in the past to improve reliability of bus services in Adelaide, including; fining bus companies (contractors) to try to improve their performances, continuously changing and reviewing time tables to suit the annual road conditions, fitting buses with Global Position System (GPS) devices, and auditing buses to determine which bus routes to focus attention on. Though the widespread adoption of automated vehicle location (AVL) systems are helping many public transport agencies all over the world, to date there has been little effort to evaluate public transport performance using such data collected in Adelaide, the capital city of South Australia.

2. LITERATURE REVIEW

In 2004 Stanley & Stanley (2004) conducted a study that showed that transport services affect social exclusion and personal wellbeing in regional communities. Given this link between public transport services and community wellbeing, increasing mobility becomes a significant goal of both local governments and public transport providers.

The term reliability itself has different interpretations for different groups and indeed various studies have associated reliability with different aspects of public transportation systems. Some studies relate reliability to consistency in journey travel time, others associate reliability with adherence to time tables, maintaining headway regularity, passenger waiting time at stops, ease of catching a bus or the proportion of passengers having to wait for the next bus due to inadequate capacity (Liu and Sinha, 2007). The Federal Highway Administration (2009) names reliability as “the consistency or dependability in travel times, as measured day-to-day and/or across different times of the day”. However (Lyman and Bertini, 2008) defines travel time reliability as the amount of congestion users experience at a given time. A network that provides a high level of service will also provide a high level of travel time reliability (Lyman and Bertini, 2008)

Transport service reliability has clearly been defined in a variety of ways. Common to many of these measures is the service timetable, making this assumption, reliability can be defined by on-time/punctuality performance and headway evenness (Mosca and Zito, 2011). Simply, in a few words, reliability for our purposes was defined as a measure of how often the services were punctual.

To assess reliability of bus services in Beijing an investigation was conducted by Chen *et al* (2009) to assess reliability in terms of two key performance parameters PIR (punctuality index based on routes) and DIS (deviation index based on stops).

Table 1: Summary of performance parameters used by Chen *et al*, (2009)

Performance parameter	Bus reliability assessment method	Level	Required data	Assessment objective
PIR	Route punctuality	Route	Terminal travel time	Route and network assessment
DIS	Stop deviation	Stop	Headway deviation boardings	Stop route and network assessment

This study showed that service reliability declined with the increase of the distance from the stop to the origin terminal. This is because more random factors impacting reliability may exist as a route's distance increases. This becomes particularly noticeable when the distance from a stop to the origin terminal is greater than 30 km.

A research paper (Liu and Sinha, 2007) investigates the measures used to assess reliability such as growth in traffic congestion, growth in passenger travel and improving the ticketing system of an urban bus network. This investigation was conducted using models of bus operation, passenger arrival and boarding for buses within a network model of general traffic. A simulation model is used to help understand the causes and process of occurrence of unreliability and to study the impacts of possible scenarios such as increased congestion, rise in passenger demand, and reduction in" per passenger boarding time" on the reliability of the test-route. Results showed that, increase in traffic congestion reduced the travel time reliability; increase in passenger demand resulted in significant increase in travel time, and reduced boarding time led to reduced travel time and subsequently increased reliability.

Closely spaced intersections along a bus route impact upon the reliability performance of that service. Carrasco (2011) conducted research into the reliability of travel times along a busy cross town bus route with 8 busses an hour in Zurich. The probability of delays both variable and systematic was observed to be as expected. This probability increased markedly around those sections of the bus route with higher activity levels and was reduced where more measures such as bus (& tram) lanes were in place to assist. Vehicle pre-emption of traffic signals, requiring highly accurate GPS data to be efficient, was shown to significantly reduce delays and variance in travel times. In the Swiss case the worst average discrepancies from the schedule are just over 3 minutes. In the Australian city of Melbourne such systems are in place but only activated when the vehicle is already late according to the (PTUA, 2009). This is an underutilization of the resources available to them and greater efficiencies could be achieved if this wasn't the case.

Liu and Sinha (2007) analyzed bus reliability in the town of York, England. In order to visualize the happenings, plots of the bus's progression along the section of the route in question were generated. This allowed them to analyze the headway variation and comment on the schedule maintenance, oddly the scheduled progression was not shown except for an indicative early morning timetable.

These past projects have shown that there are different methods to assess reliability of the bus service in route or network levels some recommend using traffic modeling with some scenarios to find the effect of variable on the reliability of the service. For example Liu and Sinha (2007) states that using micro-simulation is an easier, faster, cheaper and feasible way to test different scenarios and can also assess effectiveness of some measures which may be impossible to be conducted in the field survey. But this method needs a traffic model for the route or the network which is not available for this project. Other papers recommend using statistical analysis of AVL and APC data to assess and compare real-time data with scheduled timetables, which is more feasible for this project.

3.1. Study Area

This study used AVL data collected by DPTI on two important corridors serving the Adelaide CBD. These are the East, West corridor from stop 22 Henley Beach road through to stop 18 the Parade, and Glen Osmond Road corridor linking the South Eastern Freeway to the CBD. These corridors are shown in figure 1 where the east west corridor is marked in green and Glen Osmond, blue. The results of this analysis will provide the planning agency with information for further improving bus service reliability.

