Smarter Suffolk Project

Grit Bin Monitoring

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1 Executive Summary

Icy pavements can provide a risk to pedestrians in terms of slips and falls. Local authorities provide grit (salt and sand mix) for local volunteers to spread to assist in reducing ice on pavements. This report investigates the potential to instal fill level sensors in local community grit bins to assist the local authority with grit bin refill requirements. It sets that investigation in the context of the benefits of pavement gritting, and the policies for the provision and stocking of grit bins, both in Suffolk and in surrounding counties. This report then details research undertaken into the use of sensors for fill level monitoring, using both observational and experimental techniques. It pulls together this information in a business case assessment, and makes recommendations for grit bin stocking in Suffolk.

Grit bins are stocked by Suffolk County Council to provide a supply of grit at close to the locations of need, from where it is spread by local volunteers and managed by the parish council. Footpath de-icing using grit bins has benefits:

- Falls and slips are a significant cause of death and injury, and are more frequent in cold weather. They are exponentially more common with decreasing temperature, and cost £42 million per year in the UK in 2009-2010 in hospital admissions alone, plus costs from long term care, rehabilitation and non-admitted injuries.
- Footpath gritting is recommended to continue as a mitigation to this, supporting public safety.
- Social benefits of footpath gritting include supporting active transport, which has consequent health, mental well-being, economic and environmental benefits.
- Storage of the grit in contained and covered grit bins has environmental and economic benefits, reducing leaching of salt into the environment and loss of resource.

Suffolk County Council currently stocks 2100 grit bins, refilled pre-season, on SCC request following severe weather, and with potential for request by local councils. Bins are typically refilled up to two times per year, depending on weather. Grit Bins policies across the Eastern Region are comparable. Many councils explicitly state that mid-season refills are dependent on resource and operational availability, will be undertaken at the local authority's schedule, and ad hoc refills are not available.

The potential for sensors to support grit bin refilling was investigated within the Smarter Suffolk research and development project, using a bin fill level sensor provided by one of the project suppliers. The bin fill level manufacturer does not recommend their sensor for this use case. The sensor is battery-powered, communicates via mobile data, and provides hourly fill level readings to a web-based dashboard which provides data visualisation and extraction. Sensors were installed in two grit bins and run for six months, including the winter season. Experimental excavation was also undertaken. Data was also provided from the manufacturer to the supplier and to the project BT Data Exchange, and was compared with data extracted directly from the manufacturer's online interface. These observations and experiments indicated the following:

- Fill levels were provided hourly by the sensors continuously since installation; temperature measurements were more sporadic, but multiple temperature measurements were provided each day.
- During the initial months when the grit bin was not used and the fill level unchanged, the fill level provided by the sensor was unstable indicating daily fluctuations from completely empty to completely full.

- Following further communication with the manufacturer they adjusted sensor configuration increased stability of readings, which remained relatively stable during later months.
- Sensors appeared to identify usage during winter weather, but this was unclear due to the inherent data instability at that time.
- Sensor readings indicated excavation and refill during active experiments, but did not match the fill level changes during those experiments.
- Data provided via the BT Data Exchange (via the manufacturer and supplier to BT) was not consistent with the data extracted directly from the manufacturer. Some but not all causes of this have been identified: data loss is occurring due to times of high data flow; data padding is being applied to backfill this data loss; timestamp mismatches are being introduced during data transfer; other causes of data discrepancies have not been identified.

The business case for the use of sensors for grit bin fill level monitoring was examined. It was concluded that given current expenditure, the sensors are not considered to be an effective investment. There is little or no potential to save money or realise other benefits. The cost of stocking the bins is approximately £21pa per bin, and anticipated cost of sensor approximately £30pa per sensor. Recommendations and analysis do not support wider use of these sensors for this use case.

Other recommendations are made for the grit bin restock service:

- Creating an asset register including exact location of grit bins, with latitude and longitude, during one pre-season restock;
- Annual condition survey on annual pre-season restock;
- Restricting county council restocking to pre-season and post-event restock only, and not supporting ad hoc refills;
- Providing larger bins if required for specific locations if needed;
- Collecting fill level information, if required, from the existing volunteer users.

It is concluded that the provision of grit in grit bins for volunteer spreading on footpaths continues to provide a significant social, health, environmental and economic benefit. It is concluded that fill level sensors are not expected to improve the service provided.

2 Introduction

2.1 Grit Bins

Grit bins are provided by the county council and other land owners or managers to supply a small store of salt or grit close to locations in which it may be required. It can be used and spread by hand on local areas as required. Grit bins supported by Suffolk County Council are refilled by lorry deliveries from larger stores maintained at their highways depots, as requested by local users.

As part of the Smarter Suffolk project, Suffolk County Council wished to explore whether sensors could track the fill levels of the grit bins, and alert Suffolk Highways when refilling is required. For this purpose:

- Sensors were fitted in two grit bins to observe their function over a six month period;
- An experiment was carried out, deliberately emptying and refilling one of the grit bins to observe reported fill levels;
- Interviews were undertaken with county council employees, parish council management, and highways contractors.
- An online review of grit bin services from Suffolk and surrounding counties was undertaken.
- A literature review of relevant published papers was undertaken.

This report reviews the role of grit bins in winter management; describes the use of grit bins in Suffolk; describes the use of grit bins in surrounding counties; details the sensor trialled for grit bin fill level monitoring and experiments undertaken on the sensor; assesses the business case for the application of the sensor for this use case; and presents conclusions and recommendations.

2.2 Pavement clearing

In the UK, the Local Government Association encourages an approach in which the public are active in clearing snow from footpaths and cycle paths (Beynon *et al.*, 2011); concern around litigation following public snow clearance led to the publication of snow clearing guidelines by local authorities. In some countries self-help pavement clearing is regulatory (including Germany and some states of the USA), which is not the situation in the UK.

2.3 Literature Review

Literature review on the use of grit bins focused on two aspects: firstly, the beneficial impact on human health from winter de-icing, and secondly the negative impact on the environment of the use of salt as a de-icing agent.

2.3.1 Health impacts of winter gritting of pavements

Winter gritting is undertaken to reduce the negative results of ice forming on surfaces. Specifically, pavement gritting aims to reduce the impact of injuries from slips and falls of people walking on pavements during icy winter periods. In addition, winter gritting supports active travel (walking and cycling) which has physical and mental health benefits.

Research has shown that falls are significant (globally, falls are the second leading cause of death from accidental or unintentional injury, Beynon *et al.*, 2011) and more frequent in cold winters (Atenstaedt and Rees, 2013).

Beynon *et al.* (2011) report an exponential impact in falls on snow and ice with decreasing temperature in the UK, between 2005 and 2010. They comment that *"with responsibility for health improvement moving to local councils, they will have to balance the cost of public health measures like gritting with the healthcare costs associated with falls. The economic burden of falls on snow and ice is substantial; keeping surfaces clear of snow and ice is a public health priority."* Their analysis shows that the rate of hospital admission due to falls on snow and ice varies with gender and age. The cost of these hospital admissions during 2009-2010 (excluding Accident and Emergency visits that were not admitted, people treated by primary care services, and long term outpatient rehabilitation) was £42 million (Beynon *et al.*, 2011). This figure would be anticipated to increase with an aging population.

Atenstaedt and Rees (2013) undertook a structured systematic review assessing whether pavement gritting is an effective intervention for prevention of unintentional injuries, but did not identify any good-quality studies within the terms of their review. They comment that some UK councils gritted some pavements, and that pavement gritting provision varied across the UK. Fall-related injuries are more common during winter months, and the major contributory factor is considered to be slipping on snow and ice. They describe one study which reported between nine and sixteen injuries per 100,000 people per day during a period when 70% of the walking surface was covered with snow and ice. Another study referenced showed that half of injuries on ice and snow occur on a pavement or road, and one-fifth on yards or near dwellings. They recommend further study on the impact of pavement gritting on fall injuries, and that pavement gritting by local authorities continues as additional research evidence is collected.

The National Winter Service Research Group (2021) the Institute of Highways Engineers provides advice in their guidance '*Winter Service on Footways and Cycleways'*. They list social and economic benefits for treating footways and cycleways, including improving public safety, supporting active transport year-round thus reducing private transport use in winter, supporting physical activity for health and mental wellbeing, reducing car usage.

