EXTENDED ABSTRACT

Waste Collection Based on Real-Time Information

The case of ERSUC

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Abstract

The constant increase of competitive environment throughout the years has led companies to require improvements on its processes´ efficiencies, in order to maintain their position in the market. In waste management companies, the waste collection process is one of the core operations and contains a substantial weight on the overall costs.

In this case, ERSUC, a waste management company responsible for collecting nearly 300 000 tons of solid waste in the Portuguese districts of Aveiro and Coimbra, intends to improve its operations regarding the selective collection, while reducing the associated costs.

Therefore, two scenarios will be proposed in order to mitigate the limitations of the company´s waste collection operations. Two scenarios will be proposed. The first will attempt to optimize the route frequency of the current operation of the company, while the second will attempt to optimize the route sequence by developing dynamic routes that maximize the quantity collected while minimizing the distance travelled.

These scenarios will be tested, and their outcomes will be compared with the current waste collection operation.

Keywords: vehicle routes, waste collection systems, real-time information, information and communication systems.

1. Introduction

The overall objective of this dissertation is to improve the waste collection operation of ERSUC through route optimization and to assess the benefits of having access to real-time information provided by ICTs (Information and communication technologies) in the collection operation.

ERSUC – *Resíduos Sólidos do Centro, S.A.*, is a multi-municipal company responsible for 36 districts that cover all the area of Coimbra and Aveiro, in Portugal. Regarding its operations, it is only responsible to collect waste that was previously separated by the citizens before its disposal, named selective waste. This waste is disposed in ecopoints, which a set of three bins, differentiated by a specific color.

To collect the waste, ERSUC has 262 pre-defined routes for selective collection that are delimitated by districts, 108 routes to collect glass and 77 to collect paper and plastic respectively. These routes nowadays suffer some limitations that prevent them from achieving maximum efficiency. Upon analysis, from all the limitations identified, the sequence of the bins visited in the routes, the frequency of the routes (or time interval) and the amount of waste collected per route were identified as the ones with higher impact.

To mitigate these limitations, two alternative scenarios were proposed. The first scenario proposed is the frequency optimization scenario and proposes new route´s frequencies with the historical data presented by the company. The second scenario is the SWCRP scenario, and attempts to optimize collection routes through real-time information regarding container´s fill-levels. Both scenarios contain models to achieve the objectives mentioned previously.

2. Models of the Scenarios

The first approach that will be presented below is the Frequency Optimization approach. ERSUC defines the route´s time interval using outdated data that does not contemplate the consumer pattern changes that occurred throughout the years (Tencati et al, 2016). Thus, this approach attempts to eliminate one of the limitations of the operation – the route frequency – through the use of a heuristic. The heuristic then calculates the optimum frequency for each route iterations, while assuring that the quantity collected never surpasses the vehicle´s capacity limit. Such iterations permit finding an overall frequency, for each route, that reduces the total distance travelled in a year. It is illustrated in figure 1.

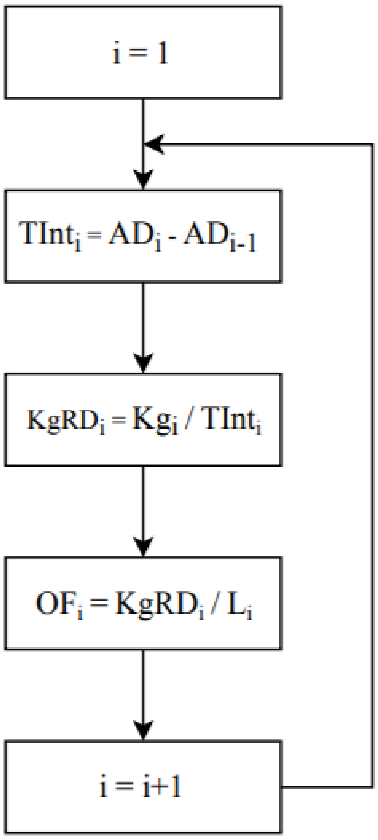

Figure 1: Heuristic of the Frequency Optimization scenario

As mentioned before, this heuristic is applied for each collection route and acts on each recorded time it was performed (i). Therefore, the first step is to calculate the time interval between routes (Tinti). This time interval is calculated by subtracting the dates of route i (ADi) and the previous one (ADi-1). The next step is to compute the daily disposal rate of each route (KgRDi). According to Nuortio, (2006), the daily waste disposal is considered stochastic, thus, this value variates between each route. The KgRDi is calculated dividing the waste collected by the time interval, for each route. The last step of the heuristic is to calculate the route´s optimum frequency (OFi), given the vehicle´s maximum weight capacity (Q). To compute the OFi, Q is divided by the daily disposal rate for each route (KgRDi).