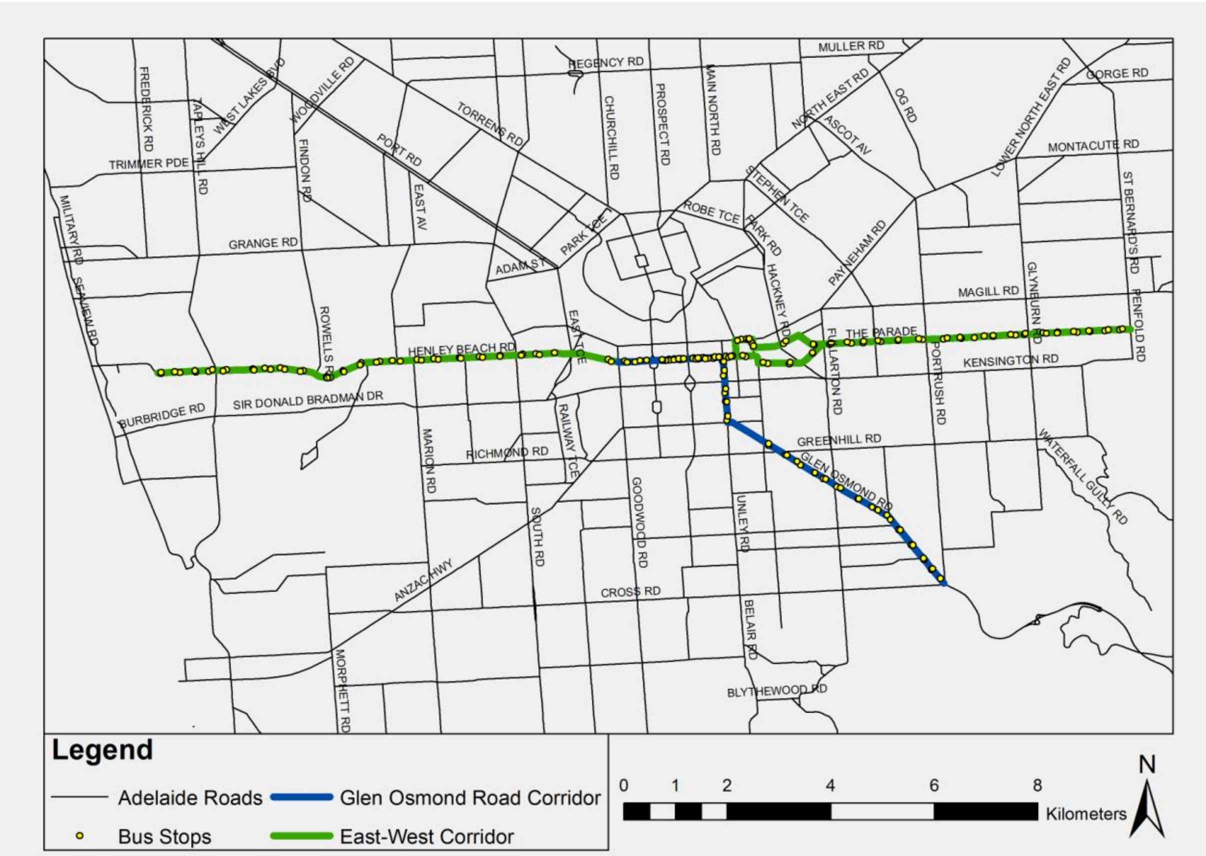

Figure 1. Corridors selected for this study

This study used graphical and statistical approaches to assess the reliability of the services. Using Geographic Information System, GIS methods to locate the AVL and timetable information along the route it became possible to compare the recorded time a service passed a location with that idealized in its timetable. From this comparison bus reliability measures were developed.

The analysis derived service performance using two techniques. The first of these is an analysis of the progress of each bus service along the corridor. This produced a plot of the bus's distance along the route with increasing time. Secondly total travel time along the corridors from end to end was compared to the timetabled times over the course of a day to investigate traffic congestion and the scale of the inevitable fluctuations.

4. DATA

4.1 AVL data issues

An AVL (Automated Vehicle Locator) system provides virtually instant bus location data for fleet management departments. An AVL system consists of a GPS device, internet communication link and software system to store data and/or monitor bus services on a microscopic level (route) or macroscopic level (network). Adelaide bus service providers are currently using AVL technology with GPS devices to transmit the location of the bus at specified time intervals up to (20 seconds), for fleet management purposes. Global positioning (GPS) data will always have errors; it is just a matter of scale. Sometimes these errors are within acceptable tolerances, ±15 meters, however unacceptable errors e.g. ±40 meters occur for a variety of reasons such as whether or the effect of trees and tall buildings (mirror effect). An earlier study of AVL data from busses conducted by Mosca and Zito, 2011 found that the largest GPS accuracy errors in the Adelaide region occurred in the CBD. This is where most of the tall buildings are concentrated. In residential suburbs performance is in the same range expected from a theoretical point of view, however as soon as the receiver is within an "urban canyon", that is, near high rise buildings, the accuracy and reliability degrades. In this case, as figure 2 shows more than 20% of the time, accuracy errors larger than 15 m occur. On rare occasions these errors can reach up to 40 metres when a location is recorded within the central Adelaide area according to Mosca and Zito , 2011.

