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Contents

1. Introduction

Implementation of sensors in waste containers to measure filling (Smart waste management)
Waste containers are fitted with sensors, throughout the south of Rotterdam. The sensors were supposed to be connected to the implemented LoRa-network.

The Netherlands has a relatively advanced waste policy in which the landfilling rate is already less than 5% of the total waste volume generated. However, further improvements are still possible – such as in waste production per person in the Netherlands, which, with a level of more than 500kg per year, is still above the EU average of 466kg/year. The Dutch policy paper on Circular Economy has therefore formulated a goal for further improvement of recycling through improved waste separation. The goal for mixed and solid household waste is set at a maximum of 100 kg per person per year in 2020 and 30 kg per person per year in 2025. Within this system, all Dutch municipalities have an autonomous responsibility in choosing the collection method and of course choosing the tariffs and levies that accompany that choice. This has led to ten widely differing ways of collecting and financing waste collection. All these processes and differing ways of collection have led to a wide variation in waste per capita and to varying tariffs charged to households.

For garbage disposal, in total, in Rotterdam 2,600 kilometres per day are driven. Smart waste traffic is achieved by using sensors to measure the degree of filling of the containers. For transporting these data, the (possible) use of the LoRa-network will be explored and the data will be monitored via a central portal. The purpose of the measure is a reduction of 20% of the number of kilometres driven. This results in a CO2 reduction, besides of course a saving of, still mostly fossil, fuel costs. After the pilot in Rotterdam South for a route to retrieve waste paper and after analysis and any amendments thereof, the system is provided to roll out the measure to the other types of waste in the beginning of 2019.

Figure 1: Collecting waste from underground containers

1.1 Dynamic waste collection, Rotterdam South.

Rotterdam is the main harbour and industrial city in the Netherlands, with a population of some 615,000, and 1.2 million people living in its metropolitan area. Part of its waste collection system consists of 6,500 underground containers for different types of waste – 2,500 for single fractions (glass, paper, textile and plastic) and 4,000 for residual waste. These containers get emptied on average two times a week, every working day. The city has a relatively large number of high-rise buildings and the cultural diversity of the city makes communication in relation to proper household waste management a challenge. Misuse of containers therefore happens quite frequently and street littering is, like in many other large cities, a common problem in Rotterdam. The municipality currently charges a flat tariff to households (i.e. not differentiated by, for example volume, weight or frequency collection). As it has a relatively high municipal waste levy compared to other municipalities, it is a political aim in Rotterdam to reduce costs and to improve the efficiency of municipal waste collection.

Therefore, in 2015 the Municipality of Rotterdam started a pilot with 250 underground paper bins that were connected with networked sensors which can measure the level to which each container is filled. The aim was to examine if fill-level information could lead to a more efficient collection with environmental as well as cost benefits for the city and citizens. After careful market analysis a Finnish sensor and data tracking system was chosen, For transporting these data the possible use of the LoRa-network was explored. During the pilot a dynamic waste collection system was developed and tested (figure 1-1). Both prior to the pilot and during the experiment attention was paid to contact with the employees – the drivers of the waste collection trucks. A choice was made to select personnel with an open mind to change for participation in the experiment. The selected personnel were actively involved and interviewed during the experiment to collect their experiences and any concerns.

The tender was done in October 2017 and the service contract was awarded to the only party that also offered their services through LoRa.

Within the service orientated contract, it was stated that the provider had to reduce traffic by ¼ and, no increase of complaints by citizens. Therefore, the supplier chose not to use LoRa because the supplier could not guarantee the desired quality, through the low quantity sending of data by the, unique, quality of the LoRa network. Due to the amount of data to be send back and forth, both parties agreed that LoRa was not accurate enough to be used. The sensors had to be installed with sim-cards to be able to send continuously the data through 3G/4G.

In Q2 of 2018, the textile collection throughout Rotterdam and in the South is also driven by the collection of paper and glass combined with dynamic route planning and guidance through the filling level. The number of journeys has decreased significantly (and therefore also the number of kilometres and CO_2 emissions). It is expected that the entire waste collection for neighbourhood containers (around 6500 pieces) will be planned and driven smart by 2019.

