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Estimating available supermarket commodities for food bank collection in the absence of information

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ABSTRACT

Food insecurity is a widespread concern in the United States. Addressing this concern is a chief goal of many non-profit organizations including food banks. Understanding the availability of donations is beneficial when addressing the demand in local communities, especially when their collection requires food bank-managed vehicles. High-volume donors such as supermarkets, however, do not provide information in regards to what items are available. This can negatively impact inventory management capabilities and cause unnecessary transportation costs.

This research evaluates four approximation methods based on their ability to estimate food availability at supermarkets including the multiple layer perceptron artificial neural network, multiple linear regression, and two naïve estimates for the average collection amount. Using a subset of the historic data provided by the Food Bank of Central and Eastern North Carolina (FBCENC), the four approximation methods are evaluated in terms of their ability to estimate collection amounts in the next planning period. Transportation cost estimates are then calculated using projections made using each approximation method and compared to those calculated using the actual transportation costs. Results suggest that the MLP-NN models provide the best approximations for each food type and provide closer estimations for transportation cost than other approximation methods.

1. Introduction

Food banks collect, store, and distribute food donated by local businesses (i.e. food producers/manufacturers, food distributors, and supermarkets) and community-serving organizations. These commodities are processed, stored, and eventually dispatched to charitable agencies. The charitable agencies, in turn, distribute the items that they receive to individuals and families experiencing food insecurity. Their warehousing capabilities, interest in providing unbiased service to the agencies, and cooperative approach to counteracting hunger make food banks an attractive non-profit agency to high-volume donors. Supermarkets are one of the high-volume donation sources for food banks. Commodities that are generated from supermarkets include food items that are usable yet for various reasons, unsellable in local markets. Examples of these edible food items include dented canned goods, bruised fruit, and non-perishable items approaching manufacturer-recommended sell by dates. The donation of these items is both good-hearted and practical because their disposal would otherwise be managed by the supermarket branch and/or franchise. Food banks welcome these items, as tight funding limits the amount of food that can be purchased in local markets.

One of the obstacles to scheduling food bank operations is the uncertainty in available supply. Food banks must make collections at supermarkets with no indication as to whether desired food items are available, and if so, how much. Unlike typical for-profit supply chains, suppliers (i.e. supermarkets) have a different objective than their downstream recipients (i.e. food banks, charitable agencies, and hunger victims). While interested in aiding the food insecure, these donors are in business to make a profit. This profit is realized by selling food items rather than donating them. Furthermore, supermarkets typically elect not to share information regarding product availability because it is either difficult to forecast Meulstee and Pechenizkiy (2008) or kept confidential. Without having knowledge of what items are available for collection at different stores, the degree to which food banks can make cost-effective transportation schedules is limited.

The goal of this research is to identify an approximation method that is useful when estimating the amounts of different in-kind food types available for collection at a supermarket branch. This extends the work of Brock and Davis (2012) to address instances

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where there is no information shared between supermarket branches and the regional food banks. As specified in the preceding investigation, quantifying food availability is complicated because (1) there is no definite time interval between food collections; (2) the availability of surplus food at supermarket branches is dependent upon product sales, internal forecast accuracy, and donations given to other non-profit organizations; and (3) food is perishable and must be collected before disposal. Given the dynamics associated with collection frequency and food availability, approximation methods must have the ability to generalize what is received in a specific collection event. Therefore, knowledge discovery and supervised machine learning approaches are used to predict food availability. In particular, multi-layer perceptron neural network (MLP-NN) models are proposed to determine the amounts of food available for a specific collection event. The models incorporate information related to the observable characteristics of a collection event, the financial wellness of communities served, and past operational decisions made by the food bank. The MLP-NN models are compared to traditional approximation methods which are not based on a uniform time step. Specifically, we consider multiple linear regressions, the overall average collection amount received from a supermarket branch, and the overall average collection amount received from a supermarket branch when collected by personnel from a specific warehouse affiliated with the regional food bank. The results of a computational study show that MLP-NN models are more effective than the traditional forecasting methods at accounting for supply uncertainty. The results also show that the improved forecasts lead to better estimates for transportation costs.

The remainder of this chapter is organized as follows. Section 2 provides a review of literature related to the forecasting problem. Section 3 provides a description for food collection events and provides a brief description for each forecasting method. Section 4 provides a detailed description for the MLP-NN model selection process. Section 5 presents a case study implemented using historic data from a food bank in the southeastern region of the United States. Section 6 compares the four approximation methods based on both prediction error and the impacts of using each method to schedule food collections. Section 7 discusses managerial insights that are concluded from the results. Section 8 summarizes the key findings of this research and identifies opportunities for future research extensions.

