Summary

The Urban Co-Creation Data Lab (UCD Lab) project aimed to support decision-making at the municipality level to provide citizens with high quality services in the areas of micromobility, waste management, parking, pollution, and emergency. The project aimed developing a new generation of public services in the context of smart cities exploiting supercomputing facilities and public and private data to analyse complex combinations of large datasets in areas of public interest. The analytical model and service presented in this document was developed for the city of Lisbon regarding waste management and was made publicly available to any interested person or institution. The UCD Lab was co-financed by CEF Telecom, the EU instrument to facilitate cross-border interaction between public administrations, businesses and citizens, and the project beneficiaries were: Universidade Nova de Lisboa, Município de Lisboa, Agência para a Modernização Administrativa, I.P., NEC Portugal - Telecomunicações e Sistemas, S.A, and Barcelona Supercomputing Center - Centro Nacional de Supercomputación.

Service description

This service allows to predict mixed waste production for 95 waste collection circuits for every week of the following month.

Analytical model

Input data and variables

In Table 1 are presented the datasets necessary to develop the analytical model for #2 Waste management use case.

Table 1. Datasets necessary for the development of the analytical model for #2 Waste management use case.

Dataset	Source	Open data
Undifferentiated waste collection loads	Urban Hygiene and Solid Residuals Department – Lisbon City Council	No
Holidays	NOVA Cidade – Urban Analytics Lab	Yes

The description of the input data necessary to run the analytical model that serve as the basis of the service is presented in Table 2.

Table 2. Input data description of the waste management model necessary to run the service.

Variable	Description	Type
Id_circuit	Unique id of the mixed waste collection circuit	INTEGER
Week_date	First day of the week (Monday)	DATE (yyyy-mm-dd HH:mm:ss)
waste_t	Quantity of mixed waste (t) collected in a specific week	FLOAT
holiday	Flag identifying holidays	INTEGER

Model

The analytical model that supports the service is a Seasonal Auto-regressive Integrated Moving Average (SARIMAX) model (Box et al., 2008). For each mixed waste circuit, a SARIMAX model was trained with data from 01/04/2017 to 31/10/2019 and tested with data from 01/11/2019 to 31/10/2020, using the optimized parameters at waste collection circuit level.

Output data

In Table 3 is presented the description of the output data provided by the analytical model.

Table 3. Output data description of the waste management model.

Column	Description	Type
Id_circuit	Unique id of the mixed waste collection circuit	INTEGER
Week_date	First day of the week (Monday) of the following month	DATE (yyyy-mm-dd HH:mm:ss)
predicted_waste_t	Quantity of predicted mixed waste (t) produced in a specific week	FLOAT

Evaluation

The model's quality for each circuit was assessed through the computation of the root mean square error (RMSE), mean absolute error (MAE) and mean absolute percentage error (MAPE) (de Myttenaere et al., 2016). In Figure 1 is presented the percentage of circuits belonging to each forecast quality category derived from Lewis (1982), based on MAPE values. In Table 4 are presented the quality measures computed for each circuit.

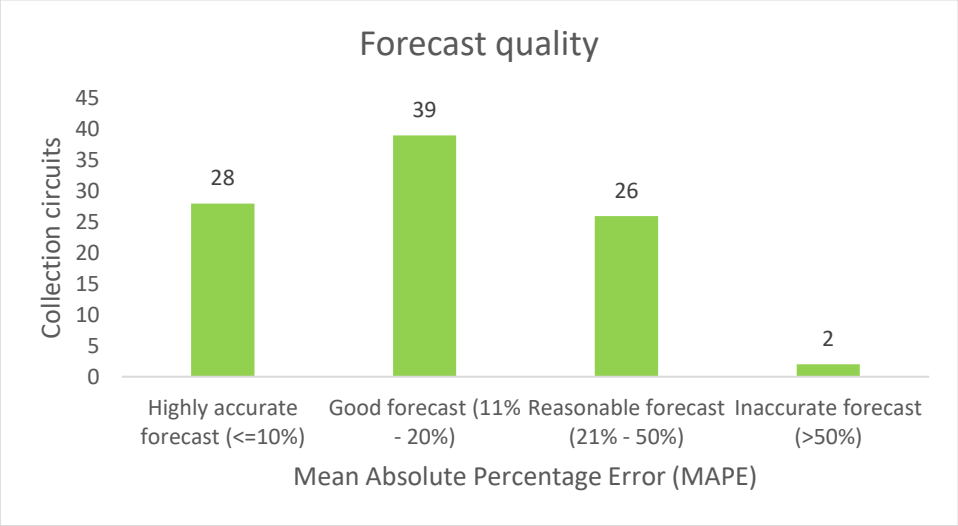

Figure 1. Number of circuits in each class regarding forecast quality based on the scale developed by Lewis (1982).