Figure 2: Misuse of waste containers and littering

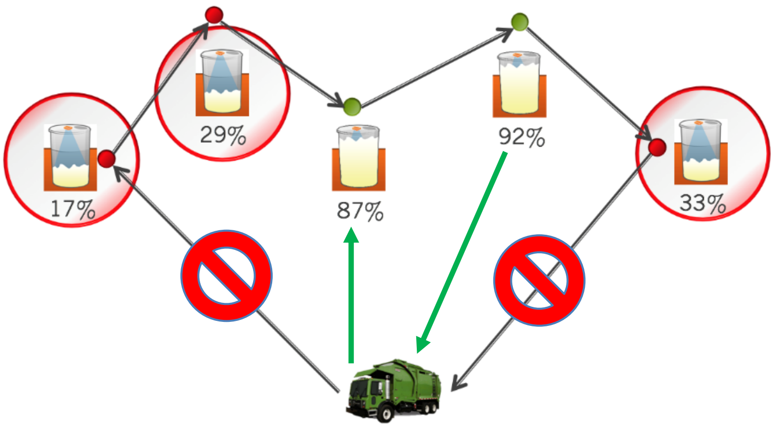
In Q1&Q2 of 2018 a test with LoRa was done, within the same department. This test was being conducted with rat traps that report whether a trap has been triggered and whether or not there is a catch (three sensors per trap).

The outcome of this test was unsatisfactory since the signal did not come through the concrete walls. The test is being conducted at the moment with an updated stronger LoRa network, results are more promising, but the final outcomes are not yet known.

2. Methods and results

In the following figures, tables and images it is shown how the dynamic waste collection is executed. According to the level of waste in the containers a map is being generated for that day and displayed on the Ipad the drivers use.
The most efficient route is being calculated, in this way the drivers can follow the dynamic route instead of the previous static route.

