Sales Forecasting for Supply Chain Demand Management – A Novel Fuzzy Time Series Approach

S. M. Aqil Burney
Department of Actuarial Science & Risk Management,
College of Computer Science & Information Systems,
Institute of Business Management,
Karachi, Pakistan
aqil.burney@iobm.edu.pk

Syed Mubashir Ali
Department of Computer Science & MIS,
College of Computer Science & Information Systems,
Institute of Business Management,
Karachi, Pakistan
mubashir.ali@iobm.edu.pk

Abstract— **Supply chain management has become an important area of research among researchers in the past decade. The reason for its growing importance is its ability to enable businesses to have strategic competitive advantage. There are various supply chain functions and demand management is one of them. It deals with the organization's ability to meet the customer needs by maintaining the required inventory. In order to achieve this goal, organizations needs to predict the demand by forecasting sales using sales patterns in order to efficiently meet customer demands. Fuzzy time series has been extensively used for forecasting problems. The aim of this paper is to propose and implement a new fuzzy time series model to predict sales for efficient demand management within supply chain. This method was developed by us and previously used to predict university students' enrolment which had a better accuracy compared to existing methods. This paper will first discuss what sales forecasting and demand management is along with explaining the basics of fuzzy time series. Later the proposed framework will be discussed and applied to a sample monthly time series for milk cartons sales in a super market for sales forecasting. Later future research areas will be highlighted to conclude this research study.**

Keywords— *supply chain management, soft computing, fuzzy time series, sales prediciton, supply chain management*

I. INTRODUCTION

Supply chain management (SCM) has become imperative for organizations in order to stay ahead of the competition. One of the main functions of SCM is demand management. Demand management is about managing the required inventory by predicting sales so as to meet customer demands in future [1]. Various approaches have been employed by the academicians and researchers for sales forecasting [2]–[6]. In order to effectively manage supply chain, accurate sales forecasting and demand management is extremely important [7].

The observation of data in series at particular time intervals is called a time series [8]. A number of fields have inherent time series data available such as temperature data within metrological department, sales data within a super market, stocks data from the stock exchange etc [9]. There has been an increase the time series data availability due to the rapid advancement in the technology as more and more data is not being digitally stored within data warehouses [10]. There are always hidden patterns that exist within the time series data as well as co-relation between past data and future data. As a result, researchers have shown keen interest in exploring and exploiting those patterns for accurate forecasting and predictive analytics. This has become one of the growing areas of research especially within the area of supply chain sales forecasting and demand management.

Demand management is one of the important areas within supply chain [11]. For any organization who wants to be on top and have strategic advantage, it is imperative to have effective supply chain demand management. In order to manage demand, appropriate inventory needs to be maintained [12]. And in order to manage appropriate inventory, sales forecasting is mandatory. Therefore this paper aims at proposing a new method to perform demand management.

This paper will introduce a new higher order fuzzy time series (FTS) based sales prediction method for managing the demand within supply chain. This new method can be used to analyze historical time series data to predict future time series taking into account the uncertainty. The authors have previously used this method to accurately forecast student enrolment at a higher education institution with better accuracy. This paper aims at proposing the same method for sales forecasting for demand management within SCM. The paper can further be extended to apply the proposed method on some actual sales data for better forecasting and may provide the decision makers useful insight knowledge for better decision making and managing customer demands.

This 1st section has given a brief introduction about this research paper. The next section will discuss about fuzzy time series methodology in detail. Section three will propose a new method involving 2nd order fuzzy time series for sales forecasting within a retail industry. Last but not the least, future research possibilities have been highlighted while providing conclusion to this research paper.

II. FUZZY TIME SERIES

When traditional time series is modified to cater to ambiguity using fuzzy logic, it is referred to as a fuzzy time series (FTS). Now we will discuss about various terms and definitions related to FTS. Song et-al were the first researchers to introduce the concepts of FTS [13].

Definition 1: Time series

Time series is defined as the set of data in sequence of equal intervals over a period of some given time.

