Logistics optimisation for waste collection

In a nutshell

Summary overview							
It is best practice to optimise the logistics of waste collection by: • installing where appropriate an alternative collection system to road transport, such as a pneumatic system in urban areas; • using Computerised Vehicle Routing and Scheduling (CVRS) technology to optimise collection rounds; • exploring collaboration opportunities with neighbouring waste management organisations; • benchmarking fuel/energy consumption and/or CO_2 emissions; • incorporating one or more environmental metrics, such as cumulative energy demand (CED) and/or CO_2 emissions, into network design and route optimisation algorithms; • installing telematics equipment in collection vehicles for real-time route optimisation based on GPS and training drivers in eco-driving techniques.							
Waste management area							
Cross-cutting	MSW - strategy	MSW - prevention	**MSW - collection**	MSW - EPR	MSW - treatment	CDW	HCW
Applicability							
All organisations involved in waste collection can implement some degree of logistics optimisation (e.g. planning the location of waste bins). However, the actions are limited in some cases by existing organisational structures (e.g. on-going contracts for outsourced waste collection services). In terms of collection strategy optimisation, logistics optimisation is secondary to optimising recycling. Pneumatic waste collection systems are more suitable for densely populated areas and are easier to install in new developments than in existing urban areas.							
Specific environmental performance indicators							
In addition to the common environmental performance indicators presented in the best practice common environmental performance indicators, the most appropriate indicators to assess the successful implementation of this best practice are: • fuel consumption per tonne of waste collected[1] (litres/t); • GHG emissions per tonne of waste and km travelled (kg CO_2e/tkm).							

[1] depending on the waste collection system in place (e.g. vehicles and/or pneumatic collection, type of vehicles) and the data available, more useful alternatives to this indicator can be: Primary energy consumption per tonne of waste collected, cumulative energy demand per tonne of waste collected, GHG emissions per tonne of waste collected.

Description

Overview

When developing a new waste collection strategy (consult also the Waste collection strategy best practice), logistics optimisation is an important aspect to consider, since it can contribute to improving the economics and the environmental performance of the waste management system. For instance, as presented in the best practice Waste Collection strategy, colour-coded bags for different waste fractions can be collected in a single refuse collection truck for transport to an optical sorting plant where separated waste streams are checked and sorted for further treatment in recycling facilities. The choice of this collection system, when defining the waste collection strategy, contributes to logistics optimisation, reducing the number of collection routes, lowering fuel consumption, traffic congestion and noise.

In general, and not only during the development of a new waste collection strategy, there is often scope for significant logistics optimisation in order to reduce the related fuel consumption, noise, traffic and costs.

Logistics optimisation ranges from the design of waste collection infrastructure and networks, including the installation of vacuum collection systems and the use of colour-coded bags, to real-time route optimisation based on GPS or geographical information system (GIS) software. The opportunities to implement the design of advanced waste collection infrastructure and networks may be limited depending on the existing organisational structures of waste collection providers – for example, outsourced collection providers may not have any opportunity to influence network design. However, all organisations involved in waste collection can implement some degree of logistics optimisation (e.g. location plan of waste bins).

Table 1 summarises the key measures to optimise logistics operations for waste collection, and the rationale underpinning them.