Figure 3 & 4: Dynamic rout planning



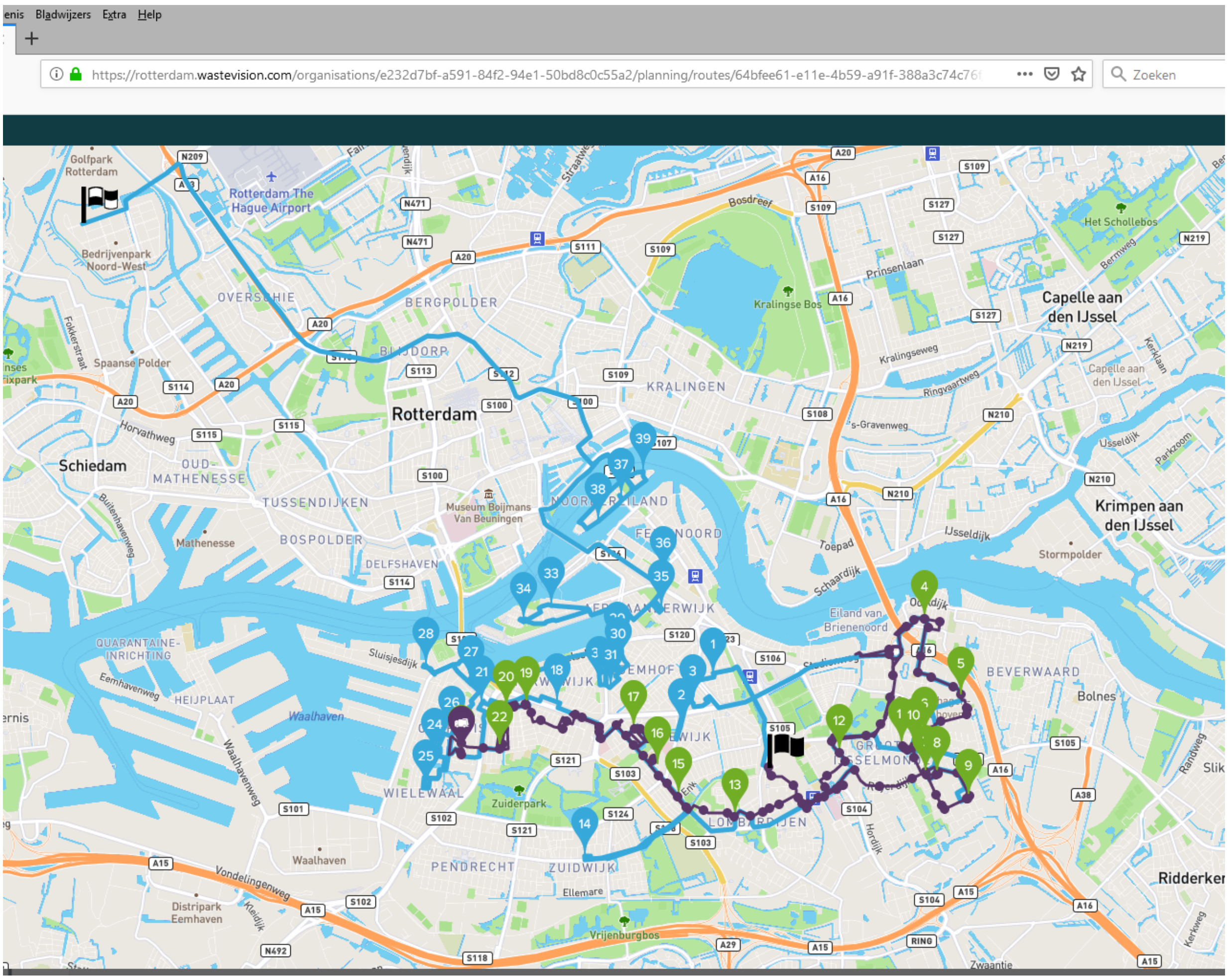
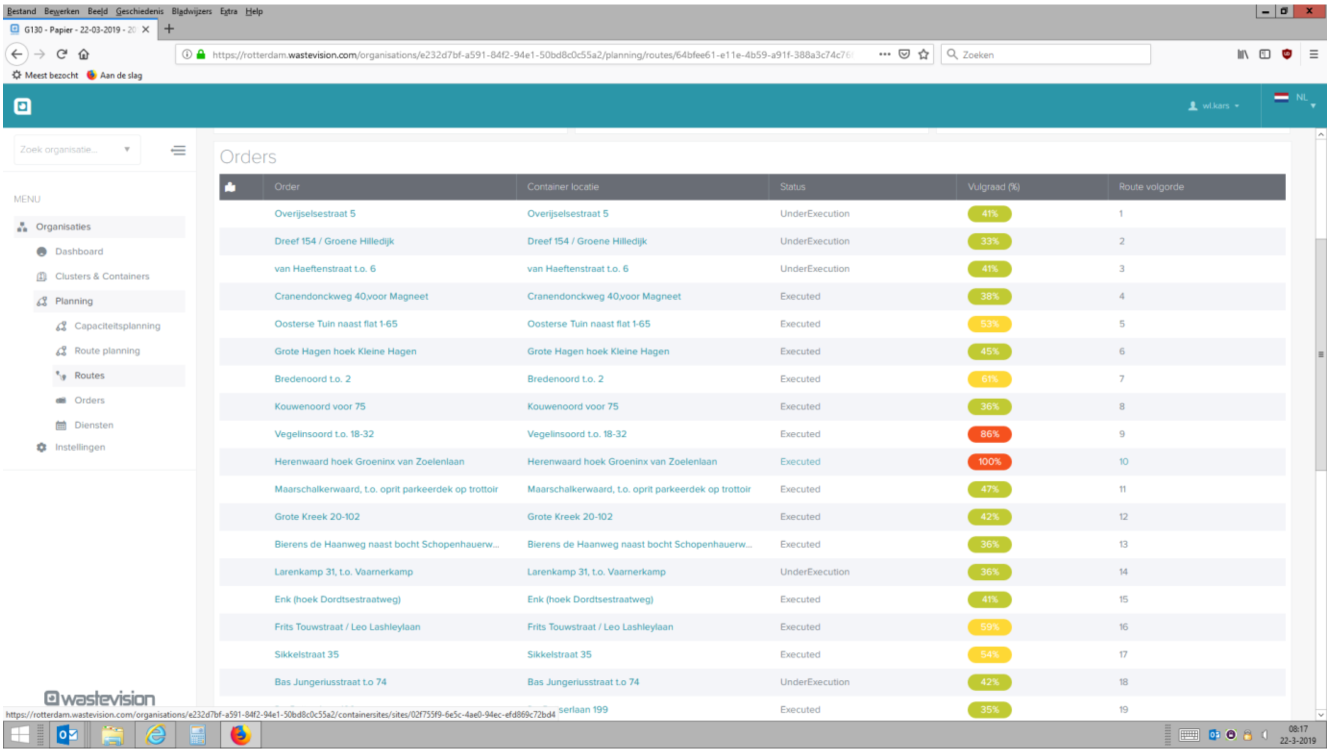