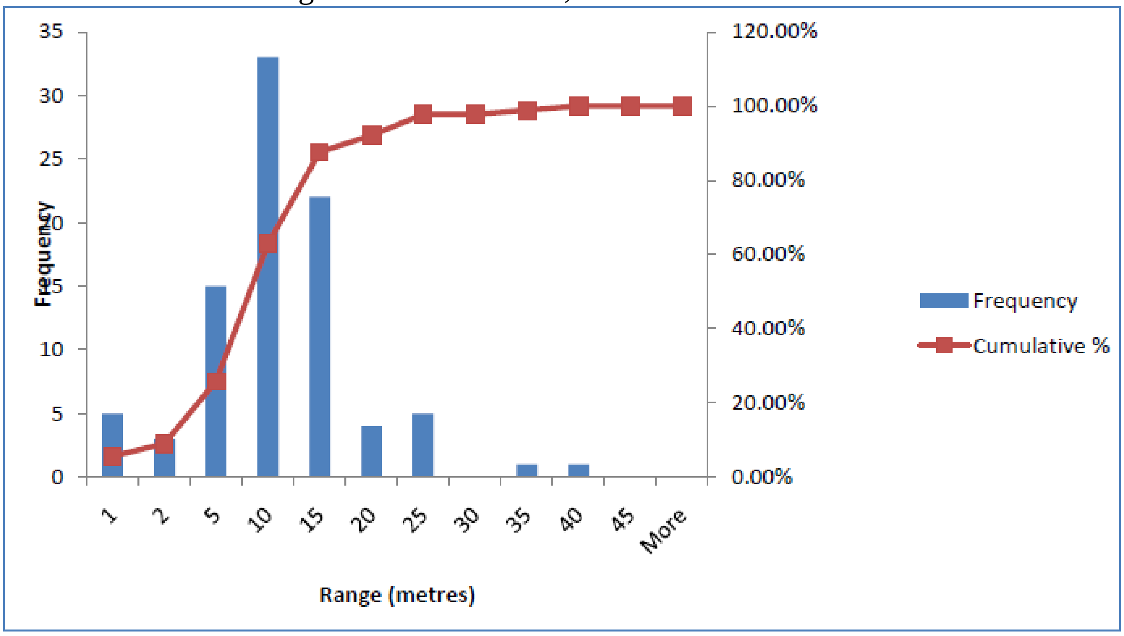

Figure 2. GPS error distribution on route 132 Adelaide CBD (Mosca and Zito, 2011)

Accurate and reliable results require accurate and reliable data input, so GPS data should have minimum errors to be efficient in the fleet management process. Mosca and Zito, 2011 also emphasized that accurate and reliable Automatic Vehicle Location systems play a major role in enabling fleet management systems (FMS) to achieve better planning and scheduling outcomes and hence provide a positive perception of the service. Although Mosca and Zito (2011) have recommended using other sensors to supplement the GPS system within the CBD it was decided that the currently achieved level of accuracy was sufficient for this investigation.

After consulting with the department of transport (DPTI) staff, the research team shortlisted two important corridors for testing the on-time performance of buses, with the idea that these selected routes will form the basis for understanding the bus service reliability issues across many other routes. Likewise the analysis of a representative day highlights the periods where issues may occur. With Adelaide Metro setting identical timetables for all days of the working week (excluding public holidays) Monday was chosen as the representative weekday. Although the boardings and traffic conditions are likely to be affected slightly because Monday is adjacent to the weekend it was decided that these influences were unlikely to have a noticeable effect on the results. Limited travel time analysis conducted on other days (Tuesday and Friday) also confirmed this assumption to be a valid one.

4.2 Data Processing

The data was originally recorded by DPTI and forward to UniSA for the purposes of this study. The data was in several database tables formatted in a .csv format. The data contained in these files consisted of a series of records containing the status and location of a bus at a particular time. These records were generated with a frequency of between 15 and 20 seconds for each bus.

The initial validity of the bus AVL data was investigated by selecting a number of sample services and plotting their progression with time on a map. To check that the correct route information was recorded the paths being taken by these vehicles were compared to the routes allocated in the timetable. After being sure that these progressions were occurring in a logical way and along the correct route no data cleaning was undertaken.

The timetables were obtained in the same format as is supplied to Google for their GIS application. This was a complete but disjointed record of what was scheduled to happen over the entire Adelaide Metro network. Of the nine files containing the data for the Google feed, two were deemed to have relevant information to the team. The first contained the positions and names of the stops and the second contained the schedules and other information pertaining to individual services at these stops. Once imported into a database the records within these files were combined (joined) using the common stop_id field. The resulting file provided a timetable that identified all the services with a unique service ID. The addition of a lookup column to equate the service ID numbers assigned to the Google data to those contained in the AVL data was the final step before this was a complete and useful timetable data base.

At this point both the timetable and bus service data sets were imported into ArcGIS to facilitate spatial correlation. The first step was to remove all the bus stops not applicable to the corridors in question. This was done by selecting all the bus stops within a 100m radius of the roads of our corridor and removing the rest. The same method was applied to the bus data to reduce the database size, removing the portions of journeys outside the corridor of our study. A large radius (100m) was chosen to eliminate the possibility of losing relevant data. Any remaining irrelevant data remaining would not pose a problem and was removed later in the data preparation process.

It was planned to append the bus stop information to every recorded bus location within a radius of the stop and then remove all those records with differing service ids. However after initial trials a reliable radius could not be established. If the trial radius was too large the program would crash mid-way through the process. Reducing the radius to avoid this error had the consequence that significant amounts of useful data fell outside the resulting circles. Eventually a less resource intensive method of combining the databases was found, the software could successfully join all those records with the same service id. However this resulting file was huge and unwieldy as it contained a record for every stop a service passed linked to every data point for that service. To get some idea of the scale of this, a single bus service records its location every 15-20 seconds over a distance of up to 15 kilometers, passing more than 30 stops! Clearly some reduction by location was still required to leave just the closest AVL points around each bus stop.

After much thought it was decided that the distance between the bus and the stop could be calculated for each of these records. The method used the difference between the latitude and longitude values. Because one minute of latitude and longitude do not represent the same distance a conversion to meters was first employed. For latitude the relationship used was, one minute of latitude equals one nautical mile or 1852 metres. Where longitude was concerned the conversion was a little more complex as the distance represented by one minute varies depending on your latitude. From a navigational chart of the Adelaide area it was determined that 1 minute of longitude was the same distance as 0.82576 minutes of latitude or 1529 meters. Finally a linier distance, as the crow flies, could be calculated and those exceeding 80m were removed.

