Department for Transport

Better Bus Areas Programme

Impact of audio-visual technology on bus patronage

Research Report

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Notice

CONTENTS

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The research reported here could not have been undertaken without the cooperation and generosity of Nottingham City Transport (NCT) and, in particular, David Astill and Rob Hicklin. They both not only provided the datasets required to carry out the analysis, but also voluntarily gave up their time to answer many questions related to changes in bus services between 2010 and 2014.

NON-TECHNICAL SUMMARY

This report presents the results of a piece of research carried out to understand whether there are any changes in bus patronage as a result of the introduction of on-bus audio-visual (AV) bus stop announcements.

The primary method for carrying out this research was to analyse electronic ticket machine (ETM) data provided by NCT before and after the introduction of AV technology to assess whether there was any impact on bus patronage. Two different ETM datasets were obtained:

- Bus patronage for all passengers (including commercial adult and commercial child ticket holders, scholars and concessionary pass holders)
- Bus patronage for concessionary pass users only

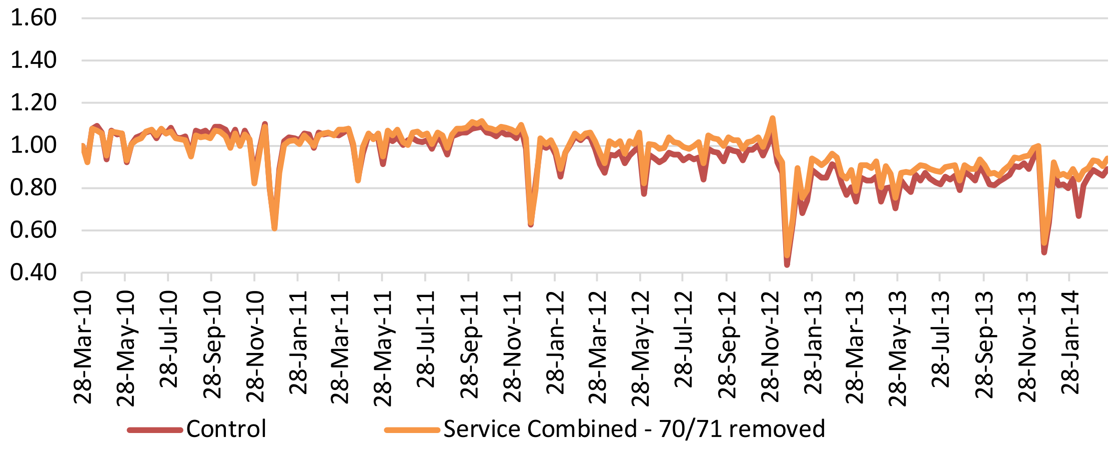
The justification for obtaining the two different datasets was firstly to assess the effects of AV on all passenger trip numbers, and secondly to specifically examine concessionary pass holder trip numbers.

To compare the effect of AV on bus patronage, a test group and control group were used. As the impact of AV could have an impact on different demographics, both the control and test group were analysed according to total passenger trips and concessionary trips.

Indexed bus patronage within each of the test sample of routes was juxtaposed with the control sample of routes. This provided an initial visual illustration of any changes (or otherwise) in bus patronage following the implementation of AV technology. Following this, statistical F-tests were used to look for unexplained variance within the test group compared to explained variance in the control group.

Figure 1 presents the difference between all passengers on the test group of routes (excluding service 70/71 due to significant changes to its services during the period of time in focus) compared to all passengers on the control sample of routes. This shows that there is a very strong visual correlation between the test group and control group before and after the implementation of AV technology.

Figure 1 Comparison of test and control group for all routes



From the data examined on each individual route, neither statistical nor trend analysis indicated that the introduction of AV equipment had any discernible effect on bus patronage. In the test group bus routes examined, no route showed a change in indices and therefore a change in patronage that could be directly attributed to the introduction of AV. Where variation in the data was observed, there was a known cause such as truncation of a route, re-routing or other mitigating circumstances.

The quantitative analysis was corroborated by a qualitative assessment of views of senior management at NCT who believe that AV is not something that, on its own, would lead to a change in bus patronage. AV is considered by the operator as a small part of a much greater package of quality aspects of bus services in Nottingham. Other quality aspects include new vehicles, at-stop real time information, raised kerbs, low floor buses (to enable level boarding) smart card ticketing, leather seats, and clean vehicles.

Finally, a review of existing literature was carried out to understand whether there is any available evidence of the impacts of audio-visual technology. This review highlighted evidence that demonstrated that on-bus audio-visual announcements can increase bus patronage by 0.34%, and that passengers (in Norway) put a monetary value on the technology. This review of existing research supports the findings of this research as the natural variance of patronage on NCT services is significantly greater than 0.34% and therefore an increase in patronage as small as that could not be discerned from the data obtained.

Overall, this research has demonstrated that there is no discernible effect of audio-visual technology, in isolation, on bus patronage on bus services in Nottingham. However, there is evidence from other research that suggests a small increase in patronage could occur as a result of audio-visual technology.

1 INTRODUCTION

1.1 As part of the evaluation of the Better Bus Areas (BBA) programme, the Department for Transport (DfT) was keen to understand the effects of introducing on-bus audio-visual (AV) technology to make bus stop announcements. In Sheffield, there is a bus service that will have AV equipment installed as a result of BBA funding, but evaluation of this could not be undertaken immediately. Integrated Transport Planning Ltd (ITP) was therefore commissioned by DfT to undertake an additional piece of research in this area, working with a bus operator in Nottingham – Nottingham City Transport (NCT) – that had installed AV equipment on a commercial basis on most of its buses by September 2014. This involved analysing bus patronage data before and after implementation of AV on different routes over a number of years to March 2014, and comparing the patterns seen with patronage on a set of control routes which did not have AV implemented until after that date.

1.2 Following this introduction, section 2 of this report describes the methodology used to analyse the data. Section 3 presents the results of the data analysis. Section 4 reports qualitative feedback from senior managers at NCT, which corroborates the results of the data analysis. Section 5 presents the overall conclusion of the research.

1.3 Where commercially sensitive figures have been presented in the analysis, they have been redacted.

2 METHODOLOGY

2.1 The primary method for carrying out this research was to analyse electronic ticket machine (ETM) data provided by NCT before and after the introduction of AV technology to assess whether there was any impact on bus patronage. When considering bus patronage, two different ETM datasets were obtained:

- Bus patronage for all passengers (including commercial adult and commercial child ticket holders, scholars and concessionary pass holders)
- Bus patronage for concessionary pass users only

2.2 The justification for obtaining the two different datasets was firstly to assess the effects of AV on all passenger trip numbers, and secondly to specifically examine concessionary pass holder trip numbers. This was done as there is a possible view that bus users who travel using a concessionary pass – who by definition are older and/or disabled people – might benefit proportionately more from AV technology than other bus users.

2.3 To compare the effect of AV on bus patronage, a test group and control group were used. As the impact of AV could have an impact on different demographics, as noted above, both the control and test group were analysed according to total passenger trips and concessionary trips.

Test Group

2.4 The test group are those routes which have had AV technology installed on board buses and on which the effects on bus patronage are assessed. The test group consisted of 16 bus routes across Greater Nottingham, all of which originate or terminate in Nottingham city centre. The data for each test sample consisted of a period from March 2010 through to AV implementation; a 4 or 5 week period in which AV is recorded to have been rolled out across all buses on that route; and a period of time post-AV implementation to March 2014.

2.5 The 16 NCT routes identified for the test group were as follows:

- 5 – City, Train Station, Trent Bridge, West Bridgford, Gamston
- 7 - City, Train Station, Trent Bridge, West Bridgford, Gamston
- 8 - City, Train Station, Trent Bridge, West Bridgford, Wilford Hill
- 9 - City, Train Station, Trent Bridge, West Bridgford, Wilford Hill
- 70 – City, Sherwood Rise, Basford, Bagnall Road, Bulwell, Bulwell (Morrisons)
- 71 - City, Sherwood Rise, Basford, Bagnall Road, Bulwell, Bulwell (Morrisons)
- 15 – City, Hucknall Road, City Hospital, Bestwood, Top Valley, Rise Park
- 16 - City, Hucknall Road, City Hospital, Bestwood, Top Valley, Rise Park
- 27 - Carlton, Westdale Lane, Mapperley, Arnold
- 68 - Sherwood Rise, Basford, Bulwell, Snape Wood
- 69 - Sherwood Rise, Basford, Bulwell, Snape Wood

- 87 - Sherwood, City Hospital, Bestwood Park, Top Valley, Arnold, Rise Park
- 88 - Sherwood, City Hospital, Bestwood Park, Top Valley, Arnold, Rise Park
- 89 - Sherwood, City Hospital, Bestwood Park, Top Valley, Arnold, Rise Park
- 11 - Train Station, Trent Bridge, West Bridgford, Ruddington
- 77 - Alfreton Road, Aspley, Strelley, Broxtowe, Bulwell, Arnold

Control Group

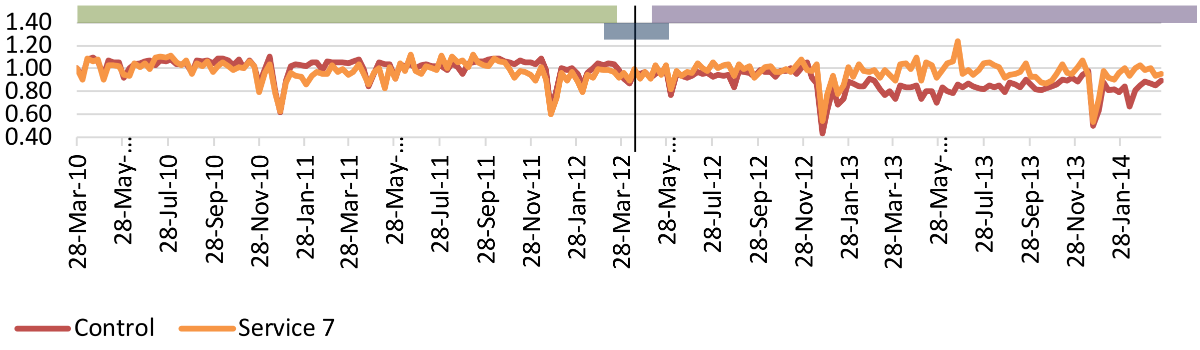
2.6 The control group was selected as to include routes that did not have AV equipment installed until March 2014 or later. After September 2014, all NCT buses had AV technology installed, which restricted any further analysis. The control group consisted of the following NCT routes:

- 4 - Train Station, Trent Bridge, Clifton, NTU Clifton, East Leake, Loughborough
- 6 - Train Station, Trent Bridge, West Bridgford, Ruddington
- 10 - Train Station, Trent Bridge, West Bridgford, Ruddington
- 17 - Hucknall Road, City Hospital, Bestwood, Bulwell, Rise Park
- 34 - QMC, Derby Road, University Park, Beeston, Chilwell, Bulwell
- 35 - QMC, Derby Road, University Park, Beeston, Chilwell, Bulwell
- 100 - Gedling, Burton Joyce, Lowdham, NTU Brackenhurst, Southwell
- 30 - Ilkeston Road, Jubilee Campus, Bilborough, Wollaton
- 58 - NCN Clarendon, Mansfield Road, Sherwood, Arnold

2.7 All the routes used in both test and control groups either originate or terminate within Nottingham city centre. There is a broad geographic spread of services across Greater Nottingham, reducing the possibility of potential bias as a result of any area-specific events. In summary, the control group has been selected to control for all known external factors that could influence bus patronage within the test group.