Definition 2: Fuzzy Time Series

Consider a set Y(t) (t=···,0,1,2…), which is a real number subset. The set can be referred to as universe of discourse through which one can define fuzzy set f_i are defined. If F(t) is a collection of $f_1(t)$, $f_2(t)$,… then this series of values is referred to as a FTS having an crisp output of Y which is depicted in figure 1. Figure 1 is about a generic fuzzy inference system on which FTS series has been developed.
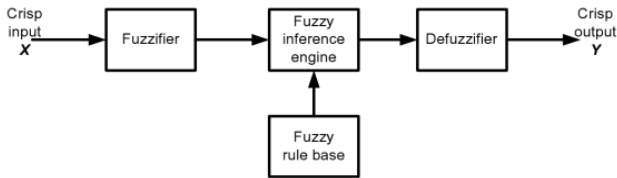

Figure 1: Fuzzy Inference System

Definition 3: 1st Order Fuzzy Time series

Suppose a FTS represented by G(t). If G(t) is a result of impact of G(t-1) only, then we can represent the logical relationship between these fuzzy values by G(t-1) →G(t). Such a relationship is referred to as a 1st Order FTS forecasting model. This paper will be proposing a model which is based on high order fuzzy time series forecasting.

Definition 4: Nth Order Fuzzy Time series

Suppose a FTS represented by G(t), If G(t) is resulted because of G(t-1), G(t-2), …, G(t-n), then we can represent the logical relationship between these fuzzy values by G(t-n), … , G(t-2), G(t-1) →G(t), then in this scenario, this time series is referred to FTS of Nth order.

III. PROPOSED FUZZY TIME SERIES MODEL

This paper is proposing a novel fuzzy time series model which will use trapezoidal fuzzy membership function in order to have better forecasting accuracy [14]. This new model was previously being proposed and implemented by us for university students enrolment forecasting [15]. The proposed model uses fuzzy trapezoidal membership functions which have resulted in increased accuracy while performing student enrolment prediction. This paper aims at using this new fuzzy time series model to forecast sales in order to perform demand management within supply chain. As an initial starting point, the authors have used the model in [16] by Chen to develop the new proposed fuzzy time series model. A number of modifications have been proposed in the model of Chen which is listed below:

- Identify and calculate the equal length intervals using the technique which was proposed by Huarng in reference [17].

- In order to define fuzzy sets, we use trapezoidal membership function instead of using triangular membership function.

- And last but not the least, established the high order fuzzy logic relationship between the time series.

The methodology of selecting the equal interval by Chen in [16] was subjective therefore we modified that method and instead selected the equal intervals using the average based length method as proposed by Huarng in [17]. This was the first modification in our proposed fuzzy time series method. Secondly, most of the previous studies using fuzzy time series such as [8], [16], [18], [19] have used discrete fuzzy sets but we have used trapezoidal fuzzy numbers. The last modification in our proposed model is the use of high order fuzzy logic relationship. Figure 2 shows our proposed fuzzy time series model. In the next section, we will implement the proposed model for sales prediction of milk cartons of a super market and check our forecasting accuracy using root mean square error (RMSE).
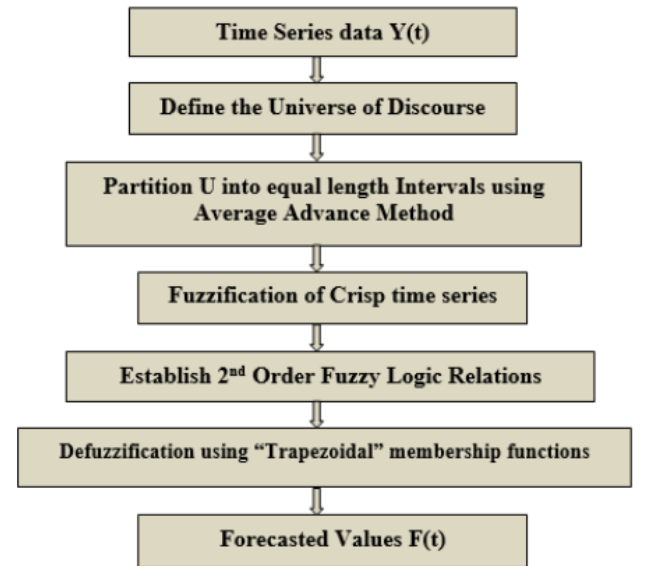

Figure 2: Proposed Model

IV. APPLICATION OF PROPOSED MODEL FOR SALES FORECASTING

In this section we will now apply our proposed model on a sales data of a super market for milk cartons monthly sales time series data obtained from reference [20] for predicting the sales for demand management within supply chain management. Table 1 shows the actual sales data for milk cartons. Table 2 shows the predicted values from our proposed methodology along with RMSE and a comparison of our

forecasted output to the previously applied time series method in [20]. Detailed step by step methodology and working will be provided in the extended version of this paper. It is evident from table 2 and figure 3 that our proposed model had better accuracy compared to the results from previous method being used by researchers in [20]. There is a major difference in the RMSE of our proposed and the previous models indicating that the proposed model has better accuracy.