2.3.2 Environmental impacts of winter gritting of pavements

The potential for environmental impact of winter gritting, salt and de-icing agents is widely acknowledged. Suffolk Highways (2019) state with respect to the provision of local grit bins: *Due to the leaching of grit into highway verges (and the underlying groundwater) and watercourses and the ineffectiveness of material being stored open to the elements, Suffolk County Council does not support the provision of grit heaps in the highway verge.*

The Environment Agency (1990) in their now-withdrawn Pollution Prevention Guide 10: Highways Depots did not comment on small-scale local storage but did state with respect of larger salt storage at depots: *"The environmental impact of rock salt is well documented …. because of the large quantities stored, there is the risk of pollution of rivers and groundwaters, due to run-off from rock salt stockpiles. This can come from both the salt itself and the sodium ferrocyanide anti-caking agent which is often added to it. Even when a stockpile is removed, the ground beneath it may remain contaminated."* The guide recommended covered and lined salt storage areas. Uncovered salt storage leads to salt loss and potential pollution. Whilst this guidance is focused on the larger salt stores in highways depots, the potential for loss of salt, the negative environmental impact, and the reduced ease of use from uncontained salt stored are relevant for smaller localised salt supplies too.

The key legislation relevant to this impact is the 1990 Environment Protection Act to prevent pollution of 'Controlled Waters' (surface water and groundwater).

Environmental concerns in addition to impact on surface water and groundwater have been identified: these concerns include impact on vegetation (such as described by Ordóñez-Barona *et al.* (2018)), and impact on insects in aquatic ecosystems (such as described by Jackson and Funk (2019)). These concerns have also been raised in newspapers (Hickman, 2010).

The National Winter Service Research Group (2021) guide referred to previously is focused on local authority treatment, rather than community use treatment, and assumes depot-based storage rather than local storage. Their guidance on Salt Storage (National Winter Service Research Group, 2020) remarks that salt must be stored well for effective and efficient use, and stocks must be covered. Details for storage are all with respect to large volumes stored in highways depots, rather than small scale salt bins.

Vignisdottir *et al.* (2019) reviewed literature on environmental impacts of winter road maintenance from spread salt. They found that articles focused on local impact, with little focus on global impact. The main local effect researched has been on water in the area, and they identified two articles on biodiversity. Local impact reported includes: air quality; changes or harm to vegetation and soils, and watersheds. Whilst these impacts are from spread salt, it can be extended that containment of salt prior to application during salt will minimise environmental impacts caused during storage, both on larger scales in highways depots and on small scales in public-use grit bins.

A study of the potential impact of salt from highway winter gritting / salting in the UK Midlands suggests likely significant impact on a local stream, and that highways salt is a potential cause of increased salinity observed in a pumped water supply well (Rivett *et al.*, 2016). They describe the typical UK winter weather conditions, legal requirements and salting methods, resulting in relatively high salt spreading rates. International studies also indicate impact on surface water and groundwater from road salt (Cooper, Mayer and Faulkner, 2014; Jamshidi, Goodarzi and Razmara, 2020).

3 Review of Grit Bins in Suffolk

Section 3 outlines the information available on grit bin management from Suffolk County Council and Suffolk Highways. It also details the user experience from an example parish council that is supplied by Suffolk Highways. Two sites that supply their own grit bins for use on private campuses in Suffolk have also been investigated, and their experience is included here as private and education sector comparisons.

3.1 Suffolk County Council and Suffolk Highways

Grit bins in public areas are owned and managed by local councils (parish, town or district councils) (Suffolk Highways, no date a, no date b), for the sole purpose of making highways safer. The owning local council is requested to monitor how and where grit is used. Suffolk Highways responds to requests for provision or and refilling of these grit bins from these councils, not from the general public. Grit bins provided by Suffolk Highways following formal application by a local council cost the local council between £150 and £450, depending on type (Suffolk Highways, no date b). Locations are agreed based on appropriateness and safety considerations, where local problem spots are not on regular

gritting routes and grit is needed, such as on hills or at junctions. Guidance for application to provide, and use of, such grit bins is provided online by (Suffolk Highways, 2019).

Loose "grit heaps" on highway verges are not supported, due to their impact on environment (in particular, highways verges, groundwater and surface water courses (see Section 2.2)), and loss of quantity and effectiveness of stored material by weathering (Suffolk Highways, 2019).

Suffolk Highways currently restock 2100 grit bins. Grit bins are refilled by Suffolk Highways at three possible times (Suffolk Highways, 2019):

- At the start of the winter season all grit bins are refilled
- Grit bins may be refilled during the season as considered appropriate
- Refilling may be requested by local councils (via the online portal or by telephone), to be carried out when Suffolk Highways has available resources.

No charge is currently made to local councils for refilling by Suffolk Highways, as it is considered part of their required service (Suffolk Highways, no date b). Grit bins may also be refilled by the local council at their own expense, though none of the councils contacted do refill at their expense.

Suffolk Highways have advised that the number of times that bins are refilled during a winter season depends on the severity of the weather that season. Some years no refilling is required. On other years, refilling of some bins on up to two other occasions may be required. It is considered unlikely that more than three filling occasions will be required during a season, even when weather is more severe. This is confirmed in interviews with parish council users.

Grit from these bins is spread by local volunteers, registered with the local council in order to be covered by Suffolk County Council insurance. Suffolk Highways encourages local councils to support volunteers and provide a community-based local service (Suffolk County Council, 2017). Further advice is provided to the public on managing safe clearance during winter season in 'The Snow Code' (Suffolk County Council, no date).

"*Grit bins are provided to support self-help in the clearance of snow and ice"* (Suffolk Highways, 2019) and are not supplied for use on privately owned surfaces such as private drives or car parks, which use would be considered theft (Suffolk Highways, no date b). Use of grit on private land or other inappropriate or unauthorised use would lead to the grit bin being withdrawn from restocking.

3.2 Parish council experience

Melton is a busy, large village in East Suffolk with a population over 4000 and both rural and more urban areas, residential and business properties.

Melton Parish Council kindly agreed to support the trial of grit bins, with discussion at a council meeting, agreeing to trial one sensor in a grit bin, and interviews with management officer and assistant clerk, Pip Adler, who manages communications with Suffolk Highways, including refilling grit bins. Melton Parish Council created a hand-annotated map of their bin locations that they have supplied to Suffolk Highways, at the request of Suffolk Highways.

In an interview on 31 May 2021, she described the process for grit bin management. Grit bins are refilled by Suffolk Highways prior to winter. During the winter season, users may contact Melton Parish Council if the bin needs refilling. Adler makes this request via the Suffolk Highways' online tool. They do not maintain records of bin refilling, but anecdotally consider bins to be restocked once at the start of the season, and on average one time per year during the season.

Melton Parish Council's management officer informally shared the following views on the service:

- They are not informed when bins are refilled during the season, which would be useful in particular to respond to repeated enquiries from members of the public. It might be possible for a simple and / or automated email to be triggered by refilling. This would assist when they are making repeated requests for restocking of specific bins.
- They consider it to be unclear if the grit bins are supplied for use on icy pavements, or for use on roadway surfaces only.
- Melton Parish Council have a hand-annotated map of their bin locations that they have supplied to Suffolk Highways, but remain aware that Suffolk Highways do not always know exactly where to find the grit bins.
- In general, the service works as expected, and is welcome during icy periods.

3.3 Industrial Campus experience

The Adastral Park technology campus houses around 150 companies, focused on technology and innovation, and including BT's research and development facilities. The campus has hosted trials in this and other aspects of the Smarter Suffolk project. Adastral Park has 45 grit bins, and one was fitted with a sensor for use in this project.

An interview was undertaken with Stephen Southgate, Facilities Services Manager for Adastral Park, on 8 June 2021, regarding winter management at the Adastral Park campus. Whilst roadway gritting is contracted out, grit bin refilling is undertaken by site services. Salt is stocked in bulk, and mixed with sand or grit for bin filling. Grit bins are for self-help use, and site users are encouraged to apply grit when required. Winter readiness preparation in October includes checking and refilling the grit bins. They will be refilled if necessary following periods of icy weather, which is estimated to occur on average once each year.