Figure 5: Filling capacity



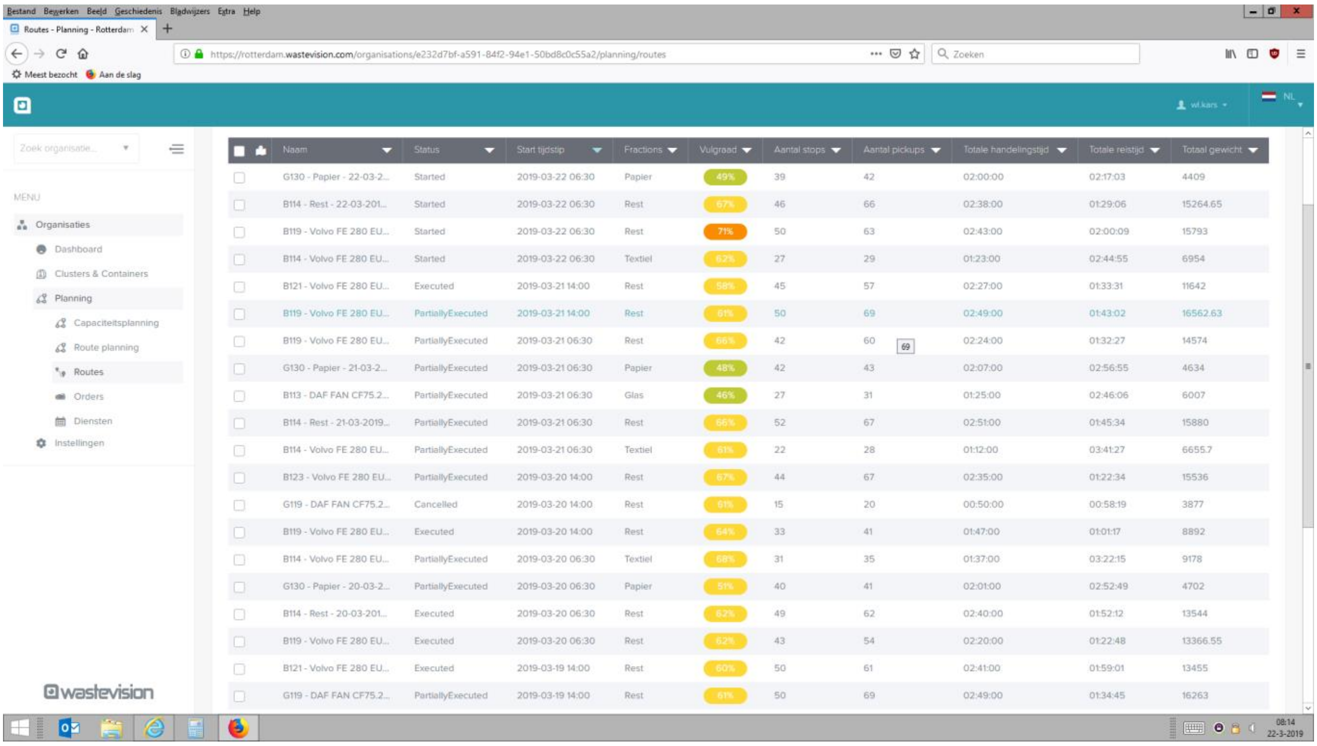


Figure 6: Filling of one container throughout the week, before and after the dynamic route was in place.