Table 4. Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) obtained for each mixed waste collection circuit in the testing sample of the SARIMAX model.

Circuit ID	Circuit	order	seasonal order	RMSE (tons)	MAE (tons)	MAPE (%)
7749	I0208MK	(1, 1, 1)	(0, 0, 0, 52)	5,56	5,09	18
7750	I0502MFL	(0, 1, 1)	(0, 0, 0, 52)	3,55	2,35	12
7751	I0503	(2, 0, 0)	(0, 0, 0, 52)	11,65	11,25	41
7752	I0515MK	(0, 1, 1)	(0, 0, 0, 52)	1,87	1,36	6
7753	I0508MK	(0, 1, 1)	(1, 0, 0, 52)	5,40	5,04	31
7754	I0414MF	(1, 1, 1)	(1, 0, 0, 52)	5,83	5,24	9
7755	I0801	(1, 0, 1)	(0, 0, 0, 52)	5,44	4,47	15
7757	I0204A	(2, 1, 2)	(1, 0, 1, 52)	2,25	1,94	6
7764	I0501	(0, 1, 1)	(1, 0, 0, 52)	2,63	2,04	9
7765	I0810	(2, 0, 0)	(0, 0, 1, 52)	5,29	4,33	13
7768	I0804	(0, 0, 3)	(0, 0, 0, 52)	5,18	4,38	13
7769	I0812	(1, 1, 1)	(0, 0, 0, 52)	6,48	5,15	9
7770	I0806	(1, 0, 0)	(0, 0, 1, 52)	7,39	6,39	16
7772	I0402	(2, 1, 1)	(0, 0, 0, 52)	3,28	2,44	6
7773	I0207	(0, 1, 1)	(0, 0, 0, 52)	8,22	7,79	27
7778	I0709	(0, 1, 1)	(1, 0, 0, 52)	6,43	5,67	23
7780	I0809	(0, 0, 0)	(0, 0, 0, 52)	4,00	3,11	11
7781	I0509MK	(2, 0, 0)	(1, 0, 0, 52)	2,41	2,02	11
7782	I0611	(0, 1, 1)	(0, 0, 0, 52)	2,14	1,80	9
7787	I0206MK	(0, 1, 1)	(0, 0, 1, 52)	1,74	1,49	25
7788	I0711	(0, 1, 1)	(0, 0, 0, 52)	8,58	7,87	15
7795	I0803	(1, 0, 0)	(0, 0, 1, 52)	5,60	4,64	15
7796	I0412	(1, 1, 1)	(1, 0, 0, 52)	9,18	5,51	37
7798	I0817MF	(1, 0, 0)	(1, 0, 0, 52)	4,93	4,39	13
7799	I0816	(2, 0, 0)	(0, 0, 0, 52)	7,80	7,33	16
7801	I0802MF	(0, 1, 1)	(0, 0, 1, 52)	5,03	4,02	19
7802	I0807MK	(2, 0, 0)	(0, 0, 0, 52)	2,71	2,44	13
7803	I0808	(0, 0, 0)	(0, 0, 0, 52)	5,21	4,45	16
7804	I0805	(1, 0, 0)	(1, 0, 0, 52)	3,09	2,47	7
7805	I0608MK	(2, 1, 1)	(1, 0, 0, 52)	1,59	1,28	4
7806	I0401	(1, 0, 0)	(0, 0, 1, 52)	3,04	2,34	10
7809	I0306	(1, 0, 1)	(0, 0, 0, 52)	8,22	7,46	23
7810	I0210MK	(0, 0, 0)	(2, 0, 0, 52)	1,87	1,28	17
7811	I0211	(1, 1, 0)	(0, 0, 0, 52)	14,61	13,68	47
7812	I0215MK	(0, 1, 1)	(0, 0, 0, 52)	1,15	1,01	35
7814	I0604	(2, 1, 2)	(2, 0, 0, 52)	3,72	3,18	8
7821	I0212	(0, 1, 1)	(0, 0, 0, 52)	11,68	10,17	27
7822	I0403	(2, 0, 0)	(0, 0, 0, 52)	2,98	2,52	10
7823	I0404	(0, 1, 1)	(0, 0, 0, 52)	3,18	2,47	8
7824	I0307	(0, 1, 1)	(0, 0, 1, 52)	6,99	6,19	18
7825	I0406 INT	(1, 0, 1)	(0, 0, 0, 52)	3,90	3,11	12
7826	I0407MF	(1, 0, 1)	(0, 0, 1, 52)	20,15	19,57	79
7827	I0612	(2, 0, 0)	(0, 0, 1, 52)	2,90	2,38	11
7828	I0302MK	(1, 1, 1)	(1, 0, 0, 52)	1,29	1,07	5
7829	I0610INT	(0, 1, 1)	(0, 0, 0, 52)	2,74	2,15	6