The main challenge encountered in winter gritting of footways is on some limited areas of plastic surfacing, which are found to be icy sooner than other areas. In these areas, more expensive chemical de-icers were found to be no more effective than salt and grit, and current process is to apply salt and grit at a higher temperature than for other areas.

Grit bin filling is considered to cost very approximately £1000 annually, and is not a significant part of the campus management costs.

3.4 University Campus experience

University of Suffolk runs a campus of multiple buildings and outside areas in the waterfront area of Suffolk. Sam Phillips, Maintenance and Services Manager, provided information on grit bin management (emails, 20/4/21 and 09/6/21). The university maintains a few small salt bins at the entrances of buildings around the Campus and in the Car Park, which are filled with salt. The main part of the winter gritting is outsourced to an external contractor, they grit

all of the car parks as and when required due to the size. The estates team salts the pathways around campus and in the event there is more ice/snowfall, they either clear or put more gravel down until the external contractor can return and grit further should it be required. Cost and resource for grit bin refilling varies each year with severity of weather.

4 Review of Grit Bins in surrounding counties

To set the policy and practice of Suffolk County Council in context, a review has been undertaken of the grit bin policies and numbers of grit bins for councils in the Eastern Region. The local authorities covered by this review are those identified by Suffolk County Council as regional comparators (Ben Cook, email 15/10/20).

4.1 Comparison of Grit Bin policies

4.1.1 Cambridgeshire County Council

Cambridgeshire County Council (2018, 2021) restock grit bins at the start of the winter season, and accept reports of grit bins that are running low via their online reporting tool, which will be *"filled as soon as* [they] *have the resources to do so'.* They support a Community Gritting Scheme of volunteers to grit footpaths.

4.1.2 Essex County Council

Essex County Council (2021a, 2021b) state that each refill uses 1000 tonnes of salt and takes 350 person-hours over three weeks. Bins are restocked prior to the winter season, and not refilled on an ad-hoc basis. Essex County Council, (2021a) explain: "*Throughout the winter our priority is to ensure the precautionary gritting network is secure. Only when this activity is completed can resources (manpower, equipment and salt) be deployed to other areas. A second stocking would be actioned following a significant and prolonged snow event if resources allow; priority will be directed to salting the network. … Bins are not stocked on an ad-hoc basis."*

Essex maintains a map of salt bin locations (Essex County Council, 2021a) viewable online, following an audit of salt bin locations and condition.

Essex supplements their salt bin service with their Salt Bag Partnership, delivering a tonne of bagged salt on a pallet (forty 25kg bags) for local community self-help to each local council if requested that year.

4.1.3 Hertfordshire County Council

Hertfordshire County Council provide a map of salt bin locations (Hertfordshire County Council, no date a) but do not state total number. They state that they will not accept new grit bin requests (Hertfordshire County Council, no date b) and fill pre-season and after prolonged snow or ice. They also deliver 1 tonne of salt in a grab-bag (or 0.68 tonne as 20kg bags) to parish councils once per year pre-season on request, and other quantities to community and resident groups, schools, and district councils (Hertfordshire County Council, no date c).

4.1.4 Luton Borough Council

Luton Borough Council have over 240 grit bins, at locations listed with street addresses (Luton Borough Council, no date) These are restocked pre-season and "*when necessary*". There is no indication that restocking will be on request.

4.1.5 Milton Keynes Council

Milton Keynes Council restocks grit in grit bins each year, and provides a location list by road as well as a map of locations (Milton Keynes Council, no date b). There is no reference to mid-season restocking. In 2017, Milton Keynes Council's proposals to remove grit bin service were met with public objections and petition, and the proposals were not pursued (MK Citizen, 2017).

4.1.6 Norfolk County Council

Norfolk County Council fill grit bins preseason (before early December), and refill if necessary by February(Norfolk County Council, no date a). They do not have a published process for requesting refilling or ad hoc refilling. Mapped locations are available online (Norfolk County Council, no date b).

4.1.7 Northamptonshire Council

Northamptonshire Highways publish their policy to select new grit bin locations when requested (Northamptonshire Highways, no date a). They inspect and restock all grit bins pre-season, and refilled depending on weather and resources. They have an online portal to request refilling.

4.1.8 Peterborough City Council

Peterborough City Council restock over 100 grit bins during the winter season, and will accept refill requests when empty (Peterborough City Council, no date).

4.2 Comparison of grit bin numbers

For most of these regional comparator councils, the number of grit bins could be found, and is compared with the miles of highway and population of the council. This is shown below.

Council	*Grit Bins*	*Road network (mi)*	*Bin/ mile*	*Pop'n*	*Bin/ '000 person*
Suffolk County	2100	4121	0.5	757,000	2.8
Essex County	1000 *	5000 approx	0.2	1,832,752	0.5
Norfolk County	1900	6125	0.3	903,680	2.1
Cambridgeshire County	not given	not found	n/a	859,830	n/a
Hertfordshire County	not given	not found	n/a	1,195,700	n/a
Luton Borough	240	459 (1)	0.5	213,052	1.1
Milton Keynes	400	777 (2)	0.5	269,457	1.5
Northamptonshire	1513	2641 (3)	0.6	753,278	2.0
Peterborough City	100	747	0.1	203,600	0.5

Table 1: Number of grit bins in regional counties, compared with miles of highway and population
**also delivering 1 tonne of bagged salt each year to requesting local councils.*
(1) (Luton Borough Council, 2018)
(2) (Milton Keynes Council, no date a) as 1251km
(3) (Northamptonshire Highways, no date b) as 4521km

This indicates that Suffolk County Council is one of the more generous councils in grit bin provision per mile of highway, and the most generous per population count. In the context of the rural and coast nature of the county this could be appropriate. As Section 2.3.1

referenced, footway gritting has health benefits that will have consequent economic benefits discussed in Section 6.2.

5 Assessment of bin sensor for use in grit bins

5.1 Introduction

One make of sensor has been assessed for use in grit bin fill level monitoring. Section 5 describes the sensor and the assessments made on its operation. The sensor manufacturer have been clear that they do not list grit bins to be a suitable use case, and Suffolk County Council were keen to explore this possibility as part of their innovative research and development Smarter Suffolk project. Suffolk County Council with a key project supplier selected the model trialled in grit bin use case; other bin fill level models from other manufacturers and suppliers are available but not investigated within this research study.

In this section, the sensor hardware, operation and data management are described, and the experiments and observations discussed. Finally, the potential of the sensor to provide useful information for grit bin monitoring is discussed.

Sensors were trialled in two grit bins, as described in Section 5.4.

5.2 Farsite NetBin

5.2.1 Introduction

Telensa, the existing primary supplier of streetlighting management to Suffolk County Council, supplied Farsite's NetBin sensor for litter bin monitoring as part of the Smarter Suffolk trial. The same sensor was proposed for assessment for potential for grit bin fill level monitoring. The sensor is supplied in a minimum order of twenty, of which eighteen were trialled in litter bins (not covered in this report) and two were trialled in grit bins, as described in this report.

Other bin sensors are available commercially, operating with similar processes.

5.2.2 Sensor hardware

The sensor is the Farsite Netbin nPod sensor which measures depth to surface using ultrasonic measurement. Vendor documentation is included in a digital archive for this report. The sensor is pictured in Figure 1. Its dimensions are approximately 140mm x 122mm x 46mm, and it has a rotatable sensor housing.

Figure 1: Farsite nPod, image from https://iot.farsite.com/products/netbin/npod-bin-monitor/ 14/06/2020

The sensor measures depth to a surface using twin 40KHz ultrasonic sensors, with a reported depth range of 0.05m to 4.0m, and accuracy of ±0.02m. It also reports temperature, and has a tilt sensor which can detect movement associated with bin emptying.

Farsite, via Telensa, provided individualized installation instructions for the sensors to be fitted in the two grit bins selected, described in section 5.3.

The sensor is IP67 rated, indicating that it is dust-tight, with temporary protection against immersion (tested for 30 minutes at 1m water depth).