2.8 Sample data selection for statistical testing (F-test analysis) is illustrated in Figure 2.1. The solid vertical black line in this figure at April 2012 shows the point at which AV technology was introduced on the route. For data prior to AV, the period covered by the green bar was used to provide the greatest sample size. Post-implementation, the period under the purple bar is used. To capture data at the point of AV introduction, the variation across the point of AV introduction and the 8 weeks prior and post AV were used.

Figure 2.1 Example of sample data selection



Data handling

2.9 The data was standardised by indexing against a known reference point. The reference point used was taken to be the control value given for March 2010. From this origin, all values (control and test samples) were indexed to give relative change. By indexing the control group, relative change can be observed to the March 2010 data point, allowing relative change in the indexed sample group to be compared to relative change in the control group over any given time period. For the identification of any significant changes in variation of patronage over a time period (the identification of a factor which had had an impact in passenger numbers), a number of statistical tools were used to look for variation in passenger numbers by passenger group (concessionary pass holder trips and all passengers).

2.10 The statistical test used consisted of; F-Test Two Sample of Variance analysis (one tail, 5% confidence interval); analysis of passenger means; standard deviation; range and co-efficient of variance (interpreted as % relative standard deviation (%RSD)).

2.11 The data for each route was split into three phases for analysis;

1. March 2010 to week before AV addition
2. 8 weeks prior, 4-5 weeks of implementation and 8 weeks post AV implementation
3. Weeks after AV addition to March 2014.

2.12 All data processing was conducted using Microsoft Excel.

F-Test

2.13 F-test was used to look for unexplained variance within the sample group compared to explained variance in the controlled group (see Equation 2.1).

Equation 2.1 F Test

$$F = \frac{explained\ variance}{unexplained\ varience}$$

2.14 When using the F-test, two values are derived that enable comparison - the F value indicating the ratio of between-group variability and within-group variability; and the calculated value of F Critical (Fcrit) which indicates the threshold which is required to be exceeded to signify that the unexplained variance has a significant probability that has arisen from a factor other than natural variation (as shown within the control group).

2.15 For this report, the F test was used to assess whether the test group sample data's variability was greater than the variability seen in the control group over the same time period. Should F be greater than Fcrit, this would indicate that at some point an event or impact had had an influence of greater 95% probability (alpha = 0.05) of being caused by non-natural variation (when compared to the expected variation seen in the control group). Where F is greater than Fcrit, further analysis is carried out to understand whether the variation is the result of a specific factor or whether the variation is so small it is negligible. It is important to emphasise that the F-test is used to identify change within a time period, not the cause of change.

Co-efficient of variance and % Relative Standard Deviation

2.16 The co-efficient of variance is a dimensionless number used to estimate data reliability. By looking at the co-efficient of variance, the repeatability and therefore accuracy of the data can be determined. By deriving the relative standard deviation (RSD), expressed as a percentage (%RSD), the percentage of variability within a data set can be observed (Equation 2.2). Knowing the %RSD gives the threshold by which an impact has to have to be observable above variation. For example if the %RSD for the data set is 10%, any change due to AV would have to exceed 10% to show any potential significance.

2.17 RSD and %RSD support the analysis by…

Equation 2.2 Percentage relative standard deviation

$$\%RSD = \frac{s}{x}\, x100$$

Where %RSD = percentage relative standard deviation; s = sample mean, x = standard deviation

LINEST function for trend observations

2.18 The high degree of variability in the data sets does not allow linear regression methods to be used, however the "least squares" method for straight line fitting does allow an estimation of calendar year annual change. By using the LINEST (Line, straight) function the degree of change between calendar years compared to the reference point can be measured.

Further information

2.19 As the data provided by the operator had little annotation to events which may have occurred either through the actions of NCT or through non-NCT related actions, additional information was gathered by the research team. Where variations were observed in the data, to ensure that these variations had identifiable causes David Astill and Rob Hicklin of NCT provided further information.

2.20 The information obtained from NCT assisted the research team to understand the external factors that could impact upon bus patronage. The operator provided a narrative for all of the occasions that services were amended during the period that it provided data for. Without this narrative, the research could draw incorrect conclusions, therefore this was essential.

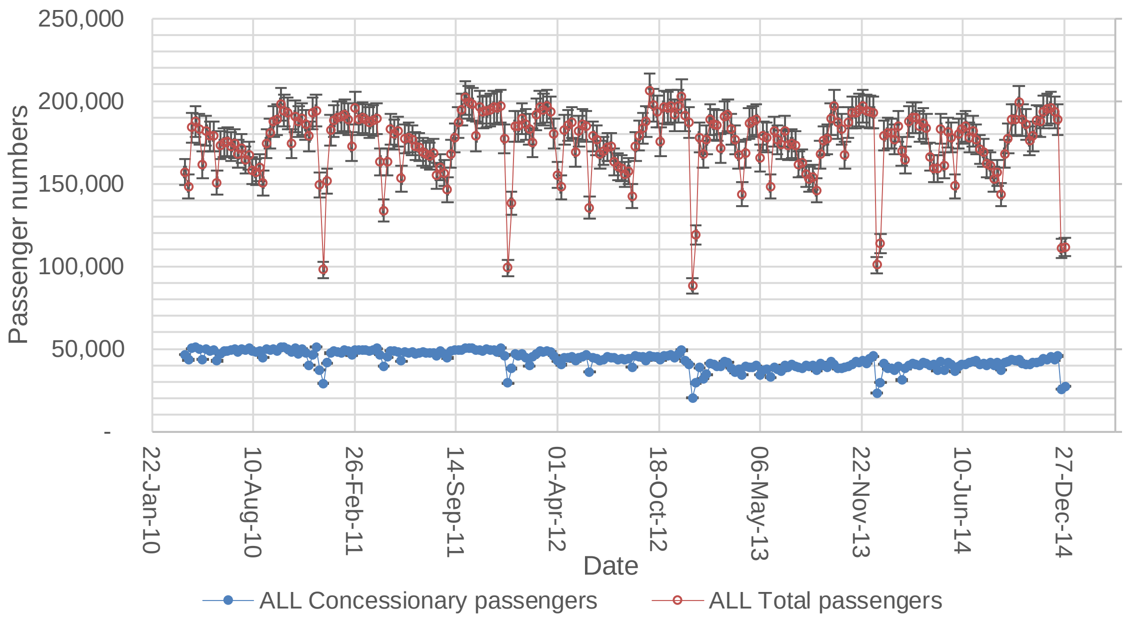
Finally, to add to the quantitative analysis presented in this report, senior management at NCT were asked for their views and perceptions of AV technology and the benefits that it brings. Interviews with NCT management were carried out on three occasions - July 2014, October 2014 and February 2015. These are reported in Section 4.

3 RESULTS

3.1 This section presents the results of the analysis of ETM data.

3.2 The data provided by NCT consisted of ETM data covering the time period of 28th March 2010 through to 31st December 2014. The data sets consisted of three data fields: date, concessionary passengers and total passengers. As all routes (including all control groups) had AV installed after 3rd March 2014, the data was limited to this date, giving 205 data points per route. All data presented is derived from these original data sets.

Figure 3.1 Natural variation in the patronage



3.3 Figure 3.1 shows the total passenger numbers carried across all service routes for both total passengers and concessionary passengers. By observing the range between the highest and lowest values compared to the standard deviation of the control groups, the natural variation can be determined. Table 3.1 shows the variation observed in the cumulative control group.

Table 3.1 – Passenger number data ranges

	Control group concessionary passengers (% of mean value)	Control group all passengers (% of mean value)
Max	113.67%	115.25%
Min	45.25%	49.24%
Standard deviation	12.15%	10.87%

3.4 The control group showed 10.87% variability in total passenger numbers and 12.15% for concessions over the whole time period. Over the same time period, the test group showed 11.13% variability for total passenger numbers and 14.14% for concessions. By removing two bus services from the analysis (routes 15 and 70/71) - these experienced significant changes to service levels - the %RSD reduces to 10.90% for total passengers and 10.72% for concessions. This analysis suggests that both groups have consistent data for comparison.

3.5 From the data produced, the sample group's %RSD was noted to be above what would be expected, indicating that the variation in concessionary passenger numbers was greater than that expected from the control group. By looking at the spread of %RSD's by route, two routes are identified which have variability much greater than the expected. The %RSD values for service 15 (28.81%) and service 70/71 (54.95%) are significantly greater than the samples groups mean (12.73%). The reason for the variations was due to a major re-routing of one service and the truncating of another in areas to the north of the city centre. By removing these two services from the analysis, the sample group concessionary %RSD is 10.72% and total passenger %RSD 10.90%, therefore within the expected variation.

3.6 **F-Test**

- For concessionary passengers, 9 of the 13 routes identified areas where F>Fcrit.
- For all passengers, 11 of the 13 routes identified areas where F>Fcrit.

The F-Test analysis implies that there is variation which can be detected between the test routes and the control group. With F-Test being a method of identifying variation but not the cause of the variation, this shows that these routes have had some impact(s) on patronage compared to the expected patronage (the control group).

The variation detected can either come from multiple low impact events or a low number of higher impact events. Routes which show greater degrees of variation throughout the trial period are likely to makes changes due to AV implementation difficult to isolate. For example, multiple causes of variance on a single route (changes of bus frequency, temporary road closures, cyclical patronage trends, promotions and others factors) can cause multiple variations which makes isolating a single causative factor difficult.

Three bus routes (services 8, 16 and 89) showed F-test characteristics in concessionary trip data which indicates a change in patronage by analysing the three time periods of pre, post and during implementation time periods independently. As the F-Test does not attribute cause, it does identify services for further investigation.

F-Test analysis of Service 77 showed greater variation solely at the time of AV implementation (variation prior to and post implementation was consistent with the control group) therefore would be a potential indicator of an AV impact.

Four routes (services 5, 11, 15 and 68/69) for concessionary passengers and two routes (service 5 and 15) for all passenger trips showed no variation through F-Test analysis across the whole time period compared to the control group. As these data sets show very low variation to the control group, the conclusion would be that any impact due to AV would have no statistical significance to bus patronage.

Graphical analysis

3.7 Within the control groups (total passenger numbers and concessionary group), two trends are observed. Total passenger index shows little change over all with a high degree of variability. Using the LINEST function (used to determine trends by the "least squares" method on annual data) to determine annual change across the whole total passenger data set, total passenger numbers remained stable across the time period while concessions showed a general decline then a stepped reduction in 2013 compared to the previous years. On an annual basis, each calendar year shows relativity little change (see Table 3.2).