Table 1. Key measures proposed as best practice and the underpinning rationale

Measure	Underpinning rationale
Install an alternative collection system, such as a pneumatic system in urban areas.	Pneumatic systems avoid the need for collection vehicles to enter built-up areas where traffic congestion, noise and air pollution effects are most problematic. They can therefore lead to significant improvement in urban environmental quality.
Utilise Computerised Vehicle Routing and Scheduling (CVRS) technology to optimise rounds.	Optimisation requires detailed modelling using specialist software, and may be undertaken in-house or outsourced. In any case, the EU rules for driving time and rest periods following (EC) 561/2006 have to be taken into account.
Explore collaboration opportunities with neighbouring waste management organisations.	Collaboration offers considerable scope for improvement through efficiency savings, such as route optimisation and depot rationalisation (AMEC, no date).
Benchmark fuel/energy consumption and/or CO_2 emissions.	Benchmarking fuel consumption and emissions per tonne of material collected and delivered facilitates continuous improvement in environmental efficiency, and also provides data necessary for LCA of material recycling chains, informing design of the circular economy.
Incorporate one or more environmental metrics, such as cumulative energy demand and/or CO_2 emissions, into network design and route optimisation algorithms.	The environmental impact of waste collection is dominated by fuel consumption and related combustion emissions, and is indirectly represented via fuel costs in economic optimisation of reverse logistics. Explicitly incorporating one or more environmental metrics, such as cumulative energy demand and/or CO_2 emissions, into optimisation algorithms can maximise the environmental benefits achieved through logistics optimisation.

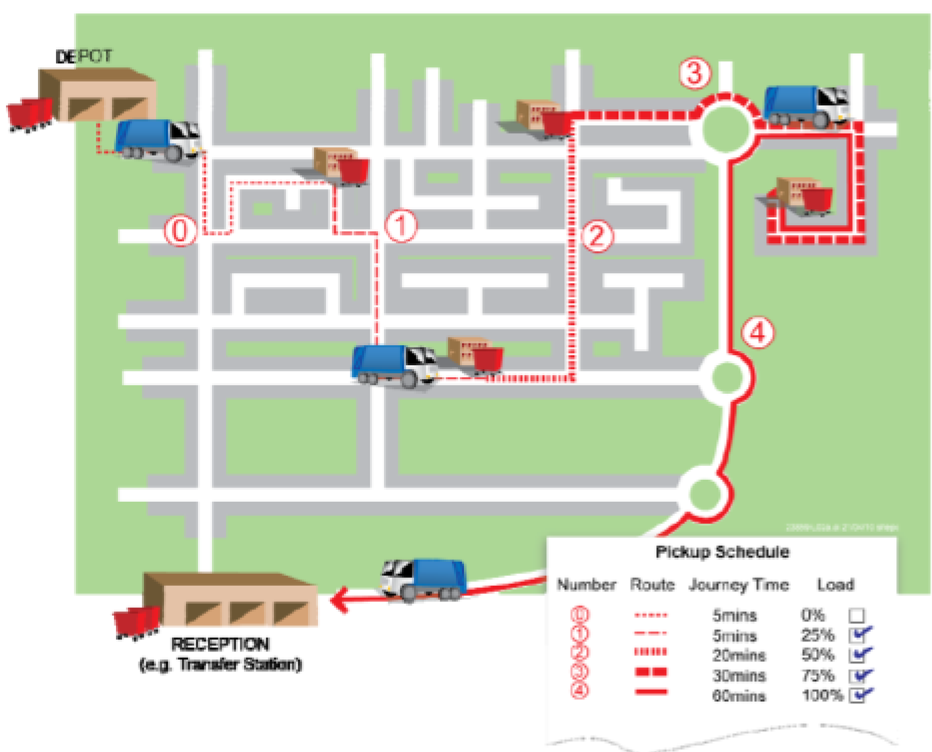
Measure	Underpinning rationale
Install telematics equipment in collection vehicles, and train drivers in eco-driving techniques.	Driving style (especially during stop-start collection) and routing depending on traffic conditions can have a significant influence on fuel consumption.

Route optimisation

Logistics operations for waste collection can be optimised with respect to[1]: (i) the type, number and location of facilities and bins, (ii) choice of the transportation means, (iii) choice of the transportation speed, (iv) choice of the transportation concept, (v) choice of the routing, and (vi) choice of the timing of collection (Dekker et al., 2012). Compared with other logistics operations, final load factors are usually high for waste collection vehicles, and there is not much choice of mode: 26-tonne collection trucks are typical (see also the best practice on low-emission vehicles), though there may be opportunities to use smaller collection vehicles for some routes and fractions.