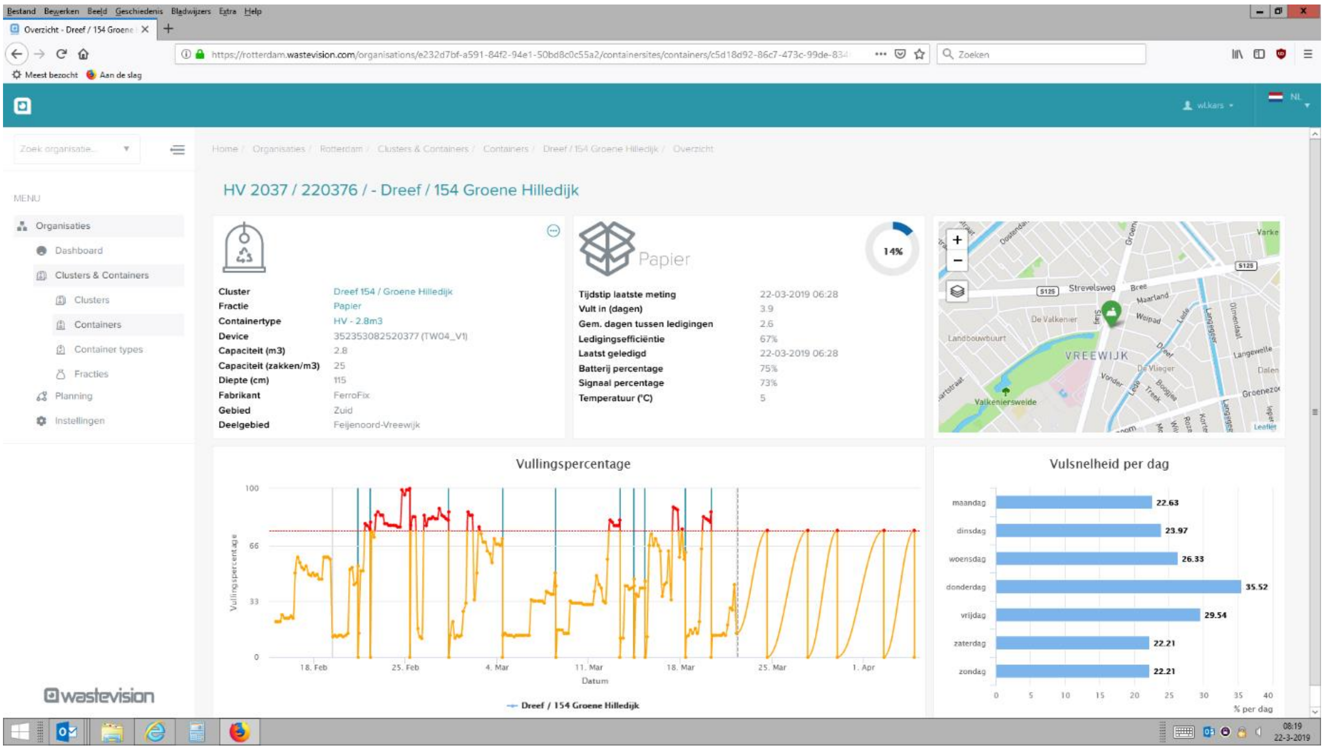


Table 2-1: Upscaling schedule for placing sensors in all waste containers in the whole of Rotterdam

Area	sub municipality	Neighbourhood	Residual waste	Date
Zuid	Charlois	Carnisse	146	20-3-2019
Zuid	Charlois	Tarwewijk	147	20-3-2019
Noord	Hill/Schiebroek	Schiebroek	126	20-3-2019
Noord	Prins Alexander	Ommoord	34	20-3-2019
Zuid	Feijenoord	Afrikaanderwijk	97	27-3-2019
Zuid	Feijenoord	Bloemhof	107	3-4-2019
Noord	Kralingen-Crooswijk	De Esch	29	3-4-2019
Noord	Kralingen-Crooswijk	Kralingen Oost	42	3-4-2019
Noord	Kralingen-Crooswijk	Kralingen West	216	3-4-2019
Noord	Kralingen-Crooswijk	Kralingse bos	2	3-4-2019
Noord	Kralingen-Crooswijk	Struisenburg	35	3-4-2019
Noord	Prins Alexander	s Gravenland	18	3-4-2019
Zuid	Feijenoord	Feijenoord	75	10-4-2019
Zuid	Feijenoord	Kop van zuid	6	10-4-2019
Zuid	Feijenoord	Kop van Zuid - entrepot	46	10-4-2019
Zuid	Feijenoord	Noordereiland	39	10-4-2019
Zuid	Feijenoord	Hillesluis	107	17-4-2019
Zuid	Feijenoord	Katendrecht	68	17-4-2019
Noord	Kralingen-Crooswijk	Nieuw Crooswijk	52	17-4-2019
Noord	Kralingen-Crooswijk	Oud Crooswijk	107	17-4-2019
Noord	Kralingen-Crooswijk	Rubroek	84	17-4-2019
Noord	Delfshaven	Bospolder	82	1-5-2019
Noord	Delfshaven	Delfshaven	65	1-5-2019
Noord	Delfshaven	Middelland	91	1-5-2019
Noord	Delfshaven	Nieuwe Westen	166	1-5-2019
Noord	Delfshaven	Schiemond	32	1-5-2019
Noord	Delfshaven	Nieuw Mathenesse	5	15-5-2019
Noord	Delfshaven	Oud Mathenesse	68	15-5-2019
Noord	Delfshaven	Schieveen	7	15-5-2019
Noord	Delfshaven	Spangen	133	15-5-2019
Noord	Delfshaven	Tussendijken	95	15-5-2019
Noord	Prins Alexander	Nesselande	112	29-5-2019
Noord	Prins Alexander	Zevenkamp	64	29-5-2019
Noord	Centrum	Cool	79	12-6-2019
Noord	Centrum	Dijkzigt	2	12-6-2019
Noord	Centrum	Nieuwe Werk	16	12-6-2019
Noord	Prins Alexander	Lage Land	86	26-6-2019
Noord	Prins Alexander	Oosterflank	101	26-6-2019
Noord	Prins Alexander	Prinsenland	36	26-6-2019
Noord	Centrum	CS Kwartier	2	10-7-2019
Noord	Centrum	Oude Westen	119	10-7-2019