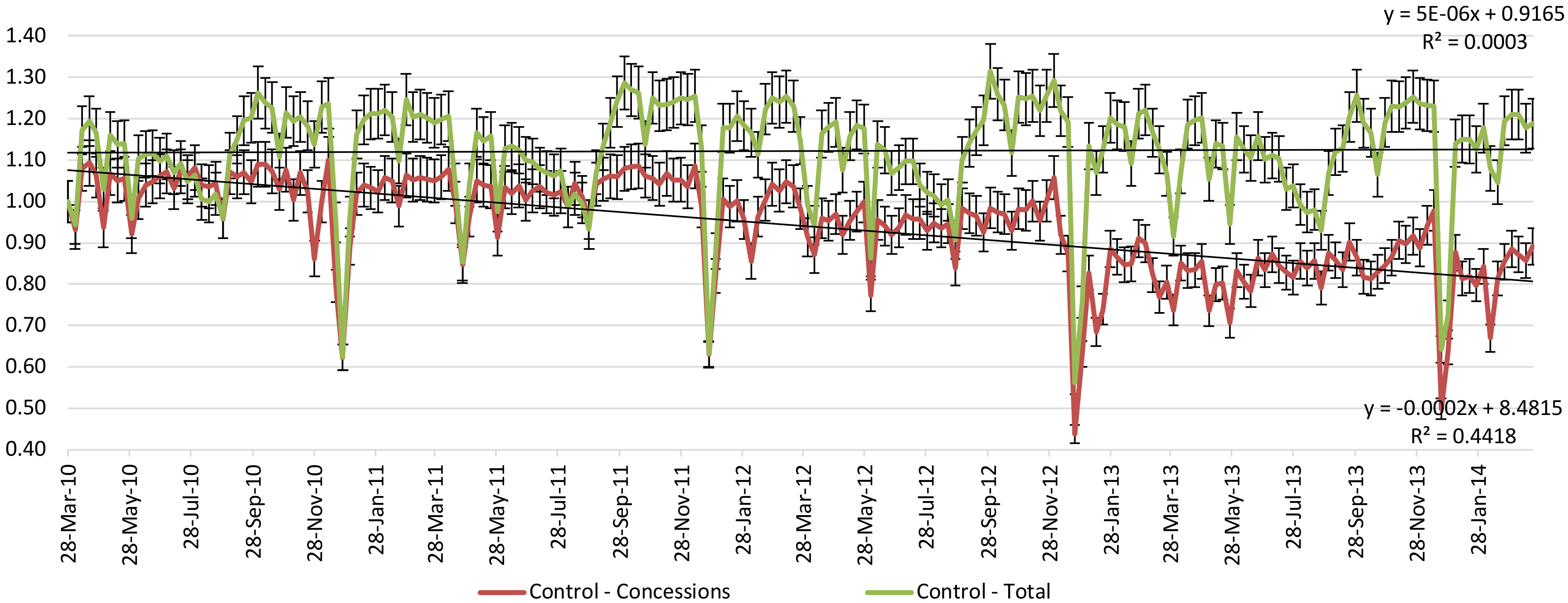
Table 3.2 Passenger change analysis

CALENDAR YEAR	CONCESSIONS		TOTAL	
	% change per year	Uncertainty	% change per year	Uncertainty
2011	2.92%	0.23%	3.24%	0.26%
2012	2.59%	0.22%	3.13%	0.26%
2013	2.38%	0.19%	2.71%	0.17%
JAN 2010 - DEC 2013	0.64%	0.03%	0.64%	0.03%

3.8 In the graphs shown for each the control groups and each service, a number of prominent trends are observed. The time period of the study covered four financial years in which four major reductions in passenger numbers are observed relating to four Christmas periods (reduction of control group indices from 1 to 0.72, 0.63, 0.44 and 0.50). These reductions are largely within expectation as the number of commuting passengers will be greatly reduced over the holiday periods. It can be suggested that the reduction in passenger numbers around the 28th April 2010, 30th April 2011, 31st March 2012 and 31st March 2013 correlate to the Easter holiday periods, whilst the reduction in the first week in May correlates to the May bank holiday week and end of school term holiday. The general reduction in numbers across the late June/early July to the start of September will be correlated to summer and school holidays.

3.9 It should be noted that in the following graphs, the control group has been shown with error bars at 5%. Error bars are a way of visually showing the error or uncertainty in the data. If you repeated the experiment 100 times, 95 results out of 100 would be within the range of the error bars. As the individual graphs for each service show the test group trend line and control group trend line to be very close to one another error bars have been omitted to allow readability.

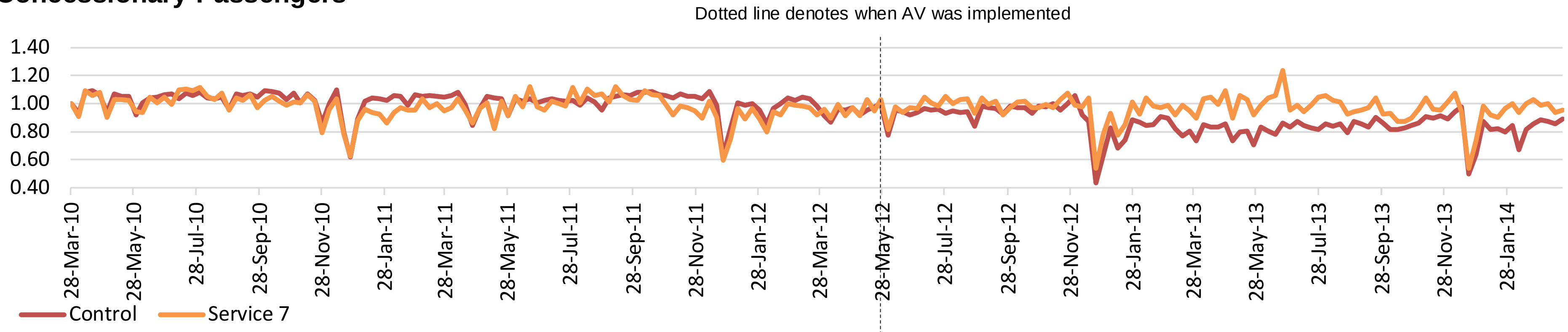
Figure 3.2 Control group trend analysis



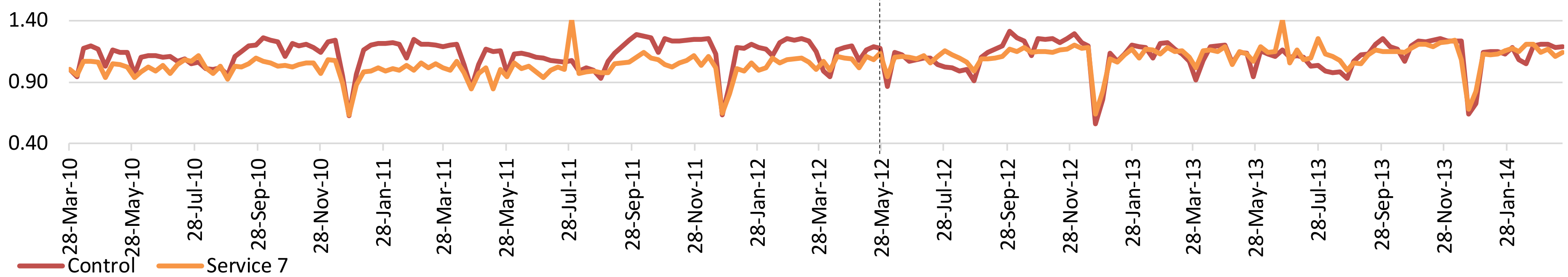
Notes: Error bars set at 5% error. The graph shows annual variance in the concessionary and total trips control groups (Total passengers: Max = 1.32, min = 0.56, median = 179.079, std.dev = 19,459, n = 204). Observable are the reductions in passenger numbers during holiday periods and the notable decrease in 2013 in concessionary passengers (see paragraph 3.8). The reduction in concessionary patronage was highlighted by NCT as being across all services. In the three financial years, the proportion of concessionary passengers as a percentage of total passengers reduced (2010/11 = 27.08%; 2011/12 = 26.48%, 2012/2013 = 24.06%). Reasons for this are thought to be the increasing age of eligibility for a concessionary pass, the stricter assessment process for eligibility for a disabled pass in Nottingham City and the possible under recording of concessionary trips due to a change in smart recording of concessionary trips.

Figure 3.3 Service 7

Concessionary Passengers



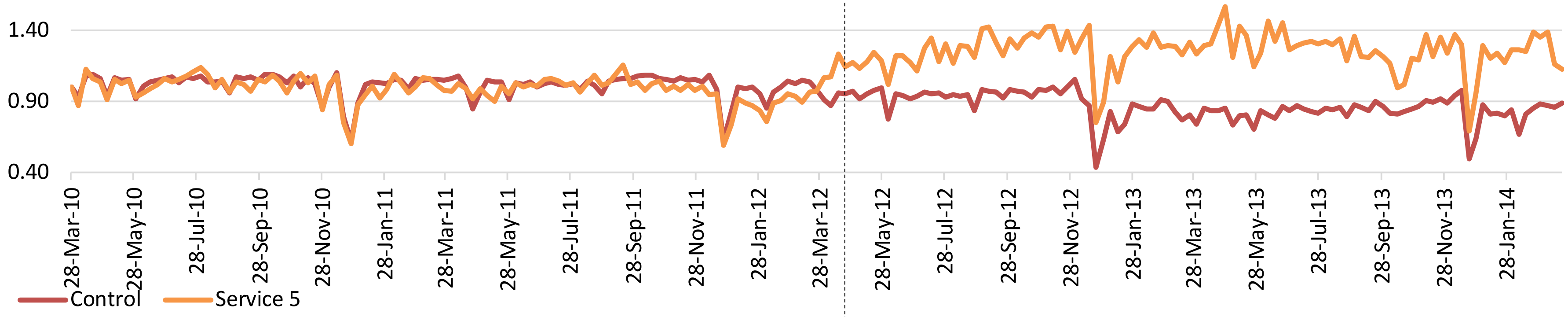
All Passengers



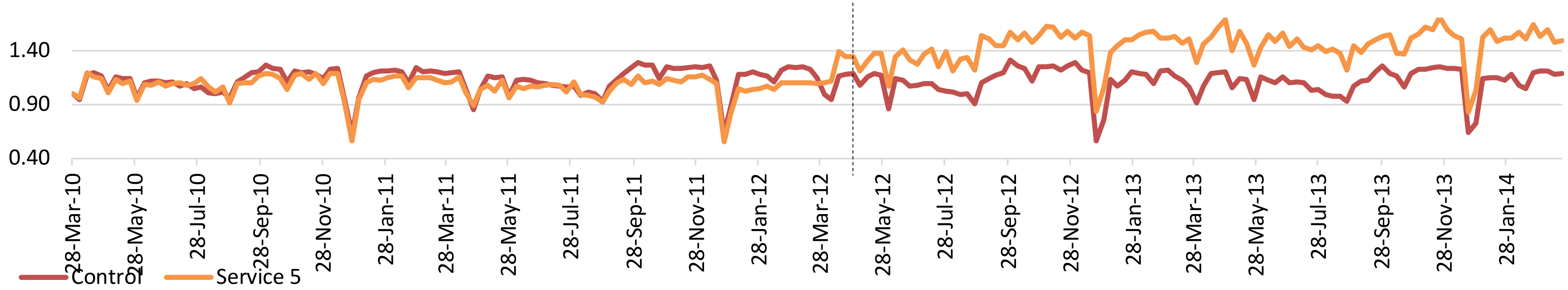
Notes: Normal variability observed across the time period (March 2010 – March 2013 %RSD = 9.37% (conc.), 9.81% (total),, implementation period = 7.77%). The three F values (0.809, 0.104 and 0.1.127) compared to the F crit values (0.728, 2.124 and 0.1.417) for pre, during and post AV implementation within the concessionary data set shows that prior to AV there was some variation, but none at the time or after AV adoption. Total trips are comparable. As there is no variation in the time period of AV adoption, it is concluded that AV has had no significant impact on bus patronage on service 7.

