A smart system to improve solid waste collection and vehicle routing problem: Case of Mediouna's landfill

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Due to economic and technical considerations, landfilling is, and will possibly remain for years, the most widely used technique to dispose of solid waste in many low-income countries. However, this technique is considered a source of numerous nuisances, representing a danger to the health of the population neighbouring the landfill site. Given the importance of this step, the Moroccan government has made considerable efforts to ensure a satisfactory level of effectiveness in the various services relating to waste treatment, including the development of the National Household and Solid Waste Program (NHSWP).
The objectives of this program, developed in 2007, include the closure and rehabilitation of all existing uncontrolled landfills by 2020.
Certainly, this rehabilitation process will contribute to the reduction of pollution flows. However, in order to maximize the gain and profits behind this operation, some technological support is also recommended.
The purpose of this paper is to establish an intelligent waste management system that will cover the optimization of collection and transport phases, combined a smart bin system equipped with sensors that identifies fullness of bin, and a vehicle routing system using the ruin and recreate (R&R) metaheuristic method which is available through an open-source software package, Open Door Logistic Studio.

Introduction

Several technological and numerical innovations have been developed allowing the optimization of sorting, collection, transport or even the treatment of waste.
In the same perspectives, some companies supply customized smart bins equipped with sensors to detect the filling level, data can even be communicated to other tools and supervisions platforms, and they can also be equipped with anti-theft or compression systems to holdup more waste. Certainly, all the real-time data provided by these intelligent systems through sensors is extremely important but in order to improve their efficiency, this must be combined with platforms allowing the notification of stakeholders in case of bins filling, or even propose the optimal route to be followed whether for waste collection or transport to the treatment centres.
We present in this paper an architecture that focuses on two features. The first is to keep track of the amount of waste and the filling of the bins. The second step is to schedule and route waste collection vehicles based on the data provided by waste bins. The garbage cans' design detects the amount of filling and only sends out those that have reached the predetermined level of fullness. Routing protocol ensures an optimized solution for waste collection from filled waste cans in high-density areas, minimizing the length of the route.
The combination of these improvements will lead to an increase in waste collection efficiency as well as a reduction in the carbon footprint.

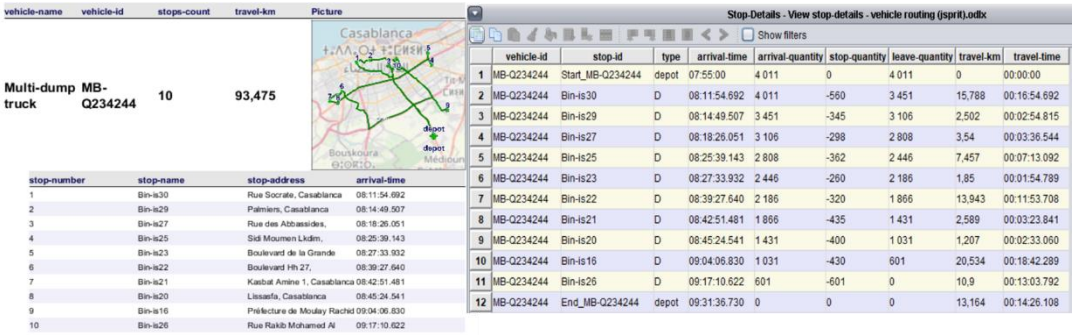
Methodology

We initially studied the various components of a waste management system in Morocco including the operations executed during the entire life cycle of a waste and determining the percentage of impact of each part in order to better define our field of study and determine the axes to be optimized.
Concluding that the collection and transport steps have a growing impact as the transportation of waste consumes energy, produces air emissions which degrades public health and generates financial costs through congestion, damages and accidents.
Appropriate waste transportation is an essential part of a successful waste management strategy. Poor organization can lead to increase operating costs, which typically constitutes 70 to 85 % of all Solid Waste Management costs (Singh, 2011).
The purpose of our strategy is to reduce these impacts, we created a design for a smart garbage can, then describe the hardware components utilized and how they are connected. Following that, the software is discussed and shown using a flowchart. The system's basic functionality is depicted in Figure 1, the prototype developed collects data from the sensors every 30min and passes it to the cloud for storage.