Waste collection round routes and schedules are typically developed over time based on driver knowledge and are revised periodically in response to changing collection requirements. For simplicity, collection rounds may be designed based on zoning for individual vehicles/crew, although this approach is likely to miss significant opportunities for optimisation (WRAP, 2010).

The modelling and optimisation of collection operations can be best performed by using a suite of commercially available software tools incorporating Computerised Vehicle Routing and Scheduling (CVRS) technology (Figure 1). This may be outsourced to specialist consultancies, or undertaken in-house following procurement of the necessary software and licenses. Information systems and data collection strategies may need to be upgraded to support CVRS.



Source: WRAP (2010).

Figure 1. Schematic example of a Computerised Vehicle Routing and Scheduling (CVRS) software system

Waste collection optimisation involves the application of reverse logistics, defined as "planning, implementation and controlling the efficient, effective inbound flow and storage of secondary goods and related information opposite to the traditional supply chain directions for the purpose of recovering value and proper disposal" (Fleischmann et al., 1997, cited in Bing et al., 2014).

Alternative collection systems

In densely populated urban areas there is increasing interest in the use of alternative waste collection systems, such as pneumatic systems that use negative pressure (vacuum) to move waste along underground pipes from inlet points where citizens deposit waste fractions to waste collection points outside residential areas. These systems may also employ positive pressure to tackle blockages, and, although expensive to install, can considerably reduce operating costs (Waste Management World, 2009). Systems can be designed to accommodate multiple waste fractions, and can even be used to automatically empty litter bins (Envac, 2015). Such systems can considerably reduce traffic, noise and odours in urban centres, and may be particularly well suited to new-build residential districts. Additionally, there is less need for (i) waste storage space in households and (ii) accessibility of vehicles in the urban centre.

Finally, note that alternative road transport vehicles are described in the next best practice.

[1] All the choices should take into account the local traffic conditions and the architecture of the examined area.

Environmental benefits

Pneumatic systems can lead to significant savings in fuel, as well as reducing noise, visual impact, odours and traffic associated with conventional waste collection systems. Installation of a pneumatic system in the Hammarby Sjöstad district of Stockholm is estimated to have reduced waste collection traffic (heavy waste collection vehicles) by 60 % (Envac, 2015). Whilst pneumatic systems may not generate environmental savings from a life-cycle perspective across the entire waste management chain, they are highly significant in the context of urban environmental quality.

The magnitude of fuel and environmental burden savings achieved through logistics optimisation is highly dependent on the pre-existing (in-)efficiency of waste collection operations.

WRAP (2010) reports on an example of CVRS application to optimise collection of MSW in the UK. The study found that CVRS could reduce transport distances and associated fuel consumption by 15 %, whilst increasing productivity by up to 9 %. This would lead to concomitant reductions in fossil resource depletion, GHG emissions, air-polluting emissions such as NO_x, PM and VOCs, and traffic.

Ricardo-AEA (2012) reports that active cruise control can reduce fuel use and GHG emissions by 1–2 % for regional delivery, which may apply to transport of waste fractions between depots (two- to four-month payback period). Telematic systems can reduce fuel consumption and associated emissions by approximately 5 % for long-distance transport, and up to 15 % for urban transport (Climate Change Corporation, 2008).

Owl Waste (2015) reports a trial with SITA UK in which they used telematics to target driver training; this allowed a reduction in fuel consumption of 12 %. Ricardo-AEA (2009) suggests that more efficient driving can reduce fuel consumption by up to 10 %

Side effects

All measures that reduce fuel consumption should reduce life-cycle fossil energy depletion and emissions of GHGs and substances affecting air quality.

Route and schedule optimisation based on economic data alone could lead to increases in fuel consumption and associated environmental burdens in some cases, especially where an environmental metric is not included in the optimisation algorithms.

In terms of network design, there may be a trade-off between minimisation of waste collection burdens and wider economic optimisation of the number of logistics hubs. Dekker et al. (2012) suggest that economic factors favour fewer, larger and more efficient waste treatment centres. This may or may not be congruent with logistics optimisation depending on the specific situation.