Figure 3.4 Bus service 5

Concessionary Passengers



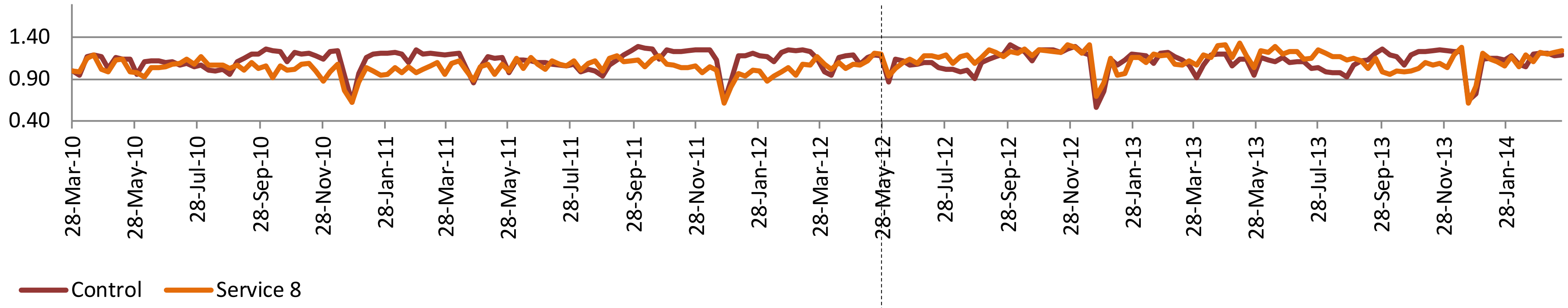
All Passengers



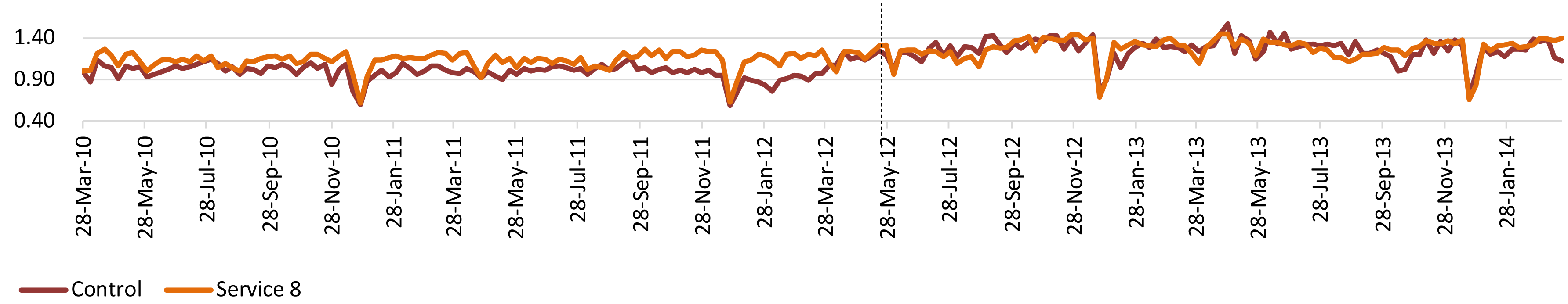
Notes: Timetable revision occurred March 2012 through an area with greater footfall – town centre routing. As such, the data from March 2012 shows around 20-50% increase on previous years data. %RSD's (9.89%, 6.78% and 10.89% for concessionary pre, during, and post-AV use) is below the 12% variation observed in the control group. The F-test values is below the Fcrit value (F = 0.237, Fcrit = 0.471) for the roll out period while post AV F test values (F = 0.544; Fcrit = 0.706) shows normal variation in an elevated passenger number after AV rollout. As increase in numbers is prior to introduction of AV and coincides with the service re-routing through an area with a known greater potential passenger numbers, the variation observed cannot be related to AV.

Figure 3.5 Service 8

Concessionary Passengers



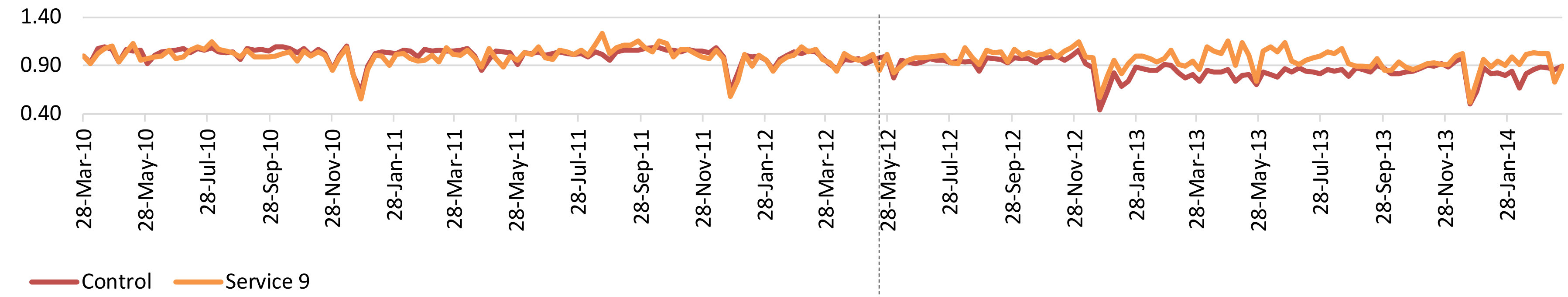
All Passengers



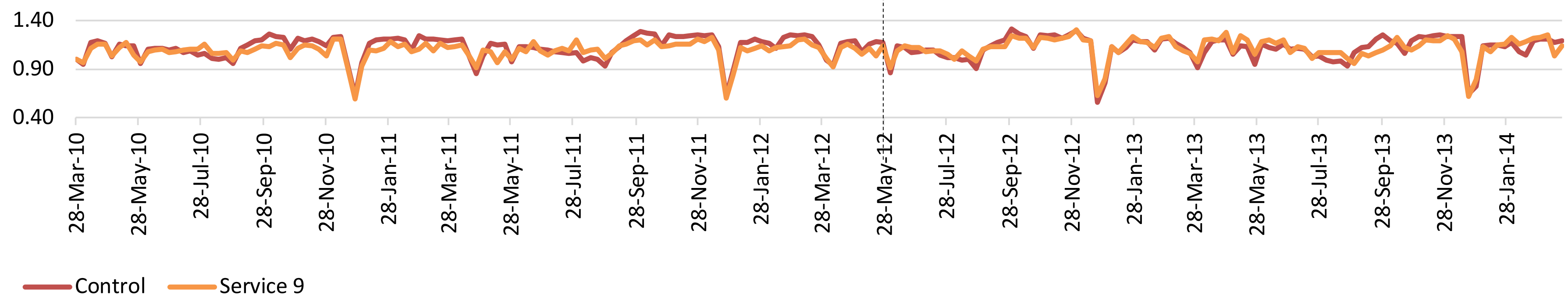
Notes: October 2012 – Change in evening service levels as service 8 and 9 are paired. No variation is observed compared to the control group in the period of AV application. In comparing the data sets, concessionary %RSD (9.30%, 8.61% and 10.84% for pre-during and post- AV rollout) compared 12% variation in the control group. F testing did show significance in the period during implementation (F = 0.622, Fcrit = 0.470) although the relatively low passenger numbers for this service, small variations will have a greater impact. From the data analysis and graphical analysis, there is little significant data to show that AV had an impact of transport choice.

Figure 3.6 Service 9

Concessionary Passengers



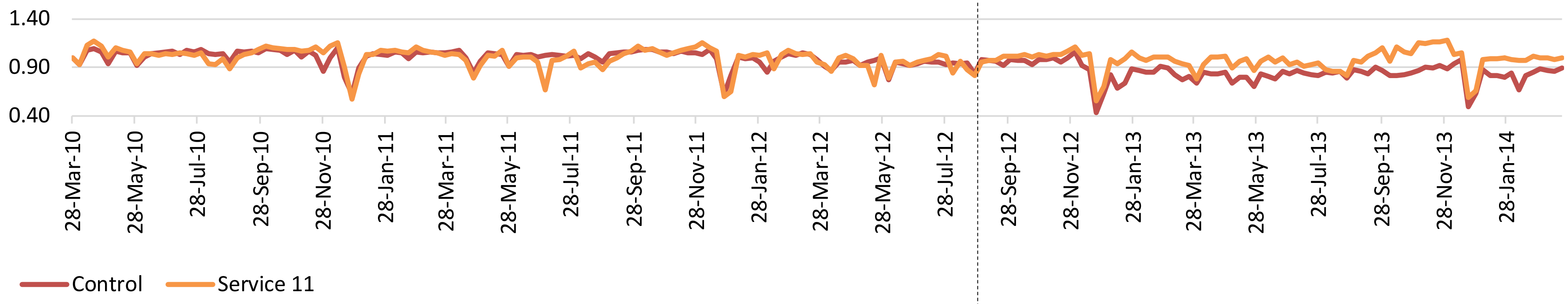
All Passengers



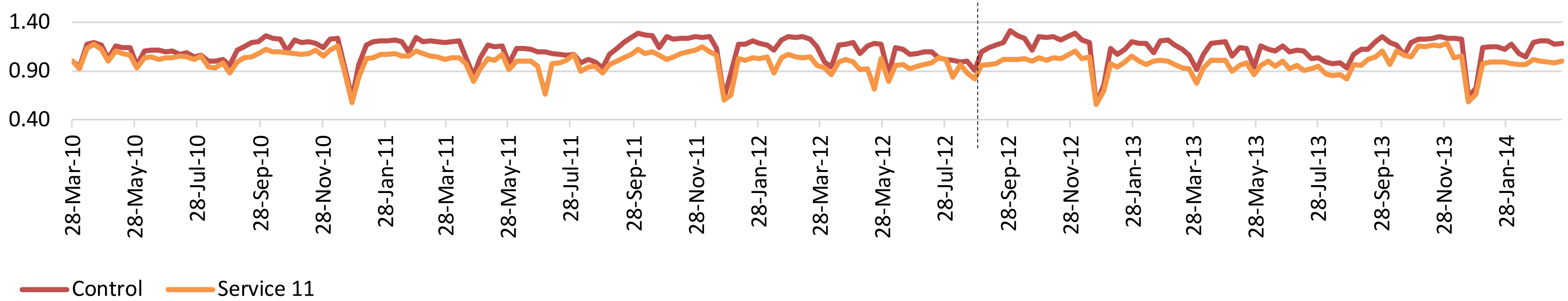
Notes: October 2012 – Change in evening service levels as service 8 and 9 are paired. No variation is observed compared to the control group. For analysis, please see service 8.