Figure 1: The system's basic operations

At the end of the day and since the collection process is performed in high-density neighborhoods on a daily basis (365 days/year) in the evening (around 9 p.m.), the Open Door Logistic (ODL) tool will be launched to generate tours in real-time instances, powered by data from an open-source algorithm called Jsprit and OpenStreetMap, the open-source software package provides a number of tools that aid in the depiction of tours, including cartography, report generating, road publishing, numerous visuals, and many others features (Lamrani, 2018).
And to maintain compatibility with other apps, ODL Studio uses files in Excel format, it allows also to modify the parameters and constraints of the model. In our case, two datasets were used: Bins DataSet (Bins Ids, types, locations with latitude and longitude values, quantities generated by sensors), Trucks DataSet (its parameters including truck capacities, number of stops, time windows, start and end locations (Mediouna's lundfill), working times, costs involved).
The script used by ODL puts all these characteristics together along with a large neighbourhood search algorithm to solve the route problems.

Results and Perspectives
ODL was able to use the resources in an efficient way, as shown in Figure 2, for exemple the distance covered by a 6-ton capacity truck was optimized in 1.5 hours while collecting waste from 10 garbage cans that should be taken in priority due to their filling level and the routing optimization in ODL Studio ranged between 15 and 45 seconds for the two input datasets, i.e. 12 trucks of different capacities, and about 30 garbage cans of various parameters and locations.



vehicle-name	vehicle-id	stops-count	travel-km	Picture
Multi-dump truck	MB-Q234244	10	93,475	

stop-number	stop-name	stop-address	arrival-time
1	Bin-is30	Rue Socrate, Casablanca	08:11:54.692
2	Bin-is29	Palmiers, Casablanca	08:14:49.507
3	Bin-is27	Rue des Abbassides,	08:18:26.051
4	Bin-is25	Sidi Moumen Lkdim,	08:25:39.143
5	Bin-is23	Boulevard de la Grande	08:27:33.932
6	Bin-is22	Boulevard Hh 27,	08:39:27.640
7	Bin-is21	Kasbat Amine 1, Casablanca	08:42:51.481
8	Bin-is20	Lissasfa, Casablanca	08:45:24.541
9	Bin-is16	Préfecture de Moulay Rachid	09:04:06.830
10	Bin-is26	Rue Rakib Mohamed Al	09:17:10.622

Stop-Details - View stop-details - vehicle routing (jsprit).odtx

Show filters

	vehicle-id	stop-id	type	arrival-time	arrival-quantity	stop-quantity	leave-quantity	travel-km	travel-time
1	MB-Q234244	Start_MB-Q234244	depot	07:55:00	4 011	0	4 011	0	00:00:00
2	MB-Q234244	Bin-is30	D	08:11:54.692	4 011	-560	3 451	15,788	00:16:54.692
3	MB-Q234244	Bin-is29	D	08:14:49.507	3 451	-345	3 106	2,502	00:02:54.815
4	MB-Q234244	Bin-is27	D	08:18:26.051	3 106	-298	2 808	3,54	00:03:36.544
5	MB-Q234244	Bin-is25	D	08:25:39.143	2 808	-362	2 446	7,457	00:07:13.092
6	MB-Q234244	Bin-is23	D	08:27:33.932	2 446	-260	2 186	1,85	00:01:54.789
7	MB-Q234244	Bin-is22	D	08:39:27.640	2 186	-320	1 866	13,943	00:11:53.708
8	MB-Q234244	Bin-is21	D	08:42:51.481	1 866	-435	1 431	2,589	00:03:23.841
9	MB-Q234244	Bin-is20	D	08:45:24.541	1 431	-400	1 031	1,207	00:02:33.060
10	MB-Q234244	Bin-is16	D	09:04:06.830	1 031	-430	601	20,534	00:18:42.289
11	MB-Q234244	Bin-is26	D	09:17:10.622	601	-601	0	10,9	00:13:03.792
12	MB-Q234244	End_MB-Q234244	depot	09:31:36.730	0	0	0	13,164	00:14:26.108

Figure 2: Vehicle Routing and Stop Details of Multi-dump truck

Another advantage of ODL is that it provides the Gantt-based vehicle planning as well as a load-on-vehicle-over-time graph, ensuring greater visibility of collection activities and monitoring vehicles routes.
Through the numerous options available to the user, the tool has demonstrated its ability to assist decision makers in decision-making even during the execution of tours. However, because the ODL tool is primarily based on a local heuristic approach, we intend to use other approches like genetic algorithms in our future contribution to expand the possibilities of improving the ODL's results.

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References
A. Singh, A. Kumar, G. Singh, Solid waste routing by exploiting ant colony optimization, *in:Advances in Computing*, (2011) pp. 7.
S. Lamrani, J. Benhra, M. Ahlaqqach, S. Mouatassim, S. Ahmed Haroun, Optimization of Vehicle Routing for Smart City: Real Case Study in Casablanca, *Smart Application and Data Analysis for Smart Cities (SADASC'18)*, (2018).