Implementation of logistics optimisation only after identification of the most efficient overall collection strategy should avoid potentially important trade-offs between minimisation of collection energy (e.g. via less frequent collection of separated fractions) and maximisation of waste separation (best practice on waste collection strategy).

There is little published information on the energy consumption of pneumatic systems. Punkkinen et al. (2012) found that a hypothetical pneumatic collection system, modelled using patchy available data, generated considerably higher GHG and SO_x emissions per tonne of waste transported than road collection. However, NO_x emissions were lower, and air pollution largely arose upstream in power stations rather than in densely populated urban areas. Electricity consumption was the dominant source of emissions, but relied on uncertain data. ISWA (2013) claims that new systems using a combination of vacuum and positive pressure use up to 67 % less energy than vacuum-only systems. There is a need for better data to be reported on the electricity requirements of pneumatic systems.

Applicability

All organisations involved in waste collection can implement some degree of logistics optimisation (e.g. planning the location of waste bins). However, the actions are limited in some cases by existing organisational structures (e.g. on-going contracts for outsourced waste collection services).

In terms of collection strategy optimisation, logistics optimisation is secondary to optimising recycling.

Pneumatic waste collection systems are more suitable for densely populated areas and are easier to install in new developments than in existing urban areas.

Economics

WRAP (2010) quotes costs in the range of GBP 5 000 to GBP 10 000 (EUR 7 042 to EUR 14 084) to model and optimise existing collection rounds for a waste management organisation running 12 collection vehicles. Adding alternative future scenarios costs GBP 2 000 to GBP 6 000 (EUR 2 200 to EUR 6 600) per scenario. In the case study example, WRAP (2010) estimates a fuel saving of up to GBP 36 200 (EUR 39 800) per year, indicating a short payback time. The study authors suggest that a return on investment can be made within one to two years, depending on the degree of change implemented and the size of the fleet (larger fleets are likely to realise greater savings).

The outsourcing of waste collection activities by waste management companies can reduce incentives for both separation efficacy and logistics optimisation, depending on how contracts are structured. In the absence of specific performance-related clauses, subcontracted collection companies may maximise revenue by maintaining high-frequency bin collections, justifying higher charges to the waste management companies. It is imperative that outsourcing of logistics operations sets clear performance objectives that avoid perverse incentives (TWG, 2015).

The installation cost of pneumatic systems is considerably greater than for conventional bin-collection systems. ISWA (2013) presents cost data for three case studies, indicating that, for apartment blocks, it can cost up to four times more to install a pneumatic system – up to EUR 15 million for 10 000 apartments. However, bin-collection systems require significant space for bin storage, which can be expensive in urban areas (estimated at over EUR 14 million for 10 000 apartments). Furthermore, collection costs for pneumatic systems are considerably lower: EUR 133 000 per year for 10 000 apartments, versus EUR 640 000 per year for conventional collection (ISWA, 2013). The economics of pneumatic systems therefore compare favourably where space (land) is expensive. Waste Management World (2009) reports that the estimated payback period for pneumatic systems is 10–12 years.

Driving forces for implementation

Increasing collection costs associated with collection of separated waste fractions, alongside the long-term upwards trend in fuel prices, are major drivers for the optimisation of transport and logistics. This is driving increasing interest in collaborative agreements across waste management organisations (AMEC, no date).

Space restrictions and high land prices are a major factor favouring pneumatic systems that avoid the need for bin storage areas.

Reference organisations

Some municipalities which have improved the logistics of waste collection are: Sefton Metropolitan Borough Council (UK), Multi-council collaboration in Hampshire (UK).

A few examples of software providers for route optimisation are: http://www.webaspx.co.uk/ http://www.fleetroute.com/k1/e.php http://www.routesmart.co.uk/case_studies.php

Participants in the EC LIFE Ewas project, in which wireless sensors and GPS tracking are being employed to optimise waste collection timings and vehicle routings: http://life-ewas.eu/en/ See PROMEDIO case study below.

