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Investigating the Demand for Short-shelf Life Food Products for SME Wholesalers

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***Abstract*—**Accurate forecasting of fresh produce demand is one the challenges faced by Small Medium Enterprise (SME) wholesalers. This paper is an attempt to understand the cause for the high level of variability such as weather, holidays etc., in demand of SME wholesalers. Therefore, understanding the significance of unidentified factors may improve the forecasting accuracy. This paper presents the current literature on the factors used to predict demand and the existing forecasting techniques of short shelf life products. It then investigates a variety of internal and external possible factors, some of which is not used by other researchers in the demand prediction process. The results presented in this paper are further analysed using a number of techniques to minimize noise in the data. For the analysis past sales data (January 2009 to May 2014) from a UK based SME wholesaler is used and the results presented are limited to product 'Milk' focused on café's in derby. The correlation analysis is done to check the dependencies of variability factor on the actual demand. Further PCA analysis is done to understand the significance of factors identified using correlation. The PCA results suggest that the cloud cover, weather summary and temperature are the most significant factors that can be used in forecasting the demand. The correlation of the above three factors increased relative to monthly and becomes more stable compared to the weekly and daily demand.

***Keywords*—**Demand Forecasting, Deteriorating Products, Food Wholesalers, Principal Component Analysis and Variability Factors.

I. Introduction

THE lifetime fixed to the food product before it reaches the deterioration period and loses its market value is known as shelf life. Certain elements in each food product decide and limit its shelf life. According to [1], the shelf life for the food products can be distinguished into three categories: perishable – extremely short shelf life, semi-perishable – medium shelf life, non-perishable – ambient temperature. Short-shelf life food products present some of the biggest challenges for supply chain management due to a high number of product variants, strict traceability requirements, demand prediction, short shelf-life of the products, and the need for temperature control in the supply chain, and the large volume of goods handled [2] (see Fig. 1). Improved demand forecasting figures play a major role in planning for short shelf life products. However, according to [3] an accurate and complete demand forecasting for short shelf life products is still an area of research that has not been covered. In demand forecasting of short-shelf life food products for SME wholesalers, several factors have an impact on the nature and quantity of products that are running through the supply chain on a timely basis (e.g. Daily).

This paper focuses on the daily demand variation problem associated with SME wholesalers and identifies the variability factors affecting the demand. The paper is organized as Section II gives current literature on factors affecting the demand and the existing forecasting techniques of short shelf life products, Section III covers the proposed methods and steps to carry out the research, Section IV gives the results of research steps, Section V discus about the consequences of results and with future work on Section VI.

II. Current Research

Since 1960, most of the food wholesalers are aiming to have precise forecast, which have also become even more important from the perspective of planning. Services, facilities and products are more concentrated as the responsibility of a company in planning, forecast of future demand has also become superior [4]. Forecasting is one of the essential elements for optimal planning as it allows organisations to determine the resource, raw material, planned maintenance, etc. ahead of time, which allows maintaining the optimal performance even in highly variable environments. Many techniques, ideas, models and methods are published in forecasting demand by considering the types of resources like people [5], Products and materials [6], [7] etc.

Customer demand is the main generator of profit for any enterprise [8]. Food wholesalers are more involved and concerned about demand forecasting, because of the product's special features like deterioration rate, quality and unpredictable customer demand (specially daily demand).

Short-shelf life food products (i.e. Fruits and vegetables) can be sold within a restricted time period, hence having a too much or too little inventory could result in waste or missing order/unsatisfied customer, hence, decreases profit margins

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[9], [10]. This section investigates the main variability factors affecting the demand forecast and also the existing techniques proposed by researchers in the food supply chain.