80m was chosen as the filter distance because this was sufficient radius to capture almost all of the services as they passed each stop while not introducing too much uncertainty. If this radius was too big a bus could be recorded as early and therefore unreliable when this wasn't the case. The frequency of the data generation, at most every 20 seconds, means that in the event of a single point up to 80 m away the maximum difference between this recorded time and the actual time at the stop must be less than 10 seconds. It was regarded as unlikely that a bus would be missed at a stop entirely needing to average higher than 30 kilometers per hour to cover the 160m diameter in 20 seconds. The creation of a distance field between the bus and the stop meant that if a bus was travelling slowly and left many points those close to the stop could be isolated, further reducing any errors. For some analysis a single point was required and the specific departure time was isolated using a macro within Excel. This departure record was defined by finding the closest record to the stop and in the event of stationary busses, as may be encountered if a driver is waiting to catch up with the timetable, the value with the latest time was selected to represent the departure time.

The preparation of the data was a time consuming but important step and while every effort was made to ensure the final data's fidelity it is possible some uncertainties may still have been introduced.

5. ANALYSIS

5.1 Introduction

The analysis of travel time variability was undertaken spatially to determine not just the extent of delays at the timetabled locations but also to gain insight into the locations of cause and propagation with distance along the entire route. The spatial analysis used bus location data obtained from the DPTI and was undertaken using Esri's ARC GIS software.

The analysis required calculation of two types of reliability measure at the bus stop level. The first of these is a headway analysis where the progress of each bus service along the corridor is plotted. Unlike the York study conducted by Liu & Sinha (2007) each plot was accompanied by its idealised timetable trajectory. This gives us a picture of deviation patterns and helps us locate the origin of any issues well before they reach the scale defined as unreliable by DPTI. Finally travel time along the corridors was compared to the timetabled times over the course of a day to investigate traffic congestion and the scale of the inevitable fluctuations. The most interesting results of these analyses are included in the next section.

5.2 Introduction to Headway and on-time performance on the East-West Corridor

Headway is defined as the difference between the first bus departure time and the next bus arrival time at that stop. On time performance at stop level is the difference between scheduled arrival and actual arrival times of a bus at a stop.

Passenger comfort increases when buses are provided regularly with maintained scheduled headways, as it minimizes the average passenger wait time at a bus stop. Unfortunately given certain conditions busses have a tendency to bunch together. These bunching decreases the headway between the busses involved but also increases the headway between the late and previous service. An Increase of headways results in a peak of passenger demand for subsequent bus services. As well as contributing to buses becoming over capacity and having to refuse potential passengers a ride this increase in loading can cause the bus to be further delayed due to the time taken for these extra people to board and alight. Overcrowded buses significantly affect customer satisfaction and perception of service quality.

A Section of the H30 route, from stop 22 on Henley Beach Road to the city centre (Figure 3) was selected for the detailed empirical observation. This route section travels along Henley Beach Road, covers 9.5 kilometers and contains 28 bus stops with a scheduled journey time of about 33 minutes during the peak period.

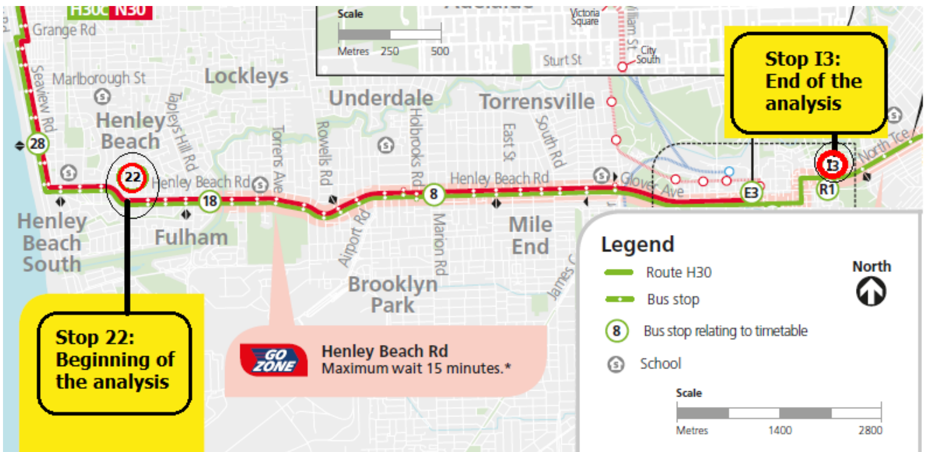

Figure 3. Selected stops of H30 route for services running towards the city centre

5.2.1 Headway and on-time performance on the East-West Corridor in Morning peak

It was recognised, using boarding data provided by Department of Planning Transport and Infrastructure, (DPTI) that for the morning peak period the predominant passenger traffic direction was from the residential areas towards the city centre.

It can be noted from the figures below that most of the actual arrival times of the H30 services (green colour) did not match the scheduled arrival times (blue colour). The difference between the scheduled and observed times was significant as it exceeded the acceptable arrival time difference (59 seconds early). The biggest variations were observed in the city centre on Currie Street. Seven out of ten services arriving on these bus stops were early, some are even up to 7 minutes early. Other variations were noted at the 8.7 kilometre mark, bus stop 18 on Henley Beach Road, where 50 % of services arrived over 5 minutes late.