Figure 3.7 Service 11

Concessionary Passengers



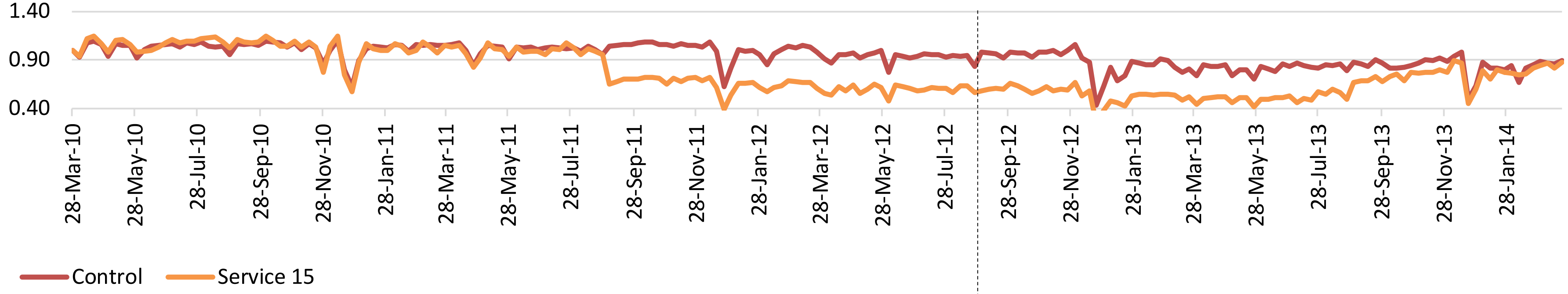
All Passengers



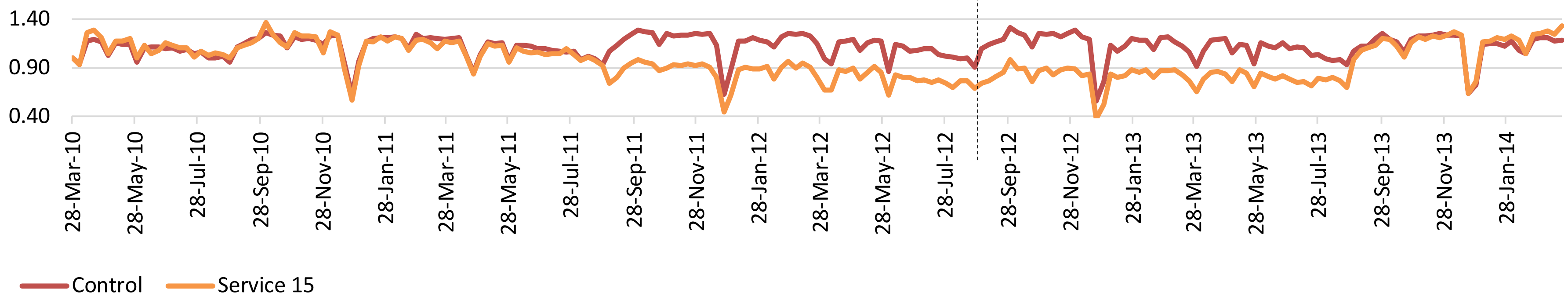
Notes: March 2012 – Daytime frequency changed from every 10 minutes to every 12 minutes. October 2012 - Evening frequency change to every 20 minutes until 9 pm. Variation within the sample data is consistent with variation in the control group. At the point of AV application, variation for concessionary passengers is close to the expected value (Sample %RSD = 4.83%, control = 3.01%) and well below the total data periods expected (12.44%). Where total passengers show an increase in August 2012, no corresponding increase is seen in the service 11 data.

Figure 3.8 Service 15

Concessionary Passengers



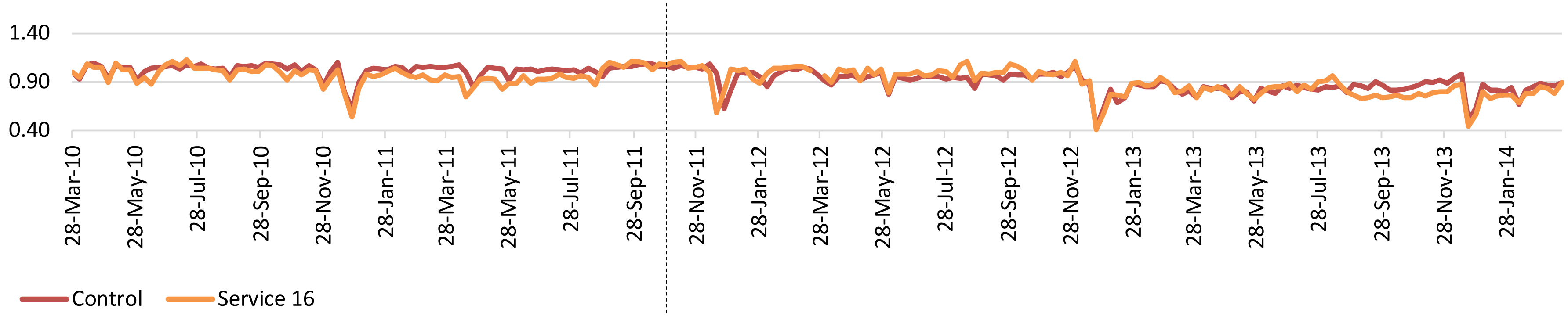
All Passengers



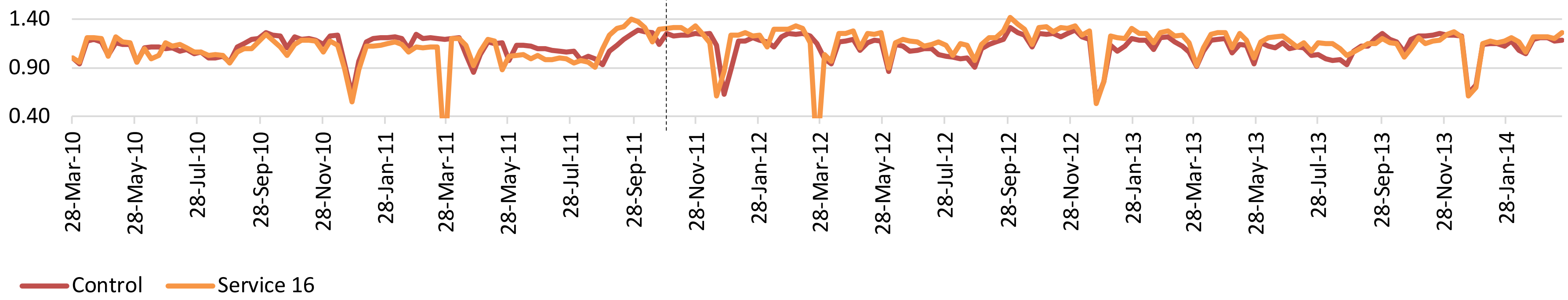
Notes: September 2013 – route extended back to Rise Park although not a like for like replacement of previous service prior to the truncated service starting from July 2011. Variation observed (concessionary %RSD over the whole data set = 28.8%) in the data is due to the route being truncated prior to the introduction of AV. In the post AV period, variation is still high (18.77% RRSD concessionary) due to the reinstating of the truncated route. In the period around AV introduction, no significant variation to the control group is observed (concessionary F = 1.923, Fcrit = 2.168).

Figure 3.9 Service 16

Concessionary Passengers



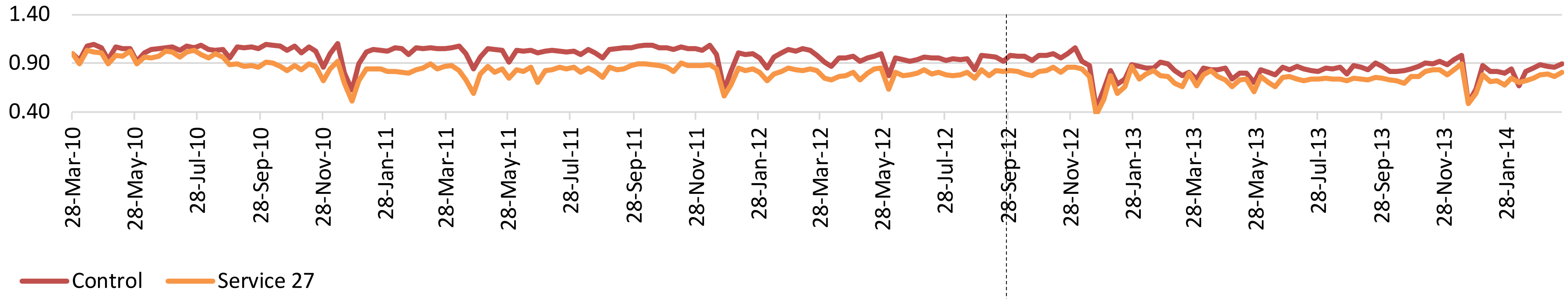
All Passengers



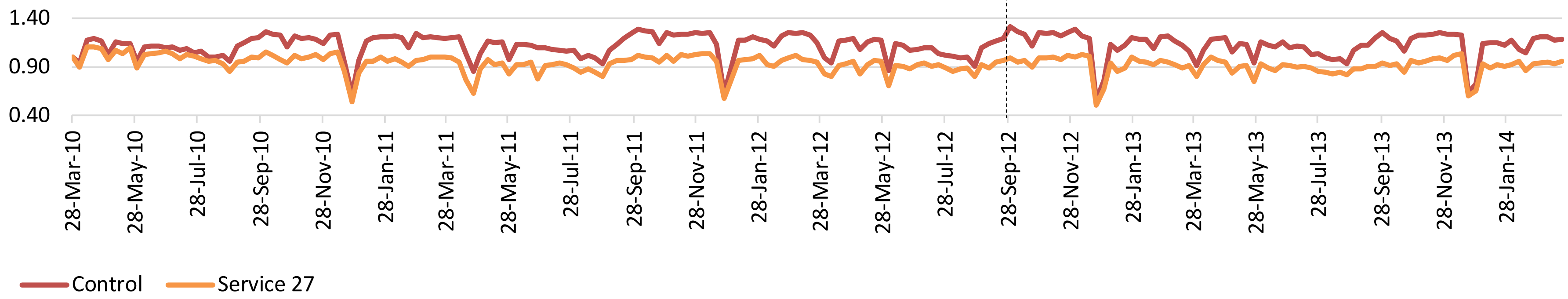
Notes: No variation is observed in the analysis of this route. No significant changes in timetables or equipment were recalled. The variability and trends in the sample date closely tracks the variation and trends of the control group. AV is not shown to have any impact on passenger numbers. Of specific interest is the time period of AV application. Although concessionary F = 0.756 compared to an Fcrit = 0.4612, %RSD is 2.31, showing that although there is variation compared to the control group, the variation in numbers on the route within the AV adoption phase has negligible impact.

