System for future towns?
Underground waste collection

J.H.R. van Duin

*Transport Policy and Logistics Organisation, Faculty of Technology, Policy and Management, Delft University of Technology, The Netherlands*

**Abstract**

Nowadays waste management receives increasing attention. Lately, due to new waste management legislation, the emphasis has been shifting to recovery, due to the high costs and environmental burdens of disposal. Recently, at regional level, municipalities have become more aware of the fact that waste collection is one of the key elements in the reverse logistics chain. For a specific new area to be built in a Dutch town, called Almere, we have carried out a feasibility study on underground waste collection. The parties in question have put up a list of criteria which has been set up to evaluate this new system. By applying a multi-criteria analysis, the underground collection system has been compared with the traditional way of collecting. Of course, the criterion costs belong to the most important evaluation criteria. Although the construction costs are extremely high, the exploitation costs of such a system show an improved performance. Based on the performances on the multi-criteria analysis, the local government of Almere have decided to make a serious step forward to a sustainable development of their city and consented to building and implementing such an underground waste collection system.

**1. Introduction**

Ever since the early fifties, as a consequence of increasing production, the volume of waste materials has grown tremendously to a multiplication factor five. Due to this growth and the negative impacts to the environment, a common
awareness led to the foundation of the Club of Rome. Under the leadership of professor Meadows the relations between population growth, food production, industrialisation, pollution and the use of non-replaceable natural resources had been investigated (e.g. Meadows¹). This report concluded that the unlimited growth of production and consumption should be restricted. Also the reuse of materials has been suggested as a solution to a more durable use of our natural resources.

In the early 80s Dutch municipalities decided to collect glass. At different spots in town glass containers were placed. The response of the population was unexpectedly high and therefore the results for reuse were very favourable (e.g. Steegh²). Ever since these favourable circumstances garbage segregation had been applied to other garbage materials like paperworks, organic materials (from the garden), clothings, metals, chemical products and remainders.

In the beginning there was a strong scepticism towards the recollection of products. Traditionally, producers manage their operations along a supply chain, which ends at the latest at the point, the sold product becomes obsolete for the customer. From an operations’ point of view the linear structure of the supply chain seems to be very advantageous. This explains the scepticism many managers show when the necessities or even the opportunities of thinking about recollecting products and recovery management are mentioned. It transforms the linear supply chain into an open supply loop, which makes it necessary to manage it in a highly integrated way. Lately, due to new waste management legislation, the emphasis has been shifting to recovery, due to the high costs and environmental burdens of disposal. Recently, at regional level, municipalities have become more aware of the fact that waste collection is one of the key elements. Managing this integration became a new opportunity on the market for specialised logistics providers collecting the materials in such a way that producers can really reuse the materials in their processes and that these materials become valuable to them again in the reverse logistics chain.

However, the key question still to be resolved is: What is an efficient and effective structure for a reverse distribution network? Because of the low product value of garbage the collection of materials must be performed very efficiently, otherwise the logistics providers cannot exploit their services in the long term. Most of the garbage collection is carried out by using of trucks and containers. These transport movements, combined with their noise, smell and exhaust gases, affect the quality of the living environment in the city. Therefore, new developments in waste collection can be observed. The plastic rubbish bags have been replaced by twin bins or underground pickup containers, sometimes equipped with an electronic eye. The electronic eye reports the inner volume of a container. With this knowledge the trucks can only pick up the container if the container is really full. Environment-friendly trucks, which will probably run on natural gas, are designed to reduce the emissions in the city. Also the working conditions have been improve, since all kinds of handling activities have been automated.
However, we have to conclude that the main part of the innovation is basically focused on efficiency improvement of the current systems instead of on radically innovative technology. For new to be built city areas one can decide to plan new garbage collection systems without using any trucks at all. One of these systems being selected as a candidate system for a new area in the city of Almere is an underground waste collection system provided by a Swedish company, i.e. Centralsug. This system is described in chapter 2. Chapter 3 contains the description of the feasibility study we have carried out for this city. By using a stakeholder analysis, we have been able to identify a list of criteria to evaluate this new system. A multi-criteria analysis has been applied to compare this new system with the traditional garbage collection system. Chapter 4 ends up with some general comments about the implementation of this system.

2. Underground garbage collection system

The basic structure of an underground garbage collection system consists of collection pillars, wires and one central collection terminal where all the garbage is being sucked in (see figure 1).

