Evaluation of Bin Fill Level Sensor Trial

Report for Enevo in partnership with London Borough of Islington Council

This report has been prepared by Paddy Knowles in July 2016

Version 5.0

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Report for Enevo & Islington Borough Council

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1.0. Executive Summary

1.1. APSE have been commissioned by Enevo in partnership with the London Borough of Islington Council, to carry out an independent analysis of a trial of Enevo Fill Level Sensors. These are being used by Islington Council on a trial round of the Council's domestic dry recycling collection service with sensors being fitted to communal dry recycling bins located around the borough. The timescale for the trial was initially set for a period of six months with two four week periods "pre and post" operation of the fill level sensor use being analysed and compared. This was extended to develop the system to obtain additional management information about the work and to improve the back office experience.

1.2. An initial meeting to scope out the parameters of the project was held at Islington Council's offices in Caledonian Road, which was followed by a period of what was called "as is data" gathering. This data would be gathered by the Enevo system before the new smart routing system going live and was intended to monitor only and not to arrange or influence the collections.

1.3. There is evidence from the analysis, that the routing system, although not being fully utilised at the moment, is having a positive effect in decreasing the number of containers visited below the initial 80% fill level, the subsequently lowered 60% level and the reduction in partial collections that the original methodology for routing the work was ineffective.

1.4 The number of sites visited between the pre and post implementation periods, indicating a fill level below 80% and 60% when visited by the vehicle were reduced by 38.9% and 44.6% respectively, partial collections were reduced by 48.95% indicating that the sensors where producing effective route lists consisting mainly of sites that were full. However there are issues with false readings which could be improved by reducing the number of false readings produced by residents not breaking down boxes, prior to placing them in the container.

1.5 Following the implementation of the smart route system and despite the crew not fully following the routes as prescribed, the number of sites visited overall each day have reduced by 44.28%. Breaking this down into containers shows a reduction in the number of containers visited each day by 52.02%.

1.6 This is against the backdrop of an increase in sites visited that are above the 80% or the adjusted 60% fill level when visited, clearly indicating that the sensors are having a dramatic and positive effect on the collections. It is also noted that between the two periods, there was also an increase in the volume and tonnage collected.

1.7 The crew are effectively paid to work a 7 hour day but in reality effectively work only between 5 and 6 hours, based on the operational time of the vehicle data. In reality the effective working time of the individual loaders will be somewhat less, with the exception of the driver who stays with the vehicles to the end of the day's work.

1.8 The analysis of fuel and mileage data, identifies a small reduction in the overall fuel usage as a result of the improved routing of the vehicle through the smart route system, which does have some small financial benefits for the service in terms of running costs of the vehicle. This could be further enhanced by replacing the current

vehicle with either a new Euro 6 vehicle or if that is not possible a younger vehicle from the current fleet.

1.9 For the purposes of continuity, two randomly chosen four week periods (Monday to Friday) were chosen as the pre and post implementation periods to be analysed. The pre implementation period in November 2015 and the post implantation period in May 2016.

1.10 Table 1 below shows some of the headline results from the two data sets downloaded in respect of fill levels and bins recorded as partial empties.

Table 1

Data Set	% Bins below 80% full when visited	% Bins below 60% full when visited	% Bins recorded as partial empties
Pre Operational Data **Monday to Friday 2nd to the 27th November 2015**	**47%**	**17%**	**41%**
Post Operational Data **Monday to Friday 2nd to the 27th May 2016**	**29%**	**9%**	**21%**

1.11 For the purposes of consistency this report uses tonnage data gathered from the Enevo system itself which calculates the tonnage using a combination of factors including volume and density of the waste collected. This means that the tonnage data recorded by the system slightly differs from the actual tonnage recorded at the weighbridge as it is an estimate based on a number of variables.

1.12 The data set for the 1st and 30th November 2015 (pre implementation) recorded by the system shows that 1,229 cubic metres of waste equating to 86 tonnes of waste was collected by the crew. The data set for the post operational period of the 1st and the 31st May 2016 indicates that 1,406 cubic metres equating to 98.4 tonnes. This is 177 cubic metres more than the pre implementation period equating to an additional 12.38 tonnes, equal to an increase in collected tonnage of 12.6% for both volume and weight.

1.13 Not all locations collected from have sensors installed for a number of reasons for example some sites are unsuitable for sensor use i.e. underground basements, those properties using sacks and some trade waste collections. The council are aware of this issue with these properties known locally as Cold Calls. Although they do not have sensors installed, they are included on the round list which can making identifying data for a specific locations on the system difficult.

1.14 The results then give figures for the total fuel usage for the pre implementation period was 839 litres at a costs of £765.71, giving a fuel usage per tonne collected of 9.76 litres per tonne and a cost per tonne of waste collected as £8.87. The fuel usage data for the post operation period indicates that the total fuel usage was 822 litres at

a cost of £734.42, giving a fuel usage per tonne collected of 8.96 litres per tonne and a cost per tonne of waste collected as £8.07.

1.15 One aspect of the project of particular interest is the carbon emissions from the activities of the round and the implementation of the route smart system. Refuse collection vehicles like the type used on this round vary from vehicle to vehicle in efficiency. The vehicle used by this round is an eight year old Dennis refuse freighter. Based on a standard carbon calculation methodology, recommend by the Fleet Transport Association shows that the carbon emissions based on fuel drawn for the vehicle for the whole period, calculated that for the pre implementation period 1st to the 30th of November 2015, the vehicle produced 2,162.09 Kgs of CO_2 or (2.16 Tonnes).

1.16 Based on the post implementation period 1st to the 31st May 2016, using the same methodology to calculate the carbon emissions, the same vehicle produced 2,122.14 Kgs of CO_2 or (2.12 Tonnes).

2.0 Introduction

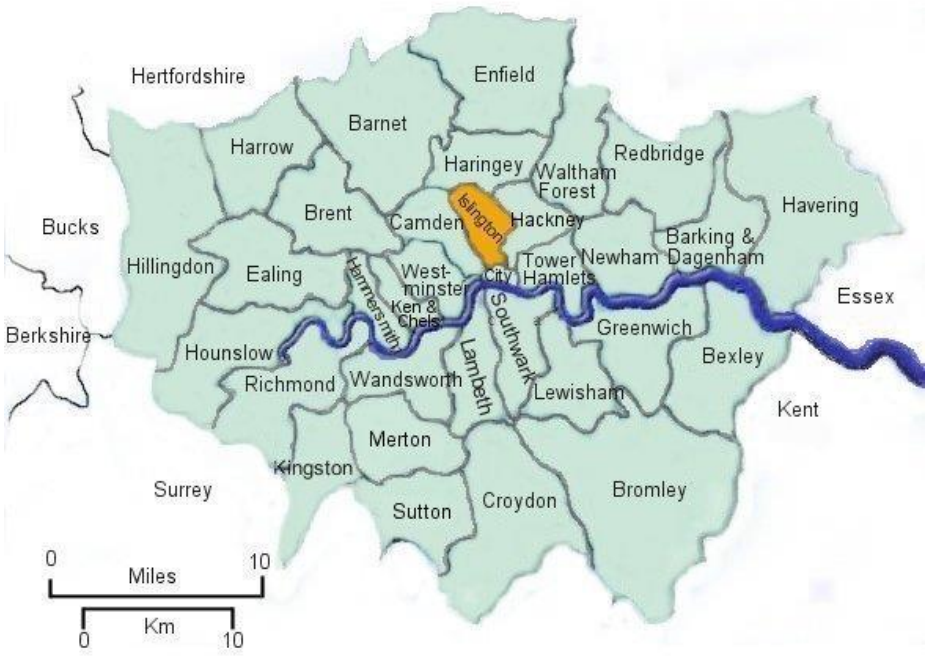
2.1 APSE Solutions were commissioned by Enevo in partnership with the London Borough of Islington Council to carry out an independent evaluation of a trial of fill level sensors fitted to on street communal dry recycling containers collected by round ER2 vehicle registration VX 57 ULG.

2.2 This work was commissioned following the successful trial of five bin level sensors in on street communal dry recycling bins, Enevo installed fill level sensors into the remaining 412, 1100 Litre to 1280 Litre bins of round ER2 in August 2015.

2.3 The London Borough of Islington is the third smallest local authority in the capital covering an area of just 14.86 kilometres square and has an estimated population of in excess of 215,667 people. The area is bordered on four sides by Haringey, Camden, Hackney and the City of London.

2.4 Islington is one of 33 Councils which form the administrative areas of Greater London and is divided into 16 wards, each electing three councillors.

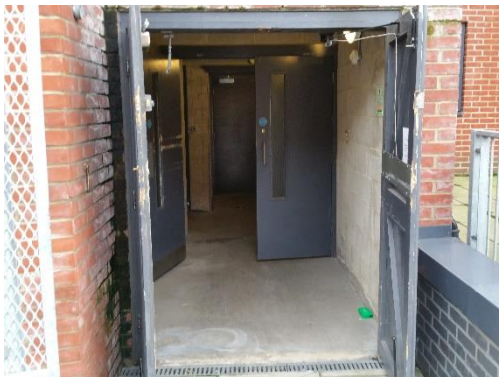
Fig 1 – Map showing the location of Islington



3.0 Current Picture

Cold Calls

3.1 Collection round ER2, is tasked with collecting a number of above ground communal bins containing mixed dry recyclable materials which are located at various property locations around the Islington area. The round is made up of mostly 1100 litre Euro containers which have, as part of the project been fitted with fill level sensors. There are also a number of locations that use communal bins that are unable to use sensors, particularly those located in underground storage areas (fig 2).



(Fig 2) Entrance to underground storage area

3.2 There are also a number of properties that are unable to use any type of bin and as with the underground storage areas are not currently recorded by the system when emptied but are included in the round list in the system, These are referred to locally as "cold calls".

3.3 With the exception of the 1100 bins used in the underground storage areas, many cold call locations use either 240 litre and 360 wheeled bins, reusable estate bags or clear sacks. The reusable estate bags are large black sacks into which waste is placed for movement to the vehicle which are then manually emptied into the wagon (Fig 3).

(Fig 3) Estate Bag

3.4 Estate bags are a large durable black sack into which the team would drag from location to location, collecting the material and dragging it to the vehicle. The vehicle lifts are then isolated and the recyclables are then manually emptied into the wagon and the sack reused for the next location.

3.5 The Council has begun a process intending to move as many of these properties over to 1100 litre communal bins so sensors can be fitted and will at that point be monitored by the new system. This has resulted in a number of sensors being installed in up to 100 x 240 and 360 litre bins around the borough. However installing sensors in all locations is not possible due to the nature of the property i.e. buildings where bins are stored inside and underground and those properties unable to accommodate any type of bin at all.

3.6 This does mean that there will always be a number of properties which are emptied by the crews but will not have the waste collected from them recorded by the system. This has an impact on the accuracy of the tonnage data recorded by the system and

should be noted when looking at certain aspects of the data from the system i.e. tonnage and property specific information.

3.7 The current round is based on standardised historical round data, however as the crew currently operate under a task and finish collection regime, crew do on a regular basis deviate from the standard round and use their own experience and local knowledge of the area to expedite the work.

3.8 Implementing the new smart route system is intended to allow the round to be planned effectively and efficiently, based on the information provided by the sensors, with the Smart Route system directing the vehicle only to those bins that have been identified by the system as being full (above 80%/60%) through Smart Plans.

Trial Methodology

3.9 The trial was initially planned to run for six months starting on 1st October 2015. With the evaluation being undertaken as desktop exercise of data gathered by the system, with three dates pre and post implementation of the smart route system to spend on site to receive training on the system itself and to observe the system in practice on the ground.

3.10 The initial trial period was further extended by an additional six months to allow for further development of the system to enable the Council to gather additional management data about the round and improve the quality of the data recorded by the system.

3.11 The evaluation centred on the following:

- **The current picture** – Based on operational data provided by Islington BC and Enevo with additional information gathered as required.
- **The current cost** – Financial information about the service area both pre and post implementation was provided by Islington Borough Council.
- **The trial data** – Data is provided in Excel format for ease of evaluation with additional data available through access to the system if required.
- **The impact on the service** – Analysis of potential efficiencies identified e.g. financial savings, CO_2 reduction and environmental impacts.

3.12 The trial round will operate, a business as usual period, for one month (four week period) to enable the gathering of data which will be used to compare with new data gathered following the full implementation of the smart plan system. Following the completion of the pre implementation period, Enevo will build the routing software which will produce the smart plans.

3.13 Following the completion of the smart plans the round would spent the same period of time (four weeks) operating under the new system, following the predetermined routes based on information received from the sensors with crews fully utilising the system and entering live data when required.

3.14 Following the completion of the four weeks work on the new system, data was downloaded and compared against the pre implementation data, to establish if the new system has increased the efficiency of the round and to gauge the environmental effect the system has had by way of reducing the carbon footprint.

4.0 Pre-Implementation Data (2nd to 27th November 2015)

4.1 To ensure delivery of a clear picture of what effect the new system had on the service, it was extremely important that the pre implementation data reflected what was actually happening on the ground prior to any influence from the fill level sensors or the software.