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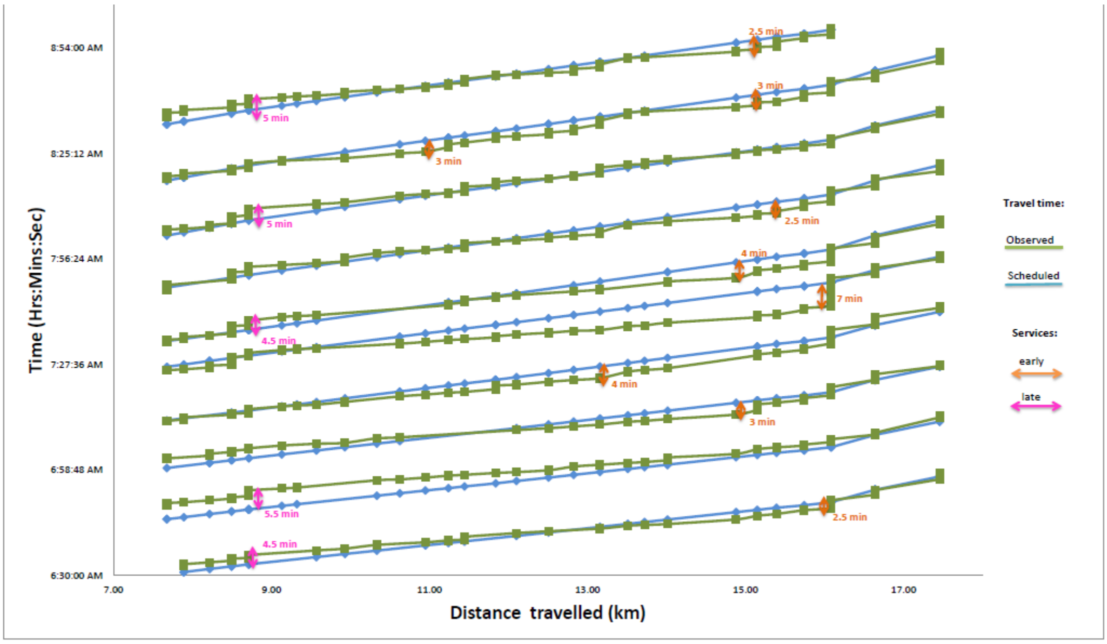

Figure 4. Recorded and Scheduled travel time vs distance for Route H30, towards the city centre in AM peak period on a typical week day (Monday)

The reasons for these unreliable arrivals during morning peak period were investigated. Firstly, boarding time calculated from ticket validation data was analysed. According to the ticket validation data provided by DPTI, bus services at stops 22, 21, 20, 19 and 18 on Henley Beach Road recorded an average of 5 validations that took an average of 20 seconds each. Because the H30 is a limited express service, after stop 18 on Henley Beach Road, no loading passengers were recorded until Currie Street in the City.

The second factor that was investigated was the traffic congestion on the selected H30 route during the morning peak. To explore if there is any significant impact from traffic congestion on service's punctuality, these results were compared to the on-time performance for a week-end (Saturday) when it is likely congestion is significantly less. The results for weekend services indicate (Figure 5) that for all services during the morning peak, observed arrival times did not exceed the required tolerance for reliability. All services recorded reliable performance by arriving no more than 59 seconds before and no more than 4 minutes and 59 seconds after the scheduled time. It must be noted that on the weekends the H30 services picked up and set down at all stops on request.

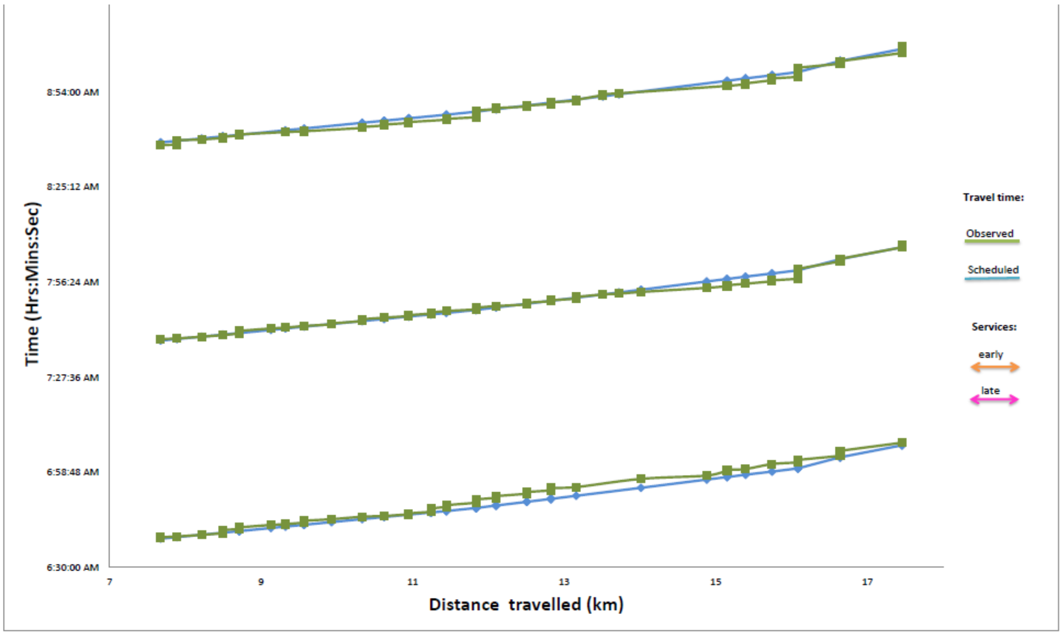

Figure 5. Recorded and Scheduled travel time vs distance for Route H30, towards the city centre in AM peak period on weekend (Saturday)

Lastly, the variations in headways were investigated. For services to have a regular headway, the trajectories should be parallel to each other, have the same gradient and a gap of 14, 15 or 16 minutes (except for one service at 7.33 am, with a scheduled headway of 7 minutes). These scheduled headways shown in Figure 6 and they can be described as regular and constant without any variations. On the other hand, Figure 7, presents observed headways that are irregular with huge variations.

