Baden-Wuerttemberg Cooperative State University

Projektrealisierung

Takeawaste — A data-driven approach to reducing food waste in the foodservice industry

Team members:	Ayman Madhour, Lukas Benner, Marius Kiskemper, Marvin Vielmeyer, Oliver Wieder, Fabian Creutz
Course:	WWI-19-DSA
Professor:	Prof. Dr.-Ing. habil. Dennis Pfisterer
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Contents

List of Figures

Acronyms

ARIMA	Autoregressive integrated moving average
MAE	Mean Absolute Error
MSE	Mean Squared Error
SARIMA	Seasonal Autoregressive integrated moving average
SDG	Sustainable Development Goals
UNEP	United Nations Environment Programme

1 Introduction

> "If food waste could be represented as its own country, it would be the third largest greenhouse gas emitter, behind China and the United States." [1]

There is no denying that the world has a food waste problem. According to the United Nations Environment Programme (UNEP), 1.3 billion tonnes of food are wasted every year, which corresponds to about one third of food produced [2]. This is a problem because not only is this wasted food also a huge waste of resources, but it also takes a toll on the environment.

Food waste is a major contributor to greenhouse gas emissions. When food waste decomposes in landfills, it emits methane, a powerful greenhouse gas. In addition, the growing and producing of food requires a lot of energy and water, which also has an impact on the environment. One kilogram of beef for example requires roughly 15.420 liters which amounts to 12.290 grams of Co2 [3].

It is estimated that if food waste were to be a country, it would be the third largest emitter of greenhouse gases, behind only the United States and China [2]. In Germany alone, 12 million tons of food is wasted every year, this means that 2.5 million hectare worth of farmland is simply wasted. This is a problem that needs to be addressed, and there are a number of ways to do so.

One way to reduce food waste is to simply be aware of it and make an effort to reduce it. This means being mindful of how much food is bought and cooked, and only buying and cooking what is needed. But besides private households, retail and food services produce the second largest amount of food waste [2].

The approach taken in this paper aims to raise awareness of the food waste problem that is associated with the food service industry. The vast amount of data available to takeaway platforms on food consumption and behavior is a not thoroughly exploited goldmine for reducing the food waste. Based on takeaway data, a forecasting system is developed that estimates the requests per dish and gives a recommendation for action to the restaurant owner. Through a periodical dashboard/newsletter, the restaurant owner can get insights into expected demand and adjust accordingly. This could help the restaurant be more mindful with current shelf-stock and avoid excess which reduces food waste long term.

TakeAwaste aims to address the following Sustainable Development Goals (SDG):

(**2**: Zero Hunger)

12: Sustainable Consumption

13: Take action against climate change

Reducing food waste could potentially help close the hunger gap (Goal 2) if the excess is fairly distributed (e.g., by using food sharing). Buying only what is needed to meet demand aids in Goal 12. Through wasting less food, less methane is produced, less farmland is needed, less water is wasted. Thus, by extension, it has a positive effect on climate change.

2 Related Work

According to [4], following private households, food services and retail[1] produced the second largest amount of food waste in the United States in 2019.

The business development institute of the Bern university of applied sciences concluded in [5] that the production of reserves is one of the main drivers of food waste in the food service industry. While some portions of food waste aren't avoidable (e.g., orange peels), overproduction can be potentially avoided. [5] differentiates between three phases. The first phase (*unprocessed*) considers food waste caused by expiration dates. Overproduction falls within the second phase (*processed* foods) and has a high potential for waste reduction. The highest waste reduction potential, however, lies with the last phase of *prepared* food. Here, most waste happens due to consumers and their leftovers. [5] suggests approaching the problem at the third and last phase by focusing on the customer and raising awareness. Certain behaviour changes or actions like e.g., reducing portion sizes, might also aid in the reduction of phase 3 waste production.

In another approach to tackle the food waste problem, Oliveira *et al.* explore in [6] potential solutions for the food service industry. Similarly, the authors differentiated between three stages of waste generation (cf. figure 2.1): during the planning stage, the preparation stage or at the consumer level. As reviewed by Oliveira *et al.*, food waste in the food service industry is largely avoidable, however it is suggested to focus on the consumer. While tackling the problem in the earlier stages (e.g., *planning*) might be helpful to reduce overproduction, restaurant owners struggle with anticipating the correct consumer demand and end up with a surplus.

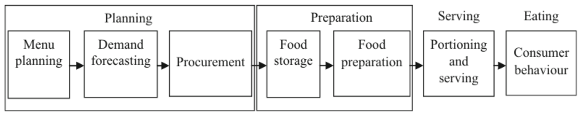

Figure 2.1: Waste generation in the food service setting.
Source: [6]

[1] jointly considered

3 Proposed Solution

Current approaches to mitigate and narrow down food waste mostly fall within the later stages of the waste lifecycle. It is often recommended to focus on raising awareness and nudging behaviour changes. Intercepting at earlier stages is often viewed as challenging, yet especially the earlier stages dictate the level of overproduction. Therefore, we aim to propose an early stage solution approach by developing recommendations for action targeted at restaurant owners. For this, the following hypothesis is defined:

> A data-driven forecasting of consumer demand leads to a reduction of food waste (and, by extension, to a reduction of green house emission).