Table 1: Milk Carton Sales Time Series

Month	Milk Cartons
January	1324
February	1352
March	1304
April	1276
May	1209

Table 2: Forecasted Sales

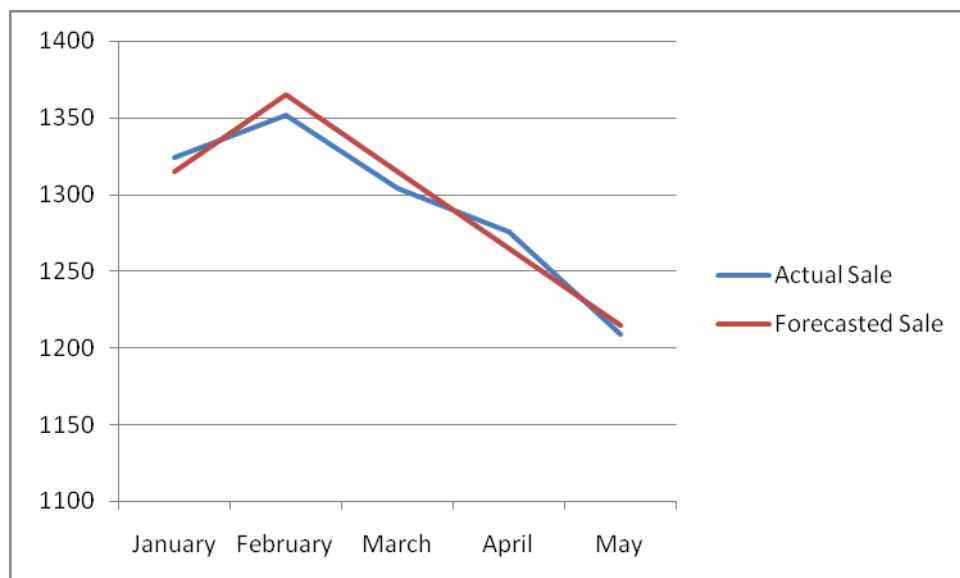| Month	Milk Cartons	Fuzzy Numbers	Forecasted Fuzzy Value	Forecasted Crisp Value	RMSE	
January	1324	A3	{1300,1310,1320,1330}	1315	Model in [20]	Proposed Model
February	1352	A4	{1350,1360,1370,1380}	1365		
March	1304	A3	{1300,1310,1320,1330}	1315		
April	1276	A2	{1250,1260,1270,1280}	1265	20.07	10.27
May	1209	A1	{1200,1210,1220,1230}	1215		

Figure 3: Actual and Forecasted Sales Chart Using Proposed Fuzzy Time Series

V. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This paper has proposed a new time series method under fuzzy environment for supply chain demand management by performing better sales forecasting. Better sales forecasting will enable the super markets to ensure appropriate inventory in their warehouses and isles in order to manage customer demand more efficiently. This paper applied the proposed model on small time series monthly sales data. In future, the same model can be applied on some longer duration time series sales data to check if it still gives the same level of accuracy or not. Also our proposed method can further be expanded to include type 2 fuzzy time series using some different fuzzy numbers instead of trapezoidal may provide different results and accuracy.

References

[1]   K. L. Croxton, D. M. Lambert, S. J. García-Dastugue, and D. S. Rogers, "The demand management process," *Int. J. Logist. Manag.*, vol. 13, no. 2, pp. 51–66, 2002.

[2]   N. S. Arunraj and D. Ahrens, "A hybrid seasonal autoregressive integrated moving average and quantile regression for daily food sales forecasting," *Int. J. Prod. Econ.*, vol. 170, pp. 321–335, 2015.

[3]   R. J. Kuo, Y. S. Tseng, and Z.-Y. Chen, "Integration of fuzzy neural network and artificial immune system-based back-propagation neural network for sales forecasting using qualitative and quantitative data," *J. Intell. Manuf.*, vol. 27, no. 6, pp. 1191–1207, 2016.