The sensor uses a Lithium Thionyl Chloride battery, and claims a ten year life based on two updates per day. Significant configuration of measurement frequency is available via the online dashboard, with a default of hourly readings and six-hourly updates. For active experiments the sensor was configured to update hourly.

5.2.3 Sensor communication

The Farsite Liquinet sensor communicates using 3GPP mobile standards, supporting GPRS(2G), 3G, LTE Cat-M1 and NB-IoT (NB1). These technologies could be anticipated to cover most of Suffolk, with some not-spots.

The sensor does not support any other network technologies.

5.2.4 Approvals, standards and compliance

The Farsite netBin nPod sensor cites the following approvals and compliance by initials in its datasheet. Abbreviations have been extended and explained for this report:

- CE: European Economic Area certification for products conforming with relevant health, safety and environmental protection standards. This would be expected to include electrical safety, radio safety, radio emissions and accepted interference, safe use and operation.
- FCC: United States Federal Communications Commission Declaration of Conformity. This certifies that electromagnetic interference from the device is within approved limits.
- RoHS2: European Union Restriction of Hazardous Substances directive 2. This restricts the use of specified substances, restricting the material content of new electronic equipment sold in the European Union, including proscribing the use of lead-based solders.
- REACH: European Union Registration, Evaluation, Authorisation and Restriction of Chemicals. This regulates the production and use of chemical substances.
- WEEE: European Union Waste Electrical and Electronic Equipment Directive sets collection, recycling and recovery targets for electrical goods.

5.2.5 Sensor dashboard and data

Data from the sensors have been made available in three ways:

- Farsite provide a web based application, netBin HUB, enabling sensor management and view. The online platform provides recent and historic fill levels as percentage, additional data, and enables configuration of sensors and alerts. Data can be visualised on the dashboard, or extracted as CSV files;
- Telensa provided data as CSV files by email;
- Telensa provided data via SFTP to the Data Exchange run for the Smarter Suffolk project by BT.

In all formats, data is available in timescales as communicated by the sensor. As data communication is one of the more power-intensive processes, the default is for fill level to be measured hourly, and communicated four times per day. Data appears to be available on the dashboard within a minute.

5.3 Installation

Sensors were installed in two grit bins (grit bin numbers are given by the grit bin owners):

- “Grit bin 4” is located in Melton outside a busy primary school, and was used with the kind permission of Melton Parish Council.
- “Grit Bin 26” is located on Adastral Park, a privately managed technology business campus in Ipswich, with the kind permission of BT’s site management.

Farsite, via Telensa, provided individualized installation instructions for the sensors to be installed in the two grit bins selected. These instructions are included in the digital archive to this report. The sensor was mounted in the lid using two M6 security bolts through the lid material.

The manoeuvrable sensor housing was adjusted to ensure the sensors were angled directly downwards: this was done using a clinometer to measure the angle of the lid, and the 15° markings on the sensor housing to adjust the sensor accordingly. Angles were confirmed as appropriate for the declination of the lids with the Farsite technical team.

Depth to the base of the bin, and to the potential maximum surface, were measured and configured in the dashboard. Fill level is reported as a percentage of maximum fill, rather than a depth to the surface.

During further correspondence regarding the bin fill level data observed, Farsite advised (John Way, by email 27/5/21): "*... we have various configuration options such as adjusting transmit power, receive gain and adding masks to cancel out echoes from the bin structure. With these Grit bins, we tried several different options and found that increasing the transmit power, made the echoes back to the nPod more consistent ...* ."

5.4 Trials

The sensors in grit bins have been trialled in two ways:

- Observations during normal use, including periods of stability and icy periods when grit was used.
- Deliberate phased excavation and refilling of the grit bin, with observations made of the actual and reported fill level.

5.4.1 Data used within trials

Bin sensor fill level and temperature data is available from three sources, as described in section 5.2.5:

- The data exchange created by BT for the Smarter Suffolk Project. Data here is populated as follows:
    - The sensor manufacturer, Farsite, collect data from the sensor. Farsite provide an API to access the data.
    - Telensa, the sensor supplier to the project, collect the data from Farsite via the Farsite API.
    - Telensa provide the data to the BT Data Exchange by hosting it on an SFTP server for collection by BT.
    - BT use an edge adaptor to provide the data to their own ingress API for onboarding into the data exchange.
    - Data Exchange users can access the data via an egress API.
- Alternatively, the sensor manufacturer Farsite also provide an online application including visualisations and data extraction as CSV files.
- The emailed CSV files provided by Telensa are identical to those extracted directly from the Farsite online application.

Data provided to the data exchange by Telensa via SFTP has been found not to be identical to the data provided by download from the Farsite application. It is similar, with many identical data points, but not completely consistent. The differences identified are:

- Data extracted directly from the manufacturer online application has sporadic missing temperature data, in periods of up to a few hours (a few consecutive missing data points). Temperature data from the data exchange, via the supplier SFTP provision, does not have gaps, but these missing data points have been filled with the last known temperature data point.
- Some other data points are not consistent between the two sources, and differ slightly (fill level as % is provided as an integer between 0 and 100. Temperature is provided as an integer around -10°C to 50°C depending on weather and environmental conditions. Differences in these values are typically between 1 and 5).

Significant effort has been applied to identify the sources of the discrepancy, but these have not been fully identified. Some of the discrepancy is due to data drop during the API creation or transfer process between the manufacturer (Farsite) and the project supplier (Telensa). These and other data drops are filled with the last known data point, rather than being presented as null. Sources of further data discrepancies have not been identified.

Given these discrepancies, the data extracted from the manufacturer's online application was used in the analyses below. This decision was made due to:

- The source of the discrepancies had not been identified. It is considered that data extracted directly from the manufacturer has undergone fewer data management, transfer and manipulation processes, during which the discrepancies may have been introduced. Data from the manufacturer's application is understood to be closer to the source.
- Data from the Data Exchange has been subject to data loss and undergone backfilling of missing data points in temperature data, which is considered to introduce inaccuracies.
- One consistent source of the data needed to be selected for analysis.

5.4.2 Observations during no use during stable period

During April 2021 the grit bins were not used, and no changes were made to the sensor configuration. This has been used as a "no use stable period".

Observations from this sensor are plotted as a timeseries (Figure 2). A daily cycle of temperature is observed, as expected. An apparent daily cycle of fill level is also observed, which is not consistent with the stability of fill level in the unused bin.

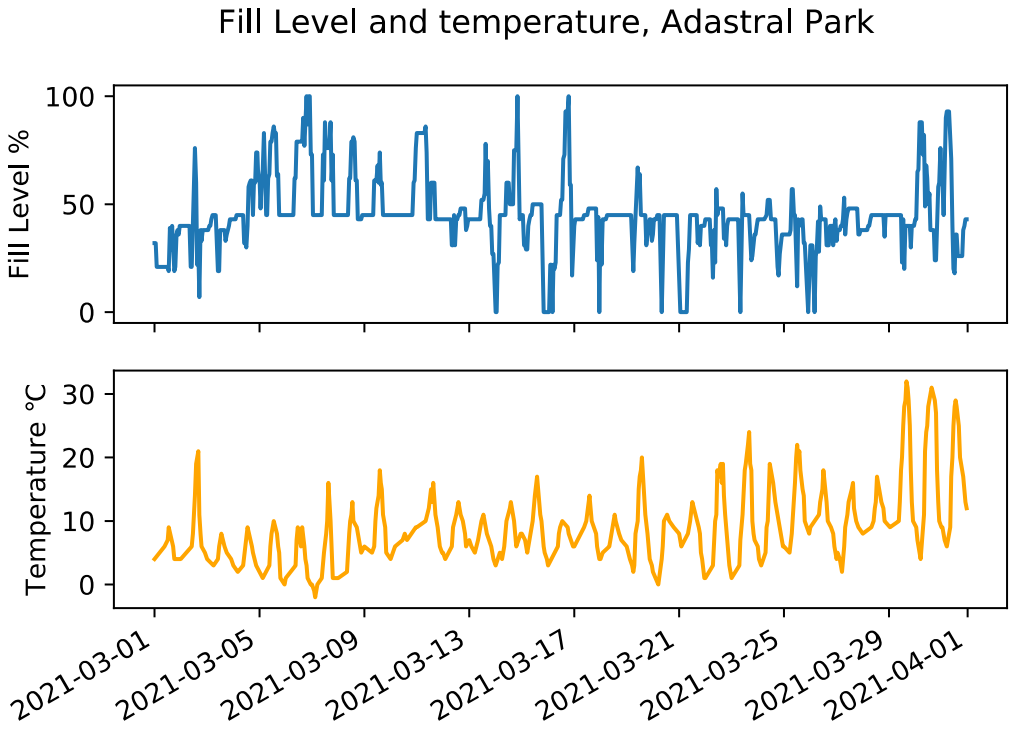

Figure 2: Fill level and temperature for sensor in grit bin at Adastral Park, during April 2021.