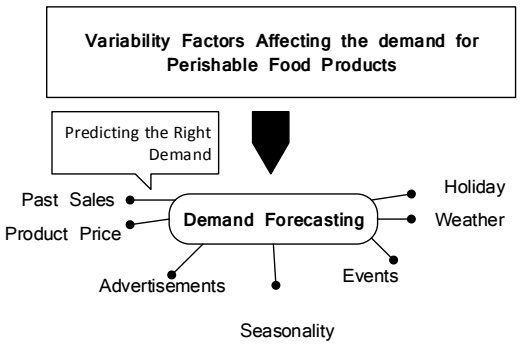


Fig. 1 Variability Factors Affecting Planning Strategy in Supply Chain of Short-shelf Life Cycle Food Products

A. Factors Affecting Demand

Some of the general variability factors considered in predicting system of food wholesalers is listed below [11].

1) Past sales
2) Product price
3) Advertisements
4) Seasonality of the Product
5) Holidays
6) Weather
7) Existence of alternative products
8) Discounts and promotions

Fig. 2 links the above factors to the food products considered by the researchers. Historical demand figures, weather, temperature, holidays and economic factors have a considerable impact on demand [12]. They also highlighted that product availability has also to be considered while referring to historical sales to accurately forecast future demand. Previous milk sales are used to predict future demand and interpreted non-systematic changes to public holidays and customer trends as in [10].

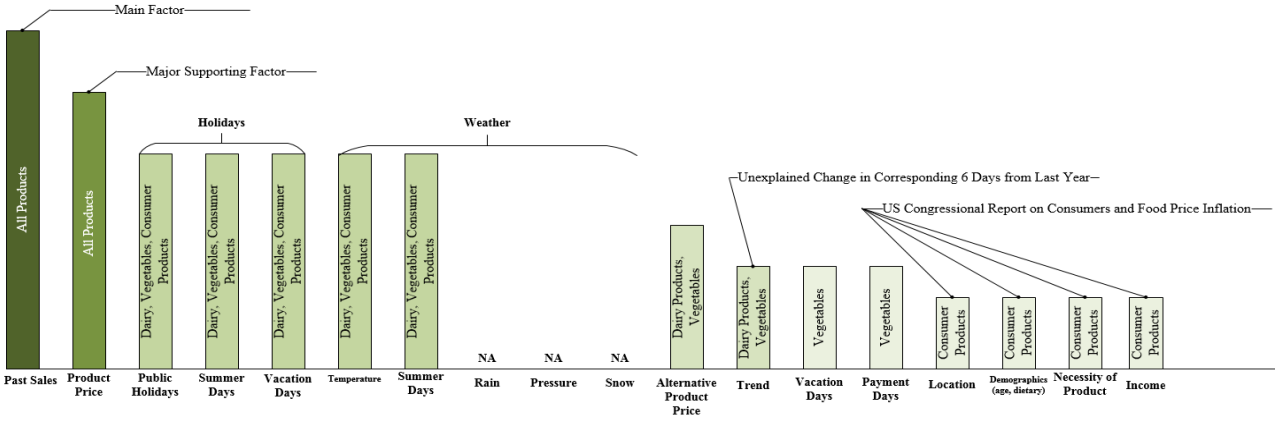


Fig. 2 Variability Factors Affecting Demand Forecast Short-shelf Life Cycle Food Products

The effect of the existence of alternative products and payment days along with the three most common factors; past sales, price and holidays have also considered in previous research, as in [11]. Reference [13] has taken the same factors, but also included weather temperature for one year instead of holidays. However, a review of previous researches (Fig. 2) has focused on a limited number of factors specific to a single product or a business type.

B. Existing Forecasting Techniques

In demand forecasting several, linear, non-linear and hybrid methods are used for prediction. Autoregressive–moving average model (ARMA) procedure is considered the main linear method which combines both auto-regression of the historical demand data and moving average model of forecasting errors [14].

Another important linear model is Holt-Winters which uses exponential smoothing to model the historical data [15]. The linear auto-regression and moving average model are replaced, individually or combined, with non-linear models such as neural network. Linear based models give the least accurate predictions among all forecasting techniques [10]. Non-linear methods are superior to linear methods, especially when used to model the relationship between sales demand and variability factors instead of moving-average error in sales demand.