4.2 It was also felt that data from as early in the project as possible would be optimal to use to ensure that the system had not impacted directly or indirectly on what the crew would normally do or influence their decisions on which sites to visit and in which order.

4.3 Based on this principle, the period between the 1st and 30th November 2015 was chosen. However, the period would start and end in partial weeks, therefore the data used for the pre implementation analysis would only take into account the four full working weeks during that period, that being Monday to Friday between the 2nd to the 27th November 2015.

4.4 Looking at the sequence of collections from the data download, it appears that the system at this stage had not influenced the crew's decision in respect of sites to visit, as from day to day and week to week, the round changes appear random.

4.5 It is impossible to identify from the data, but it is feasible, that some of the changes in route may be as a result of influences beyond the crews control such as poor access to bins and traffic difficulties. In the absence of any real evidence it is assumed that it is based on the crew's local knowledge and experience of where they believe bins will be full and if there is some element of re-routing to avoid traffic or because of an access issue, it must be accepted as part of the normal routine.

Data Anomalies

4.6 The downloaded data highlighted a number of anomalies, which, following consultation with the service management have been identified as result of work being carried out by other crews, using the ER2 vehicle but working on different shift patterns, potentially emptying contaminated containers or addressing complaints about collections.

4.7 These collections were shown on the data as taking place outside normal working hours, late nights and weekends.

4.8 A number of examples of this can be seen below and are particularly anomalous as the service manager reports that no vehicles would be working so late into the evening that collections would be carried out at midnight:

- Sunday the 29th November 2015, the bin at Piper Close was emptied at 17.42 in the afternoon.

- Sunday the 1st November a container on Skinner Street was registered as being emptied on the system 22.15 pm.

- Monday the 2nd November, a container on Liverpool Road was registered as being emptied at 26 minutes past midnight.

4.9 The data recorded that on both Saturday and Sunday of every weekend during November, one, or in most cases many more than one bin was recorded as being emptied although there does not appear to be a pattern or programme to these collections. Although, according to service manager, a number of programmed collections are carried out at the weekend as well as a number which are due to issues like poor access or contamination.

4.10 It is based on this, that the decision was been taken to use the normal working week (Monday to Friday) as the target period for analysis as this appears to be the most consistent data set.

4.11 The system also recorded that on some week days, there are large periods of time elapsing between the penultimate collected bin and the last bin of the day being emptied, in some cases over 2 hours. It cannot be substantiated if this is the crew taking a break or if the crew have returned to the depot and another crew is using the vehicle.

4.12 As the evidence gathered indicates that on most days the crew completes its work between 12.30pm and 13.00pm, it is assumed that these are potentially contaminated bins being emptied by another crew.

4.13 This has since been confirmed by the service manager as being the case, however when looking at the contaminated bin data supplied by the council, it was impossible to match the locations recorded on the contaminated bin report against the data downloaded from the Enevo system.

4.14 This may be as a result of colloquialism when recording contaminated bins onto system with an element of local names being used rather than the prescribed description used on the Enevo system.

4.15 An analysis of the data for this period can be seen in Appendix 1.

Round Routing

4.16 Not having any routing software operational during this period, it is assumed that the crew have based the collections on a combination of what is perceived to be historical round information and their own personal knowledge and experience of Islington, based on many years doing the job and working out their own routes.

4.17 The effectiveness of this almost self-routing practice is shown by the data to be inefficient and flawed.

4.18 The analysis of the data for the November 2015 period, identifies that:

- An average of 47% of the bins visited throughout the period were below the 80% full level when the crew visited the site.

- An average of 40.86% of those sites were left with bins still containing materials following collections, which could be a mixture of contaminated bins and or the crew not emptying bins with only a very small amount of waste in them.

- An average of 41% of sites visited in this period were recorded as receiving only a partial collection by the system. This also reflects the above.

4.19 At this time, the system does not record whether or not any or all of these partial collections where as a result of contamination or not, although when the Enevo One system is fully operational the crew will have the ability to log contamination issues. However, as there is no benefit to the crew in leaving bins with acceptable waste in them, it is not unreasonable to assume that this is the case and if contamination is the main reason for the crew leaving bins. It poses another issue for the service of how to reduce contamination levels, to a level where the collections can be further enhanced.

4.20 In any case, there is no doubt that the current practice of almost self-routing is inefficient and ineffective and regardless of the crews past experience and knowledge of the area. There is no definitive way for them to know what the fill level of any one particular location on the route will be when they arrive, therefore it is at best, an estimate.

Working Time

4.21 On almost all of the days recorded in the Enevo round data for November 2015, it identifies that the round has an average start time of around 7.15am to 7.45am and an average completion time of 12.30 pm to 13.00pm. These timing relate to the wagon leaving and returning to the depot. The loaders would normally leave the wagon either at the point of the last bin being loaded into the wagon or as soon as it returns to the depot leaving the driver to tip the wagon. This extends his working time to approximately 5.56 hours.

4.22 The data recording starts at the point where the vehicle leaves the depot and ends when the vehicle returns to the depot, and is based on a week's work, Monday to Friday, excluding the weekends and times outside what would be perceived as the normal working day of 7 hours.

4.23 Based on the information available, the analysis shows that on average, effective work time equates to approximately 5.25 hours or 75% of the 7 hour working day. This includes travelling between jobs including cold calls, and may also be influenced by other things like heavy traffic etc. It does not include the periods of time the vehicle is parked in the depot waiting to leave first thing in the morning, breaks during the day or the 45 minutes to an hour that is reported by the driver to tip the vehicle on their return to the depot.

Waste Collected

4.24 Because of the way fuel allocation and usage is recorded by the Council, it was impossible from the downloaded data to make any analysis of the, cost of fuel against

the tonnage collected based on a daily or weekly use. The only figures available are based on the usage for the whole month. Therefore, these figures were used and show that between the 1st and 30th November, 1,229 cubic metres of waste was collected equating to 86 tonnes of waste.

4.25 It should be noted that a number of bins recorded as being emptied during this period are likely to have contained some level of contamination, therefore an unknown proportion of the 86 tonnes is likely to be contaminated waste and sent for disposal not recycling.

4.26 During the 4 weeks of the pre-implementation period analysed, the crew collected from 1,142 locations, an average of 228 locations per week or an average of 60 individual locations per day. In terms of individual containers during this period, the crew collected on average 2,357 containers, an average of 471 collections per week or 123 collections per day.

4.27 Based on the average working day of 5.25 hours this equates to an average of 23 containers per hour.

Enevo One

4.28 The original version of the system was extremely useful in enabling APSE to gather data on how the round operated pre system implementation and before the work could be influenced by the new "route smart" system.

4.29 The new version of the system has retained the same functions as the original version used to download the initial data set enabling a consistent approach in terms of the information moving forward, but is presented in a way that is more functional, operator friendly and in more detail.

4.30 The new system also introduces the "Smart Route's" which will be used to direct the collection crew on the most efficient route available for the work on that day.

4.31 The system now records and enables the crew to clearly identify abnormalities such as missed bins and bins not emptied as a result of contamination.

Enevo One (Smart Route) System Implementation

4.32 The Enevo One, Smart Route system went live on Monday 18th January 2016 with the crew being shadowed by a manager from the waste team to ensure they were fully up to speed with how to use the system.

4.33 The crew began to use the new system independently on Monday the 25th January 2016 and on the 26th January, APSE joined the crew for the day to observe the system operating live.

4.34 The crew consisted of a driver and two loaders, who through discussion with them appeared to be quite enthusiastic to be involved with the

(Fig 4) Typical bin type collected on the round

project and very willing to make the system work to their benefit.

4.35 Unfortunately a technical issues which was later diagnosed as the crew inputting the incorrect password into the tablet used, meant that the tablet was not available and therefore the crew had to work from a printed version of the route supplied by their manager. A copy of the smart route for the day APSE spent with the crew, downloaded from the system can be seen at Appendix 3.

4.36 Even at this early stage in its development and use, the system appears to be having a positive effect on the percentage of bins visited being below the 80% full level, as the data for the 26th January indicates that the number of bins visited indicated as being below the 80% fill level was a total of 15 against an average in the downloaded November data of 27.

Site visit – observation with the Crew – 26th January 2016

4.37 APSE joined the crew at the main depot at approximately 7.00am and stayed with them until the wagon returned to the depot at approximately 12.00pm. No observation was made of the vehicle tipping the material collected as this did not impact on the efficiency of the sensors and therefore it was not felt necessary to observe it.

4.38 Throughout the day it was obvious that the crew were making good progress and there was absolutely no indication that they were not working in anyway different than they would had APSE not been there. They were helpful and co-operative in answering any questions put to them in respect of the use of the system.

4.39 With the tablet normally used by the driver to record incidents and confirm collections not working, the crew were required to use a printed copy of the plan. When the loaders saw this, their initial reaction was that they were uncertain that they would be able to complete the work within the day and questioned the time allowed to complete the work which was indicated at the top of the sheet as 4.44 hours.

4.40 This initial reaction proved to be unfound as it became obvious as the day progressed that the crew would complete the work within the normal working day.

4.41 The printed smart route was in effect a list of addresses for the containers and the crew suggested that if in the future they would be required to work of printed routes rather than from the tablet, that perhaps more detailed information such as, the number of containers at each location and if needed door or access codes should be included. Since the initial visit, the crew suggestion have been taken on board and have been fully implemented.

4.42 Although not considered a difficulty for the regular crew members, it was felt that this could be a problem, if for any reason all the members of the regular team became unavailable and a scratch crew was put on the round as they may have considerable difficulty finding their way around, finding the containers and when they did accessing them if a code or key was required.

4.43 Throughout the day the vehicle visited a number of sites where the system showed bins as full or ready for collection. However, when we arrived on site, there were bins which were not yet full. These were bins that may have registered as full due to the fact they had a large cardboard box or some other item in them that hadn't been broken down by the resident, giving a false reading (Fig 5).

(Fig 5) Possible cause of false sensor reading

4.44 This happened at a number of sites and although impossible to completely eradicate, did raise a potential miss-use and education issue for the authority.

4.45 It was also observed that there were a number of locations that as the crew drove past, were obviously full as the lids were up and waste could be seen overflowing from the bins.

4.46 These were not on the round list for that day and there was some debate as to whether or not these should be emptied by them. Although not all, the crew did empty a number of these bins as they were directly passing them. Following the site visit, the service made us aware that through complaints raised, some of these properties are often being emptied off plan.

(Fig 6) One of the tight street corners navigated by the crew Drovers Way

4.47 Among the other issues observed which have the potential to make collections difficult are congested traffic conditions and the vehicle having to navigate very narrow streets containing double parked cars (Fig 6).

4.48 On the day APSE spent with the crew it was obvious from what was observed and the feedback from the crew that the system having both a positive and a negative effect on some areas of the service. However, it was also obvious that at this stage in the systems development and in the trial itself that there were still a number of both operational and technical issues to iron out, and that the team needed further time to develop their relationship with the system and for the software to be tweaked to remove any technical issues which should be expected with a new system.

4.49 It is also true to say that up to this point which was confirmed by the driver, that the crew had not actually completed any single days work following the prescribed route provided by the smart route and had gone off route and back to self-routing to get the work completed, although no reason was given for this.

4.50 A second site visit was planned for May 2016 to again spend the day with the crew to see how the system has developed and how the crew had adapted to the new collection system.

5.0 Monitoring Period

5.1 Between the first programmed site visit in January 2016 and the second in May 2016, the system, went through a period of development.

5.2 Although no formal in depth analysis of this period has been undertaken it was felt prudent to regularly monitor the system through the overview page and route plan pages to enable an up to date picture to be formed of how the crew were adapting to using the system following the initial visit and in particular their compliance with the smart routes presented by the system each day.

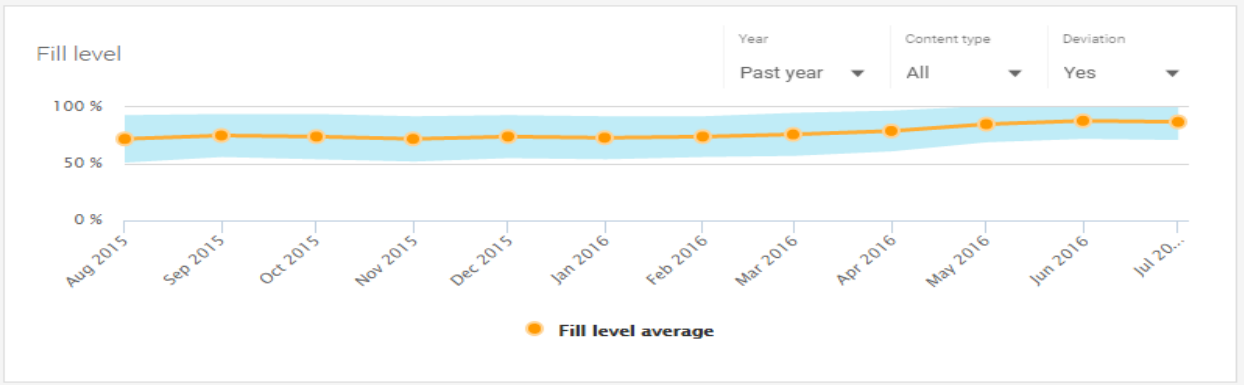
5.3 Not following the designed smart route has been an issue that had previously been observed on the system and on the ground during the first site visit, with the crew deviating from the prescribed route and on some days not using the system at all to log completed work or contaminated bins. There are a number of reasons to explain this including the app used failing to work properly and if the crew are using a different vehicle, issues around charging the tablet as the regular vehicle has the charging system hard wired into the vehicle.