Figure 1: Scheme of underground garbage collection and transport system

Figure 2: Examples of collection pillars
Garbage Offering
A person offers his/her garbage at an inlet. The inlet could be located in a house, at an arbitrary floor in an apartment, at a central place in a building or at a special place somewhere outside. Each inlet contains one or more (usually 3) throwing hatches. The hatches for green waste and residual waste generally have an opening with a diameter of 280 mm. For paper works and coarse garbage special openings can be realised (see figure 2).

After the garbage is thrown into the inlet, it is caught in a buffer zone or chute. Based on the offering pattern, the dimensions of buffer zones can be scaled to different sizes. The chutes can also be equipped with level sensors sending a signal to the control system to empty the inlet if a maximum level is reached. This will avoid outside placement of garbage.

All the inlets are separated from the collection wires by a discharge valve. It is located at the bottom of the chute. By opening the valve, the buffer is emptied due to an underpressure in the wires. One by one, the discharge valve under each of the inlets is opened and the garbage falls down into the pipe network as a result of the gravity. For example, in Kista and Stockholm this happens twice a day with an average duration of 7 till 10 seconds, whereas Walt Disney World in Florida opens 30 times a day.

The size of the diameter of the transport wires is usually 500 mm. This allows a maximum diameter for the throwing hatch-opening of 400 mm. If this size is still too small, a cutter can be placed in between.

The transport wires are situated 1 or 2 metres below the surface and can make a maximum curve of 20 degrees. Due to the suction capacity, the maximum length of each wire is 1.8 kilometres. The life-cycle duration of such a network is about 30 till 60 years. The electrification and pressure wires needed for the pneumatic system will be built together with the building transport wires.

Periodically, or when needed, the buffer zones can be emptied. Automatically, the suction installation becomes operative. In the wires an airflow of 15 till 22 cubic metres per second is generated. If this air speed is reached, the discharge valves will be opened. The garbage falls into the transport wires and
will be transported in 30 to 60 seconds to the collection terminal. In Kista, Stockholm, the total collection process will take 1 hour and 15 minutes. This is an average time for a system with 182 buffer zones connected to 3500 households, a daily waste production of 9 tons or 90 m³, and a two-day collection and a total wire length of 9 kilometres.

The collection terminal is the last part of the underground garbage transport system (see figure 4). The garbage enters the collection terminal via a cyclone that separates the garbage from the air. The garbage falls down into a compactor, which compacts and cuts the garbage into the sealed container. The volume of the garbage will be reduced to a third part of its original volume. A common container size is 25/30 m³. Inside the container (25/30 m³) a signal system is placed to indicate that the container is almost full. A roll-on roll-off system places the container on a truck. The transport air now passes through dust- and deo-filters and a silencer. If the system is designed for recycling an additional inlet, chute, discharge valve and container are required. The size for a collection terminal for 4500 households requires a square space floor of 250 m².

Figure 4: Collection terminal

3. Feasibility study

At the beginning of the study all actors involved had been interviewed. The main actors in this field are:

1. the municipality, with its sanitation department, local government, and the department of public works. They decide whether this system will be implemented;
2. the disposers of waste, i.e. the households, offices and shops. As potential users of the system, they can ask for specific requirements;
3. the suppliers, i.e. the project developers, consultancy firms and system suppliers.
4. and other actors, i.e. the regional and national governments, garbage collection services and subsidy providers.
The main criteria for evaluation, which are considered to be important by the actors, are spatial adaptation in the environment, the costs, and other criteria like user convenience, the nuisance and improvement of the liveability and accessibility of the city. In order to have some reference-values for the criteria, we have compared the findings and values with the findings and values of the traditional garbage collection.

3.1 Spatial Adaptation

Both systems can be spatially integrated in the city. The total required space for the collection terminal and the inside spaces for collection is comparable to the container stacking spaces needed for the traditional system, i.e. 1118 m² and 924 m² respectively. The underground system will contain 302 inlets, which means that for apartment buildings one inlet will serve three floors. 195 Throwing hatches are required with a total buffer zone volume of 563 m³. The underground wires have a total length of 6 kilometres and will be 1.7 metres below ground level. At the end of the network the collection terminal will be built under the curved ground level. The floor space for this terminal will be 350 m². The collection activity will take place twice a day with a total collection time between 85 and 145 minutes.

