Exposé Master Thesis

Zero Waste - Forecasting Residual Waste Production of Frankfurt City Resident

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1. Motivation

Climate change has become without a doubt one of mankind's greatest challenges. This is a problem that resulted from the emission of greenhouse gases that affect our environment. Several causes of global warming are contributing to the climate crisis and burning waste is also one of the contributors to climate change. Burning waste in plants produces greenhouse gases, and even produces additional greenhouse gases while adding carbon support to burn waste. Increasing waste production means increasing greenhouse gases is a critical issue that will significantly impact our society, environment, and economy in the coming years. We must investigate techniques to reduce waste, adapt to upcoming changes, and alleviate the harmful effects of climate change. [1]

As we continue to face the challenges of waste management, it is essential to forecast future trends in waste generation and identify potential solutions to address them. It may be possible that residents of different cities have different outcomes from the same forecast analysis. Through this thesis, this research aims to forecast the future trends in the organic waste generation of Frankfurt residents who generate a high amount of waste and analyze the potential solutions that can help reduce waste and promote sustainable living. “Current goals according to the climate change and environment department head of Frankfurt municipality Ms. Heilig are Reduction of the amount of residual waste per capital and year of Frankfurt city resident from the current (around 205kg) to 120 kilograms by 2035. Second, is, Reduction of the total quantity of municipal waste per capital and year by two percent annually.” [2]

2. Research question

For this thesis, I limit my research scope to developing time series analysis models for residual waste (which cannot be recycled or reused) by Frankfurt residents only. The following research questions can be investigated to support our zero-waste target.

1. Is it conceivable to forecast waste production among Frankfurt city residents, which is as of yet unknown, valid, explainable, and actionable?
2. Which forecasting technique performs best in the prediction of waste production?
3. Can waste generation forecasts with reasonable quality support the campaign for a waste reduction of 2% per year?

As a result of these research questions, an assumption of future waste production will be generated and the best methods for households, city areas, etc. for waste forecasting will also be identified. This allows us to take the necessary steps to achieve the goal of Zero Waste.

3. Approach

3.1 Data collection

- Time series data of waste collection is required of residents Kalbach-Riedberg, Frankfurt. Source: Frankfurter Entsorgungs und Service GmbH (FES)
- Additional data collection of each household regarding the characteristics of property and residents. Source: Deutsch Post Direkt

3.2 Data understanding

Data provided by FES from the district Kalbach-Riedberg and Nieder-Eschbach contains waste data of residual waste on a continuous time frame.

3.3 Data preparation

- Time series analysis (TSA) requires data within a specific period of time. Datasets need to be complete and not have any gaps or missing values or outliers [3]. For example: when a lorry is out of service or under maintenance (MCAR), waste bins are not provided by households (MCAR).
- Outlier detection in time series data refers to the identification of data points that deviate significantly from the expected pattern or behavior of the time series. Anomalies can be caused by various factors such as errors in data collection, equipment malfunctions, or sudden changes in the underlying process being measured. Outliers can be handled by investing in real reason [4]. In our data, when an old tenant leaves and a new tenant comes into the same house then a sudden hitch can be found (outlier) in the dataset. Other reasons are construction work or holidays or a relative's visit and so on.
- Some pre-processing is also required to ensure data is stationary. Transformation of the data is necessary if data is stationary [5]. For example, households may dispose of the same amount of residual waste every time.

4. Forecasting methods

After the completion of data preparation, we can implement the forecast model. Several different concepts, techniques, and different levels of granularity(day, week, month) can be used in time series analysis such as **Statistical Analysis** (ARIMA) [6], **Deep learning** (LSTM) [7], **Additive model** (Prophet), and **Machine learning model** (XGBoost) [7]. They differ in performance, usability, and features offered.

5. Evaluation

Our prediction models can be evaluated by comparing predicted data with upcoming data collection from FES. This helps to find the best accurate model based on residual analysis.
Evaluation can also be done based on some performance measures such as MAPE, MAE, MSE, and RMSE. The best model has lower MAPE [8].

After applying the forecasting model, the future of residual waste creation can be analyzed which can help to measure waste reduction. According to the result of waste forecasting, we will be able to modify existing planning to reduce waste generation. This led us to our goal of zero waste.

6. Literature

Zero waste refers to a variety of measures aimed at eliminating waste and challenging conventional thinking. In aiming for zero waste, waste must be viewed as a potential resource with value to be realized, rather than as a problem to be solved. [9].*"A zero-waste vision can and should be applied to most current societal challenges – be it climate, businesses, cities, our lifestyle."* – Joan Marc Simon, Executive Director at Zero Waste Europe. Zero Waste Europe organization is working actively with the European municipalities that have openly committed to the goal of continuously reducing waste generation and improving waste separate collection and hence redesigning the relationship between people and waste [10]. On the other hand, cities, companies, and other organizations want to realize zero waste goals despite continuously increasing per capita waste creation. However, the existing waste issues cannot be solved straightforwardly. Thus, the zero waste goals might not be accomplished in the intended period without comprehensive and strategic planning [11]. This drive towards reducing computational waste in deep learning literature has so far focused on reducing inference time. Numerous approaches for boosting deep learning models focus on building more effective architectures which can build forecasting models to accomplish goals.

7. References

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