Noord	Centrum	Stadsdriehoek	87	10-7-2019
Noord	Noord	Bergpolder	95	24-7-2019
Noord	Noord	Blijdorp	111	24-7-2019
Noord	Noord	Blijdorpsepolder	1	24-7-2019
Noord	Spaanse Polder	Spaanse Polder	1	24-7-2019
Noord	Noord	Oude Noorden	205	3-8-2019
Noord	Noord	Agniesebuurt	51	10-8-2019
Noord	Noord	Liskwartier	82	10-8-2019
Noord	Noord	Provenierswijk	52	10-8-2019
				*
Zuid	Charlois	Heijplaat	12	Dynamic
Zuid	Charlois	Oud Charlois	133	Dynamic
Zuid	Charlois	Pendrecht	116	Dynamic
Zuid	Charlois	Wielewaal	3	Dynamic
Zuid	Charlois	Zuiderpark	8	Dynamic
Zuid	Charlois	Zuidplein	3	Dynamic
Zuid	Charlois	Zuidwijk	141	Dynamic
Zuid	Feijenoord	Vreewijk	63	Dynamic
Noord	Hill/Schiebroek	Hillegersberg Noord	47	Dynamic
Noord	Hill/Schiebroek	Hillegersberg Zuid	98	Dynamic
Noord	Hill/Schiebroek	Molenlaankwartier	15	Dynamic
Noord	Hill/Schiebroek	Nieuw Terbregge	32	Dynamic
Zuid	IJsselmonde	Beverwaard	53	Dynamic
Zuid	IJsselmonde	Groot IJsselmonde	135	Dynamic
Zuid	IJsselmonde	Lombardijen	115	Dynamic
Zuid	IJsselmonde	Oud IJsselmonde	20	Dynamic
Noord	Overschie	Kleinpolder	69	Dynamic
Noord	Overschie	Overschie	73	Dynamic
Noord	Overschie	Zestienhoven	22	Dynamic
Zuid	Pernis	Pernis	14	Dynamic
Zuid	Hoek van Holland	HvH Dorp	42	Static
Zuid	Hoek van Holland	HvH Strand en Duin	4	Static
Zuid	Hoogvliet	Hoogvliet-Noord	33	Static
Zuid	Hoogvliet	Hoogvliet-Zuid	63	Static

*
Dynamic = Dynamic route
Static = this area is too far away for dynamic waste collection

3. Discussion and Conclusions

The results of the pilot were very positive. The main quantifiable results reported were:

- 20% reduction of mileage of waste trucks.
- Collections reduced from 5 days to 3 days per week and from 10 routes per week to 6.
- Less overflow of waste from the containers.
- A more agile organization stemming from more flexible work schedules.
- 123,500 litre / year of diesel consumption avoided and 321 ton / year of related CO2 emissions avoided.
- Other benefits, such as noise reduction (as trucks only come when needed) and odour prevention (from avoided litter).
- Regarding cost reductions, it was calculated that scaling up the technology to all underground containers in the city could potentially save the Municipality 1.37 million euro per year (25% reduction of the costs for personnel and equipment).

After the pilot, a decision to fully implement the system for all underground waste containers in Rotterdam was taken and, as a first step, in January 2017 the Municipality issued a public procurement process. The 'Best Value Procurement' method that was used for this was also innovative: it was set up in such a way that the Municipality will buy the 'service' of providing a system that leads to the cost reductions instead of the 'product' of purchasing the sensors and infrastructure). Hence, the Rotterdam waste management case can be considered a threefold innovation: technological (application of autonomous networked sensors), organizational (changing municipal waste collection routines) and business model related (implying a business model innovation towards performance- and service-based contracting).

Figure 7a-b: Driver making use of the dynamic route planning tool.

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