This daily cycle in fill level as well as temperature is shown in the NetBin online Hub, and replicated in the other sensor installed in a grit bin in Melton. Screenshots from the two sensors for this time period are shown below (Figure 3).

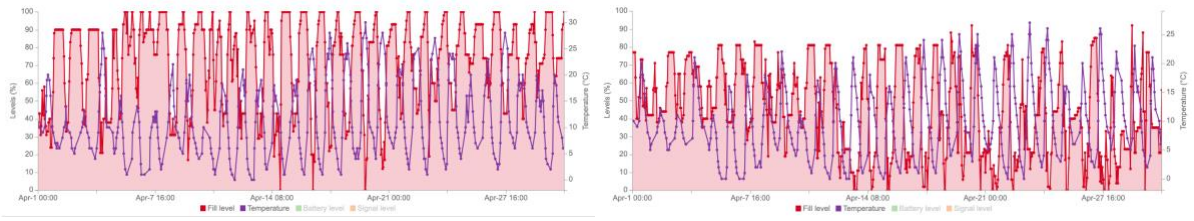

Figure 3: Fill level and temperature for sensor in grit bins, during April 2021, screengrabs from NetBin Hub, Left hand figure for sensor at Adastral Park, right hand figure for sensor at Melton.

It was suggested that this variation in apparent fill level might be due to fluctuations in temperature, as temperature does have an impact on ultrasonic signals (Panda *et al.*, 2016). However, the impact of temperature on ultrasonic speed should be less than 1% for temperature changes in the range 0°C to 50°C and not able to account for the range of variation in fill level observed. A comparison of fill level with temperature during April 2021 does not indicate a clear correlation (Figure 4).

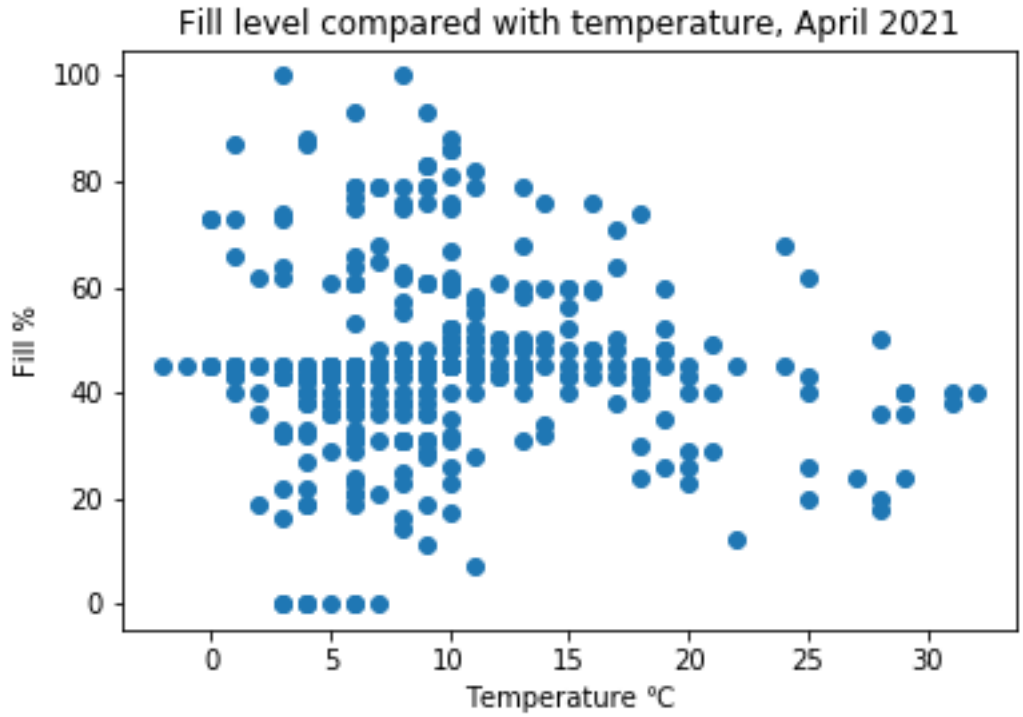

Figure 4: Correlation of fill level with temperature, Sensor at Adastral Park, April 2021,

Following communication with the sensor manufacturer about these inconsistent fill level data and daily fluctuations, further configuration adjustments were made, and stability of fill level observations improved. Sensor data from June 2021 (2 June 2021 to 28 June 2021) are plotted as a timeseries (Figure 5). A daily cycle of temperature is observed, as expected. However, there is less variation in fill level data than during April. Occasional variation in fill level remains observed in both sensors, but the majority of the data is more consistent. This

pattern of greater stability with some fluctuations is also observed in the NetBin online Hub, as show for each sensor in screengrabs from their interface (Figure 6).

The manufacturer stated: *In order to deal with problem bins, we have various configuration options such as adjusting transmit power, receive gain and adding masks to cancel out echoes from the bin structure. With these Grit bins, we tried several different options and found that increasing the transmit power, made the echoes back to the nPod more consistent. The inconstant echoes, could be due to the bin form factor, nPod install position/barrel angle etc. To find the exact cause, we would have to do much more investigation.* (John Way, Farsite, 27 May 2021, by email). The Smarter Suffolk project team would like to thank Farsite for communication on this issue and adjustments made.

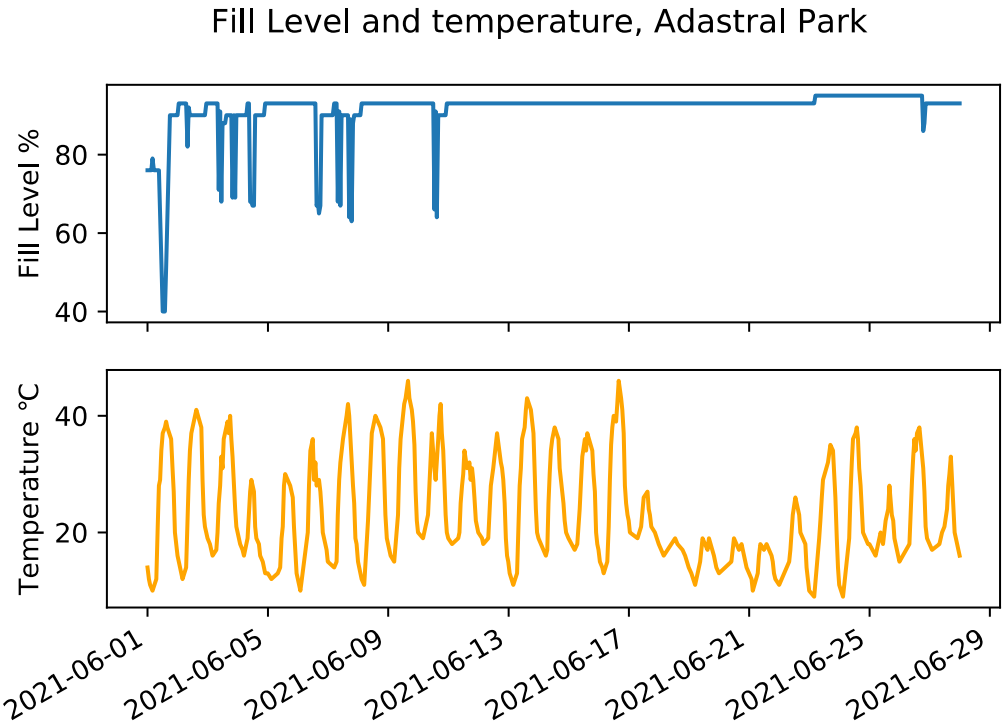

Figure 5: Fill level and temperature for sensor in grit bin at Adastral Park, during June 2021.