A hybrid system of non-linear methods; genetic algorithm for variable selection and adaptive Radial Basis Function (RBF) artificial neural network are used to model the relationship between variables and sales volume [10]. A hybrid system that integrates linear and nonlinear methods [11], where ARMA was used for linear autoregression and Neural Network for modelling of forecasting moving average errors.

This technique produced errors by 28.8%; however, in comparison with [10], the same technique produced more accurate results (i.e. 8.2%) which could be related to the business domain (milk [10], and vegetable oil [11], [13]); whom were also researching milk demand forecasting, have used a hybrid non-linear system consisting of Gray relationship analysis for variable selection and artificial neural network to represent the relationship between selected

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variables and demand.

C. Limitations

The weather has the greatest impact on demand; however, the conclusions are made based on consideration of temperature only [12]. Forecasting variable error is reduced using the hybrid nonlinear RBF technique to 4.61% with consideration of a small number of factors [10]; however, including other factors (e.g. price) can further improve the accuracy of the technique. Also, the forecasting error can be related to the business domain which can explain the low accuracy in forecasting of vegetable oil comparable to milk.

PCA technique determines the significance of factors by transforming the variability factors into regioned non correlated PCA factors which helps in determining which variability factors are giving the same representation and therefore remove the insignificant ones [16]. Therefore a more generic forecasting technique that includes all possible factors and their significance on demand as well as produce accurate results regardless of the product is still a need and it will be the scope of forecasting demand part of this research.

III. Methodology

A. Data Collection

This research is part of a Technology Strategy Board project and the data used were taken from one of the UK based medium size wholesaler.

The collected internal data set were chosen based on the following criteria:

1) Date: Researchers have considered 'past sales' as an important variable in capturing the future customer demand. This relationship gradually decreases with the increase of time (e.g. last year sales are more relevant than the years before), hence the past sales were collected from 2009.
2) Business Type: To analyse the trend pattern of different products for different business types (e.g. pub, restaurant, schools etc.,), the data were collected from 19 different business types for various short-shelf life products.
3) Products: Short-shelf life food products represent mainly four categories (i.e. vegetables, fruits, dairy and prepared food) therefore one product representing each category is selected.
4) Location: Each location has its own population, events, weather etc., to analyse the effect of these factors on sales demand the data were collected from seven different locations of the midlands.

The data were collected for different short-shelf life products and business types in the main market location of the company. Analysis was carried out for product 'Milk' and business type 'Café' in 'Derby' location as it has got the highest amount of sales orders from 2009 until 2014.

B. Identifying Different Patterns for Demand

The sales demand of short life products can be affected by changes in the number of customers or from one year to another. It can also be affected by demand peaks; which can make the prediction of demand using the normal current sales demand not accurate. Hence, this step is used before starting the analysis, to identify whether there is any trend within the actual sales. Therefore, in this step, the sales demand was adjusted using the following:

Normalisation of Order Quantity: the sales demand was normalised based on

$$Normalisation\ 1 = \frac{Total\ _{order}\ quanity\ per\ day}{Total\ order\ quanity\ per\ year}$$

$$Normalisation\ 2 = \frac{Total\ order\ quanity\ per\ day}{Total\ number\ of\ customers\ per\ year}$$

Lagged orders: this part is concerned with the investigation of the effect of time on the demand. The orders were lagged on daily and weekly time window basis to analyse if the predictor variable has an effect on lagged demand.

C. Investigating and Gathering of Different Variability Factors Affecting the Demand Forecast

There are common factors and also a particular factor representing demand fluctuation have an effect on each product, as the variations in sales demand are controlled by weather, price change, discounts, food habit etc., besides seasonal changes, local festivals and events.

Several variability factors affecting the short-shelf life food products were identified. Apart from the factors identified from the literature, few other factors were also discovered from the several meetings within the collaborators. The identified variable factors such as 'Weather', 'Past sales demand', and 'Holidays' were expanded into many sub-levels considering the state of consequences (i.e. situations). In addition, new variability factor 'Events', 'Seasons' and few other sub levels for the existing factors were also introduced.