A number of case studies of pneumatic waste collection systems are available on the Envac website: http://www.envacgroup.com/references

Box 1. SITA UK telematics and driver training

In 2010, CMS SupaTrak began working with SITA UK to explore the potential benefits of implementing a telematics system throughout their fleet. An initial trial was carried out with "EcoTrak" fuel-saving technology on 12 municipal and recycling vehicles from the Warwick depot. EcoTrak is a telematics system which records driver behaviour in real time, measuring vehicle and driver performance against parameters including speed, idling time, harsh braking and accelerating, over-revving and excessive throttle use. This information can then be used to target remedial driver training to promote more fuel-efficient practices.

Following a two-week benchmarking period during which driver behaviour was covertly recorded and translated into summary reports, driver training and coaching was delivered by trainers with industrial experience and knowledge.

The trial resulted in fuel savings of 12 %, which were extrapolated up to an annual GHG emission reduction of 3 000 tonnes. Following on from the success of the trial, SITA UK has decided to roll out EcoTrak technology across 650 vehicles based around 32 sites, and the trial has been replicated across other SITA operations throughout Europe. The technology is compatible with all vehicle manufacturers.

Source: Owl Waste (2015).

Box 2. Optimisation of collection rounds for a new waste collection strategy by Sefton Council, UK

Sefton Metropolitan Borough Council (MBC) is a local authority covering 120 000 households. The council engaged a consultancy to develop optimised waste collection rounds following the development of a new strategic waste collection plan that involved changing to alternate week collection of refuse and garden waste in wheeled bins, replacing weekly collection of refuse sacks, and (for 80 % of households) garden waste sacks. A private contractor managed kerbside-sorted weekly dry recycling collection. Sefton Council required the new collection schedule to meet the following objectives:

- high levels of time and fuel efficiency;
- balance workloads across crews and vehicles;
- flexibility to accommodate different productivity rates and yields.

The consultants employed by Sefton MBC had worked with over 50 other local authorities, which enabled them to calibrate their models with regionally applicable productivity rates and yields for different types of households. The modelling identified the minimum number of vehicles and crews required to produce workable rounds to maximise productivity rates and yields. Feedback from the crews was used to refine the round optimisation, and designed rounds were tested for sensitivity to productivity rates and yields.

Sefton MBC said of the work: "The combination of AMEC and Webaspx's powerful optimisation technology, together with their experience of working with many authorities on round design, has helped us develop a solution of acceptable risk. We feel that the outcome has produced optimised and balanced workloads that will enable the new collection service to be introduced successfully."

Source: AMEC (no date).

Box 3. Logistics optimisation through multi-council collaboration and depot rationalisation in Hampshire, UK

Background

Project Integra is a partnership of the 15 parties (including waste collection, disposal authorities and Veolia) in Hampshire formed to find common, efficient waste collection solutions. Project Integra commissioned AMEC to evaluate the potential logistics benefits of joint refuse and recycling collections across six partner authorities (Basingstoke and Deane, East Hampshire, Hart, Havant, Portsmouth and Winchester).

Method

RoundManagerWM software was used, and a collection model parameterised using data provided by operational staff. An initial scenario maintained all existing depots and facilities across the six partner authorities, using a standardised set of design rules underpinned by the collection pick-up rates and yield data provided by each authority. A subsequent scenario modelled the impact of depot rationalisation, in which two depots were removed.

Results

Tactical models identified savings of nearly 400 000 km per year, 235 000 kg CO_2 and six vehicle equivalents (including drivers and loaders), resulting in financial savings of approximately GBP 1 million (EUR 1.4 million) per year. The potential logistics savings were slightly reduced in the depot rationalisation model, although closing down two depots could save GBP 250 000 (EUR 340 000) per year.