5.4 However, it is true to say that at no time up to the point of the second site visit in May 2016 or since, have the crew followed the prescribed route from start to finish, despite a specific request from APSE to the crew for them to follow the route on one day to enable a view to be taken as to the effectiveness of the routing system.

5.5 During this period and using the Overview front page on the system to look at the performance of the round, in particular in respect of increasing the amount of bins that are recorded as full when visited by the vehicle, it can be seen as having a very positive effect since the system went live in January 2016.

5.6 Fig 7 below is taken from the Overview page of the system and clearly indicates that since the system was set up in July 2015 with the exception of July itself, the average fill level recorded had remained constant at between 72% and 73%. Since the smart route system went live in January 2016 the average fill level had risen consistently month on month, from an average of 73% in January 2016 to an average of 87% in July 2016.

Fig 7.

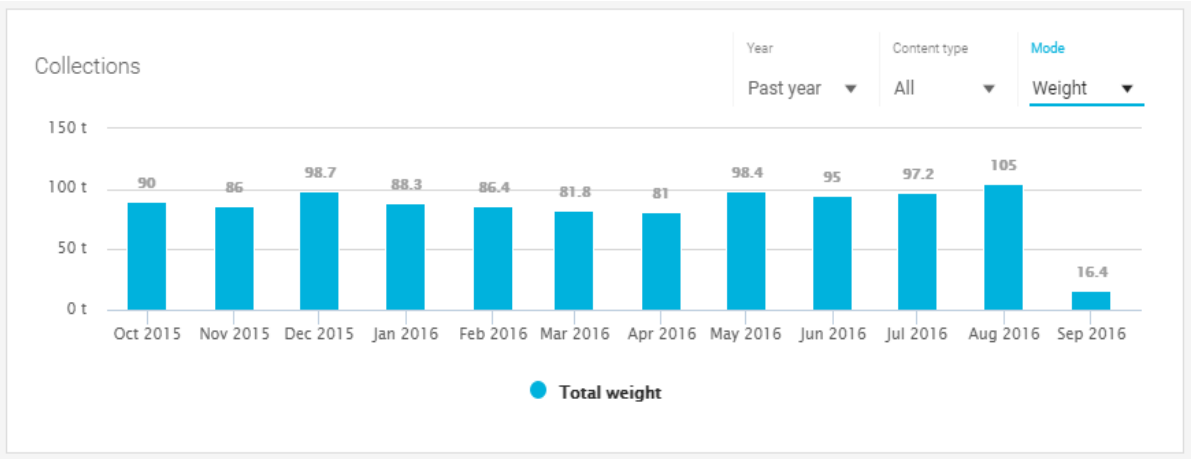


5.7 Interestingly, the system also shows, as can be seen in Fig 8 below, the weight collected in KGs in the initial stages of 2015 growing consistently to a peak in December which to a degree could be seen as a seasonal peak due to the Christmas festivities. At the point that the system went live in January there then appears to be a period where the tonnages consistently reduce up to May when there is another peak.

5.8 This peak could be contributed to an event such as the European football championships which began in May and there was also a period of good weather which could have resulted in additional recycling from BBQs etc.

5.9 The reduction in weight over the months January to April equated to a reduction of by 8.2% with weights being between 80 and 90 tonnes per month. Only time and further monitoring will tell if the peaks recorded are one off event or seasonal peaks. However. Looking at the data for preceding months up to September 2016 shows tonnages and volumes remaining consistently high with a great peak to 105 tonnes in September.

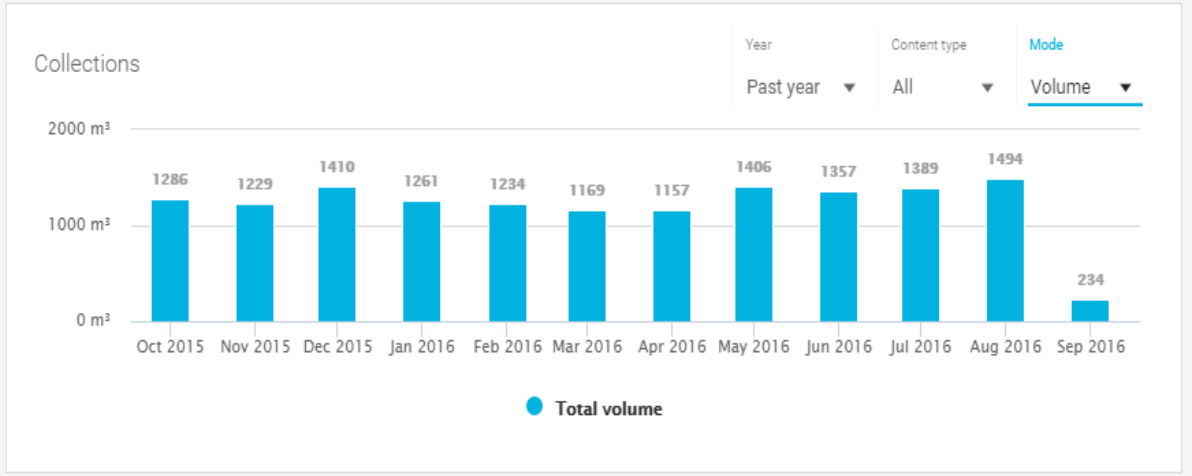
Fig 8.



5.10 Looking at Fig 9 below, it shows a reasonably consistent picture with that of the tonnage in Fig 6 above. The same peaks can be observed appearing in the data and since the implementation of the system it can be seen that the volumes of waste collected again consistently reducing over the first 4 months of 2016, again by 8.2% between 1261 m^3 and 1157 m^3 with May's figure peaking as in the tonnage data.

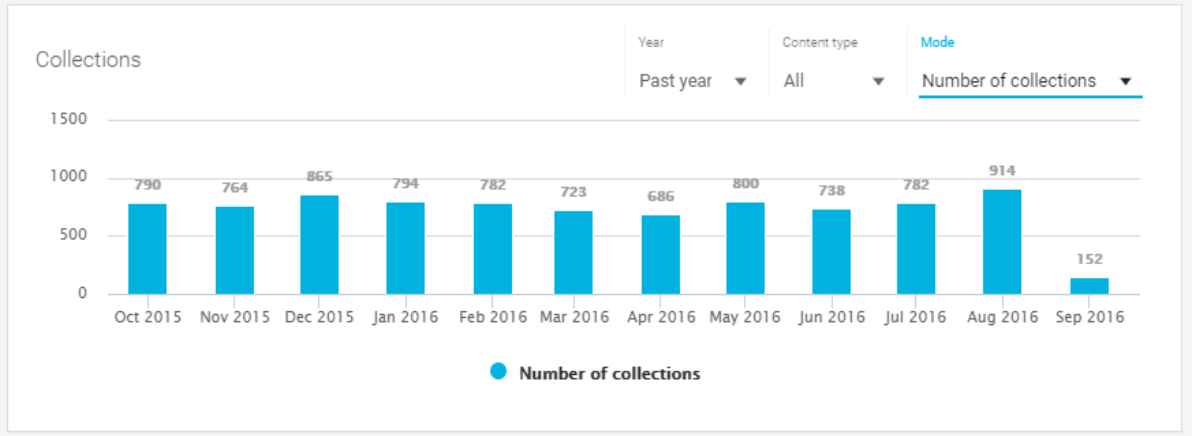
5.11 As expected, volumes and tonnages data appear to be directly correlated and follow the same trend. It also gives the opportunity to observe potentially where peaks in demand will arise in the future.

Fig 9.



5.12 In contrast, Fig 10 below shows that following the implementation of the system going live in January there is again a consistent month on month reduction in the number of collections made but equating to a considerably higher degree (13.6%). This increased reduction in the number of collections is greater than the reduction in volume and tonnage of 8.2%, and could indicate that the team is making less collections overall with only a minimal effect of volume and tonnage collected.

Fig 10.



5.13 Although not definitive, this is possibly the first indication that the system may be having a positive effect on the service provision and if the current issues regarding compliance with the given route could be resolved, these efficiencies might be further enhanced.

5.14 This initial hypothesis, will of course be investigated in more detail through the analysis of the two sets of downloaded data.

Smart Route Compliance

5.15 One of the most important aspects of any project involving route optimisation is compliance with the route produced by the system. There has been a number of issues with getting the crew to comply with the smart route issued by the system in its entirety and there are a number of potential explanations for this including;

- The fact that the routing system does not recalculate the optimised route when they divert, like a normal Sat-nav might do.

- Traffic and access issues.
- The crew believing that their local knowledge is better than the system.

However, although the system does show the crew going off route every day since the system was activated, it should also be noted that the crew do follow large stretches of the plan, although not always in the order they appear on the plan.

5.16 Discussions with the service management, indicate that the only person on the team that appears to have any confidence in using the system is the Driver and when he is off on leave or sick, the loaders feel unable to operate the system and none of the replacement drivers have been trained to use the system.

5.17 This is an obvious issue if this system was to be adopted across the service.

6.0 Analysis of Post Implementation Data (2nd to 27 May 2016)

6.1 Following a period of implementation and adjustment and as a result of the second site visit on the 26th May 2016, it felt appropriate that the post implementation data should be taken from the period between the 1st and 31st of May 2016. However, as with the pre implementation data period, this period also starts and ends in partial weeks. As with the initial data set, for the purpose of consistency the post implementation data follows the same principle and takes into account the four full working weeks during that period, that being Monday to Friday between the 2nd to the 27th May 2016.

6.2 An analysis of the data can be seen in table form in Appendix 2.

Data Anomalies

6.3 The anomalies identified in the pre implementation data download in November 2015 are still evident but can now be explained as a result of work being carried out by other crews and working on different shift patterns and weekends, potentially emptying contaminated containers or addressing complaints about collections.

Round Routing

6.4 At this stage of the trial the crew now have complete access to the routing system, however, it is noticeable that the crew has still, for whatever reason, not completed any one single day's work since it was introduced, following the prescribed route.

6.5 It has been explained to the crew by both their manager and by APSE how important it is for the trial, to be able to test the effectiveness of the routing system. Despite their service manager going out with them, the crew have not yet been able to complete one single day on route and have consistently gone off route at several points in the working day as can be seen from the route plan for the 26th May 2016 in Appendix 4.

6.6 For operational reasons, before the second analysis was carried out the decision was taken to reduce the sensors fill indicator from 80% to 60% in an attempt to improve fill indication as this was reduced and the system not triggering a collection due to the area at the back of the bin not being fully utilised when the lids were locked. Table

2 below shows the comparison of the data sets in respect of these issues, including the percentage increase or decrease in each aspect.

6.7 The analysis clearly shows that following the implementation of the new system and despite the fact that the routeing system is not being used to full effect, both the percentage of bins recorded as below 80% and following the resetting of the fill level to 60% when visited by the wagon, decreased by 18% and 8% respectively dramatically increasing the number of bins recorded as full. The system also recorded that the percentage of bins containing waste following the collection and the recorded partial collections also reduced dramatically by 19% and 20% respectively.

Table 2

	80% fill level	60% fill level	Bins left with materials in following emptying	Bins recorded as Partial Empties
Pre Operational Data Monday to Friday 2nd to the 27th November 2015	% Bins below 80% full level **47%**	% Bins below 60% full level **17%**	% Bins left with materials inside following collections **41%**	% Bins recorded as partial empties **41%**
Pre Operational Data Monday to Friday 2nd to the 27th November 2015	Bins above 80% **53%**	Bins above 60% **83%**	% Bins completely emptied **59%**	% Bins completely emptied **59%**
Post Operational Data Monday to Friday 2nd to the 27th May 2016	% Bins below 80% full level **29%**	% Bins below 60% full level **9%**	% Bins left with materials inside following collections **22%**	% Bins recorded as partial empties **21%**
Post Operational Data Monday to Friday 2nd to the 27th May 2016	Bins above 80% **71%**	Bins above 60% **91%**	% Bins completely emptied **78%**	% Bins completely emptied **79%**

Waste Collected

6.8 To ensure consistency, the analysis of the post implementation data was carried out on the same basis as the initial November 2015 data. Looking at the analysis, the tonnage of waste collected during the May 2016 data period, indicates that between the 1st and 31st May 2016, 1,406 cubic metres of waste which equates to 98.4 tonnes, equal to an increase in collected tonnage over two periods of 12.6% for both volume and weight.

6.9 As with the November data, it should be noted that during this period this tonnage is likely to contain some level of contamination and an unknown proportion of the 98.4 tonnes is likely not to be sent for disposal not recycling.