Figure 3.10 Service 27

Concessionary Passengers



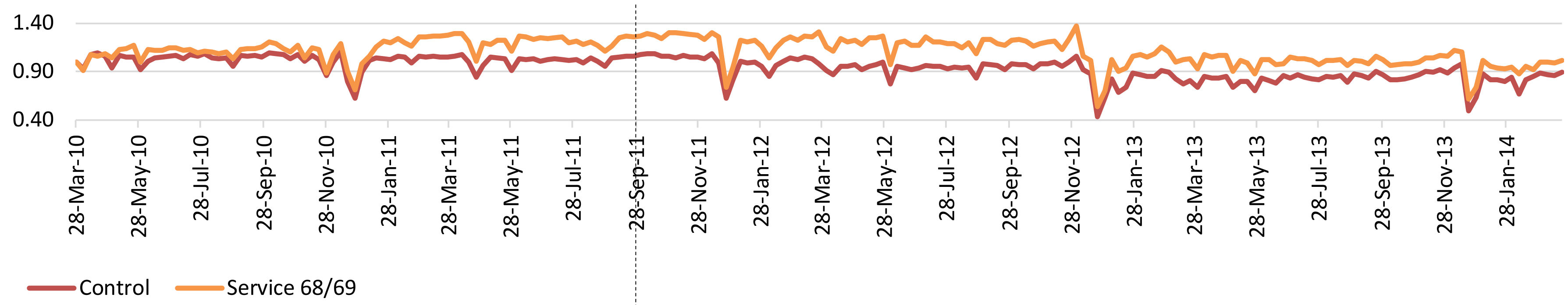
All Passengers



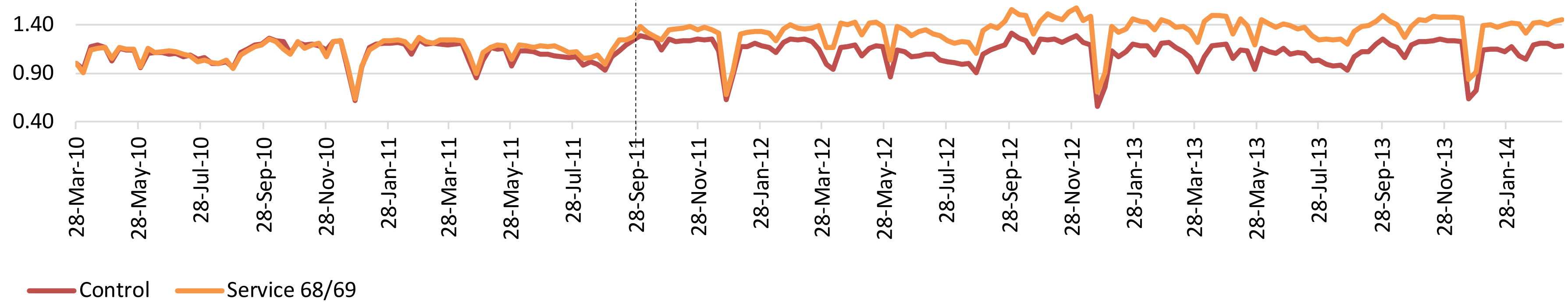
Notes: Service frequency remained the same in August 2010, but a service also operating along Carlton Road increased its frequency, leading to reduction in patronage on route 27. F-tests shows variability across the whole time period with no specific impact at the time of AV roll out. As the variability is spread and the %RSD is close to the control group (12.9 vs. 12.4% and 9.9 vs. 11.0% for concessionary and total trips respectively), there are no specific indicators that AV has influenced passengers numbers.

Figure 3.11 Service 68/69

Concessionary Passengers



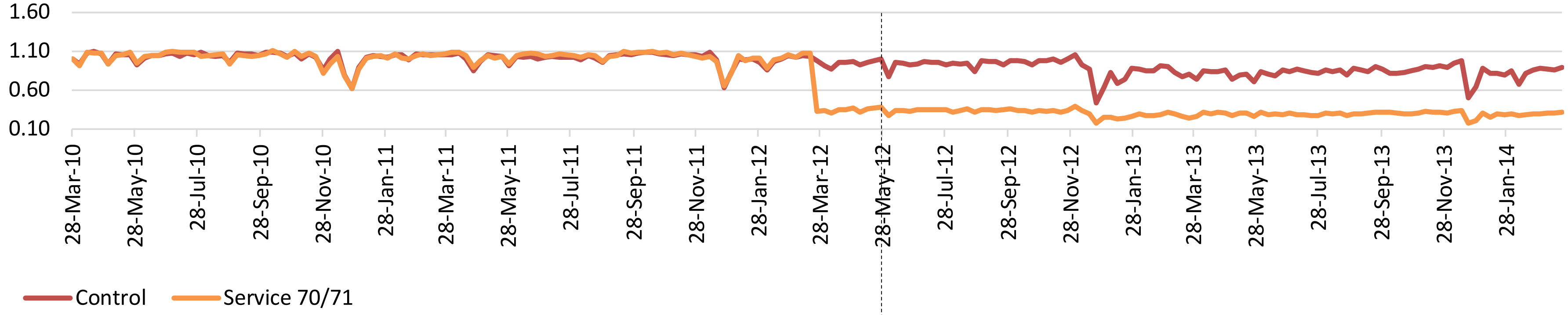
All Passengers



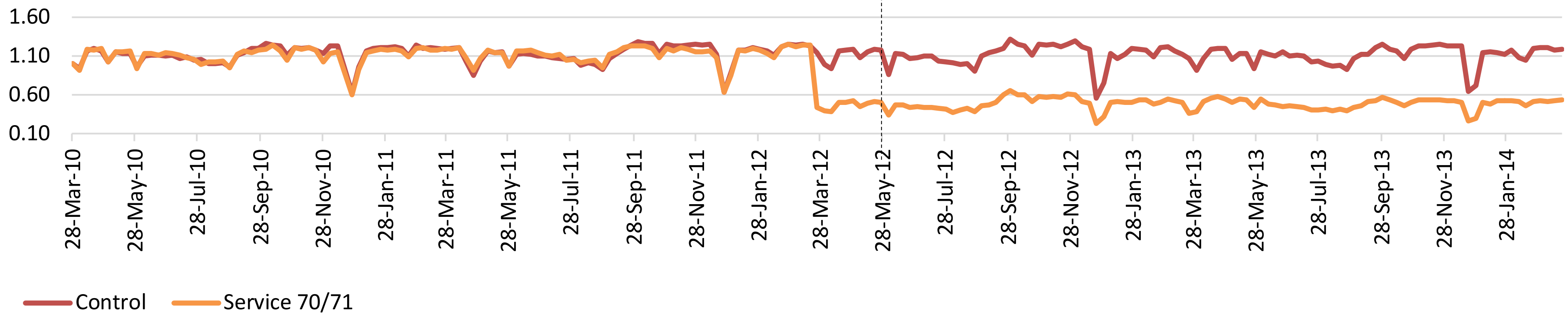
Notes: January 2011, increased bus frequency from every 10 minutes to 7-8 minutes. October/November 2011, single deck buses replaced with double deck. F-test and %RSD are consistent with the control group (concessionary %RSD at time of application = 1.88%, F = 0.621, Fcrit = 0.471) with the F test showing a significant increase at the time of AV roll out. The increase in passenger volume around the point of AV introduction has multiple variables (frequency and bus type) therefore cannot be solely attributed to AV.

Figure 3.12 Service 70/71

Concessionary Passengers



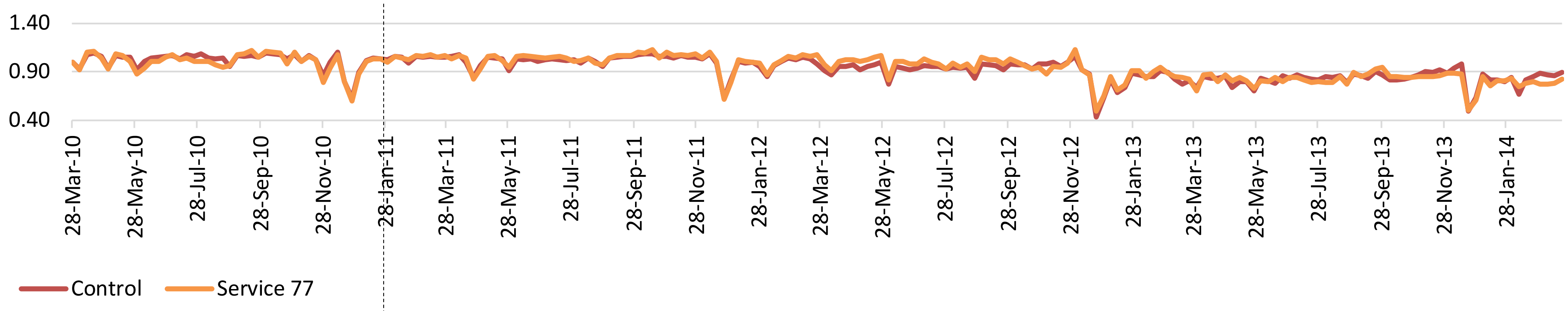
All Passengers



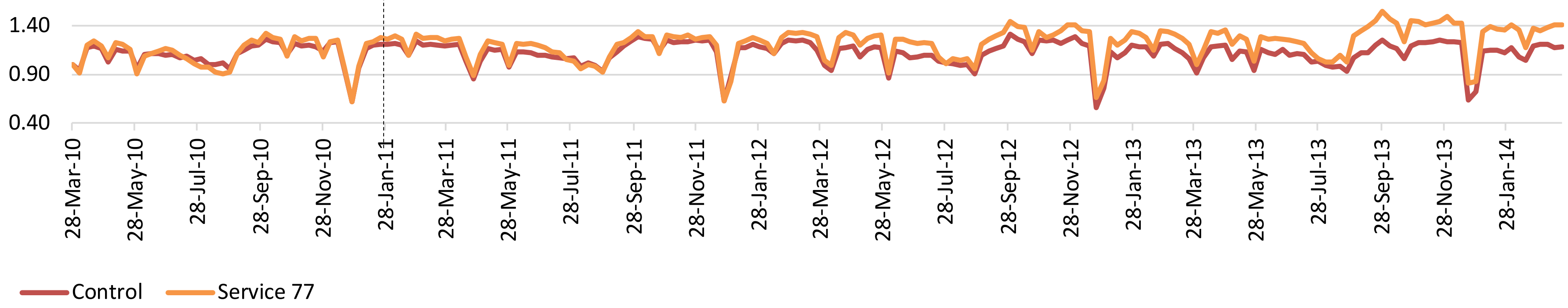
Notes: Service prior to March 2012; Notts – Arnold via Bulwell. Post March 2012; Notts – Bulwell. In statistical analysis, the variation observed is prior to AV addition. The concessionary %RSD and F-test analysis shows significant variation post AV and in the March 2012 period. Pre-AV, %RSD = 17.78%, F= 0.213 Fcrit = 0.728; during AV %RSD = 10.82%, F = 0.065, Fcrit = 0.442; and post-AV, %RSD = 12.29, F = 7.211, Fcrit = 1.417. Although variance is observed, the greatest impact on passenger numbers in service 70/71 has been rerouting. Variation in the comparative analysis shows that the greatest sample-control variation was in a time period well after AV introduction.