The second approach that will be applied is the one developed by Ramos et al (2018), the Smart Waste Collection Routing Problem (SWCRP), that considers the real-time information about the bins´ fill-level to determine the number of bins to visit (if any) and the best visiting sequence. In an ideal setting, the real-time information regarding the fill-level is given by volumetric sensors placed inside the bins. However, such setting is not possible in this case study since no sensors are installed at ERSUC. Thus, in this case, the information registered by the drivers will be used as the "sensors readings", to simulate a scenario where that information is known a priori, i.e., before a route is performed. The model of the SWCRP scenario is a VRPP (Vehicle Routing

Problem with Profit) conjugated with a heuristic for optimization. Figure 2 displays the flow of the model.

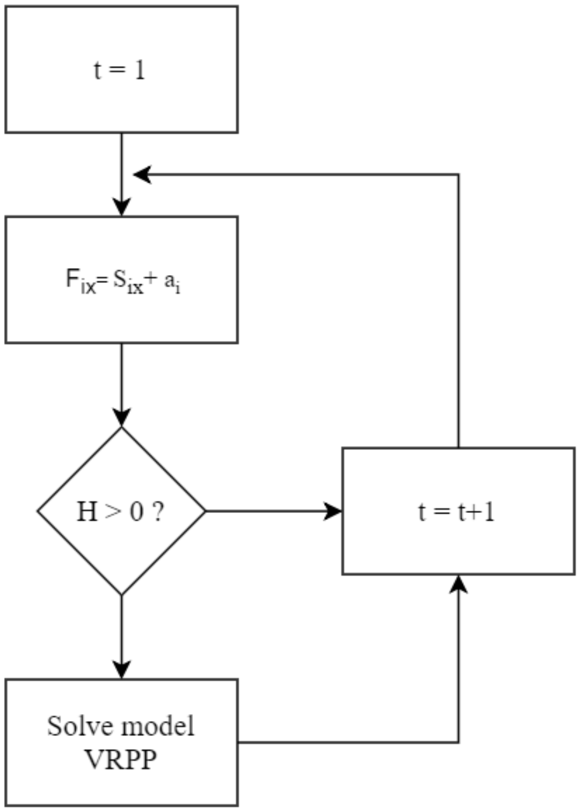

Figure 2: Flowchart of the SWCRP scenario

The first step of the process is the heuristic. For each day t and each bin *i*, the heuristics analyses its amount of waste (S_{ix}) provided by the optical measures of the drivers, and its expected accumulation rate during the day (a_i), calculated previously. If it surpasses the maximum capacity of the bin (E_i), then the number of bins overflowing (*H*) is bigger than 0, and the VRPP model runs. The VRPP model is mathematical algorithm that creates waste collection routes with the objective function of maximizing the profit, as a result of subtracting the value gained by selling the recyclable waste, by the transportation cost of collecting it. It is based on the Two Commodity Flow Formulation (Baldacci et al, 2004), a formulation that consists on adding a copy of the depot to the initial set, and where two paths are created one where the vehicle starts at the real depot and ends in the copy depot, and another where the vehicle starts in copy depot and ends on the real depot.

To feed the models presented, data was given by ERSUC. However, in order to serve as a legitimate input, it needed to be treated. More specifically, since information given by sensors was not a possible scenario, the bin´s initial amount of waste (S_i) and daily accumulation rate (a_i)

was information that was rather given by the drivers measures. Moreover, this information was not enough, thus, some assumptions were considered and will be explained.

Regarding the initial amount of waste, or Si, which is the amount of waste each bin contains at the beginning of each day. This value is given by the driver´s measures when visiting the bins for its collection. However, this information is not given every day, and since the model runs daily, the bin´s daily fill-level needed to be calculated. Therefore, it was assumed that the bin´s fill-level on the remaining days is calculated through a linear waste variation occurred between two measures.