6.10 During the 4 weeks of the post-implementation period analysed, the crew collected from 662 individual locations, an average of 132 locations per week or an average of 26 individual locations per day. In terms of individual containers during this period, the crew collected on average 1,176 containers, an average of 235 collections per week or 59 collections per day.

6.11 Based on the average working day of 5.64 hours this equates to an average of 10 containers per hour.

Site visit – observation with the Crew

6.12 APSE arrived at the depot to join the crew at 6.30am on the 26th May 2016, however the driver was delayed and the crew were unable to leave the depot until 7.52. APSE again stayed with the crew until the wagon returned to the depot at approximately 12.48pm. As with the first visit in January 2016, no observation was made of the vehicle tipping the material collected as again this did not impact on the efficiency of the sensors.

6.13 Again as with the previous visit and despite starting late, the crew made good progress and there was again no indication that they were not working in anyway different to their normal practice. The crew were helpful and co-operative with the driver answering any questions put to him in respect of the use of the system and demonstrating that in practice.

6.14 As on the previous visit, the crew again did not follow the prescribed route which can be seen in the downloaded route plan and map in Appendix 4.

6.15 There were also, as on the first visit, a number of sites where the system must have been showing bins as full or ready for collection to have included them on the route, but when the crew arrived the bins were not yet full. However, it should be noted that the number of occasions this happened during the second site visit was significantly lower (20%) than on the first (Fig 5), and again were as a result of the same issue, boxes not being broken down by the resident, giving a false reading (Fig 11).

(Fig 11) Possible cause of false sensor reading

7.0 Conclusions

Collection data

7.1 It is clear from the analysis that in terms of productivity, the system has had quite a dramatic effect on some areas of the service, such as the number of locations visited, the number of containers emptied per week, the number of collections recorded as

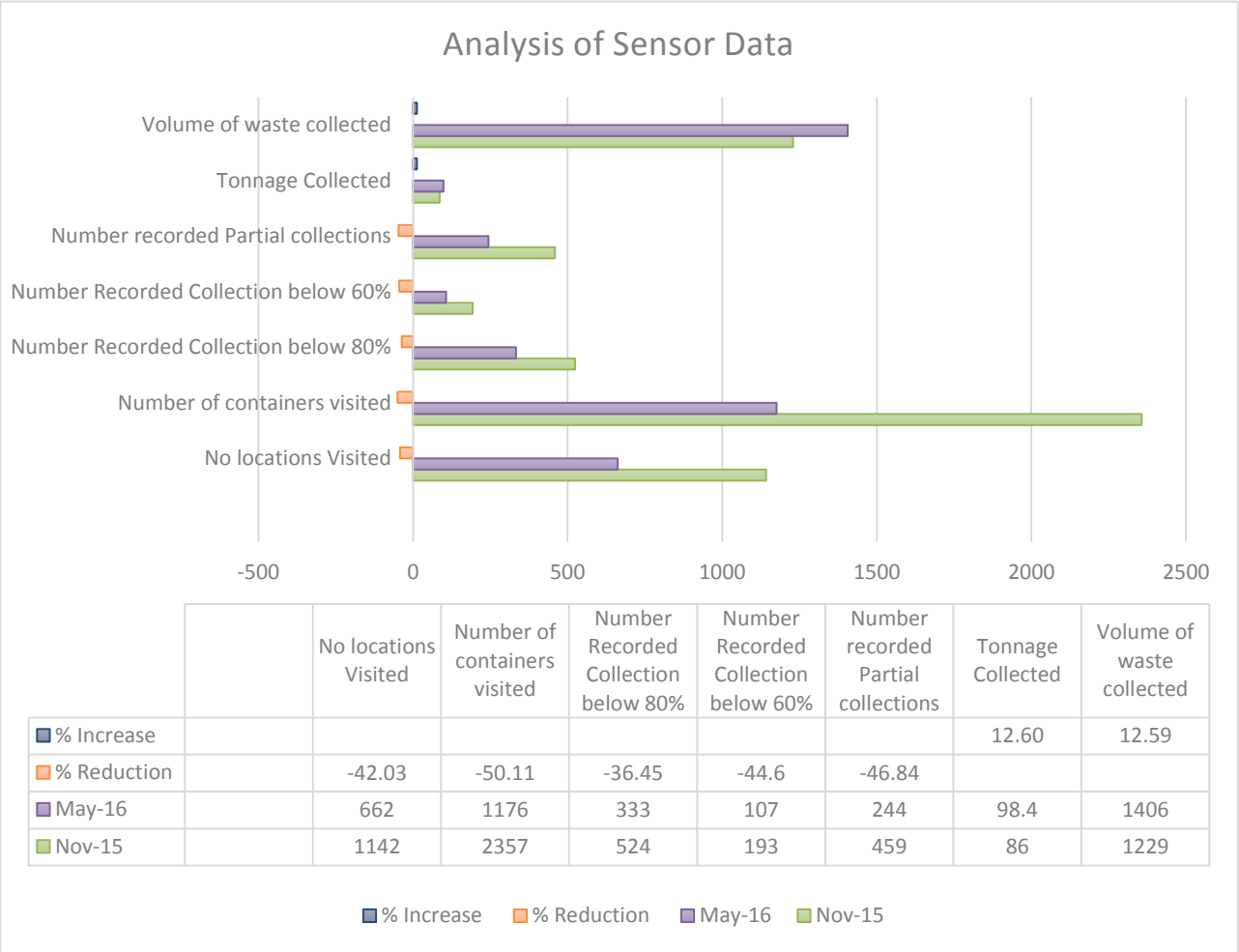
below the initial fill level of 80% and the subsequent 60% level the sensors were reset to part way through the project and to a lesser degree the tonnage collected.

7.2 The analysis of the pre and post implementation data periods show that there have been significant decreases (44.28%) in the number of locations visited, a (52.02%) decrease in the number of containers visited and a (38.9%) reduction in the number of bins visited recorded as below the initial 80% level and a (44.60%) reduction in the number of bins recorded a below the reset 60% fill level, whilst the tonnage of waste collected has increased slightly.

7.3 It is also interesting to note that as expected, the volume of waste collected over the two data periods has increased to a similar extent as the tonnage by (12%). Although this is not generally reflected in the 5 months between the two data periods as can be seen in figure 12 below.

7.4 Fig 12 below pictorially represents the results of the analysis of the collection data for the pre and post implementation periods.

Fig 12



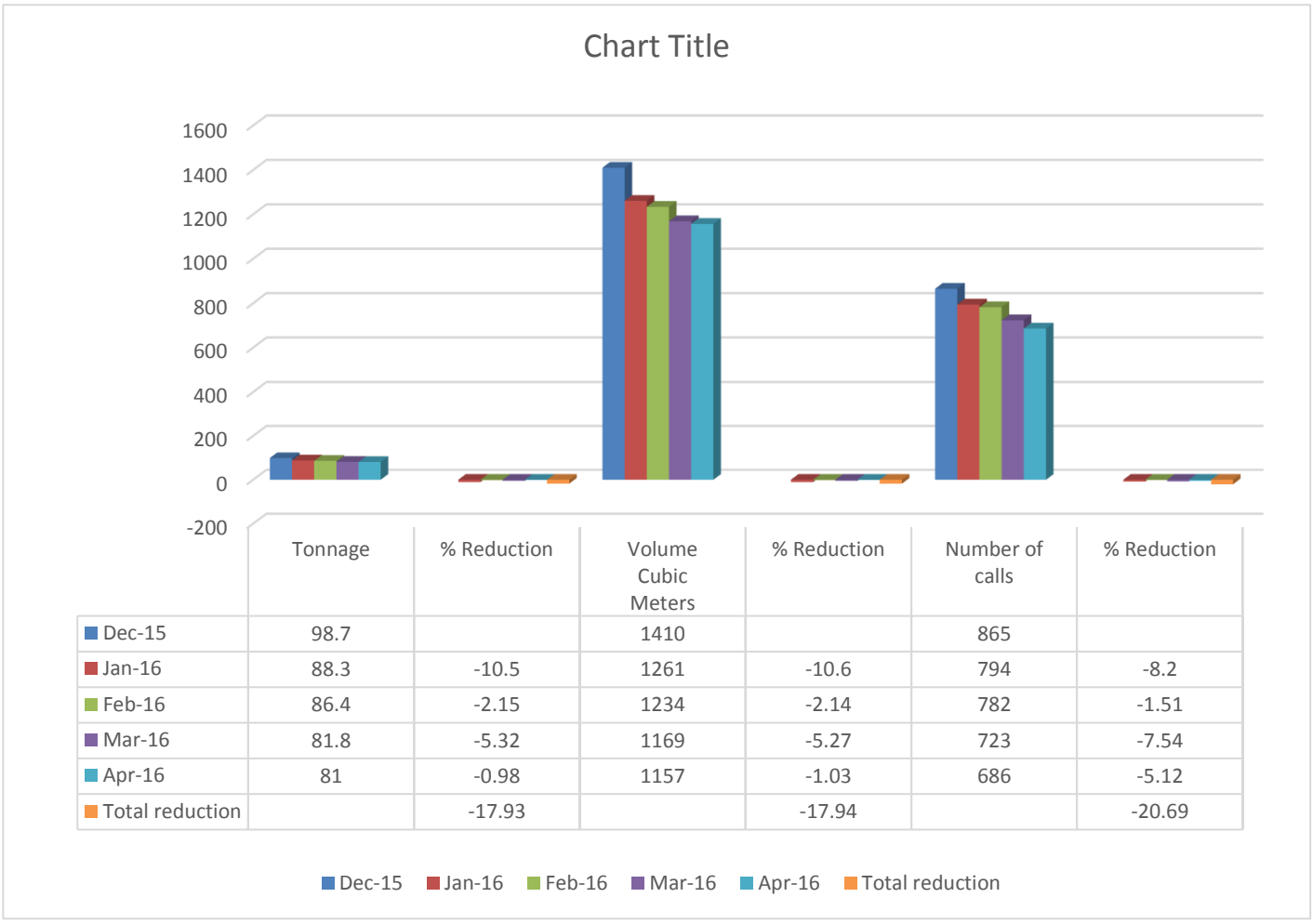
		No locations Visited	Number of containers visited	Number Recorded Collection below 80%	Number Recorded Collection below 60%	Number recorded Partial collections	Tonnage Collected	Volume of waste collected
% Increase							12.60	12.59
% Reduction		-42.03	-50.11	-36.45	-44.6	-46.84		
May-16		662	1176	333	107	244	98.4	1406
Nov-15		1142	2357	524	193	459	86	1229

7.5 It should be noted at this stage that the comparison between the two individual four week periods, is a snapshot look at the effect over a short period. Therefore, due consideration needs to be given to the five month period between the two data periods which shows that during that time there were fluctuations in the results shown on the overview page of the system.

7.6 Figure 13 below is an analysis of the data from the overview page, for the 5 months between the pre and post implementation data set and shows a consistent reduction in tonnage collected, volumes of waste collected and number of calls made of between 17% and 21% with tonnage and volume following a similar trend, however it should be recognised that tonnage and volumes of waste did not reduce as steeply as the number of locations visited.

7.7 There are a number of reasons that could account for this drop off, seasonal variations, the crew getting used to the new system, changes in manning of the crew when the driver or other full time team members are off sick or on leave, and possibly the crew not following the smart route to its full effect. It is impossible to justify any one reason at this time.

Fig 13



	Tonnage	% Reduction	Volume Cubic Meters	% Reduction	Number of calls	% Reduction
Dec-15	98.7		1410		865	
Jan-16	88.3	-10.5	1261	-10.6	794	-8.2
Feb-16	86.4	-2.15	1234	-2.14	782	-1.51
Mar-16	81.8	-5.32	1169	-5.27	723	-7.54
Apr-16	81	-0.98	1157	-1.03	686	-5.12
Total reduction		-17.93		-17.94		-20.69

Working Time

7.8 The service currently operates a task and finish work regime. In essence, once the work for the day is completed the crew are free to go home. On both of the two days spent with the crew, one of the regular loaders left the vehicle as soon as the last bin was loaded with only one of the loaders (agency) returning to the depot with the wagon.

7.9 The data does not record or identify the effective working time of the individual crew members but does identify effective use of the wagon which speaking to the service

management, the time allocated to completing the work was calculated through work carried out by Eunomia taking into consideration factors such as allocated breaks, vehicle checks and tipping times and is set into the Enevo system for the wagon and is reflected in the daily working times shown on the smart routes.

