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Improving collection efficiency through remote monitoring of charity assets

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ABSTRACT

Collection costs associated with servicing a major UK charity's donation banks and collecting unsold goods from their retail shops can account for up to 20% of the overall income gained. Bank and shop collections are commingled and are typically made on fixed days of the week irrespective of the amounts of materials waiting to be collected. Using collection records from a major UK charity, this paper considers what vehicle routing and scheduling benefits could accrue if bank and shop servicing requirements were monitored, the former using remote sensing technology to allow more proactive collection scheduling. A vehicle routing and scheduling algorithm employing tabu search methods was developed, and suggested time and distance savings of up to 30% over the current fixed schedules when a minimum bank and shop fill level of between 50% and 60% was used as a collection trigger. For the case study investigated, this led to a potential revenue gain of 5% for the charity and estimated CO_2 savings of around 0.5 tonnes per week across the fleet of six heterogeneous vehicles.

1. Introduction

Donation banks (i.e. receptacles for receiving donated goods) (Fig. 1) are often provided by charities at supermarkets, recycling centres and public car parks, as a convenient way for the general public to donate unwanted clothes, shoes, books and other materials. Alternatively, members of the public may prefer to deliver their unwanted goods directly to a charity shop. In both cases, the quality of the donated goods can vary widely, with some goods having no value (waste), other goods having some recycling value and the best quality goods being suitable for re-use, including items of high resale value such as wedding dresses and rare books. A 2009 survey of UK charity shops indicated that over 363,000 tonnes of textiles are sent on for reuse and recycling by charity shops every year and that around 2% of materials donated to charity shops end up in landfill (Charity Retail Association, 2013). The collection requirements associated with emptying donation banks and removing unsold/unsaleable items from shops can be considerable. This paper considers how a greater temporal visibility of both bank and shop fill rates, the former using remote monitoring sensors, could aid a major UK charity to more dynamically manage its collection schedules in order to reduce the CO_2 footprint, save time and increase revenue.

A perceived problem with the fixed collection rounds often used in charity logistics, and a problem experienced in this case study, is that some banks may contain relatively few items when visited, while other banks may have been full for several days before a collection was made. In this case a more dynamic and flexible collection scheduling approach may be appropriate particularly where containers fill at highly variable and unpredictable rates, or, where unnecessarily long trips to only partially filled banks are being made (Johansson, 2006). This more dynamic and flexible approach can be enabled through remote monitoring of banks and other assets, Remote monitoring may also help in identifying incidences of theft from banks and could, in principle, affect the collection policy (e.g. visit more frequently), although this aspect has not been considered here.

Many charities also offer ad hoc services such as house clearances where a vehicle will be scheduled to visit a domestic

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Fig. 1. Charity donation bank.

dwelling or workplace to collect a quantity of items (books, clothes etc.). Such activity can be quite lucrative in terms of the potential quality of goods available and more informed logistics decisions could be made where remote monitoring identifies the relative worth of visiting certain banks in time over a request for a house clearance. The scale of the benefits depends on the flexibility in the collection schedule which in the case of some charities is limited by the need to service shops on a regular fixed interval basis, an activity undertaken in tandem with bank servicing. Aside from the scheduling benefits, remote monitoring of banks can also help charities quantify their performance in terms of average yields by area and time of year. This can also aid bank placement strategy, which may need to be more temporal dependent on yields, theft rates and the changing characteristics of the local population.