Table I shows the detailed collection of variability factors gathered from various sources. Furthermore, collected weather data contains noise as they are changing frequently, hence noise in the weather data is smoothed using the following time windows:

Forecasting of Daily/Weekly Demand:

1) Average of 2/3/4/5/6 Days
2) Average of 2/3 Weeks

D. Reduction of Variability Factors

This step looks at determining the demand trend of short shelf life products and check if the variable factors can be reduced using Principle Component Analysis (PCA) technique. The demand pattern was analysed from one year to another based on daily, weekly and monthly orders.

The PCA technique was used to investigate, if the variability factors can be minimised based on how many variables are enough to describe the variability.

E. Data Analysis on Causal Relationship

Once the variability factors are reduced using principal component analysis (PCA), the factors are incorporated with the past sales customer demand to generate the causal relationship between the identified factors and demand. The

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correlation analysis is done to check the dependencies of variability factor on the actual demand. The analysis is carried out for product 'milk' ordered from 'Café'. The complete correlation analysis is done for daily, weekly and monthly.

TABLE I
VARIABILITY FACTORS SOURCE INFORMATION

Variability Factor	Sub- Levels	Data for	Source
Holidays	Summer holidays	England	UK Government Publications
	Public holidays	England	UK Government Publications
	School holidays	Leicester	Leicester City Council
	Weekends	World	Calendar
Weather	Outdoor Cloud Cover Humidity Outdoor condition Temperature Visibility Precip Intensity Precip probability Summary Wind bearing Wind speed	East Midlands	Met Office
Seasons	Winter Summer Autumn Spring	East Midlands	Met Office
Events	Premier league	England	Barclays Premier League Official Website
	Champions league	Europe	The Union of European Football Associations (UEFA) Official Website
	World Cup	World	Fédération Internationale de Football Association (FIFA) Official Website
	Olympics	World	Official Website of the Olympic Movement

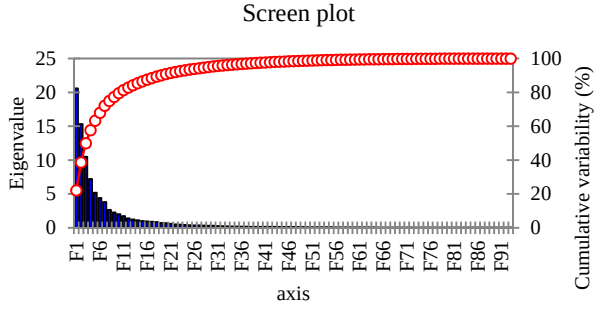


Fig. 3 Relationship between variability factors using PCA factors 1 and 2

IV. Results

PCA Analysis was carried out for the purpose of reducing the variability factors and determining if there is any relationship between factors for all Milk orders in Cafes. Fig. 3 shows the Eigenvalue of the PCA factors. It can be seen that the relationship between factors is insignificant since it has taken PCA 93 factors to define the variability in the system.

PCA factors F1 and F2 accounts for 40% of the variance and therefore the relationship between factors were determined using these two factors as shown in Fig. 4.

The results suggest that the following factors can be reduced to one since they always have the same value for PCA factor:

1) Outdoor and Temperature.
2) Precip Intensity and Precip Probability.
3) Outdoor Condition and Summary.
4) All lagged orders can be reduced to one.
5) All normalised weather data can be reduced to one for each parameter.

The correlation of all factors is low, excluding outdoor condition, cloud cover and summary (see Table II). The correlation of the above three factors increased relatively to weekly compared to the daily demand. The correlations for all factors on monthly demand decreased from that of weekly for the two highest factors, but increased for others and become more stable.