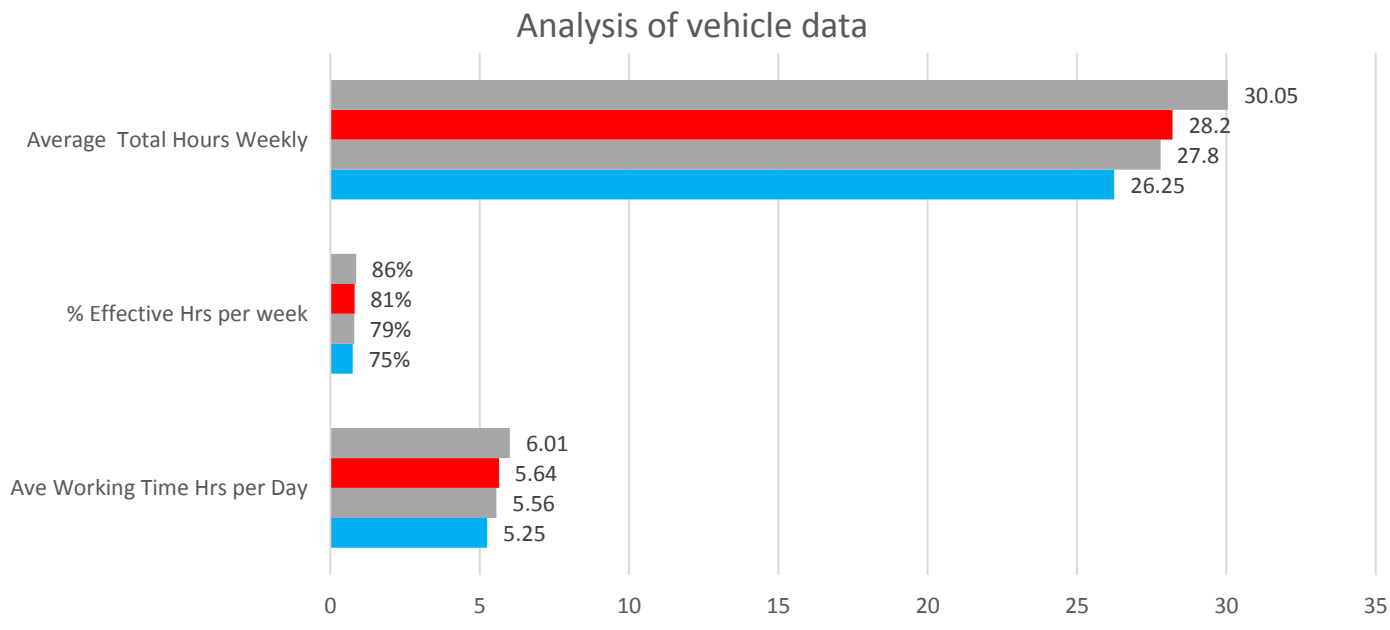
7.10 The data shows that there is little difference between the two periods with only a slight increase in the effective hours and average working time per week between November 2015 and May 2016 but with a slight increase in the average hours worked.

7.11 Figure 14 below, shows the effective working hours of the crew and vehicle. It should be noted that the hours indicated for the individual months 2015 and 2016 show the time the vehicle starts and finishes collections at the depot and the time including tipping the vehicle is shown separately. However, in the case of the effective hours worked by the loaders in as in many cases they leave the wagon before the vehicle returns to the depot, the effective working hours for the loaders will be much less in every case.

7.12 It is true to say that the only crew member's time that can effectively be considered as accurate is the driver as they are with the vehicle until it is parked up.

7.13 It is unknown at this time if the effectiveness of the wagon would be further improved by the crew following the smart route, as it is issued to them, as so far throughout the trial they have failed to follow it.

Fig 14



	Ave Working Time Hrs per Day	% Effective Hrs per week	Average Total Hours Weekly
Inc tipping	6.01	86%	30.05
2016	5.64	81%	28.2
Inc tipping	5.56	79%	27.8
2015	5.25	75%	26.25

7.14 Figure 15 below shows the average collection data for the number of collections and containers over the two periods and shows the effectiveness the routing system has had on collections with the crew visiting less locations and containers per week / day whilst tonnage and volume has increased.

7.15 During the four weeks of the pre-implementation period analysed, the crew collected from 1142 locations, an average of 228 locations per week or an average of 60 individual locations per day. In terms of individual containers during this period, the crew collected on average 2,357 containers, an average of 471 collections per week or 123 collections per day.

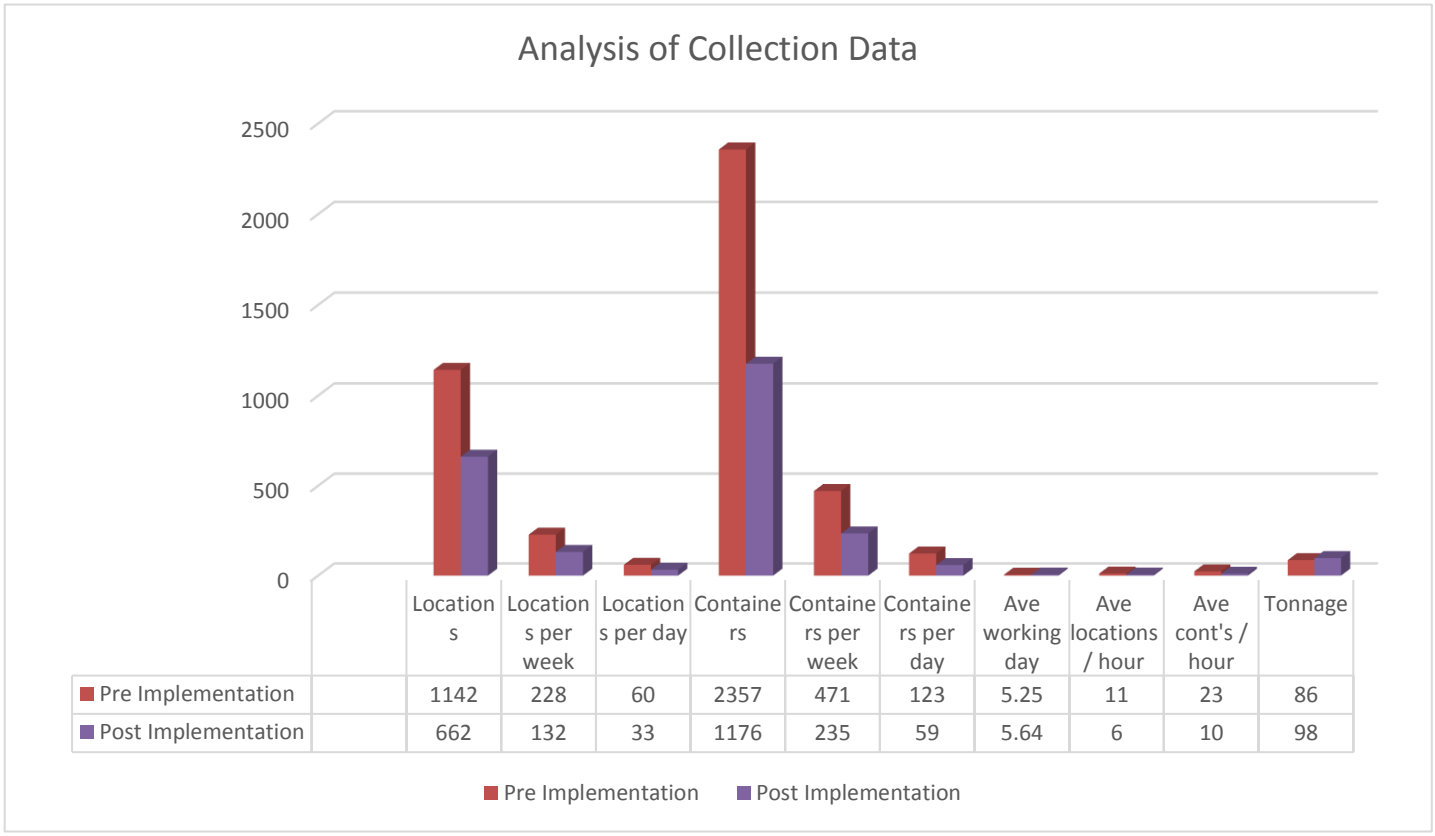
7.16 Based on the average working day of 5.25 hours this equates to an average of 23 containers per hour

7.17 During the 4 weeks of the post-implementation period analysed, the crew collected from 662 individual locations fitted with sensors, an average of 132 locations per week or an average of 33 individual locations per day. In terms of individual containers during this period, the crew collected on average 1,176 containers, an average of 235 collections per week or 59 collections per day.

7.18 It should be noted that the figures quoted in 7.17 above does not take account of the cold calls on the route and it should be noted that the actual number of sites visited per week and per day will be greater. It is understood that sensors have now been fitted to a large number of cold calls locations which should make any further analysis more accurate.

7.19 Based on the average working day of 5.64 hours this equates to an average of 10 containers fitted with sensors per hour.

Fig 15



	Locations	Locations per week	Locations per day	Containers	Containers per week	Containers per day	Ave working day	Ave locations / hour	Ave cont's / hour	Tonnage
Pre Implementation	1142	228	60	2357	471	123	5.25	11	23	86
Post Implementation	662	132	33	1176	235	59	5.64	6	10	98

Fuel Usage

7.20 Because of the way the work is structured, this section will, as it is impossible to identify the usage on a daily basis, cover the whole period including the weekends.

7.21 The downloaded data set for the 1st and 30th November 2015 (pre implementation) shows that 1,229 cubic metres of waste equating to 86 tonnes of waste was collected by the crew. The data set for the post operational period of the 1st and the 31st May 2016 indicates that 1,406 cubic metres equating to 98.4 tonnes, some 177 cubic metres more than the pre implementation period. This equates to 12.4 tonnes, equal to an increase of 12.6% for both volume and weight.

7.22 Table 3, below is an analysis of data taken from fuel usage information supplied by Islington Council and shows that the vehicle "VX57 ULG" (ER2), used during the pre-implementation period 839 litres / 184 gallons of fuel during November 2015 at an average cost of £0.91p per litre, making the total cost of fuel for this period £765.71p or an average fuel cost per day of £25.52p. In terms of tonnage this equates to a fuel usage per tonne collected of 9.76 litres per tonne and a cost per tonne of waste collected as £8.87p.

Table 3

Date & Time	Vehicle Reg	Litres Used	Gall Used	Fuel	PPL	Cost £	Start Km's	End Km's	Miles	Km	MPG	km per litre
02/11/2015 08:20	VK57ULG	110	24.19	DSL	0.92	101	50562	50623	37.9	61	1.57	0.554
04/11/2015 18:20	VK57ULG	110	24.19	DSL	0.92	101	50623	50707	52.19	84	1.57	0.763
09/11/2015 13:01	VK57ULG	110	24.19	DSL	0.92	101	50707	50793	53.44	86	1.57	0.781
09/11/2015 21:00	VK57ULG	44.7	9.83	DSL	0.92	41.04	50793	50823	18.64	30	1.89	0.671
13/11/2015 10:31	VK57ULG	110	24.19	DSL	0.9	99.21	50823	50916	57.79	93	1.57	0.845
16/11/2015 06:59	VK57ULG	66.9	14.71	DSL	0.9	60.34	50916	50969	32.93	53	2.24	0.792
16/11/2015 14:57	VK57ULG	39.4	8.67	DSL	0.9	35.53	50969	51000	19.26	31	2.22	0.786
19/11/2015 07:14	VK57ULG	106.7	23.47	DSL	0.9	96.23	51000	51082	50.95	82	2.17	0.768
23/11/2015 13:32	VK57ULG	101.9	22.41	DSL	0.92	94.21	51082	51161	49.09	79	1.79	0.775
23/11/2015 20:58	VK57ULG	39.1	8.6	DSL	0.92	36.15	51161	51192	19.26	31	2.23	0.792
	Total	**839**	**184**			**765.71**		**630**	**391**	**630**		
	Average				**0.91**						**2.12**	**0.75**

7.23 Table 4 below shows the same analysis for the post implementation period and shows that the vehicle used 822 Litres / 181 gallons of fuel at an average cost of £ 0.90p per litre, making the total fuel cost for the period £734.42p or an average fuel cost per day of £23.69p. In terms of tonnage this equates to a fuel usage per tonne collected of 8.96 litres per tonne and a cost per tonne of waste collected as £8.07p.

Table 4

Date & Time	Vehicle Reg	Litres Used	Gallons used	Fuel	PPL	Cost £	Odo Kms	Odo Miles	MPG	km per litre
03/05/2016 9.05	VK57ULG	91.7	20.17	DSL	0.88	81.19	54497	33864		
05/05/2016 13.23	VK57ULG	110	24.19	DSL	0.88	97.39	54593	33923		
11/05/2016 9.04	VK57ULG	98.9	21.75	DSL	0.9	88.03	54671	33972		
16/05/2016 7.16	VK57ULG	101.8	22.39	DSL	0.9	90.61	54760	34027		
20/05/2016 7.2	VK57ULG	110	24.19	DSL	0.9	98.96	54851	34084		
23/05/2016 8.39	VK57ULG	89.6	19.71	DSL	0.9	80.6	54937	34137		
25/05/2016 12.57	VK57ULG	110	24.19	DSL	0.9	98.82	55032	34196		
30/05/2016 11.08	VK57ULG	110	24.19	DSL	0.9	98.82	55121	34252		
	Total	**822**	**181**			**734.42**	**624.00**	**387.75**		
	Average				**0.90**				**2.14**	**0.76**

7.24 It should be noted that there is a reduction in fuel costs between the two periods of £31.29, which potentially could indicate a saving on this wagon of £375.48 per year in fuel costs. If this system was rolled out across the full 6 recycling rounds a potential saving of £ 2,252.88 per year might be achieved, this would vary with the varying efficiencies of each wagon on the service.