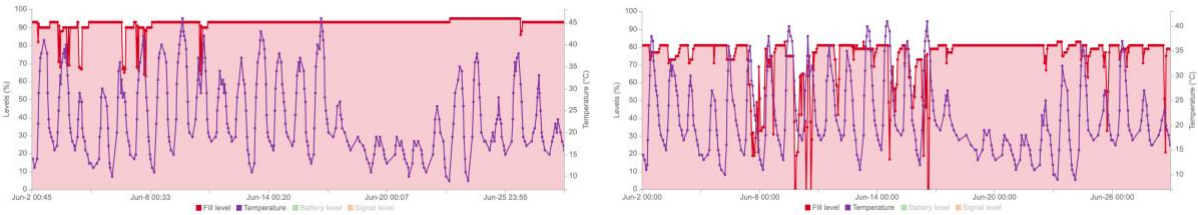

Figure 6: Fill level and temperature for sensors in grit bins, during June 2021, screengrabs from NetBin Hub, Left hand figure for sensor at Adastral Park, right hand figure for sensor at Melton.

5.4.3 Observations during normal use during icy period

Snow and icy conditions during early February led to significant grit bin use in Melton, followed by a subsequent refill of the grit bin. The grit bin at Adastral Park was not used during this period, as the technology campus is very lightly used due to COVID-19 restrictions. Sensor data during this period indicated a possible indication of bin use in Melton during 10 to 13 February 2021, followed by refilling.
Communications from Melton Parish Council stated that the bin was emptied over several days, and not in a single day, and was emptied to the base before being refilled by Suffolk

County Council. The observation data from the bin sensor indicate that the bin was emptied on 10 February 2021 during the most icy weather, and refilled on 13 February 2021.

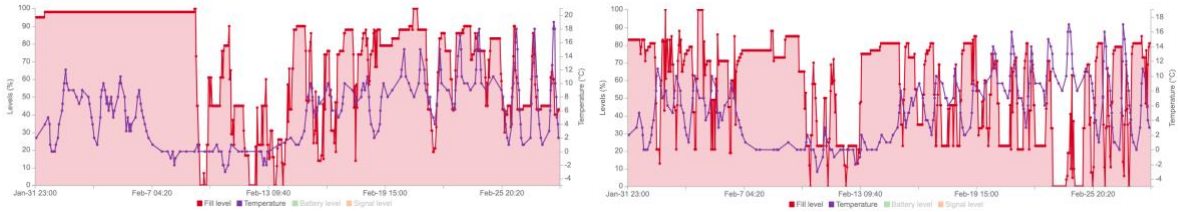

Figure 7: Fill level and temperature for sensors in grit bins, during February 2021, screengrabs from NetBin Hub, Left hand figure for sensor at Adastral Park, right hand figure for sensor at Melton.

However, similar pattern from the unused bin at Adastral Park, and continuing unexplained variations in bin fill level during the latter part of February, when the bin was not used, mean that the observations would not be adequate to be relied on for service delivery.

5.4.4 Observations during experimental excavation and refill

On 1 June 2021, the response of the sensor in one bin was explored by gradually emptying the grit from the bin, and refilling it. This experiment was undertaken in the bin at Adastral Park, due to the private nature of the site, and because the bin has smaller dimensions.

This experiment was undertaken as follows.

- Grit was dug from the grit bin in four stages, at intervals of an hour.
- The surface of the grit was left level after each stage.
- At each stage, measurements were made of the depth to the grit surface from the level of the sensor, using a measuring meter stick and tape.
- After four stages the bin was empty.
- Grit was placed on heavy duty polythene sheeting adjacent to the grit bin.
- The grit bin was left empty for two hours.
- The grit bin was then refilled in three stages.
- Depth measurements were made as before.
- Depth measurements were converted to fill level using the depth to empty and depth to full of the bin.
- Measured fill level is compared with reported fill level from the sensor.

The results of this are shown in Figure 8 comparing as a timeseries fill level (as %) as measured by tape from the level of the sensor, and fill level (as %) as reported by the sensor. These are shown as a scatterplot in Figure 9, with a line of x=y added, to which the data would match if the sensor data and the measured data were the same. Figure 10 shows the NetBin Hub visual from the same period.

These show that at around 60% full (33cm below the sensor level) the sensor data and the measured data matched, the sensor reported a smaller range than occurred during the experiment, when the bin was completely emptied.

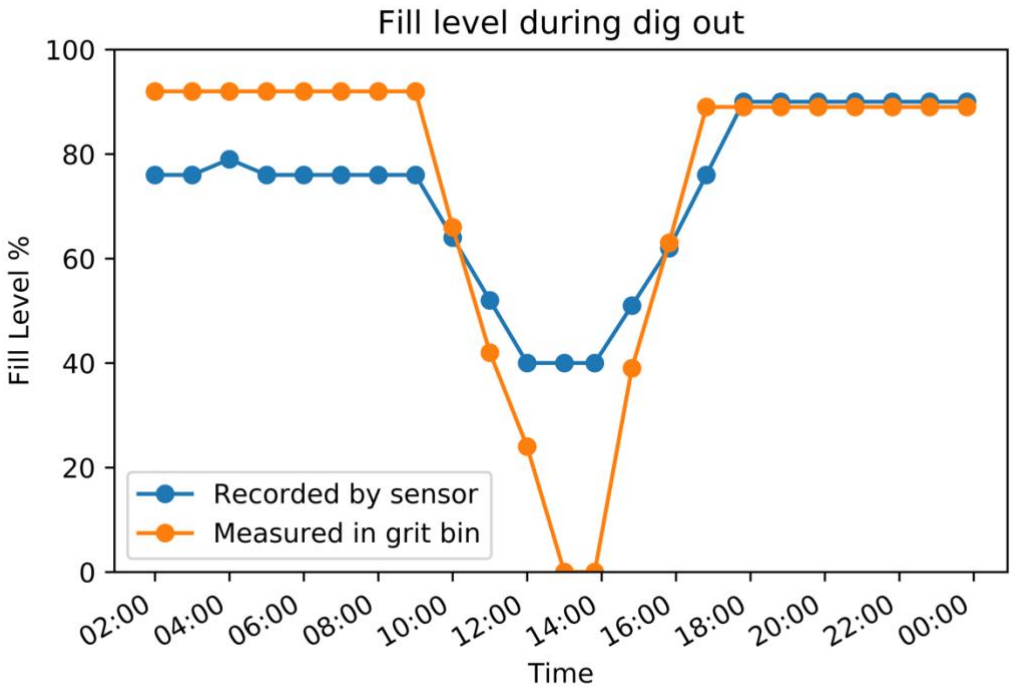

Figure 8: Fill level (as %) as measured by tape from the level of the sensor, and as reported by the sensor