Source: AMEC (no date)

Box 4. PROMEDIO waste collection optimisation

Wellness Telecom and PROMEDIO implemented a project in the Spanish province of Badajoz to monitor 50 bins for 12 months, using electronic sensors to record bin weight at collection. The study was part of the EU LIFE-funded “Ewas” project, and revealed the following:

- only 20 % of bins have a fill rate high enough to require weekly collections;
- 18–20 % of bins are collected with a content below 40 % to 50 %;
- 75–80 % of bins are collected at least once a year with a content below 40–50 %.

From these findings, Wellness Telecom proposed the following measures to PROMEDIO:

- Identify a list of bins that need to be collected weekly due to a higher service demand. Reorganise collection site locations and enhance service availability, with additional bins in nearby locations.
- The rest of the bins should be collected every two weeks.

This will provide a basis from which to further optimise collection routes and frequency, saving in fuel and human resources. Continued monitoring of bin fill level through use of a simple electronic tool (“e-Garbage”) is proposed to identify full bins requiring earlier collection. Expected savings in fuel are around 5 000 litres per year, whilst workforce savings are in estimated to be 40–50 %, switching from weekly to fortnightly collection.

Source: Wellness Smart Cities and Solutions (2015).

Literature

AMEC (no date). Design of New Alternate Week Waste Collection Rounds: Sefton Metropolitan Borough Council. AMEC website: http://www.amec-ukenvironment.com/logistics/Downloads/pp_1207.pdf Last access on July 2015.

AMEC (no date). Building the Business Case for Joint Working Waste Collections: Hampshire County Council. AMEC website: http://www.amec-ukenvironment.com/logistics/Downloads/pp_1298.pdf Last access on July 2015.

Bing, X., Bloemhof-Ruwaard, J.M., van der Vorst, J.G.A.J. (2014). Sustainable reverse logistics network design for household plastic waste. Flex Serv Manuf Journal, 26, 119–142.

Climate Change Corporation, CCC (2008). How greener transport can cost less. http://www.ettar.eu/download/press_ETTAR.pdf Last access September 2017.

Dekker, R., Bloemhof, J., Mallidis, I. (2012). Operations Research for green logistics – An overview of aspects, issues, contributions and challenges. European Journal of Operational Research, Volume 219, Issue 3, 16 June 2012, Pages 671-679, ISSN 0377-2217.

Envac (2015). Hammarby Sjöstad case study page. Available at: http://www.envacgroup.com/projects/europe/hammarby_sjostad Last access December 2015.

Harris, I., Naim, M., Palmer, A., Potter, A., Mumford, C. (2011). Assessing the impact of cost optimization based on infrastructure modelling on CO_2 emissions. International Journal of Production Economics, 131, 313–321.

MA 48 (2014). Stadt Wien, MA 48 – Abfallwirtschaft, Straßenreinigung und Fuhrpark. Leistungsbericht 2013 (Performance Report 2013; in German). March 2014.

Owl Waste (2015). SITA UK choose EcoTrak as their fuel and carbon saving solution. Case study available at: http://www.owlwaste.com/case-studies Last access December 2015.

Punkkinen, H., Merta, E., Teerioja, N., Moliis, K., Kuvaja, E. (2012). Environmental sustainability comparison of a hypothetical pneumatic waste collection system and a door-to-door system, Waste Management, 32, 1775-1781.

Ricardo-AEA (2009). Review of low carbon technologies for heavy goods vehicles. UK Department for Transport, London.

Ricardo-AEA (2012). Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle. Ricardo-AEA Ltd, London.

TWG (2015). Technical Working Group Kick-Off Meeting, Leuven 30th September-1st October, 2015.

Waste Management World (2009). The future of waste collection? Underground automated waste conveying systems. Available at: http://waste-management-world.com/a/the-future-of-waste-collection-underground-automated-waste-conveying-systems last access September 2017.

Wellness Smart Cities and Solutions (2015). eGarbage: A challenge for sustainable urban planning.

WRAP (2010). Use of Vehicle Routing and Scheduling Software in CDE Waste Collection. Report written by Entec for WRAP, Oxon.