7.25 Even greater efficiencies could be achieved by replacing the current vehicles with the more efficient Euro 6 model, and also, potentially by the crew following the prescribed route as it is produced by the smart route system, instead of the current practice whereby the crew follow the route part of the time and do their own thing the for the remainder.

8.0 Environmental Implications

Carbon Emissions

8.1 Carbon emissions from multi modal refuse vehicle like the type used here will vary from vehicle to vehicle and there are a number of factors that can effect this including the age and condition of the vehicle, maintenance regimes and even the way the vehicle is driven by the individual driver, in particular where vehicles are double shifted.

(Fig 16) Vehicle ER2 (VK57ULG)

8.2 The vehicle identified as normally being used by round ER2 (Fig 16) is an 8 years old Dennis refuse freighter, which in terms of operational refuse vehicles is quite old and possibly coming towards the end of its useful life as a front line vehicle, therefore it may not be as efficient in terms of fuel usage as a new or newer vehicle.

8.3 A daily breakdown of fuel usage and mileage data for round ER2 was not available due to the way the council records fuel and mileage data, therefore daily carbon emissions were not able to be calculated on a day to day basis but only averaged from the data available. Information based on the fuelling up of the vehicle for the month, which includes mileage data between fuelling gives us information which can be used to calculate the carbon impact of the vehicle for the particular target periods does allow some estimates to be made in this respect.

8.4 The fuel data supplied by the authority identified the following:

- In November 2015 the vehicle travelled 391 miles.
- In May 2016 the vehicle travelled 387 miles.

- In November 2015 the vehicle did on average 2.12 miles to the gallon
- In May 2016 the vehicle did on average 2.14 miles to the gallon.

- Fuel type = Diesel

- In November 2015 the Fuel Usage = 839 Litres / 184 Gallons
- In May 2016 the Fuel Usage = 822 Litres 181 Gallons

8.5 Based on a standard carbon calculation methodology, recommend by the Fleet Transport Association[1] a calculation to identify the CO_2 created by the vehicle for the two data periods based solely on mileage and fuel data supplied by Islington Council is shown in table 5 below.

1. http://www.fta.co.uk/export/sites/fta/_galleries/downloads/logistics_carbon_reduction_scheme/ghg_freight_guide.pdf

Table 5

	Distance travelled	Vehicle MPG	Gallons used	Conversion from Gallons to Litres	Litres used	Carbon emissions factor	CO2 Emissions Kgs CO2	Ave per day
Nov-15	391	2.12	184	4.54609	838	2.5813	2162.09	72.07
May-16	387	2.14	181	4.54609	822	2.5813	2122.14	68.46
Average	**- 1.02**	**+ 0.99**	**- 1.75**		**- 1.90**		**- 1.85**	**- 5.00**

8.6 Table 5 above shows the carbon emissions calculations for the miles travelled by the vehicle during the two data periods and gives a fairly clear picture of the impact of the vehicle on the environment during the two months analysed.

8.7 As expected, over the two periods, the overall miles per gallon did not change to any great extent increasing by 0.99% with only a slight reduction in overall distance travelled but a slight increase in MPG by the vehicle post implementation.

8.8 The carbon emissions calculated for the pre implementation period 1st to 30th November 2015 show that 2,162.09 Kgs of CO_2 or (2.16 tonnes) had been created by the vehicle. Potentially this equates to a daily CO_2 output of 72.07 Kgs of CO_2, which when extrapolated to a potential annual figure would indicate that this vehicles carbon emissions for a whole year could be in the region of 18,738.20 Kgs of CO_2 or (18.74 tonnes).

8.9 Post implementation carbon calculations indicate that between the 1st and 31st may 2016, carbon emissions were recorded as being 2,122.14 Kgs of CO_2 or (2.12 tonnes), potentially giving an average daily carbon figure of 68.46 Kgs of CO_2, and an annual figure of 17,780 Kgs of CO_2 or (17.78 tonnes).

8.10 This is a decrease in carbon emissions between the two monthly data sets of 39.95 Kgs of CO_2 or – 1.85% and a potential daily reduction in carbon emissions of 3.61 Kgs of CO_2 or 5.00%.

8.11 Interestingly, a study carried out by the Forestry Commission at the Kielder Forest, which gives an indication of the environmental impact of the vehicle, estimates that one single tree can lock up 2 Kgs of CO_2 per year. This means that to offset the potential CO_2 emissions for the potential figure for 2015, an estimated 9,369 trees would have to be planted and for 2016, 8,890. [2]

8.12 An issue, which has already been highlighted that has the potentially to affect this calculation is vehicle idling time. It is true to say that a refuse crew will on most days, start their vehicle first thing in the morning and leave it with the engine running for 5 or 10 minutes to warm the cab up for the crew before moving out or while the driver carries out his daily checks, as was the case on both days APSE spent with the crew. This will have been included in the above figures for the two test periods.

2. http://www.forestry.gov.uk/pdf/6_planting_more_trees.pdf/$FILE/6_planting_more_trees.pdf

8.13 This will also happen at varying times during the working day, particularly in winter or in wet weather, when the engine is left running during break times to dry wet clothing or keep the crew warm whilst taking their break. This will obviously be different at different times of the year and could be looked at in more detail over the year.

9.0 Recommendations

9.1 It is evident from the analysis, that the routing system, although not fully utilised, is having a positive effect in decreasing the number of containers visited below the initial 80% fill level, the subsequently lowered 60% level and the reduction in partial collections that the original methodology for routing the work was ineffective.

9.1.1 Sites visited between the pre and post implementation periods, indicating a fill level below 80% and 60% when visited by the vehicle were reduced by 38.9% and 44.6% respectively, partial collections were reduced by 48.95% indicating that the sensors where producing effective route lists consisting mainly of sites that were full.

9.1.2 Observations on site indicate that fill levels could be further improved by reducing the number of false readings produced by residents not breaking down boxes etc, prior to placing them in the container.

- It is recommended that an information and education programme is developed and implemented with the aim of improving participation in the service and to educate residents in both the reduction in contamination and encouraging residents to break down boxes where required.

9.2 The two four week periods analysed, pre and post implementation, indicate that before the system was introduced, the number of sites visited overall and regardless of fill level were high in comparison to the number of calls recorded by the system in the pre implementation period against the data gathered by the post implementation data and the introduction of the new route smart system.

9.2.1 Following the implementation of the smart route system and despite the crew not fully following the routes as prescribed, the number of sites visited overall each day have reduced by 44.28%. Breaking this down into containers shows a reduction in the number of containers visited each day by 52.02%.

9.2.2 This is against a backdrop of an increase in sites visited that are above the 80% or the adjusted 60% fill level when visited, clearly indicating that the sensors are having a dramatic and positive effect on the collections. It is also noted that between the two periods, there was also an increase in the volume and tonnage collected.

9.2.3 However, it is true to say that this has not been the case for the whole period the system has been in place. A less detailed analysis, using the information from the Overview page shown in Fig 6, 7 and 8 shows that there was a gradual albeit minor reduction in volume, weight and the number of collections during this period.

- Further analysis is therefore recommended to establish if the drop off identified in the first 4 months of 2016 is as a result of the crew getting

used to the new system and the system bedding in, as a result of seasonal changes or some other currently unknown reason.

9.3 There are clearly identifiable operational efficiencies to be gained through the use of the sensors and in the routing system, albeit restricted somewhat by the crew's inability to follow the route as prescribed.

- It is therefore recommended that the reasons for this inability to follow the route be identified and addressed and further investigations made to establish what effect this has on the results identified so far.

- It is further recommended that consideration should be given, following a full operational and financial analysis, to fully investigating further, the potential for the council to roll out this system across the recycling service and possibly other service areas that might benefit from their use to maximise the potential efficiencies identified.

9.4 Although not having a direct impact on the effectiveness of the sensor operation itself, it is assumed that the purpose of using the sensors is to enable the council in conjunction with other good practices to maximise the effective use of the physical resources involved in delivering the service.

9.4.1 The task and finish regime currently operating is having a dramatic effect on the operational effectiveness of the crew and the vehicles work, although in the case of the vehicle, it is utilised in other areas following the completion of the day's work on ER2, albeit by a different crew, which could still be done if the effective working hours of the crews was to be extended.

9.4.2 The crew are effectively paid to work a 7 hour day but in reality effectively work only between 5 and 6 hours, based on the operational time of the vehicle data. In reality the effective working time of the individual loaders will be somewhat less, with the exception of the driver who stays with the vehicles to the end of the day's work.

9.4.3 It is clear from the data and from observing the individual smart route's that there has been a time limit set on what is perceived to be the effective hours the crew are able to work which has been set between 5 and 6 hours per day.

- It is recommended that the effective working time should be further investigated to ensure that all the allowed breaks and allowances are being accounted for. This might potentially be achieved through some work study / Method study work to update and re-establish the allowances allocated through the work carried out by Eunomia some time ago.

9.5 It is assumed that the whole service operates on the same 'task and finish' basis and it must be assumed that the same, limited effective working hours, situation exists on the domestic and commercial waste collection services.

- It is therefore recommended that a full diagnostic review of all three collection service areas (Domestic, Recycling and Commercial collections) be carried to establish:

- Effectiveness and overall performance of the service.
- If the current service is providing Value for Money for the authority.
- Demand management including levels of demand and failure demand (Missed collections and complaints)
- Recommendations for increased productivity, financial efficiencies and potential income generation opportunities.

9.6 The analysis of fuel and mileage data, identifies a small reduction in the overall fuel usage as a result of the improved routing of the vehicle through the smart route system, which does have some small financial benefits for the service in terms of running costs of the vehicle. This could be further enhanced by replacing the current vehicle with either a new Euro 6 vehicle or if that is not possible a younger vehicle from the current fleet.

9.6.1 A number of indicators have been identified, including the improvements as a result of better routing, which shows among other things, a 40% to 50% decrease in the number of sites and containers being visited each day whilst recording an increase in tonnage and volume of approximately 12.5%.

9.6.2 The average effective working time of the vehicle and crew and the potential decreased carbon emissions from the current vehicle, indicates that there is potential capacity within the service to investigate the potential for further efficiencies including the potential for reducing in the number of rounds currently operated.

- It is recommended that as part of the review recommended in 9.3.4 above, the potential for an urgent programme of vehicle replacement be considered to enable the service to take further advantage of the efficiencies being identified through the use of the sensors.
- It is further recommended that investigations be undertaken into the viable use of sensors on the domestic refuse collection rounds that use communal bins with a view to potentially removing the need for scheduled collections of bins that are potentially not yet full.

Appendix 1 (Analysis of downloaded “as is data”)

Analysis of Downloaded "As is Data" 2nd to 27th November 2015

Day	date	No locations Collections	Average No Locations per week	No of Bins	Ave Bins per week	Number Collection below 80%	% bins per day below 80%	Weekly % bins below 80%	No Partial collections	% Partial collections	Average per week	1st bin lifted	Last bin lifted	Working Time Hrs	% Effective Hrs	Ave Working Hrs/Day	Total Hours Weekly
Mon	02/11/2015	77		160		26	34		29	37.66		7:22 AM	14:07 PM	6.85	92.57		
Tues	03/11/2015	65		118		30	46		24	36.92		7:30 AM	12:29 PM	4.99	67.43		
Wed	04/11/2015	54		128		27	50		26	48.15		8:28 AM	18:02 PM	9.74	131.62		
Thurs	05/11/2015	58		113		26	45		19	32.76		7:43 AM	12:36 PM	4.93	66.62		
Fri	06/11/2015	39	58.6	76	119	25	64	47.8	18	46.15	40.33	7:50 AM	12:29 PM	4.79	64.73	6.26	31.3
Mon	09/11/2015	73		168		26	36		20	27.40		7:33 AM	12:29 PM	4.96	67.03		
Tues	10/11/2015	76		144		43	57		28	36.84		7:32 AM	12:20 PM	4.88	65.95		
Wed	11/11/2015	34		72		21	62		14	41.18		8:43 AM	12:18 PM	3.75	50.68		
Thurs	12/11/2015	66		136		32	48		28	42.42		7:32 AM	16:15 PM	8.81	119.05		
Fri	13/11/2015	38	57.4	79	119.8	17	45	49.6	21	55.26	40.62	8:08 AM	11:53 AM	3.45	46.62	5.17	25.85
Mon	16/11/2015	88		197		40	45		36	40.91		7:17 AM	12:27 PM	5.10	68.92		
Tues	17/11/2015	63		121		31	49		27	42.86		7:54 PM	12:13 PM	4.59	62.03		
Wed	18/11/2015	46		94		21	46		19	41.30		7:23 AM	11:39 AM	4.16	56.22		
Thurs	19/11/2015	57		122		29	51		30	52.63		7:37 AM	12:15 PM	4.78	64.59		
Fri	20/11/2015	49	60.6	85	123.8	25	51	48.4	18	36.73	42.88	7:55 PM	11:44 AM	3.89	52.57	4.50	22.52
Mon	23/11/2015	76		162		27	36		27	35.53		7:37 AM	12:32 PM	4.95	66.89		
Tues	24/11/2015	76		142		29	38		32	42.11		7:29 AM	13:09 PM	5.80	78.38		
Wed	25/11/2015	48		111		12	25		18	37.50		7:53 PM	12:11 PM	4.58	61.89		
Thurs	26/11/2015	63		133		29	46		29	46.03		7:46 AM	13:14 PM	5.78	78.11		

