How AI beats spreadsheets in modeling future volumes for city waste management

March 29 2021

Growing cities tend to run out of land for waste management and new landfill sites. Machine learning can help city managers create more powerful long-term forecasts of solid waste volumes and landfill requirements, even with missing or inaccurate data, researchers from the University of Johannesburg have shown. Credit: Therese van Wyk, University of Johannesburg

All over the world, large cities are running out of space for municipal solid waste. Existing landfill sites are rapidly filling up and no one wants

a new site anywhere near their homes or businesses. Meanwhile, taxpayers aren't interested in higher costs for quality waste management.

One way of significantly extending the working life of existing waste management sites is recycling. Recycling can also provide employment, help to establish a circular economy or move toward zero waste. But often, households are highly resistant to recycling.

A recent study reports a powerful artificial intelligence (AI) technique to forecast landfill requirements for a city in the long term. The researchers used machine learning to forecast municipal solid waste in a large African city. The forecast shows how much waste there will be in 30 years if levels of recycling stay the same.

Dr. Olusola Olaitan Ayeleru and Mr Lanrewaju Ibrahim Fajimi published their research in the *Journal of Cleaner Production*. Both are at the Department of Chemical Engineering at the University of Johannesburg.

Planning for waste with spreadsheets

Predicting when a city's landfill sites will run out of space is difficult, even when accurate information is available. However, conventional statistical forecasting using a spreadsheet may be good enough to plan 30 years ahead.

At the same time, spreadsheets with lots of manually adjusted formulas and macros are hard to understand. These can also be time-consuming and difficult to maintain.

But forecasting for different recycling scenarios may not be possible on spreadsheets. Taking population growth, types of waste, weather and other datasets into account in such a forecast may not be possible, either.

In developing countries, information about the waste generated in a city is often missing or inaccurate. Here, spreadsheets are unlikely to give city managers forecasts for long-term planning.

However, machine learning models can be trained from the data that is available, and from more data added later. Also, machine learning is better suited to take advantage of multiple datasets in different formats.

A rapidly growing city

Johannesburg is the economic hub of South Africa and the biggest city in the country. It attracts people from other provinces and foreign nationals in search of jobs.

For this study, only the City of Johannesburg Metropolitan Municipality was included. This spans from Diepsloot and Midrand in the north to Ennerdale/Orange Farm in the south; Doornkop/Soweto in the west to Bruma in the east. The neighboring cities of Ekhurhuleni, Tshwane, Mogale, Merafong, Rand West, Emfuleni, Midvaal and Lesedi were excluded from the study.

Between 1996 and 2001, the City of Johannesburg population grew from 2.59 million to 3.22 million. By 2011, the city's population was 4.43 million, according to the national census data. The same year, 90% of an estimated 59 million tons of general waste produced in South Africa ended up in landfills, while 10% was recycled. Nationally, 12.9% of metropolitan households self-reported that they recycled, followed by 10.8% of households across urban areas.

For 2021, the city's population was forecasted at 5.3 million, according to its 2019/2020 Integrated Development Plan.

The city currently operates four landfill sites. In September 2020, the

COO of Pickitup, the city's waste management company, reported that four and a half years of capacity are left at these sites.

In 2018, the city started a separation-at-source recycling program. The department recycles plastic, paper, glass and cans, as well as household-generated garden waste. In February 2021, Pickitup announced a co-production program with 48 companies. The goal is to increase waste picking, street cleaning and recycling awareness and education in the city. Fifteen new Pickitup staff per ward will coordinate the program.

Data plugged into AI

Ayeleru and Fajimi used machine learning to forecast the solid municipal waste in Johannesburg in 30 year's time using a standard notebook computer with a i7 processor. The researchers used census data from 2011 indicating population, formally employed, unemployed and the number of family units. The data was supplied by the national government agency StatsSA. They combined this with data about total annual solid municipal waste at the city's four landfill sites, from 1996 to 2008. This data was supplied by the City of Johannesburg.

In this study, Fajimi used two kinds of machine learning to generate 30-year forecasts of total solid waste generated in the city. Both algorithms are known for accurate predictions and consistency.

The first type is artificial neural networks (ANNs). This type of model can learn by itself. The researchers used five-,10-, 20-, 30- and 40-neuron models to create five forecasts The researchers used MATLAB software, which has a robust ANN neural fitting toolbox.

The second type is called supported vector machines (SVMs). The researchers used linear, quadratic, cubic, one gaussian, medium gaussian and coarse gaussian methods in MATLAB software to create another six

forecasts.

The 10-neuron model produced the best ANN forecast. Among the SVM's the linear model produced the best forecast.

The AI bottom line

The 10-neuron model predicted that the population in the City of Johannesburg is likely to increase from 5.3 million in 2021 to 6.4 million in 2031; and to 8.4 million in 2050. In contrast, the model didn't forecast the same increase in municipal solid waste. Instead, it forecasted an increase in total annual waste from 1.61 million tons in 2021 to 1.72 million tons in 2031; and to 1.95 million tons in 2050.

"One may expect that waste generation ought to increase as population increases, but this is also dependent on factors like low or high purchasing power or source of income," says Ayeleru.

"When citizens lose their source of income or the purchasing power is low, the amount of waste generated would be reduced since they would be doing cooking of food at home compared to buying ready-made food at restaurant, for example."

Next steps

In follow-up research, Ayeleru and Fajimi are investigating how to use AI to forecast the waste types and how much income the city could generate from each of those. "The City of Johannesburg is currently doing much better in its waste management compared to other large cities on the continent. This AI forecast can help facilitate the city's design of future waste management infrastructure," says Ayeleru.

"In the short term, the first step the city can take is educating people, so they start recycling more. Secondly, the city may need to look beyond what they are doing at the moment to generate income from solid waste ."

More information: O.O. Ayeleru et al, Forecasting municipal solid waste quantity using artificial neural network and supported vector machine techniques: A case study of Johannesburg, South Africa, *Journal of Cleaner Production* (2020). DOI: 10.1016/j.jclepro.2020.125671

Provided by University of Johannesburg