TABLE II
DESCRIPTION OF SIGNIFICANT VARIABILITY FACTORS

Factor	Description
Cloud Cover	Cloud content (mass)
Outdoor Condition	Temperature
Summary	Overall weather condition (e.g. sunny)

V. Discussion

In this paper, several factors were investigated along with possibility of noise and time shift in the customer orders. Other factors such as 'Events' indicates sudden increase in demand due to local/national events in particular years and the factor 'Public Holidays' it is more important to consider the wholesalers and suppliers that works and does not work and customers might also pre-order more stock because of the imminent public holiday.

The factors representing noise and time shift are not of high significance according to results from PCA and therefore it can be excluded from the demand forecasting. It also suggests that cloud cover, weather summary and temperature are the most important factors to be included in the forecasting.

Several linear and non-linear forecasting techniques were investigated by researchers for the purpose of predicting demand for short-shelf life products. Non-linear based techniques such as neural networks proved to be more accurate than linear methods with an accuracy error reaching as small as 4.6% for milk product. However, generalization of the results of the non-linear technique to other products and factors is still an area of research.

VI. Future Work

The results from the preliminary analysis will be used to develop an improved forecast method for predicting the daily demand in short shelf life products for SME wholesalers. The analysis will be extended for other products using the same methodology and results will be fed to the forecasting technique.

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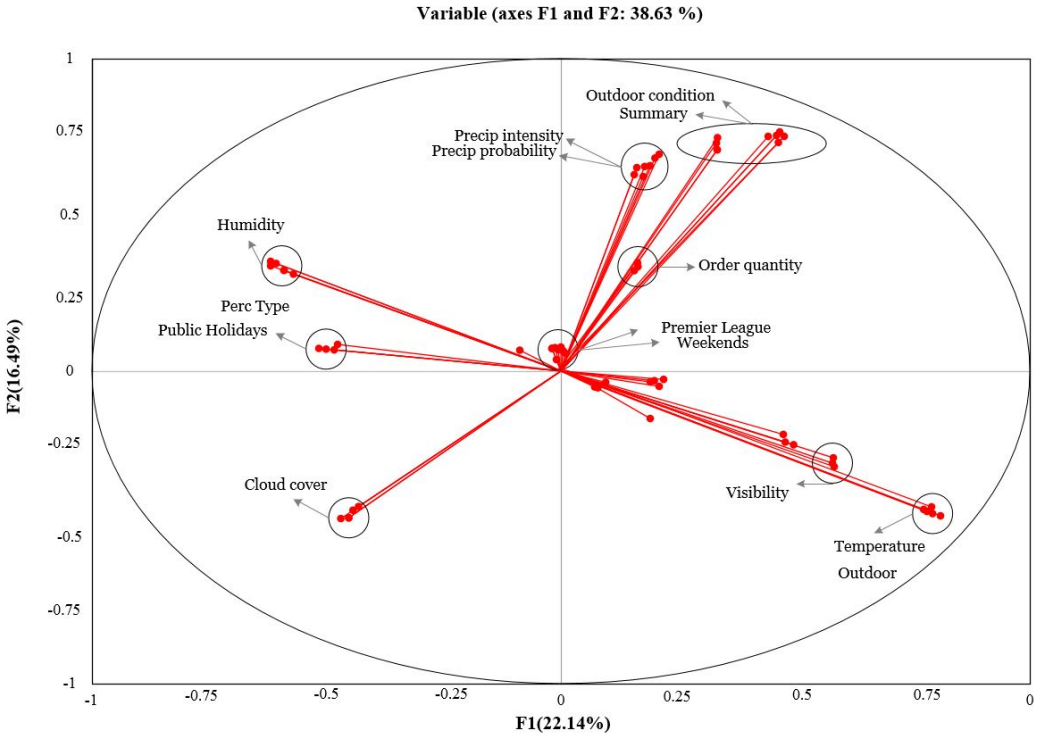


Fig. 4 Relationship between variability factors using PCA factors 1 and 2



Fig. 5 Relationship between variability factors using PCA factors 1 and 2

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