[4]   P. Ramos, N. Santos, and R. Rebelo, "Performance of state space and ARIMA models for consumer retail sales forecasting," *Robot. Comput.-Integr. Manuf.*, vol. 34, pp. 151–163, 2015.

[5]   S. Kolassa, "Evaluating predictive count data distributions in retail sales forecasting," *Int. J. Forecast.*, vol. 32, no. 3, pp. 788–803, 2016.

[6]   A. Pole, M. West, and J. Harrison, *Applied Bayesian forecasting and time series analysis*. Chapman and Hall/CRC, 2018.

[7]   S. A. Burney, S. M. Ali, and S. Burney, "A survey of soft computing applications for decision making in supply chain management," in *Engineering Technologies and Social Sciences (ICETSS), 2017 IEEE 3rd International Conference on*, 2017, pp. 1–6.

[8]   T. A. Jilani, S. M. A. Burney, and C. Ardil, "Fuzzy metric approach for fuzzy time series forecasting based on frequency density based partitioning," *World Acad. Sci. Eng. Technol. Int. J. Comput. Electr. Autom. Control Inf. Eng.*, vol. 4, no. 7, pp. 1194–1199, 2007.

[9]   S. A. Burney, M. A. K. Barakzai, and S. E. James, "Forecasting Monthly Maximum Temperature of Karachi City using Time Series Analysis," *Pak. J. Eng. Technol. Sci.*, vol. 7, no. 2, 2018.

[10]   H. K. Chan, S. Xu, and X. Qi, "A comparison of time series methods for forecasting container throughput," *Int. J. Logist. Res. Appl.*, vol. 22, no. 3, pp. 294–303, May 2019.

[11]   T. Efendigil, S. Önüt, and C. Kahraman, "A decision support system for demand forecasting with artificial neural networks and neuro-fuzzy models: A comparative analysis," *Expert Syst. Appl.*, vol. 36, no. 3, pp. 6697–6707, 2009.

[12]   Arshinder, A. Kanda, and S. G. Deshmukh, "Supply chain coordination: Perspectives, empirical studies and research directions," *Int. J. Prod. Econ.*, vol. 115, no. 2, pp. 316–335, Oct. 2008.

[13]   Q. Song and B. S. Chissom, "Forecasting enrollments with fuzzy time series—part II," *Fuzzy Sets Syst.*, vol. 62, no. 1, pp. 1–8, 1994.

[14]   M. A. H. Monil and R. M. Rahman, "VM consolidation approach based on heuristics, fuzzy logic, and migration control," *J. Cloud Comput.*, vol. 5, no. 1, p. 8, Jul. 2016.

[15]   S. M. A. Burney, S. M. Ali, and M. S. Khan, "A Novel High Order Fuzzy Time Series Forecasting Method with Higher Accuracy Rate," *Int. J. Comput. Sci. Netw. Secur.*, vol. 18, no. 5, p. 9, 2018.

[16]   S.-M. Chen, "FORECASTING ENROLLMENTS BASED ON HIGH-ORDER FUZZY TIME SERIES," *Cybern. Syst.*, vol. 33, no. 1, pp. 1–16, Jan. 2002.

[17]   K. Huarng, "Effective lengths of intervals to improve forecasting in fuzzy time series," *Fuzzy Sets Syst.*, vol. 123, no. 3, pp. 387–394, Nov. 2001.

[18]   T. A. Jilani and S. M. A. Burney, "M-Factor High Order Fuzzy Time Series Forecasting for Road Accident Data," in *Analysis and Design of Intelligent Systems using Soft Computing Techniques*, P. Melin, O. Castillo, E. G. Ramírez, J. Kacprzyk, and W. Pedrycz, Eds. Berlin, Heidelberg: Springer, 2007, pp. 246–254.

[19]   T. A. Jilani, A. S. Burney, and C. Ardil, *A New Quantile Based Fuzzy Time Series Forecasting Model*, vol. 42. World Academy of Science, Engineering and Technology, 2008.

[20]   M. Shetty N, V. Nawada N, K. Pai K, and R. Kumar H S, "Predicting Sales In Supermarkets," *Int. Res. J. Eng. Technol.*, vol. 05, no. 03, pp. 994–997, Mar. 2018.