Fri	27/11/2015	42	61	90	127.6	29	69	42.8	15	35.71	39.37	8:02 AM	12:16 PM	4.14	55.95	5.05	25.25
Average			59.40		122.55	27.25		47.15			40.80					5.24	
Monthly Totals		1188		2451		545			478	40.80		7.53	12.46	5.25	70.89	5.25	104.92

Appendix 2 (Analysis of post implementation data)

Analysis of Downloaded Data 2nd to 27th May 2016

Day	date	No locations / Collections	Average Collections per week	Number of containers	Average per week	Number Collection below 80%	% bins per day below 80%	Weekly % bins below 80%	No Partial collections	% Partial collections	Average Collections per week	1st bin lifted	Last bin lifted	Working Time Hrs	% Effective Hrs	Ave Working time/week	Total Hours Weekly
Monday	02/5/2016	28		55		12	25%		15	29%		7.21	13.05	5.84	79%		
Tuesday	03/5/2016	27		37		19	51%		11	29%		6.09	15.31	9.42	127%		
Wednesday	04/5/2016	38		77		21	24%		14	18%		7.54	16.36	8.82	119%		
Thursday	05/5/2016	24		44		4	9%		4	9%		7.27	12.22	4.95	67%		
Friday	06/5/2016	39	31	60	55	20	33%	28%	7	12%	19	7.14	11.40	4.26	58%	6.66	33.29
Monday	09/5/2016	41		67		15	23%		13	19%		7.53	12.54	5.01	68%		
Tuesday	10/5/2016	35		56		17	30%		13	23%		7.58	12.49	5.01	68%		
Wednesday	11/5/2016	35		45		6	13%		8	18%		11.09	13.05	1.96	26%		
Thursday	12/5/2016	28		94		25	20%		20	23%		7.26	17.27	10.01	135%		
Friday	13/5/2016	25	33	33	59	11	33%	24%	6	18%	13	7.37	11.27	3.09	53%	5.02	16
Monday	16/5/2016	29		58		18	31%		6	10%		7.23	12.12	4.89	66%		
Tuesday	17/5/2016	30		63		8	14%		13	19%		7.19	11.38	4.19	57%		
Wednesday	18/5/2016	35		63		14	26%		19	30%		10.57	18.27	7.70	104%		
Thursday	19/5/2016	28		51		12	35%		8	16%		7.22	12.07	4.85	66%		
Friday	20/5/2016	39	32	68	61	28	43%	30%	20	29%	13	7.28	13.00	5.72	77%	5.47	27.35
Monday	23/5/2016	34		60		17	28%		9	22%		7.32	11.53	4.21	57%		
Tuesday	24/5/2016	35		59		21	38%		14	23%		7.50	12.50	5.00	68%		
Wednesday	25/5/2016	40		71		23	32%		15	21%		7.49	12.39	4.90	66%		

Thursday	26/5/2016	32		53		19	37%		12	22%		7.31	14.46	7.15	97%		
Friday	27/5/2016	40	36	62	61	23	30%	33%	17	27%	13	7.54	13.26	5.72	77%	5.40	26.98
Average			31		59			29%			14.5			5.63	77%	5.64	25.91
Monthly Totals		625		1176		333	30%		244	21%		7.63	13.29				

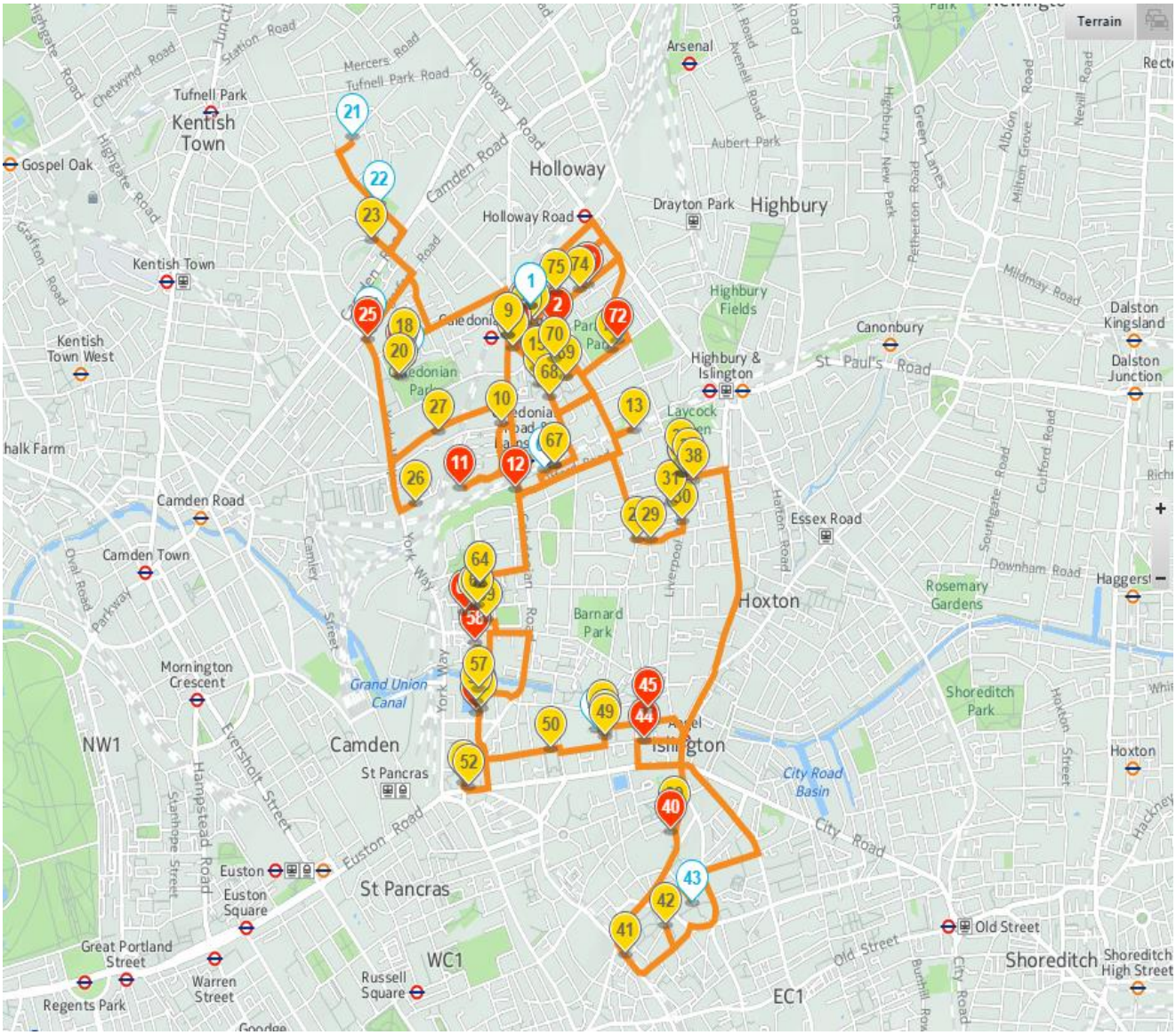
Appendix 3 (ER2 Site Visit 1)

Start	Tue, Jan 26, 2016 (7:20 AM)
End	Tue, Jan 26, 2016 (12:04 PM)
Total distance	25.01 km
Total time	4 hours 44 minutes
Total volume	45.65 m^3
Total weight	3195.37 kg
Total CO^2 emissions	33.27 kg

	SITE NAME	ARRIVAL TIME	FILL LEVEL	WEIGHT	CUMULATIVE WEIGHT
1.	Re-use & Recycling Centre	7:20 AM	-	-	0 kg
2.	Lough Road, Bramall Court	7:25 AM	96 %	74 kg	74 kg
3.	Piper Close Jct with Watkinson Road	7:28 AM	82 %	74 kg	148 kg
4.	Piper Close Orion Court (in bin store at front of block)	7:30 AM	93 %	84 kg	232 kg
5.	Piper Close Gazelle Court (in bin store at front of block)	7:31 AM	75 %	67 kg	299 kg
6.	Watkinson Road Anguila House (in bin store in car park)	7:34 AM	97 %	87 kg	387 kg
7.	Roman Way 88, Roman Court	7:36 AM	80 %	0 kg	387 kg
8.	Caledonian Road 465A, Community	7:38 AM	80 %	0 kg	387 kg
9.	Caledonian Road 465. UCL Student Accommodation	7:39 AM	80 %	0 kg	387 kg
10.	Quarto Publishing, 6 Blundell Street	7:43 AM	80 %	0 kg	387 kg
11.	Bunning Way 81-108	7:46 AM	98 %	176 kg	563 kg
12.	Caledonian Road 349, Lionswood	7:52 AM	99 %	77 kg	640 kg
13.	Blackthorne Avenue Block E	7:57 AM	80 %	0 kg	640 kg
14.	Armour Close 12-15	8:03 AM	80 %	0 kg	640 kg
15.	Roman Way 58, Mackenzie Group Practice	8:05 AM	80 %	0 kg	640 kg
16.	Chris Pullen Way 59-73	8:12 AM	69 %	107 kg	747 kg
17.	Chris Pullen Way 2-42	8:15 AM	101 %	78 kg	825 kg
18.	Chris Pullen Way 1-41	8:16 AM	80 %	124 kg	949 kg
19.	Drovers Way 49-81, ClockTower Estate (access from Shearling Way)	8:20 AM	77 %	60 kg	1009 kg
20.	Drovers Way 85-125, Clock Tower Estate (access from Shearling Way)	8:22 AM	82 %	63 kg	1072 kg
21.	Anson Road 77, Dalmeny Mansions	8:31 AM	62 %	169 kg	1242 kg
22.	Dalmeny Avenue, Outside 72-122	8:37 AM	48 %	216 kg	1458 kg

23.	Hilldrop Crescent Jct of Hilldrop Road (opposite Buckhurst House)	8:48 AM	73 %	187 kg	1645 kg
24.	Hungerford Road, Hungerford Primary School (in bin store)	8:56 AM	44 %	40 kg	1685 kg
25.	Hungerford Road The Bridge Primary School (in bin store accessed via Hungerford	8:57 AM	92 %	83 kg	1768 kg
26.	Vale Royal 15-23, Antony Gormley	9:03 AM	80 %	0 kg	1768 kg
27.	Brewery Road 29-31, Big Sky Lighting	9:07 AM	80 %	0 kg	1768 kg
28.	Barnsbury Street 60-62	9:17 AM	80 %	0 kg	1768 kg
29.	Barnsbury Street 44, Drapers Arms	9:19 AM	80 %	0 kg	1768 kg
30.	Liverpool Road 285, Pugin Court	9:21 AM	80 %	0 kg	1768 kg
31.	Brooksby Street, Cara House	9:23 AM	80 %	0 kg	1768 kg
32.	Haslam Close 25-32	9:26 AM	80 %	0 kg	1768 kg
33.	Haslam Close 17-24	9:28 AM	80 %	0 kg	1768 kg
34.	Haslam Close 9-16	9:29 AM	80 %	0 kg	1768 kg
35.	Haslam Close 33-40	9:31 AM	80 %	0 kg	1768 kg
36.	Haslam Close 41-49	9:33 AM	80 %	0 kg	1768 kg
37.	Haslam Close 1-8	9:35 AM	80 %	0 kg	1768 kg
38.	Islington Park Street 34, Elfrida Society	9:36 AM	80 %	0 kg	1768 kg
39.	Arlington Avenue 2, Arlington House	9:44 AM	74 %	57 kg	1825 kg
40.	Myddleton Passage, Worthington House	9:46 AM	124 %	96 kg	1921 kg
41.	Farringdon Road 92-94, The Quality Chop House	9:51 AM	80 %	0 kg	1921 kg
42.	Exmouth Market 34-36, Moro Restaurant	9:54 AM	80 %	0 kg	1921 kg
43.	Skinner Street 13, Michael Cliffe House	10:00 AM	28 %	92 kg	2013 kg
44.	White Lion Street 58-62	10:12 AM	116 %	54 kg	2066 kg
45.	Tolpuddle Street, Sainsbury's Car Park	10:16 AM	109 %	197 kg	2263 kg
46.	Risinghill Street Elizabeth Garrett School	10:20 AM	49 %	196 kg	2459 kg
47.	Penton Street 49-51, Hayward House	10:28 AM	80 %	0 kg	2459 kg
48.	Penton Street 53-55, Harvest Lodge	10:30 AM	80 %	0 kg	2459 kg
49.	Penton Street 47, St Silas'S Church	10:32 AM	80 %	0 kg	2459 kg
50.	Collier Street 48, Hugh Cubitt Centre Community Café	10:35 AM	80 %	0 kg	2459 kg
51.	Caledonian Road 1, Camino Restaurant Ltd	10:40 AM	80 %	0 kg	2459 kg
52.	Keystone House Ltd, 272-276 Pentonville Road (access Omega Place)	10:42 AM	80 %	0 kg	2459 kg
53.	New Wharf Road 5, Gattis Wharf	10:46 AM	101 %	78 kg	2537 kg
54.	New Wharf Road 12-13, The London Canal Museum	10:47 AM	80 %	0 kg	2537 kg
55.	New Wharf Road 10, Marina 1	10:49 AM	80 %	0 kg	2537 kg