7830	I0411MF	(1, 0, 0)	(0, 0, 0, 52)	5,71	5,02	12
7831	I0811MF	(1, 0, 1)	(0, 0, 0, 52)	14,52	13,45	23
7832	I0304MK	(0, 1, 1)	(0, 0, 0, 52)	6,36	5,62	23
7836	I0301MK	(0, 1, 1)	(1, 0, 0, 52)	1,67	1,39	5
7837	I0601	(2, 1, 1)	(0, 0, 0, 52)	3,74	3,17	8
7838	I0303	(1, 1, 2)	(2, 0, 0, 52)	2,03	1,46	5
7839	I0511MK	(0, 1, 1)	(0, 0, 0, 52)	2,58	2,12	14
7840	I0703	(1, 1, 1)	(0, 0, 0, 52)	7,65	7,03	23
7845	I0510	(1, 0, 0)	(1, 0, 0, 52)	6,93	6,38	22
7847	I0603	(0, 1, 1)	(0, 0, 0, 52)	5,99	5,41	19
7849	I0605	(1, 1, 1)	(2, 0, 0, 52)	4,34	4,15	16
7850	I0606MF	(0, 1, 1)	(0, 0, 0, 52)	3,06	2,63	12
7851	I0413	(2, 0, 0)	(0, 0, 0, 52)	2,72	2,23	5
7853	I0712	(1, 0, 1)	(0, 0, 0, 52)	4,33	3,62	10
7855	I0602	(1, 1, 2)	(1, 0, 0, 52)	4,16	3,80	14
7865	I0704	(0, 1, 1)	(0, 0, 0, 52)	7,27	6,69	23
7874	I0702	(0, 0, 0)	(1, 0, 0, 52)	6,04	5,01	13
7875	I0513	(0, 1, 1)	(2, 0, 0, 52)	7,87	7,21	24
7877	I0710	(3, 0, 1)	(0, 0, 0, 52)	5,06	3,49	7
7880	I0512MFL	(1, 0, 0)	(0, 0, 0, 52)	6,54	5,97	19
7882	I0713INT	(1, 0, 2)	(0, 0, 0, 52)	2,59	2,25	12
7885	H0801	(1, 0, 0)	(1, 0, 0, 52)	4,90	4,19	10
7887	I0708	(0, 1, 2)	(0, 0, 2, 52)	4,60	3,50	9
7891	I0705	(0, 0, 0)	(0, 0, 0, 52)	6,87	6,53	21
7892	I0813	(1, 0, 0)	(1, 0, 0, 52)	6,73	5,84	20
7893	I0716	(0, 0, 0)	(2, 0, 0, 52)	6,34	5,96	21
7894	I0607	(1, 0, 0)	(1, 0, 0, 52)	7,72	7,35	28
7895	I0505	(3, 1, 1)	(0, 0, 1, 52)	6,35	5,75	29
7897	I0609MFL	(0, 1, 2)	(1, 0, 0, 52)	2,50	2,10	9
7901	I0707	(0, 0, 4)	(0, 0, 0, 52)	3,76	3,10	11
7902	I0714	(1, 0, 1)	(0, 0, 0, 52)	5,18	4,13	14
7904	I0504MF	(2, 0, 0)	(0, 0, 0, 52)	8,31	7,72	36
7906	I0613	(1, 0, 0)	(1, 0, 0, 52)	3,05	2,28	4
7963	M9901	(0, 1, 1)	(1, 0, 0, 52)	5,66	5,19	16
8112	I0105	(0, 1, 1)	(0, 0, 0, 52)	5,54	4,78	13
8114	I0202MK	(0, 1, 1)	(0, 0, 1, 52)	1,88	1,20	32
8115	I0201MK	(0, 0, 0)	(0, 0, 1, 52)	3,49	3,01	52
8116	I0214MK	(1, 0, 0)	(0, 0, 0, 52)	2,68	2,00	34
8117	I0209	(0, 1, 1)	(0, 0, 0, 52)	5,95	5,29	15
8118	I0107MK	(2, 1, 1)	(0, 0, 0, 52)	1,73	1,41	6
8120	I0106	(0, 1, 1)	(0, 0, 0, 52)	6,58	5,92	16
8122	I0104	(0, 1, 1)	(0, 0, 2, 52)	2,46	2,18	10
8123	I0103	(3, 0, 1)	(0, 0, 0, 52)	4,71	4,13	16
8124	I0102	(0, 0, 0)	(0, 0, 0, 52)	8,17	7,02	28
8128	I0205	(2, 1, 1)	(0, 0, 0, 52)	4,35	3,95	15
8136	I0203MK	(0, 1, 1)	(0, 0, 1, 52)	8,02	7,02	29
8336	I0701	(0, 1, 1)	(0, 0, 2, 52)	4,95	4,65	16
16369	I0715	(4, 0, 1)	(0, 0, 0, 52)	2,13	1,53	4
16372	I0108MFL	(1, 1, 2)	(0, 0, 2, 52)	6,17	5,75	29
16520	IESA01MF	(1, 1, 1)	(0, 0, 0, 52)	10,85	8,68	15