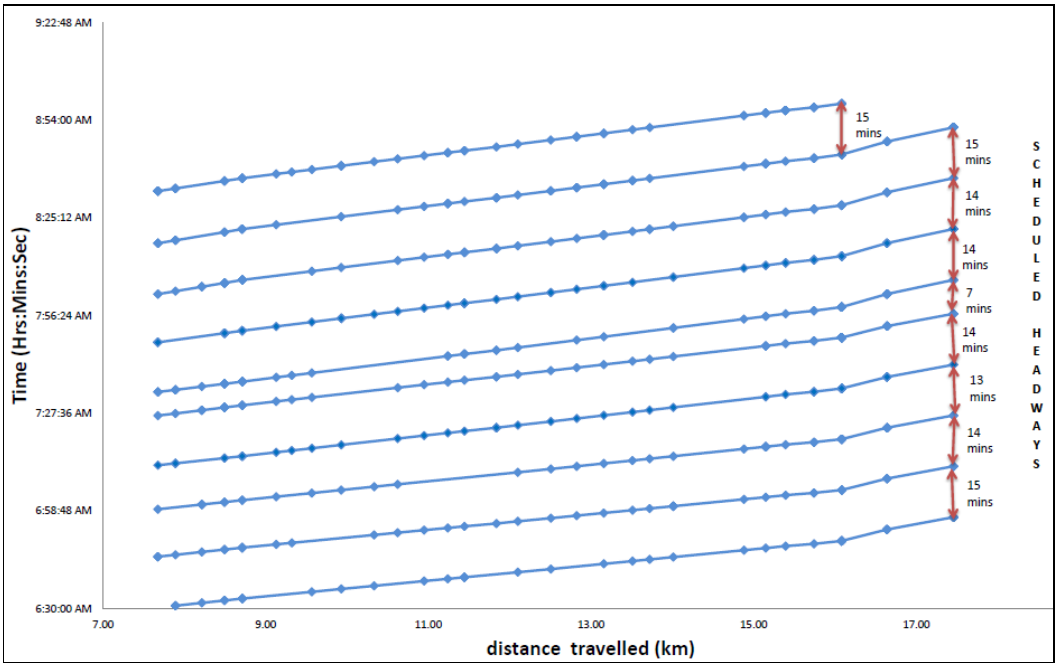

Figure 6. Scheduled headways for Route H30, towards the city centre in AM peak period

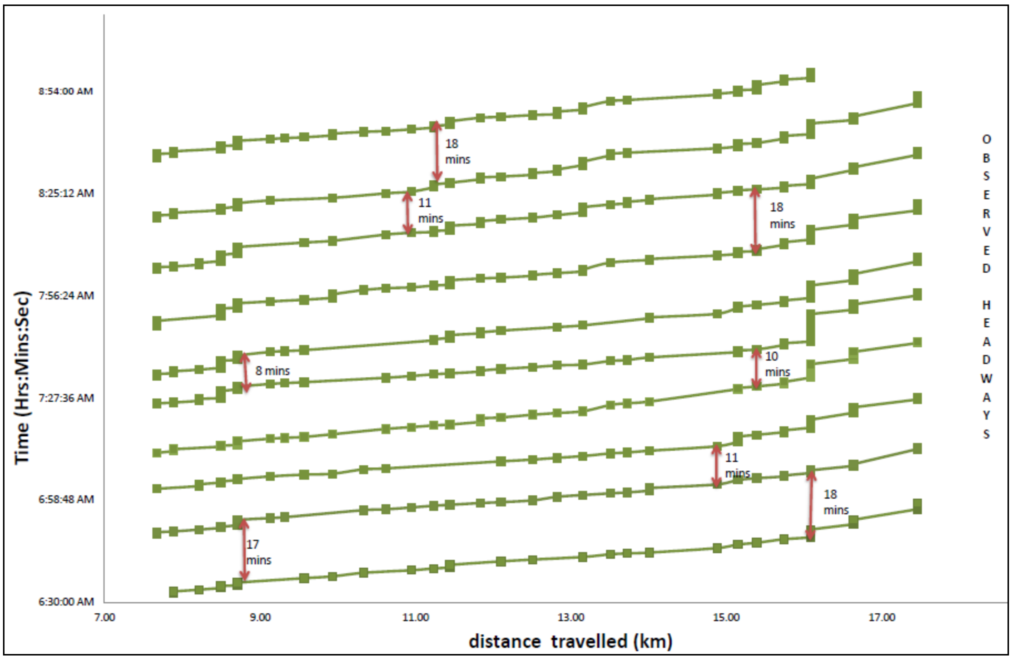

Figure 7. Observed headways for Route H30, towards the city centre in AM peak period

5.2.2. Inter-peak period for services running towards the City Centre

During the inter-peak period, (9 am to 3 pm), most of the actual arrival times matched the scheduled arrival times. The differences between the scheduled and observed arrival time did not exceed the tolerances of reliability. It was found that there were not as many boardings during inter-peak period and this is a possible reason for the increase in reliability along with an expected reduction in traffic congestion. Lastly, the variations in headways were investigated and noted that the scheduled headways were set at 30 minutes intervals. It was observed that the trajectories are parallel to each other and they have the same gradient, this is an indication that headways were regular and without any variations.