For the traditional garbage collection we estimated 1049 twin containers (1 container per household). To pickup and collect these containers, 66 container collection points are required with a total floor space of 924 m² (=14 m² per collection point). The collection will take place twice a week.

3.2 Costs

The following cost-structure has been applied to define the running costs. We differentiate in our calculations between construction costs and costs for buildings. Together these costs from the costs of realisation. While we compare these cost with the traditional costs of garbage collection, we have to take into account the costs of interest in our calculations from total costs to costs per year. These capital costs added up with the operational costs result in the running costs. The construction costs for the wires (6 km), terminal, thrown hatches (195), buffer zones (56), inlets (302), truck (1) and containers (5) were estimated at € 5,910,000. This information was provided by the supplier Centralzug. Also the costs for design and management should be added to this amount, i.e. € 1,136,363. The building costs are on average € 1600 per m² gross floor space (e.g. Van Kleef1). For each system component the actual floor space has been measured. The total floor occupation added-up to 768 m² making the total building costs at € 5,454,545. The capital costs per year can be calculated by means of an annuity method. The system life cycle is determined at 30 years (i.e. the minimal life cycle!) with an interest level of 6 % a year. Total investments
Waste Management and the Environment

Costs are € 7,590,910. The capital costs per year will be approximately € 5,454,545. The operational costs are derived from the cost price per household of € 27, - per year (e.g. Victoring®). The total number of households in Almere will be equivalent to 4500 households, so the costs for operations will be € 121,500. The maintenance costs and costs of transport should be added up to this amount, which will lead to a maximum of 181,181 €

For the traditional garbage collection the building costs will be much less than the costs of underground transportation. The building of the container depots will cost € 95,000. Buying expenses for 1049 twin-containers and 198 rolling containers will be € 168,181. The running costs are estimated at a maximum of € 668,181 a year.

Summarising, as to the criterion costs we have to admit that the costs of realisation will be € 7,272,727 higher than the costs of traditional garbage collection. Balancing these high investments with the running costs will make the costs 20% higher. If the investments will be fully subsidised, then the running costs of the underground system can be 73% less than the costs of traditional garbage collection.

3.3 User convenience, nuisance and improvement of the liveability

In this study the user convenience is defined as the logistics system characteristics which have a strong influence on the customer service aspects of disposing garbage. The first criterion is the allowable time window for offering garbage. The traditional system allows just a small time window for offering garbage. For households the garbage should be brought to the pickup locations between 9.00 pm and 8.00 am, only once a week. Offices and shops can bring their garbage during two hours a day. The underground systems allows a 24 hour –service, but it will probably be forbidden after 10.00 pm due to the possible noise. The walking distances to the nearest pick-up locations will be smaller in case an underground system will be applied.

The underground system produces a noise of 50-70dB twice a day. The collection trucks of the traditional system cause 90-120 dB twice a week. The chance of bad smell is much higher in the traditional garbage collection, whereas at home or even in the containers the green waste can start to decompose. Another inconvenience of the traditional system is the chance of forming street litter. Regarding the liveability and accessibility of the city these performances will be much improved by the introduction of an underground system. In the traditional system collection trucks ride slowly through busy streets and main streets twice a week and therefore cause a lot of congestion. Underground garbage collection will bring on also container transport from the collection terminal, but this could be situated at a more quiet location.
4. Conclusions

Due to our growing population and our growing needs for consumption we can see a growing attention for waste management at all managerial levels of the government. The time for waste management has begun. From the perspective of sustainable thinking the attention for the redistribution networks has increased. To gain value out of garbage, a low product value, the collection of materials must be performed very efficiently otherwise the logistics providers cannot exploit their services in the long term. Traditional garbage collection is carried out using of trucks and containers. These transport movements, combined with their noise, smell and exhaust gases affect the environment. Therefore the municipality of Almere has made the decision to build an underground transportation system for garbage collection. Although the initial investments are € 7,272,727 higher than traditional collection systems and will lead to higher costs in the long run, the municipality sets more value on the criteria spatial adaptation, user-convenience and improvement of the liveability waste management. Of course, the fact that the ministry of environmental affairs will subsidise part of the investments, has influenced the decision making. Based on the results of this study we are sure that underground transportation systems for garbage collection can be a real sustainable and efficient solution for areas with a very high population density a system of the future!

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References