Regarding the expected daily accumulation rate (ai), this is needed to forecast the amount of waste that will be generetad during the day, since the sensors readings (in this case, the driver´s measures) are assumed to be transmitted in the morning. This value is computed based on data regarding the amount of waste variations inside each bin during a specific time horizon. In other words, it is the average daily Si increment for each bin.

3. Results of the Scenarios

To test the models, it was agreed to narrow the municipality range of ERSUC in order to be able to have a comparison between all the outcomes of the different models. Thus, from the 36 districts, a sample of 2 – Soure and Condeixa - were chosen based on its data reliability. Additionally, the time horizon was also narrowed to one month, November, so that the total number of model iterations decreased. Each scenario contained a route to collect a type of bin in each district. Therefore, the scenarios were evaluated according to the information displayed in table 1.

Table 1: Types of bins for Soure and Condeixa

District	Waste collected
Soure	Paper/Cardboard
	Plastic
	Glass
Condeixa	Paper/Cardboard
	Plastic
	Glass

Through the data given by the company, a number of Key Performance Indicators (KPIs) could be calculated, that will help to evaluate and identify the efficiency of the routes. Among all, the more relevant KPIs are the distance travelled, the Kg/Km ratio and the vehicle occupation rate.

Table 2 displays percentage variations of the two proposed scenarios when compared with the current situation of the 3 more relevant KPIs, in order to help determining in which KPIs one scenario outstands the others.

Table 2: Percentage variations of the KPIs between scenarios

			KPIs		
Scenario	**District**	**Type of waste**	**Distance travelled (km)**	**Kg/Km**	**Vehicle Occupation**
Frequency Optimization	**Soure**	**Paper**	39%	24%	22%
		Plastic	23%	17%	15%
		Glass	31%	0%	4%
	Condeixa	**Paper**	-40%	-50%	-44%
		Plastic	-20%	-20%	-20%
		Glass	0%	-25%	-25%
SWCRP	**Soure**	**Paper**	64%	72%	61%
		Plastic	58%	67%	56%
		Glass	35%	48%	47%
	Condeixa	**Paper**	26%	23%	0%
		Plastic	58%	54%	13%
		Glass	36%	51%	24%

Upon analyzing Table 1, the frequency optimization scenario contains some negative values when compared to the current. This negative impact occurs specially on Condeixa, where all the KPIs are worst than the current scenario with exception to the distance travelled in Condeixa glass, where there is no variation. Nevertheless, in the Soure district the frequency optimization scenario is a better approach than the current scenario for all the routes.

Regarding the SWCRP, there is no doubt that it is the best scenario of three, since every KPI is superior when compared to the other two scenarios except one where there is no variation. The biggest improvement occurs in Soure paper and Soure plastic, where every KPI is above the 50%, and the least improved is Condeixa paper, where the vehicle occupation suffers no improvement improvement on the vehicle occupation, maintaining its value on 94%.

4. Conclusions and Future Work

Nowadays, companies face an extreme competitive environment that requires constant improvements in order to maintain their position in the market. For ERSUC, a waste management company responsible ERSUC is responsible for the waste management operations of 36 districts along Aveiro and Coimbra, the waste collection operation constraints were a major limitation. Upon a more extensive analysis of the routes, its constraints were identified. Among all, the sequence of bins visited in a route and its frequency are considered the ones with higher impact. To mitigate these limitations, two alternative scenarios for the waste collection operation are proposed. The first scenario attempts to optimize the overall frequency of the routes without ever surpassing route´s restrictions. The second optimizes the route sequence, in order to maximize the profit. Once the models ran, the outcomes could be analyzed and compared. A set of KPIs, such as the total quantity collected, distance travelled, Kg/Km ratio and vehicle occupation were considered for a better comparison of the scenarios and the current waste collection operation. This way, the SWCRP scenario was identified as the better approach, since its KPIs were considerable better than the two other scenarios.

As future remarks some suggestions can be presented. The first is the use of sensors sensors placed inside the waste bins to indicate its fill-level. The second suggestion is to study the scenarios for all the districts, instead of only two. Each district variates in terms of number of bins, overall travel distance and waste disposal rate The third suggestion is to increment the time horizon. Different seasons contain different values on the disposal rate.

References

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