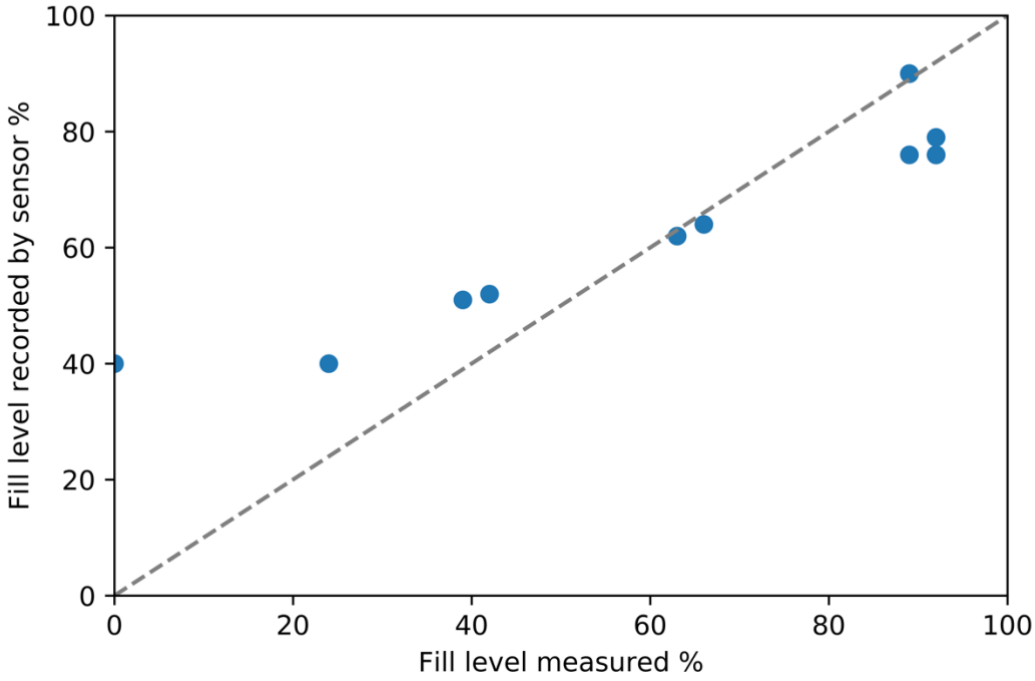

Figure 9: Comparison of measured fill level with sensor readings during excavation, 1 June 2021
Dotted line indicates 1:1 correspondence if measured and recorded fill levels were identical

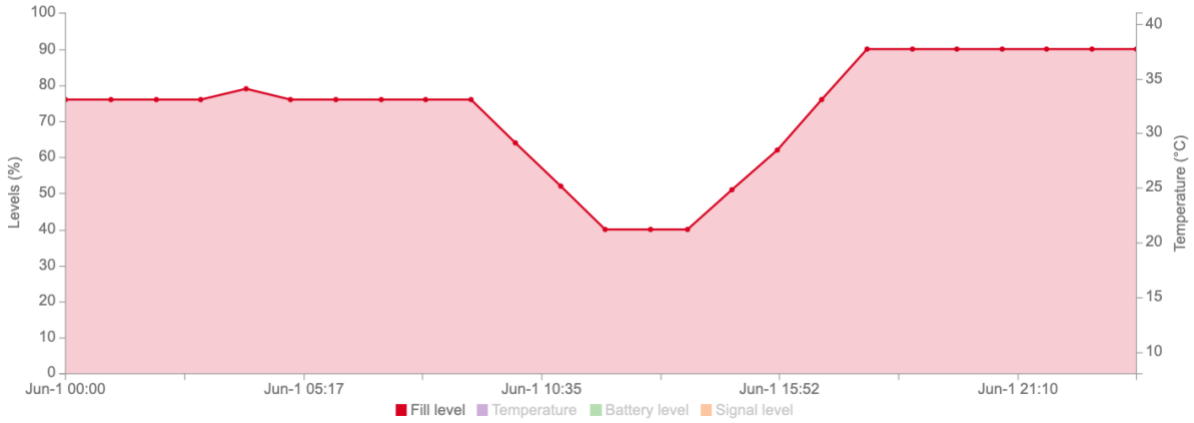

Figure 10: Fill level for sensor in grit bin at Adastral Park, 1 June 2021, screengrabs from NetBin Hub

5.5 Assessment of data

5.5.1 Reliability

The NetBin sensors have operated relatively reliably since installation. Fill level data from the NetBin Hub has had limited data gaps or loss. Temperature data has been more inconsistent, but has returned multiple data points each day. The frequency of fill level data available from the NetBin Hub could be considered acceptable for non-critical use.

Data from the project Data Exchange has been more problematic, with data padding disguising frequent data loss, and other discrepancies. Investigations to identify and resolve the source of the data errors are ongoing at the time of writing.

5.5.2 Accuracy

The accuracy of the sensors has been problematic. For much of their operational period, daily fluctuations in reported fill level have been observed despite the bin not being used. When fill was removed, data from the sensor did not match the fill levels measured, and the bin was reported as being 40% full when completely empty. This could be partly improved with additional work on sensor barrel angle, but that would not account for all the difference in measurement.

This consistent level of inaccuracy would not be appropriate for the use of these sensors in grit bins.
This report would not like to comment on the potential for use of these sensors in litter bins, which is their main active and design use case.

6 Business Case Assessment

6.1 Resupply analysis

Winter road maintenance in general, including winter road gritting, has significant financial value to the wider economy, in many ways. It's been claimed that for every £1 spent on winter road maintenance, about £8 is saved in the economy (Salt Association, referencing Thornes, 1999). Small scale local grit bins for local use have a beneficial economic impact, from health benefits as discussed in section 2.3.1, requiring the refilling of these bins as

necessary. This economic analysis focuses solely on the use of sensors in the bins to inform refill requirements.

6.1.1 Current cost of service

Guidelines on costs for grit bin refilling have been obtained from Suffolk County Council, and the main contractors who undertake the work. These figures address the costing from different perspectives, and do correlate.

Suffolk County Council advise (Ben Cook, in email from Richard Webster, 24/6/21) that grit bin services cost the council around £45,000 in the 2019-2020 year. This cost varies significantly between years depending on the frequency and duration of icy periods during the winter.

SCC have approximately 2100 grit bins, so this can be calculated as an annual cost of approximately £21 per bin per year.

Kier, contractors to Suffolk County Council, advise that refilling grit bins costs include:

£450-£500 per day per crew including vehicle and fuel
Six days for a complete county wide refill, therefore:
£2700 to £3000 for a county wide refill.
Salt costs ~£45/tonne; sharp sand costs ~£22/tonne, therefore:
90% sand mix = 0.9*45+0.1*22 = £24.3/tonne
Approximately 600 tonnes used for a complete refill, therefore:
£24.3*600 = £14,500 to refill all the bins

This would indicate a total cost of
£3000 + £14,500 = £17,500 per county-wide complete refill
Assuming 2.5 refills per year (one pre-season and 1.5 during season)
£17,500 * 2.5 = £43,750
Which is comparable with the cost indicated by SCC

Comparing these figures based on bin volumes:

Bin volumes usually between 50l and 350l, assume an average of 200l
2100 bins therefore total volume approximately 420,000l = 420m^3
Dry bulk density of sharp sand = ~1600kg/m^3;
Dry bulk density of road salt = ~1200kg/m^3;
Dry bulk density of 90:10 sand:salt mix = 1560kg/m^3
Total bin volume of 420m^3 requires 420*1560 kg of sand:salt mix
~ 650 tonnes which compares with the figures above.

Both these sets of figures indicate a resupply cost of approximately £21 per bin per year to the council, or £8 per resupply visit.

6.1.2 Cost of sensor provision

The sensors used in this trial are from Farsite and are usually offered as litter bin sensors. They do not have a current publicly available standard list price. They were supplied to the project via Telensa acting as a third party reseller in a quantity of twenty units at a cost of £640 per sensor, including communications and data management.

Sensor installation was found to be relatively straightforward after the first one. Based on installation of the same sensors in litter bins, crews were installing around fifteen sensors in a day. Using the day rates in Section 6.1.1, this provides a cost of installation of around £30 per sensor, making a total cost of £670.

Assuming a lifetime of 10 years for the sensor, this would work out at an annual cost of around £67 per sensor.

This cost can be compared with the cost of the current method to acquire fill level information: as described in Section 3.2.

6.1.3 Financial comparison

Based on a cost per bin per resupply visit of £8, the sensors would need to have the potential to save more than eight visits per year to provide a return on investment.

One can reasonably assume that a pre-season visit and inspection, including fill where necessary, is required for all grit bins. Most years in Suffolk, an additional one or two visits are required, depending on weather. It would not be possible for the bin sensors to provide a return on investment in the use case of grit bin refilling.

Other locations with more icy weather would have a greater frequency of grit bin resupply required. However, with the winter season in the UK, it is considered unlikely that any locations are currently resupplying grit bins enough times during the winter season that a reduction in resupply visits of eight fewer per year would be possible. Therefore it is considered highly unlikely that grit bin sensors would provide a return on investment in the UK. Whilst grit bins may be refilled more frequently in colder locations outside the UK, it is however considered likely that alternative solutions (discussed in 6.4) are likely to provide a more cost effective approach to information gathering than installed sensors.