Service

A report with predictive capabilities was developed in a dashboard with the information about the weekly prediction of mixed waste (Figure 2). The report contains visuals that allow to compare the observed and predicted mixed waste produced, for the studied period, for specific cultural/sports events and holidays. The waste production prediction can be also assessed by parish or for a specific or all mixed waste collection circuits.

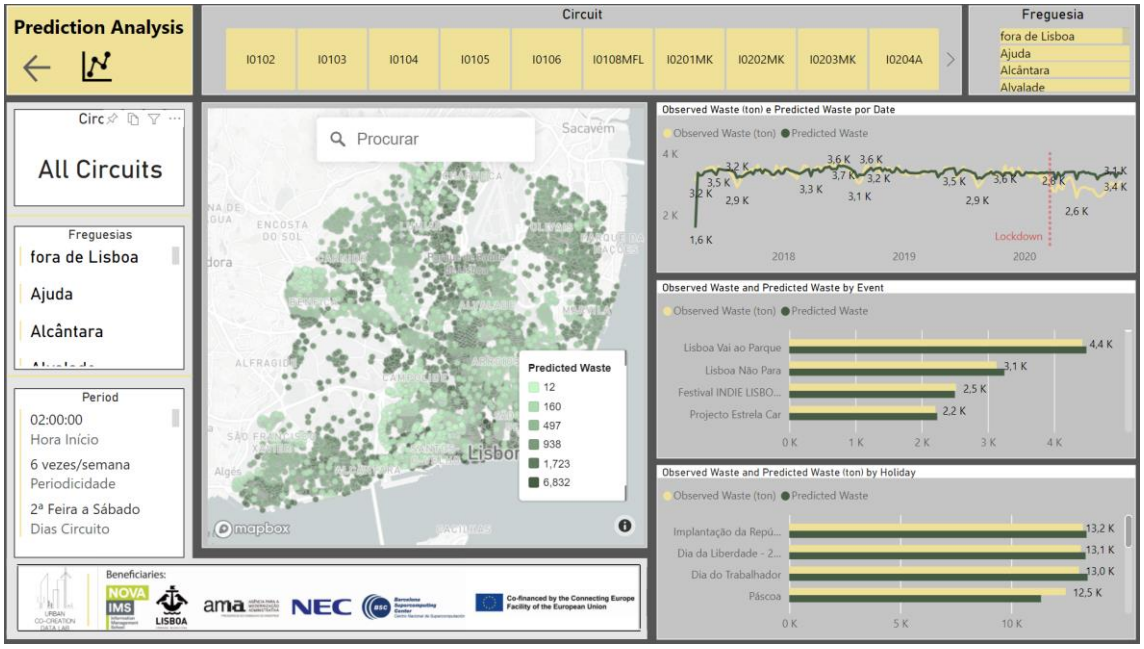

Figure 2. Report on the prediction of mixed waste by waste collection circuit.

References

Box, G., Jenkins, G., & Reinsel, G. (2008). *Time Series Analysis* (4th Editio). Hoboken.

de Myttenaere, A., Golden, B., Le Grand, B., & Rossi, F. (2016). Mean Absolute Percentage Error for regression models. *Neurocomputing*, *192*, 38–48. https://doi.org/10.1016/j.neucom.2015.12.114

Lewis, C. D. (1982). *Industrial and business forecasting methods*. Butterworths.