In keeping up with the hypothesis, a forecasting model is to be developed in order to estimate the consumption per day. The forecasting model fetches consumption data periodically to train and fine-tune the prediction. This results in an expected consumption prediction for the subsequent period, which is loaded back into the database. From there, the prediction data is loaded into a dashboard or reporting tool to visualize the upcoming demand. The dashboard is intended as a recommendation for action to facilitate the anticipation of the correct consumer demand, based on historical data.

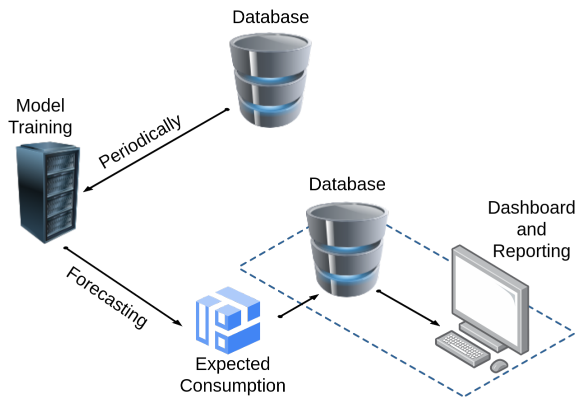

Figure 3.1: Proposed system architecture of a data-driven customer demand forecasting.

3.1 Data and Forecasting

Because the proposed forecasting system architecture relies heavily on the availability of historical consumption data, this paper is limited to a subcategory of the food service industry, namely takeaway.

In 2020, the dutch online platform *Just Eat Takeaway.com* received a total of approximately 588 million orders. The platform acts as an intermediary between customers and restaurants, putting it in an advantageous position to potentially collect data on consumer behavior and demand over time [7]. We recognize this potential as an untapped opportunity to address the problem of food waste with a data-driven approach.

For the protoype development of the proposed solution, a dataset with similar intricacies to the data accessible by takeaway platforms is desired. This includes item name with the date and time, as well as the quantity of the order.

To find a fit dataset, we conducted a search on the Dataset search database of Google[2] with the keywords `"takeaway"` and `"orders"`. This returned 100+ results but to further narrow down the search, a filter on the data format was added to only include tabular or archived data. This narrowed it down to two datasets of which "Takeaway Food Orders" by WebAI [8] were deemed the most suitable .

The dataset consists of 33.000 orders, spread across 200.000 rows of items, from two indian takeaway restaurants in London, UK. The breakdown into items instead of orders is especially useful as it allows the demand analysis on an item level.

In the subsequent step, the item orders were subject to forecasting. A total of three models were implemented and tested: FbProphet, Autoregressive integrated moving average (ARIMA) and Seasonal Autoregressive integrated moving average (SARIMA). To decide for one model, both the Mean Squared Error (MSE) and the Mean Absolute Error (MAE) were computed. ARIMA calculates a moving average which results in a short term pre-

[2] `https://datasetsearch.research.google.com`

diction. However, it does not account for any seasonality that occurs over time and is mostly limited to short term predictions. SARIMA similarly uses past values to make a prediction, but it also takes into account any seasonality patterns. Its shortcomings, however, become imminent when trying to get granular, day to day, prediction. FbProphet, a forecasting model developed by Facebook,[3] had the best overall metric score and was therefore deemed most suitable for the intended dataset. Because FbProphet considers other aspects of timeseries, such as the trend, daily seasonality and outliers such as public holidays, it proved to be the most robust [9].

Model	Score
FbProphet	MSE: 5.2 MAE: 2.3
ARIMA	MSE: 6.7 MAE: 2.1

Table 3.1: MSE and MAE for tested forecasting models.

3.2 Metric

The degree of food waste reduction, as mentioned in the hypothesis, is measured in reduction of total Kg wasted. This translates to the amount of dishes saved F, which is is the difference between the usual orders and the recommendation. To account for model error, the MSE ϵ is added.

$$\text{usual orders}^* - (\text{recommendation} + \epsilon) = \text{F} \tag{3.1}$$

To get a kilogram estimate, the average amount of food saved per dish is around 500 grams. Therefore to get F is to be multiplied by 500 grams.

$$F \times 500g = \text{Kg food saved} \tag{3.2}$$

3.3 Results

The forecast with FbProphet is loaded into a database which is connected to the data visualization tool Tableau.[4] In Tableau, a dashboard containing various views of the predicted period is displayed. The restaurant owner receives a recommendation for the demand per day, as well as the quantity to be prepared. Following the previously defined metric, the restaurant owner who followed the the data-driven forecasting avoided a total of 406,5 Kg of food waste in the period under review as opposed to a dataless approach.

4 Conclusion

A few assumptions had to be made for the purpose of this prototype. Therefore, the results are not yet generalizable for other sectors. This, however, does not detract from the overall results.

The prototype demonstrated that the forecasting was successful in reducing overestimation and total Kg food wasted. The simple data-driven approach as such is also scalable going on. Takeaway platforms possess valuable data that, when leveraged properly, can aid in managing food waste and by extension climate change.

[3] `https://facebook.github.io/prophet/`
[4] `https://www.tableau.com/`

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