2. Related literature

Aspects of food insecurity have been addressed in literature. Topics studied include food quality and food bank workforce (Tarasuk & Eakin, 2005; Teron & Tarasuk, 1999), hunger studies (Mosley & Tiehen, 2004; Vinopal & Cooper, 2011; Weinfield et al., 2014; Winter, 2009). Quantitative research which identifies strategies to counteract food insecurity is more limited. Topics addressed include pre-positioning, food collection and distribution (Bartholdi, Platzman, Collins, & Warden, 1983; Ghoniem, Solak, & Scherrer, 2012; Gunes, van Hoeve, & Tayur, 2010; Lien, Iravani, & Smilowitz, 2008). Phillips, Hoenigman, and Higbee (2011) perform a quantitative study to suggest how the average supply amount generated from donor sources is sufficient to satisfy demand.

While there is considerable research that is relevant to forecasting organ donation (see e.g. Darwiche, Feuilloy, Bousaleh, & Schang, 2010; Lee & Cheng, 2011; Moore, 1971) and monetary donations (see e.g. Britto & Oliver, 1986; Malthouse, 2010) few researchers have addressed the challenge of quantifying in-kind food donations. Jiang, Davis, De Mleo, and Terry (2013) study the historic donation receipts obtained by the Food Bank of Central and Eastern North Carolina (FBCENC) using different data mining and visualization techniques. The researchers identify the change in donation patterns, and classify donors based on the number of times they contribute food items. Their results indicate an increase in total monthly donation receipts. The results also show that most one-time donors make low-volume contributions, whereas repeat donors make high-volume contributions. Davis, Jiang, Morgan, and Harris (2013) and Davis, Jiang, and Terry (2013) present quantitative models for estimating the average amount of food supply received from monthly from different donation sources.

The idea of using data mining for planning purposes is not new. In fact it has been utilized in a number of applications including engineering design (Feng & Wang, 2003; Feng, Yu, & Kusiak, 2006) and production and maintenance scheduling (Luxhoj, Williams, & Shyur, 1997; Sha & Liu, 2005). While there is little work published in the context of in-kind donations forecasting, there is considerable work published that is relevant to demand forecasting. A partial review of recent work addressing demand forecasting is provided. For a comprehensive review of demand forecasting methods, the reader is referred to Zhang, Patuwo, and Hu (1998). Meulstee and Pechenizkiy (2008) address the challenges associated with wholesale food suppliers estimating demand for food items sold. This problem posed in their investigation is similar to this research in that the forecasted outcome (i.e. product sales) is perceived as affected by some unknown context (i.e. consumer preference, habits, interests, etc.). The problem is motivated by the need for food suppliers to improve forecasting ability. The researchers incorporate ensemble learning approaches to predict product sales. The ensemble model incorporates sales for different product types, past weather conditions, and school holidays as inputs for estimating future demand. Gutierreza, Solisb, and Mukhopadhyay (2008) evaluates forecasting methods that are appropriate for products with intermittent demand. Such forecasts are used when there may be long periods when items are not demanded followed by periods when demand is elevated. In their investigation, they compare MLP-NN models, simple exponential smoothing and the smoothing approximations of Croston (1972) and Syntetos and Boylan (2005). Shahrabi, Mousavi, and Heydar (2009) evaluates different forecasts when determining long-term demand for car components. In their investigation, the moving average, exponential smoothing, exponential smoothing with trend, support vector regressions, and MLP-NN models are compared. Forecasting methods are also utilized to assess demand for limited resources including water (Adamowski, 2008; Firat, Yurdusev, & Turan, 2009; Pulido-Calvo, Montesinos, Roldán, & Ruiz-Navarro, 2007), energy consumption in buildings (Ekici & Aksoy, 2009), and energy consumption by communities (Geem and Roper, 2009; Murat and Ceylan, 2006; Wang & Liang, 2009).

To our knowledge, only Brock and Davis (2012) consider the need to differentiate between food quantities received from donors based on observable characteristics of the collection event. The researchers propose the use of feed-forward neural networks which fits the description of the MLP-NNs. The model is used to approximate the amounts of different food types available for collection assuming that food banks to know with certainty which food types are available for collection. A single neural network model is selected to model the relationship between the observable characteristics of food collection events and the amount of food received from the supermarket. The data used in this investigation reflect collection outcomes, the financial wellness of supermarket customers, and operational decisions made prior to the collection event. The selected neural network is compared to a multiple linear regression model using data reflecting supermarket receipts collected by FBCENC. Results show that the neural network provides acceptable estimates for food collection and is noticeably more effective at estimating food availability than the regression model.

The problem presented in this study is one where food banks must be able to estimate how much of each in-kind food type is