The UK charity studied in this research was interested in understanding how the adoption of new remote fill rate monitoring sensors fitted into its network of textile donation banks could help optimise its collection strategy on a day-to-day basis. This paper uses real and simulated donation data to quantify the impacts of various collection strategies assuming different minimum fill level collection triggers and maximum fill level penalties. In reality, estimating bank fill level can be difficult given that bags of clothes may not lie flat in the bank or may shift as new donations are added. In this application, an infra-red sensor was mounted on the underside of the roof of each bank, measuring the distance to the top of the pile of materials lying below, translated into a percentage fill estimate for the bank. The fill level was transmitted via GSM (Global System for Mobile Communications) to a webserver every 12 h. Initial indications from a trial of the sensors suggested that the fill estimates were accurate to within 20%. Another practical concern is the battery life of the sensor and the need to replace or recharge batteries. Other remote sensing technologies are potentially suitable for waste and recycling applications: for example, Rovetta et al. (2009) reported the use of ultra-sonic, light emitting diode (LED) and pressure sensors installed in waste containers in Shanghai, China.

1.1. Background to the routing problem

Devising a service schedule where a collection vehicle has to visit specific points on fixed days and others, depending on dynamic fill rate information, is an extension of the well-studied capacitated vehicle routing problem (CVRP), with a heterogeneous vehicle fleet (HVRP) and time window constraints (HVRPTW). This problem is considerably harder to solve compared to the CVRP and a number of mathematical models and solution algorithms have been proposed (Yaman, 2006; Baldacci and Mingozzi, 2009; Brandão, 2011). The literature on the HVRP is relatively scarce and this is more so where time windows are included (HVRPTW). Studies by Paraskevopoulos et al. (2008) and by Ceschia et al. (2011) both describe variable neighbourhood tabu search algorithms to solve the HVRPTW, the objectives of which are to minimize total cost. Vehicle routing and scheduling algorithms have been applied to a wide variety of waste collection problems: for example, Kim et al. (2006) considered time windows associated with commercial waste collections; Angelelli and Speranza (2002) compared alternative collection methods, with varying types of containers and vehicles used; and Amponsah and Salhi (2004) focused on waste collection problems faced in developing countries. Practical applications of remote monitoring in the waste/recycling sector have included cardboard collection in Sweden (Johansson, 2006) and the collection of disassembled materials from cars (Krikke et al., 2008) where, in both studies, the authors estimated potential vehicle mileage savings of 26% through dynamic scheduling.

2. Defining the case study

The case study concerns a subset of the logistics operation undertaken by a leading UK charity operating a network of around 650 shops selling new and used goods, and approximately 1300 donation banks across the UK. The charity operates a complex reverse logistics process across several separate vehicle fleets, servicing these shops and banks. This enables the charity to transport goods, primarily second-hand books and textiles, from banks to shops or processing centres, and to move goods between its shops for resale. The logistics operation also feeds recyclate generated by shops back into recognised commercial recycling streams and provides the return of low-grade clothing to a central sorting facility for separation and onward processing. The part of this reverse logistics system being considered here concerns the collection of rejected or unsold goods from 75 shops and donated goods from 58 textile bank sites, undertaken by the same vehicle fleet, to a regional depot near Milton Keynes, UK (Fig. 2). The collection region covers an area of approximately 11,000 km^2, including the towns/cities of Oxford, Cambridge, Northampton and Peterborough.

Previous research (McLeod et al., 2013) found that the charity's existing requirement to maintain fixed collection days for the shops severely constrained the vehicle schedules and that remote monitoring of banks under such a scenario returned small benefits in overall round time and distance savings due to the primary requirement to service shops. Of increasing interest is whether the traditional fixed-interval shop collection schedule is too onerous and whether a more dynamic approach could be adopted. This concept would work in a similar way to the remote bank monitoring, with shop managers reporting their actual collection requirements each day (or potentially via remote monitoring the stock room) to better understand actual servicing needs. In this research, the collection requirements for the shops are relaxed by treating them in a similar way to banks, only visiting them as and when required, based on how near capacity they are. This temporal relaxation provides much greater flexibility in when both shops and banks can be visited and should improve logistical performance. Since shops can accumulate rejected/unsold goods at varying rates, it is envisaged that, in practice, shops managers would report their collection requirements on a daily basis, or as and when they would like a collection to be made. A smart phone