56.	New Wharf Road 14, Marina 2	10:50 AM	80 %	0 kg	2537 kg
57.	New Wharf Road 17, Ice Wharf	10:52 AM	80 %	0 kg	2537 kg
58.	York Way Court Site 2	10:59 AM	101 %	156 kg	2693 kg
59.	Clayton Crescent 9, Flats 1-25	11:04 AM	80 %	0 kg	2693 kg
60.	Brydon Walk, Opposite Number 15	11:06 AM	103 %	80 kg	2773 kg
61.	Wellington Square 24	11:08 AM	80 %	0 kg	2773 kg
62.	Wellington Square 2	11:10 AM	80 %	0 kg	2773 kg
63.	Pembroke Avenue 4, Flats	11:12 AM	80 %	0 kg	2773 kg
64.	Pembroke Avenue 3	11:13 AM	80 %	0 kg	2773 kg
65.	Offord Street 1-5 (code:1515)	11:19 AM	65 %	30 kg	2803 kg
66.	Roman Way 149, Super Cleaning & Laundry Ltd	11:21 AM	80 %	0 kg	2803 kg
67.	Roman Way 149, Hammerton Brewery Ltd	11:22 AM	80 %	0 kg	2803 kg
68.	Wellington Mews 1-28	11:26 AM	80 %	0 kg	2803 kg
69.	Vulcan Way 1-108	11:30 AM	80 %	0 kg	2803 kg
70.	Vulcan Way 109-125	11:31 AM	80 %	0 kg	2803 kg
71.	Sheringham Road Freightliners Farm	11:35 AM	82 %	74 kg	2877 kg
72.	Sheringham Road 3, Martin Luther King Adventure Playground	11:37 AM	99 %	77 kg	2954 kg
73.	George's Road St James's School Flats	11:41 AM	109 %	68 kg	3022 kg
74.	George's Road Sacred Heart School	11:43 AM	71 %	174 kg	3195 kg
75.	Eden Grove 62, Sacred Heart Church	11:48 AM	80 %	0 kg	3195 kg
					3195 kg
76.	Re-use & Recycling Centre	11:54 AM	-	-	45648 L
1.	Re-use & Recycling Centre	12:04 PM	-	-	3195 kg


Terrain
Arsenal
Tufnell Park
Kentish Town
Gospel Oak
Holloway
Holloway Road
Drayton Park
Highbury
Kentish Town
Kentish Town West
Highbury Fields
Canonbury
Dalston Kingsland
Dalston Junction
Highbury & Islington
St Paul's Road
Laycock
Camden Road
Camden Town
Essex Road
Hoxton
Rosemary Gardens
Haggerston
Barnard Park
Mornington Crescent
Grand Union Canal
Shoreditch Park
NW1
Camden
St Pancras
City Road Basin
Euston
Euston Square
St Pancras
Great Portland Street
Warren Street
Regents Park
Russell Square
WC1
Old Street
Shoreditch
Shoreditch High Street
EC1

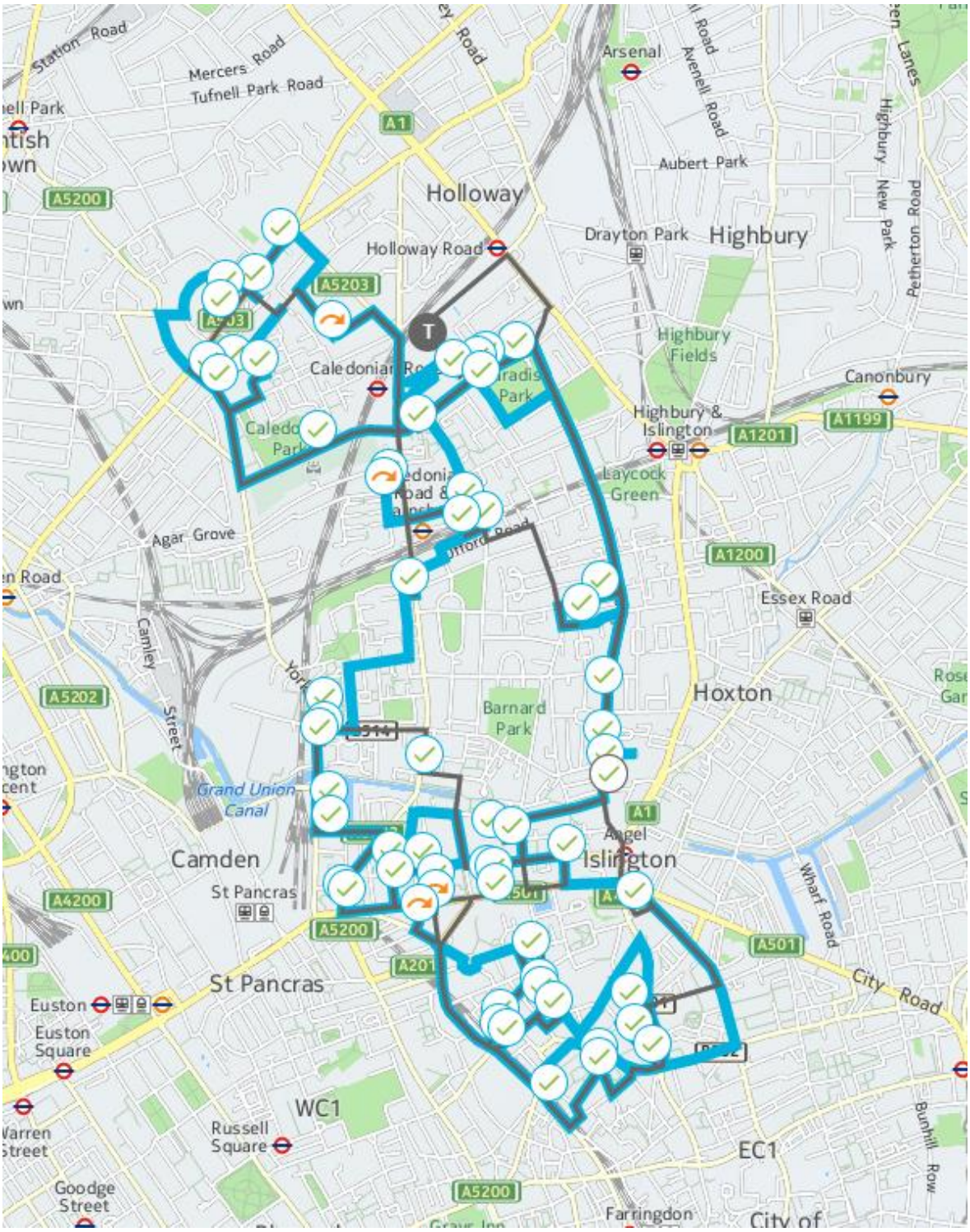
Appendix 4 (ER2 Site Visit 2)

	site name	arrival time	fill level	Truck Fill		
1	Upper Street 52, Business Design Centre (access from Liverpool Road) (Open 00:00 - 08:00)	07:45		0%	**Start time**	7:45 AM
2	Liverpool Road (back of Business Design Centre)	07:45	109%	3%	**End time**	12:55 PM
3	Risinghill Street 1-4	07:53	80%	4%	**Duration**	5h 10min
4	Risinghill Street Elizabeth Garrett Anderson School	07:58	94%	8%	**Route length**	23 km
5	Baron Street 12-20, Groundwork Islington And Scarman Trust	08:07	80%	9%	**Breaks**	None
6	Caledonian Road 160, All Saints Church	08:14	80%	10%	**Unloading**	1 Stops
7	York Way 146, The Old School (code 3008)	08:19	91%	11%	**Total weight**	3959 kg
8	York Way 130, Café Express	08:23	80%	12%	**Total volume**	57 m^3
9	York Way 126, Star Of Kings	08:25	80%	13%	**CO^2 emissions**	30 kg
10	York Way 70-78, York Central Flats (accessed from Crinan Street)	08:29	80%	13%	**Start time**	7:45 AM
11	Trematon Walk 3 (C1589Z)	08:32	80%	14%	**End time**	12:55 PM
12	Caledonian Road 1, Camino Restaurant Ltd	08:38	80%	15%	**Duration**	5h 10min
13	Keystone House Ltd, 272-276 Pentonville Road (access Omega Place)	08:41	80%	16%	**Route length**	23 km
14	Cumming Street 1-9 Manneby Prior	08:45	45%	16%	**Breaks**	None
15	Collier Street. 8 Henley Prior	08:47	87%	18%	**Unloading**	1 Stops
16	Killick Street Winton Primary School - Car park	08:51	81%	20%	**Total weight**	3959 kg
					Total volume	57 m^3

17	Mildreds, Unit 3, 200 Pentonville Road	08:55	80%	21%	**CO^2 emissions**	30 kg
18	Lorenzo Street 1, Idea Works	08:58	80%	21%	**Start time**	7:45 AM
19	Pentonville Road 189-205, outside Dinwiddy House	09:01	87%	23%		
20	Pentonville Road 124, Hill House	09:06	99%	25%		
21	Cynthia Street 10, New Gower School	09:08	40%	25%		
22	Pentonville Road 101	09:11	59%	26%		
23	Lloyd Baker Street 1, Riceyman House (in bin compound)	09:16	51%	26%		
24	Great Percy Street, Cable House (rear of Soley Mews)	09:20	69%	28%		
25	Margery Street, Charles Rowan House (in bin storage area)	09:26	66%	30%		
26	Naoroji Street 6, West City One	09:32	80%	32%		
27	Margery Street 30, Merlin's Court (code 1963)	09:35	63%	33%		
28	Margery Street 69-85, The Children's Society	09:38	29%	33%		
29	Margery Street 2, Bagnigge House (in bin compound)	09:40	36%	34%		
30	Farringdon Road 92-94, The Quality Chop House	09:43	80%	34%		
31	Northampton Road 42, Bourne and Hollingsworth (Open 00:00 - 12:00)	09:46	80%	35%		
32	Exmouth Market 34-36, Moro Restaurant	09:49	80%	35%		
33	Skinner Street, Charles Townsend House	09:54	35%	36%		
34	Skinner Street 13, Michael Cliffe House	10:00	79%	39%		
35	Myddelton Street, Hugh Myddelton Primary School	10:05	45%	40%		
36	Owen Street Angel Southside (code 25684)	10:13	83%	41%		
37	Liverpool Road 107, Olive Court	10:22	80%	42%		
38	Liverpool Road 172 (code 1977)	10:24	78%	43%		
39	Lofting Road, Lofting House	10:29	80%	43%		
40	Barnsbury Street 44, Drapers Arms (Open 09:00 - 12:00)	10:32	80%	44%		
41	Roman Way Tealby Court (on junction of Watkinson Road) The RIngcross	10:40	84%	45%		
42	Roman Way 149, Super Cleaning & Laundry Ltd	10:43	80%	46%		

43	Centurion Close , J/W Wheelwright Street	10:46	80%	48%
44	Caledonian Road 309-311, Fast Signs	10:52	80%	48%
45	Sutterton Street (at side of 1 Blundell Street)	10:56	96%	51%
46	Quarto Publishing, 6 Blundell Street	11:01	80%	52%
47	Hartham Road (side of 1-24 Thornton Court)	11:07	135%	53%
48	Camden Road 346, Fairdene Court	11:11	46%	53%
49	1-5 Tansley Close	11:14	80%	53%
50	Camden Road 376-380 (in bin store behind gate)	11:18	83%	54%
51	Camden Road 259 (at rear of property)	11:21	70%	55%
52	York Way 400-404, York Way (C0416)	11:23	80%	56%
53	Hungerford Road The Bridge Primary School (in bin store accessed via Hungerford	11:27	133%	58%
54	Hungerford Road 253 (in bin store behind silver doors)	11:29	110%	59%
55	2-34 Goodinge Close	11:32	80%	60%
56	Market Road Islington Tennis Centre	11:37	68%	61%
57	Lockhart Close	11:43	80%	61%
58	Brightwell Court, 121 Mackenzie Road	11:46	80%	62%
59	Lough Road 55, St David's Apartments	11:50	103%	64%
60	Lough Road, Prichard Court	11:54	132%	65%
61	Brooke Lodge, 137 Mackenzie Road	11:56	80%	66%
62	Mackenzie Road 164, Paradise Park Childrens Centre	12:04	86%	67%
63	Re-use & Recycling Centre	12:11		67%
64	Upper Street 52, Business Design Centre (access from Liverpool Road) (Open 00:00 - 08:00)	12:55		0%

It can be seen from the plan below that the crew have again not followed the rout smart plan which is shown in black. The actual route taken is shown in blue.




LOCAL SERVICES
LOCAL SOLUTIONS