Figure 3.13 Service 77

Concessionary Passengers



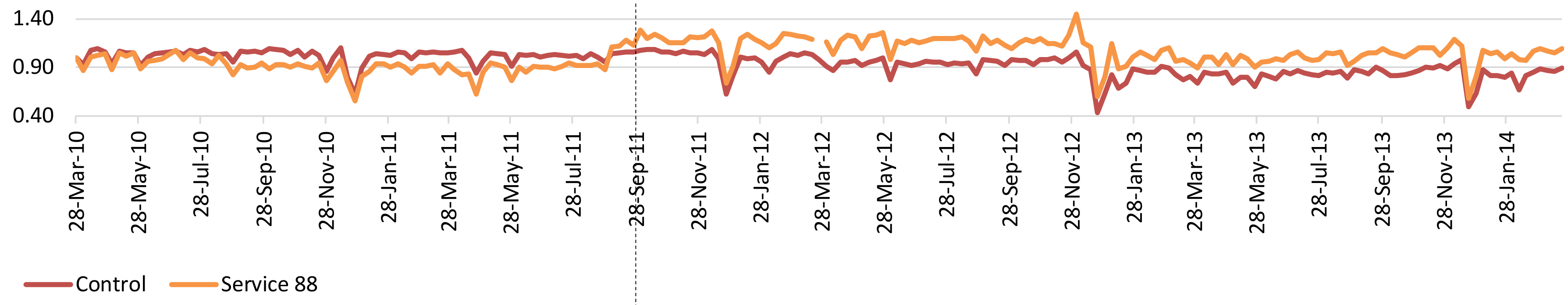
All Passengers



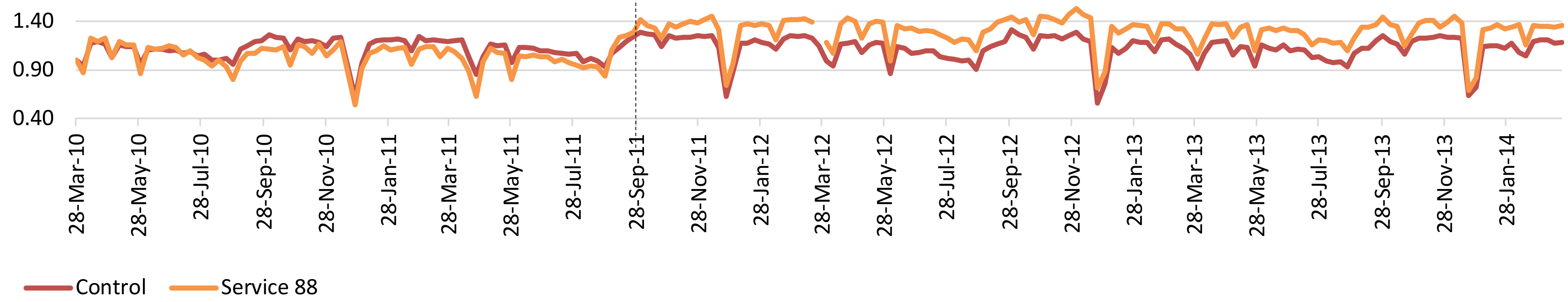
Notes: Route 77 is one of NCT's routes with the highest passenger use, therefore the passenger sample size is large for data analysis. Concessionary passengers closely follows the control group whereas the total passengers number shows variation from January 2012 – a year after the introduction of AV to the route. Interestingly, in pre-, during and post-AV application, F values are all above the expected Fcrit values in concessionary passengers (pre F= 0.8021, Fcrit = 0.654, during F = 0.719, Fcrit = 0.461, post-AV, F = 0.878, Fcrit = 0.755), although %RSD's are all below or within the expected (pre- = 9.0%, during = 4.0%, post AV = 13.53%). Rom the data shown, there is no conclusive evidence that AV is the significant factor in the variation observed.

Figure 3.14 Service 88

Concessionary Passengers



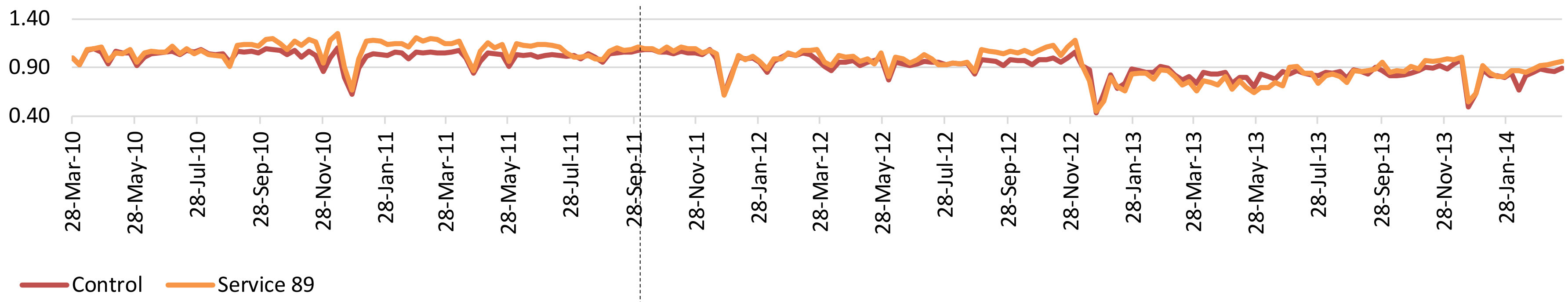
All Passengers



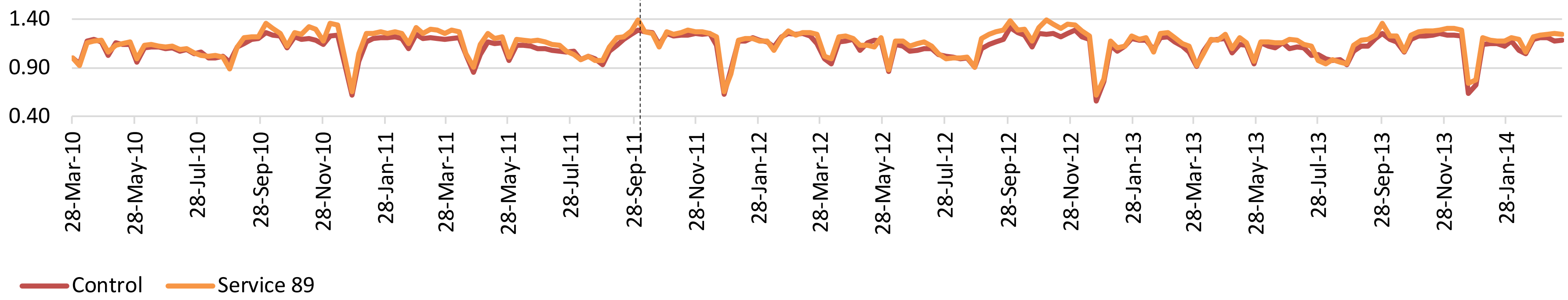
Notes: September 2011 – frequency increased from every 20 minutes to every 10 minutes and revised route in Rise Park to encourage customers. From the data analysed the post AV period does show variation in the concessionary passengers to the control group (F = 0.797, Fcrit = 0.748) with a %RSD of 11.84%. However, the immediate period of AV rollout shows less variance (F= 0.433, Fcrit = 0.470, %RSD = 4.57%). As the rise in indices compared to the control group maintains a raised level for the remainder of the test period, and the more significant impact of increasing bus frequency, there is no explicit link between AV and changes in patronage.