5.2.3 Afternoon Peak period (3 pm to 6pm) for services running towards Henley Beach

In the afternoon peak period, the major passenger traffic direction was from city centre towards the Western residential areas and H30 services traveling this way were considered. As in the morning period, most of the actual arrival times (green colour) shown in figure 8 did not match the scheduled arrival times (blue colour). The difference between the scheduled and observed arrival times was significant as it exceeded the reliability tolerances. When the reasons for these unreliable arrivals during the afternoon peak period were investigated, it was found that there were significant boardings in the CBD that were recorded during this time. The time used for loading passengers and ticket validation investigated and it was found that an average of 10 validations that took an average of 2 minutes occurred at each stop. After the last stop in the City until bus stop 18 on Henley Beach Road, no passenger loadings were recorded and some time was made up. As 2 minutes boarding time at each of the 7 City stops is significant, this ticket validation was classified as a contributing factor towards late arrivals at those bus stops. As with the AM period a comparison with the results from the weekend (Saturday) indicates that the traffic congestion on Monday (weekday) during the afternoon peak is a contributing factor for maintaining and propagating bus service delay along the route.

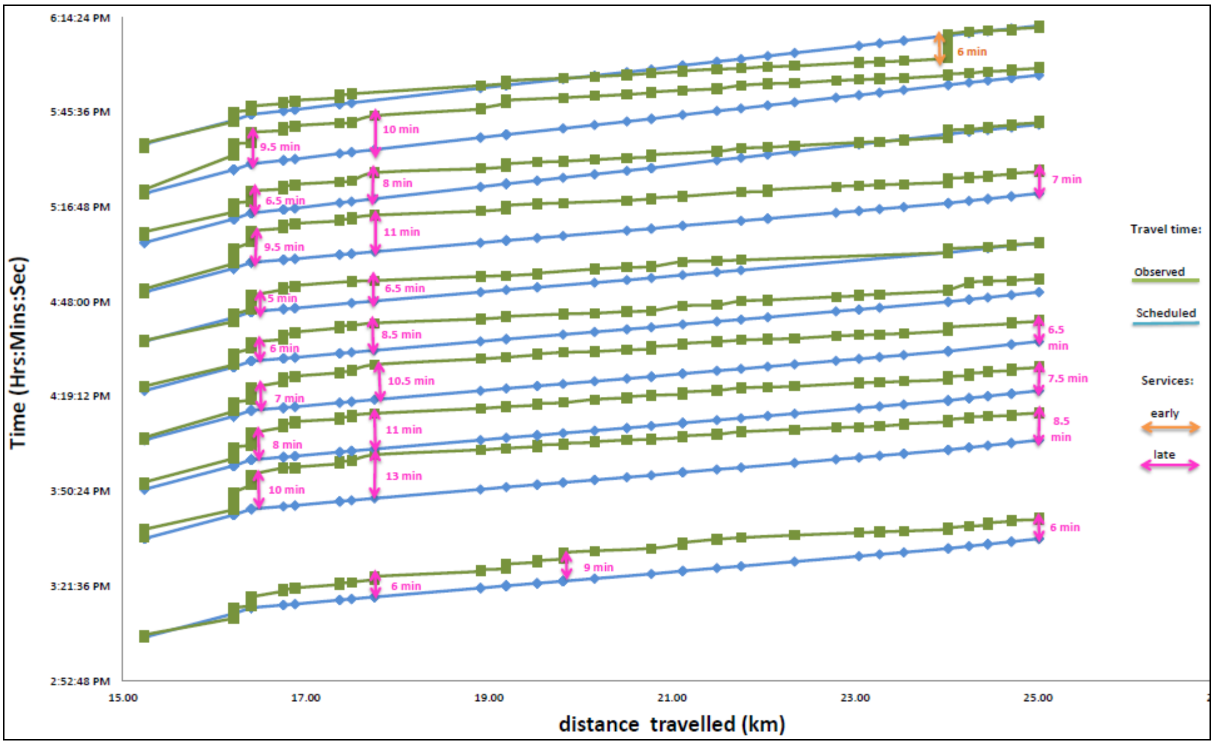

Figure 8. Recorded and Scheduled travel time vs distance for Route H30, towards the Henley Beach in PM peak period

Lastly, when the variations in headways were investigated, the scheduled headways varied from between 15 to 21 minutes. The observed headways are irregular with many variations. These differences in the scheduled and observed headways are significant.

5.3. Glen Osmond Road Corridor Analysis and findings

The services along glen Osmond Road varied significantly in terms of running time. This makes it difficult to timetable services accurately. Many of these services towards the CBD performed reliably until encountering the streets of the CBD where the headways became more varied. This was encountered across all time periods and because this road is busy for most of the day this implied that it was a traffic issue rather than one of boardings. A plot of the travel times against those timetabled for each 861 service along Glen Osmond road is shown in figure 9 note that the scheduled travel times drop to the interpeak levels before 9 am.