An alternative approach would be if one sensor could inform the refill requirements of more than one grit bin. This would assume that grit bins emptied at similar rates, so a sensor in one bin could realistically indicate the fill level of other bins, potentially in the local area. This is considered an unreliable assumption on the basis that bins are of significant differing volumes, varying from 50l to 350l capacity, bins serve different locations with a different surface area of gritted path or junction, and bins are used by different volunteers, who could be applying a different volunteering schedule or salt spreading approach. Further research could indicate the extent to which bins could be categorised in terms of grit usage rates.

Refill of bins on an area-wide basis as at present, rather than individual bins on request, has significant financial and environmental benefits.

6.2 Environmental and social analysis

As described in Section 2.3.1, footway gritting provides positive health impacts. Environmental benefits of managing salt in contained grit bins is described in Section 2.3.2. There is therefore a health and environmental benefit from supplying grit as needed, in quantities within the container limits. All regional councils provide salt either in bins or bagged. Minimising unintentional spread of salt is important for environmental and economic reasons.

Conversely, the provision of Internet of Things and "Smart City" sensors in general also has some environmental disbenefits (Alsamhi *et al.*, 2019; Yang *et al.*, 2021) including: the manufacture, delivery and installation of the sensors; the energy required for their ongoing operation; energy for their data communication, management, storage and access; and end-of-life disposal.

The use of the sensors provides environmental and social benefits when decisions made based on the data received enable a reduction in transport or a reduction in any periods during which there is no grit for use on the footways. Some limitation of refill of the bins when needed is due to management of local authority resources to priority work during icy periods (discussed in Sections 3.1 and 3.2), and availability of resources for refill requires planning.

6.3 Innovation Portfolio Builder

Proving Services have supplied an Innovation Portfolio Builder which includes the following options:

- 1740 Dynamic Winter Treatment & Route Planning
- 1400 Road Maintenance & Winter Services on Private Roads and Commercial Estates
- 1410 Road Maintenance & Winter Services on Public Sector & Regulated Services Estates

The potential impact for installing sensors in grit bins has not been assessed using this tool, as these options were significantly broader than the specific case.

6.4 Alternative solutions and challenges

Currently the grit bin refilling schedule is managed from the combination of two inputs:

- Refills requested by the parish council via the Suffolk Highways reporting tool.
- Refills requested by Suffolk County Council following periods of icy weather.

Grit bins are used by volunteer grit spreaders managed by the parish council. These people are aware of fill level whenever they use the bin. Should fill level changes be required, this could be requested from the volunteer grit spreaders: the collection of such information in this way would not have a cost. Information management could be improved with a dedicated section or focused improvement of the existing reporting tool if desired.

A combination of user-reporting and weather-related refills could continue to be a sufficiently accurate way to know when to refill, without any additional costs. Suffolk County Council might state that their refill process includes stocking bins prior to the winter season, with a refill action following significant snow when resources allow (with priority given to highways gritting), and no ad hoc filling on request. In locations where stored volume does not adequately supply usage during the period of a cold weather event, consideration could be given to replacing with a larger grit bin to store a larger volume of grit prior to county or domain-wide restock.

6.5 Wider challenges (location)

Discussions with users and contractors identified a couple of different areas for potential improvement, which could be considered by Suffolk County Council.

6.5.1 Parish Council View

Melton Parish Council reported that there was no response made to reports via the online reporting tool. They would be interested in notification when requests had been actioned.

Specifically in the context of grit bins, volunteers report that a grit bin needs refilling, and the parish council report it online. When the volunteers make another request concerning the same grit bin, the parish council do not know whether the grit bin has been refilled in the interim, and been emptied again, or whether the bin is waiting refill following the initial request. They would find notification of action on requests made useful.

6.5.2 Winter contractors view

Suffolk Highways contractors report that their concern regarding grit bins is in locating them. Their record of location includes street names and sometimes finer locations, but not fine scale location information. Such information is particularly useful when there are changes in personnel, and would save time during pre-season stocking and refilling during the winter season. GPS location information for the bins was suggested. As the bins do not move, fitting them with GPS sensors would not be necessary. A one-off asset survey would enable an asset record to be compiled including latitude and longitude or easting and northing location of the bins, together with bin capacity or condition if required. Essex Highways completed an audit and maintains an online "salt bin map" in such a way. This could support and maintain knowledge about the locations of grit bins in Suffolk.

7 Conclusions and Recommendations

7.1 Conclusions

This report concludes that the provision of grit / salt mix for local use for pavement de-icing is beneficial:

- Significant health and (direct and indirect) economic benefits in reducing pedestrian falls and slips, potentially leading to injury;
- Environmental and economic benefits in providing grit/salt in contained grit bins, minimising environmental impact and resource loss by leaching.

This report concludes that Suffolk County Council appear to provide a number of grit bins comparable with surrounding local authorities in the region (for population number and highways length), and a similar restock process.

Observational and experimental research for this project has shown that the sensors trialled did not consistently provide a reliable record of levels of grit/salt in the grit bins in which they were installed. During experimentation, the excavation of the salt was noted by the sensor-reported readings, although the fill level (as a percentage) was not accurate (reported as 40% full when empty). Additional adjustments may have resulted in more accurate measurements, though the sensors were installed, set up and configured as instructed.

Business case evaluation comparing the cost of the sensors with the cost and frequency of restocking concludes that the sensors cannot become cost effective within their projected lifetime.

Interviews with service providers and users suggest that grit bin fill levels can be and are monitored by the volunteers who use them; they currently inform the council when refilling is required. County-wide refilling is also requested by SCC managers following periods of severe weather, when heavy usage will have occurred. It is more efficient to restock multiple grit bins than individual bins on an ad hoc basis. Restocking is managed in association with

the other demands on resource during winter weather, when priority is given to maintaining the priority highways networks with highways gritting.

Should Suffolk Highways or Suffolk County Council wish for more frequent fill level monitoring, it could be provided by inviting the volunteer users to provide such information following each use. A tape measure would enable measurements, and an online reporting application could automate the compilation of this data.

Suffolk County Council would benefit from an accurate inventory of grit bin locations, with precise locations known. This view has been shared by parish council users, volunteers, and service suppliers. Suggestions for the implementation of this with an annual condition survey are included in the conclusions.

7.2 Recommendations

This report recommends consideration of the following:

- Sensors are considered unlikely to provide a cost-effective way to gain fill level information for grit bins, without very significant decrease from current sensor costs and significant increase in service costs.
- Sensors were not found to provide reliable information on fill levels in grit bins during this trial. Discrepancies in data provided via different paths was also of concern in information integrity.
- SCC continue to request widescale restocking following known periods of winter weather, taking into account demands on resource during these periods.
- SCC could use the existing requests to refill, and additional volunteer observations, to track grit bin fill levels if required.
- SCC would benefit from an accurate asset location map, which could be compiled as a one-off exercise prior to or during pre-season stocking on one occasion, and would require a time investment on that occasion. Location information can easily be obtained via a smart phone or tablet, and recorded in a spreadsheet or more formal asset register. A condition survey and updating of this asset register could be undertaken on each annual pre-season fill.

7.3 Final Summary

The research within the Smarter Suffolk Live Labs project suggests that it is possible to install sensors within grit bins. The sensors trialled use ultrasonic measurements to track grit bin fill levels, are battery powered and communicate via cellular data. They were relatively easy to install, though not designed for grit bins. Their manufacturer and the company supplying them were responsive with queries. However, during use the sensors did not provide accurate fill level data.

Literature review confirms that supply of grit/salt has social and economic benefits, and the use of contained grit bins has environmental and economic benefits.

Recommendations for management of the grit bin service have been made, but this research does not support the wider use of these sensors in grit bins. The sensor manufacturer concurs with this conclusion.

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9 Document History

Date	Version	Author	Notes
Aug 21	Draft	H Steventon	Reviewed with Prof N Caldwell
Sept 21	Issue 1.0	H Steventon	Issued to Suffolk County Council