Figure 3.15 Service 89

Concessionary Passengers



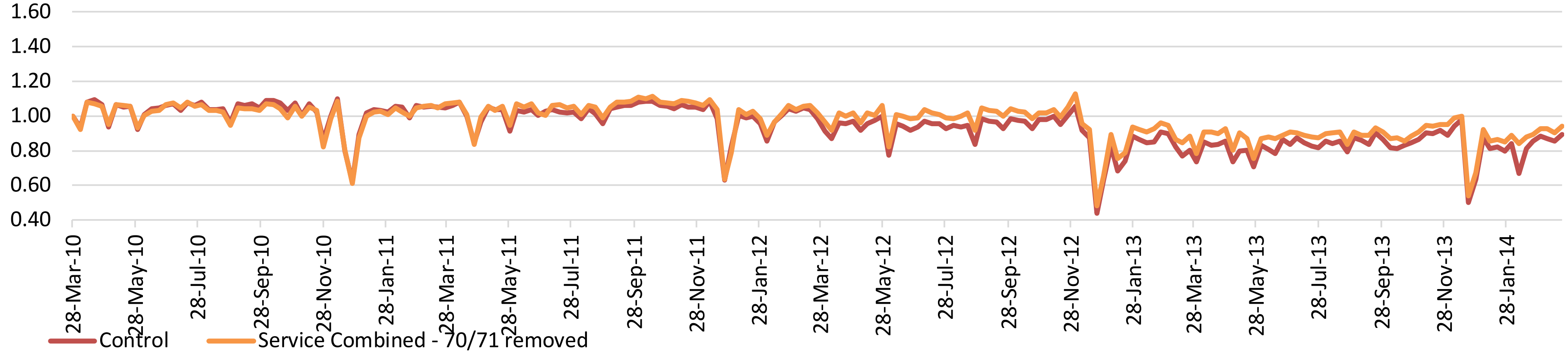
All Passengers



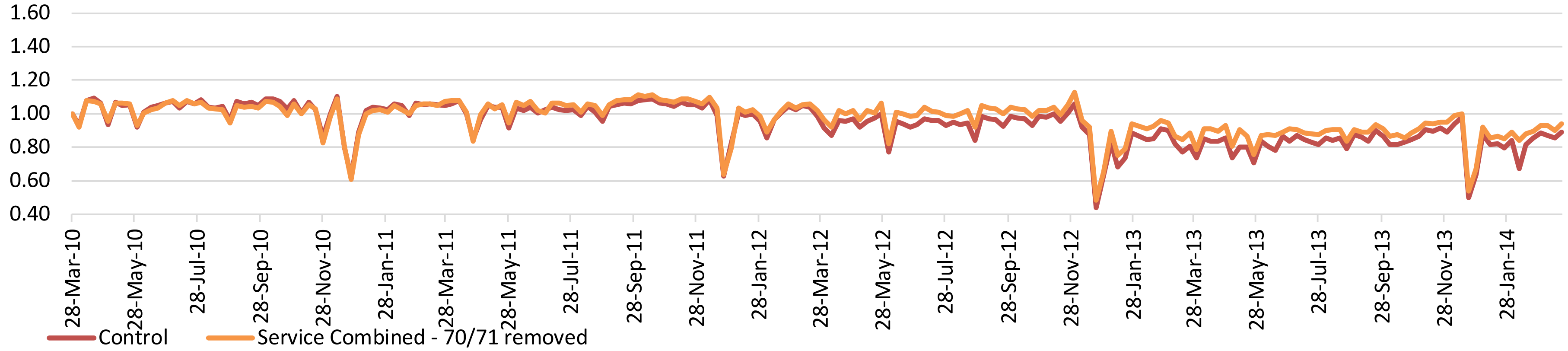
Notes: The data for service 89 is consistent with the control group. Notable points in the data analysis shows that at the time of AV introduction, F test values show a significant change in pattern in concessionary passengers (F=0833, Fcrit = 0.470) however %RSD is low (1.77%). This indicates that although a short term effect was observed around this time point, the impact was non-significant. Of greater impact was a period after AV introduction (October – December 2012) which caused %RSD to increase 15.65%.

Figure 3.16 Combined data

Concessionary Passengers



All Passengers



Notes: For the comparison of sample groups to the control group, service 70/71 has been removed due to the high variability caused by the route being truncated and then reinstated. From March 2010 through to March 2014, variation in the sample group is consistent with the variation in the control group. In the period between March 2010 and March 2012, the two dataset have very high similarity with concessionary passenger F= 1.002, Fcrit = 1.529, sample %RSD = 8.01%, control = 7.97%; total passengers F = 1.109, Fcrit = 1.528, sample %RSD = 10.90%, control

%RSD = 10.49%. Difference between the data set seen between March 2012 and March 2014 are likely due to changes observed in service 15 as the effect is seen over an extended time period, not a single short term event. In analysis of the period after which all test samples have AV, concessionary passenger F = 1.01, Fcrit = 1.419, sample %RSD = 10.72%, control %RSD = 11.63% while total passengers F = 1.067, Fcrit = 1.419, sample %RSD = 11.03% and control sample %RSD = 11.03%. The comparison of the cumulative sample group to the control group shows that with the exception of the circumstances in service 70/71, all the data was consistent with trends across the data provided. As such, no spikes or variations in the data cannot be attributed directly to the use of AV.

4 CORROBORATION OF RESULTS

4.1 In order to interpret the results from the quantitative assessment, two additional tasks were carried out. Firstly, the views of senior management at NCT were sought in relation to the introduction of AV technology on buses. Specifically, the management were asked about what benefits the technology brings to their services and whether this results in an increase in patronage.

4.2 Secondly, a review of existing literature was carried out to understand whether there is any corroborative research that can benefit the interpretation of this research.

Interviews with bus operator

4.3 Various discussions were held between the research team and NCT as part of this research with the views of David Astill (Operations Manager), Mark Fowles (Managing Director) and Rob Hicklin (Finance Director) all sought.

4.4 The operator is of the opinion that AV technology has had no impact on bus patronage on its services – which corroborates the findings of this research. It should be noted that the operator stated this view before the quantitative analysis was undertaken. NCT believes that AV technology is a small part of an overall package of quality measures that encourage people to choose or continue to use NCT services. On its own, however, AV is highly unlikely to encourage anyone to use the bus more often.

4.5 While NCT doesn't think that it will impact on bus patronage, it is of the view that AV technology is a "nice thing to have" and provides some passengers with a slightly better experience when using the bus. The operator tries to continually improve its services and the introduction of AV is a small addition to what is otherwise a high quality bus service with real time information at many bus stops, low floor buses, raised kerbs, leather seating, and smart card technology for fare payment, amongst other quality attributes.

4.6 Interestingly, when discussing the issue of AV technology with a different bus operator (Trent Barton), they suggested that the introduction of audio announcements led to compliments from some passengers, but also complaints from others for being too loud.

Review of existing research

4.7 During carrying out this research, a brief review of existing literature provided an indication of the potential effects of on-board audio and visual next stop announcements. There are three studies that had some relevance to this research, although only one of these provides a direct comparison for the results of this research.

4.8 Fearnley et all (2009)[1] established a financial value derived from passenger valuations of measures for the universal design of public transport. This study, using on-board stated preference surveys in three Norwegian cities, monetises the benefits to passengers that accrue from different public transport design features. This research established that there

[1] Fearnley N, Flugel S, Killi M, Dotterund Leiren M, Nossom A, Skollerund K, Aarhug J (2009) Passengers' valuation of measures for universal design of public transport, accessed at https://www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2009/1039-2009/1039-summary.pdf

was a benefit of NOK4.20 (Norwegian Krona in June 1999 prices, without adjusting for purchasing power) for passengers.

4.9 To put this benefit in context, the research[2] monetised the benefits of the following selected factors:

- Screen with real-time information = NOK4.05
- Low-floor vehicle and adjusted (elevated) curb at the stop = NOK2.07
- Shelter with seating = NOK5.10
- Satisfactory cleaning = NOK3.62

4.10 This research is not directly applicable to the research in this report, however is helpful for broader context that bus passengers have put a monetary value on audio announcements and other quality aspects of bus services.

4.11 In 2009, AECOM carried out a research study on behalf of the DfT, titled 'the role of soft measures in influencing patronage growth and modal split in the bus market in England'[3]. This work established that audio announcements reduce generalised journey times by 1.22 minutes, compared to CCTV at bus stops of 2.91 minutes (amongst other soft measures). Overall, the research showed that there is a beneficial impact of audio announcements, however the benefits in terms of changes to bus patronage are very small.

4.12 A synthesis of evidence of increasing urban bus markets by Currie and Wallis (2008[4]), using evidence from Australia, illustrated the effects of different 'soft' bus improvements on bus patronage. Figure 4.1 presents the outputs from this synthesis of findings, and notably, suggests that electronic next stop sign and announcements increase patronage by 0.34%, compared to services that have no information.

4.13 It is not entirely clear how this value was derived. However this is the only other research, to the knowledge of the authors, which has attempted to establish the effects of on-bus audio-visual next stop announcements.

[2] Fearnley N, Flugel S, Killi M, Dotterund Leiren M, Nossom A, Skollerund K, Aarhug J (2009) Passengers' valuation of measures for universal design of public transport, accessed at https://www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2009/1039-2009/1039-summary.pdf

[3] AECOM (2009) The Role of Soft Measures in Influencing Patronage Growth and Modal Split in the Bus Market in England

[4] Currie G, Wallis I (2008) Effective ways to grow urban bus markets – a synthesis of evidence, Journal of Transport Geography 16 419–429, Elsevier

Figure 4.1 Outputs from Currie and Wallis' (2008) synthesis of findings[5]

'Soft' bus improvement		Valuation[a] (in-vehicle time minutes)	Notes	Estimated patronage impact (%)[b]
Boarding	No step	0.1	Difference between two and no steps	0.17[c]
	No pass show	0.1	Two stream boarding, no show pass vs single file past driver	0.17
Driver	Attitude	0.4	Very polite helpful cheerful well presented vs businesslike and not very helpful	0.68
	Ride	0.6	Very smooth compared to jerky	1.02
Cleanliness	Litter	0.4	No litter compared to lots of litter	0.68
	Windows	0.3	Clean windows, no etchings compared with dirty windows and etchings	0.51
	Graffiti	0.2	No graffiti compared with lots	0.34
	Exterior	0.1	Completely very clean compared to some very dirty areas	0.17
	Interior	0.3		0.51
Facilities	Clock	0.1	Clearly visible digital clock with correct time vs no clock	0.17
	CCTV	0.7	CCTV, recorded, visible to driver plus driver panic alarm compared to no CCTV	1.19
Information	External	0.2	Large route number and destination sign front, side and rear plus line diagram on side vs small signs	0.34
	Interior	0.2	Easy to read route no. and diagram compared to none	0.34
	Info of next stop	0.2	Electronic next stop sign and announcements vs no information	0.34
Seating	Type/layout	0.1	Individual shaped seats with headrests all facing forward vs basic double bench some backwards	0.17
	Tip-up	0.1	Tip up sets in standing/wheelchair area compared with all standing area in central aisle	0.17
Comfort	Legroom	0.2	Space for small luggage vs restricted legroom and no space for small luggage	0.34
	Ventilation	0.1	Push open windows giving more ventilation vs slide opening windows	0.17
		1.0	Air conditioning	1.70

Summary

4.14 This chapter has examined two different sources of information to corroborate the findings from this research. The first established that bus operators do not believe that AV technology on board buses would encourage people to travel more often, which supports the findings of this research. That said, the operator does still value the introduction of AV technology as it does represent a small improvement in the quality of bus service that they offer.

4.15 The second source was from a review of available literature on the effects of AV technology. This showed that passengers can put a monetised value on AV technology, and that it can lead to an increase in patronage of 0.34%. This also supports the findings from this research as it was not possible to discern any effects of AV, which it would not be able to do if the effects were as low as 0.34%.

[5] Currie G, Wallis I (2008, Table 2) Effective ways to grow urban bus markets – a synthesis of evidence, Journal of Transport Geography 16 419–429, Elsevier

5 CONCLUSION

5.1 From the data examined, neither statistical or trend analysis has indicated that the introduction of audio-visual equipment has had any effect on passenger numbers. In the test group of bus routes examined, no route showed a change in indices and therefore a change in patronage that could be directly attributed to the introduction of AV. Where variation in the data was observed, there was a known cause such as truncation of a route, re-routing or other mitigating circumstances.

5.2 The quantitative analysis was corroborated by a qualitative assessment of views of senior management at NCT who believe that AV is not something that would lead to a change in bus patronage. The operator does, however, state that it values the AV technology that it now has on its buses as it is a 'nice thing to have' and benefits some passengers.

5.3 The analysis was also supported by findings from past studies which established that on-bus AV technology would increase patronage by around 0.34%. Given that this increase is small, it would not be discernible from the data obtained from NCT in this study, particularly as the general variability within single route datasets was around 11%.

5.4 Overall, this research has demonstrated that there is no discernible effect of audio-visual technology on bus patronage on bus services in Nottingham, however this is not to say that there is no effect of the technology. Corroborative research suggests that there are positive effects of on-bus announcements that can increase bus patronage by a small amount.