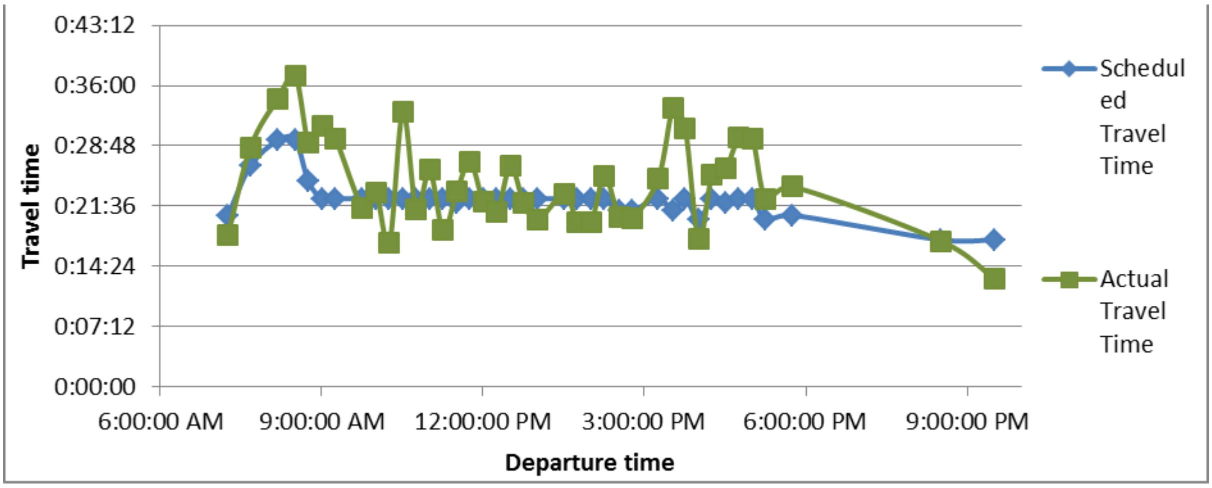

Figure 9. comparing scheduled travel time with observed travel times along rotue 861 towards the Adelaide CBD

Traffic and boardings appear to be the most significant causes of unreliability. Services running in interpeak or the weekend where a reduction in both of these variables is expected have significantly higher reliability. One feature noted in the timetables along both corridors was an apparent reduction in the travel time allocated at the end of the morning peak period and an increase at the beginning of the afternoon peak that is not representative of actual travel patterns.

6. CONCLUSIONS

This research used schedule adherence information from an AVL system to analyze the bus transit on-time performance for few corridors in Adelaide metropolitan area. This study has shown that boardings and traffic congestion have significant impact on bus service reliability. During the morning peak period, the role of traffic congestion was less pronounced but during the afternoon/evening peak period both boarding times and traffic congestion have had significant detrimental effect on service reliability.

Recently Adelaide Metro has implemented some significant network changes including the recent introduction of the new metro-card ticketing system. Metrocard is a system where passengers simply touch their card on a validator as they board public transport and the appropriate fare is automatically deducted. This should substantially improve bus service reliability by reducing the passenger boarding time.

The largest delays occurred where significant numbers of passengers were boarding. For instance during the PM peak in the CBD large delays occurred. This contrasts to the semi-express section of the H30 route (city to stop 18) where few boardings took place and little delay was introduced. In the AM period delays assumed to be from boardings outside the study area were made up as the service progressed. So much time was gained along this section of route that many services arrived early. In the PM period however the bus had made up only some of the time it lost in the CBD. This indicates that other hindrances such as traffic congestion may exist during this period. Reducing the time taken by passengers boarding would have a significant positive impact on service reliability. This study provides a good benchmark for further analysis after the recent introduction of the Metrocard ticketing system. This

Around when this data was collected bus priority lanes through the CBD were introduced. It is unlikely that the full benefits of this are represented here. Traffic congestion, particularly during the peak period in the CBD was noted and a further study is required to determine the impact of the newly introduced priority lanes.

Finally the study has also shown that there is a need to refine the timetables especially limited stop bus time tables.

7. ACKNOWLEDGEMENTS

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REFERENCES

Adelaide Metro. (2012). Public Transport in Adelaide. Bus Service Performance, from: http://www.adelaidemetro.com.au/bus-service-report**.** [Accessed 20th August 2012]

Australian Beaurau of Statistics (ABS) (2009). Public Transport use for work and study., from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Chapter10102008 [Accessed 15th August 2012].

Carrasco, N. (2011). Quantifying public transport reliability in Zurich - paper presented at the 11th Swiss Transport Research Conference. Monte Verita, Ascona.

Chen, X., Yu, L., Zhang, Y., and Guo, J. (2009). Analyzing urban bus service reliability at the stop, route, and network levels. *Transportation Research Part A: Policy and Practice*, 43(8), 722-734.

Department of Planning, Transport and Infrastructure (DPTI) (2011) Annual report from http://www.ops.fhwa.dot.gov/congestion_report/executive_summary.htm[Accessed 2nd June 2013].

Federal Highway Administration Report (2009), Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation from http://www.ops.fhwa.dot.gov/congestion_report/executive_summary.htm [Accessed 3rd June 2013].

Kelton, S. (2012). More commuters avoiding Adelaide's buses [Online]. Adelaide: The Advertiser from http://www.adelaidenow.com.au/news/south-australia/more-commuters-avoiding-adelaides-buses/story-e6frea83-1226403572012 [Accessed 1st August 2012].

Liu, Ronghui and Sinha, Shalini (2007) Modelling Urban Bus Service and Passenger Reliability. *I*n: The Third International Symposium on Transportation Network Reliability, 19-20 July 2007, The Hague, Netherlands

Lyman, K. and R. L. Bertini (2008). Using Travel Time Reliability Measures to Improve Regional Transportation Planning and Operations. *Transportation Research Record: Journal of the Transportation Research Board* 2046,1-10

Mosca,N and Zito, R. (2011). Positioning needs for public transport Paper presented at the Australasian Transport Research Forum, Adelaide.

Public Transport Users Association (PTUA)(2009) Common Urban Myths About Transport, from http://www.ptua.org.au/myths/priority.shtml[Accessed 3rd June 2013].

Stanley, J. and J. Stanley (2004). Improving public transport to meet community needs: A Warrnambool case-study, report prepared for Bus Association fo Victoria, 1-92