Demand Forecast model for Fashion Replenishment supply chain: A review

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Abstract: Demand forecasting is a crucial subject for many retail operations. It is particularly important for the fashion retailing service sector because of the unstable nature of product demand and the condensed nature of product life cycles. This paper conducts a thorough literature review and selects a set of papers in the literature on fashion replenishment demand forecasting. Here we have examined the benefits and cons of several analytical techniques for predicting fashion retail sales. It is revealed how each forecasting technique has changed over the past years. Important future research directions are explored along with issues pertaining to fashion retail sales forecasting models real-world implementations.

Keywords— Replenishment supply chain, demand forecast, fashion

1. INTRODUCTION

A key component of fashion replenishment operations is inventory planning. Replenishment and supply chain management, which aids in supply and demand balancing, significantly depends on precise future demand forecasting. Sales forecasting really refers to making predictions about future demand (or sales), supposing that the same variables that have an impact on demand now will continue to do so in the future. Although tough to do, the duty is crucial.

Forecasting itself can be viewed as a "service" in the fashion retailing sector, which is defined as the retailing of fashion products such as clothes, shoes, and beauty products. This "service" refers to the collection of analytical tools that help businesses decide how to best predict the future. Unquestionably, a good forecasting service system can aid in preventing understocking or overstocking in retail inventory planning, which is further related to other crucial supply chain operations like due date management, production planning, pricing [1, 2], and achieving high levels of customer service [3]. To achieve an efficient and profitable result a company should adopt a demand forecast model.

It is abundantly evident from the above comments that fashion retail sales forecasting is a very significant subject in practice. Numerous research papers have been reported in the literature during the last ten years. Each forecasting technique, however, has limitations and disadvantages. For instance, the properties of the time series data are heavily reliant on traditional statistical approaches, which has a significant impact on predicting accuracy. Although traditional statistical forecasting models can perform more accurately, artificial intelligence (AI) solutions often take significantly longer and demand more processing capacity. As a result, several academics suggest combining different approaches to create a brand-new "hybrid technique" to complete forecasting work quickly and accurately.

The following is a breakdown of how this paper is organized. In Section 2, we examine the purely statistical techniques for predicting fashion replenishment systems. In Section 3, we go through the pure AI-based approaches to forecasting fashion sales. In Section 4, we examine a variety of distinct hybrid fashion replenishment forecasting techniques. In Section 5, we look at forecasting techniques' uses in the retail clothing market. In Section

6, we address the development of methodologies as well as potential future research directions.

2. FORECASTING USING STATISTICAL METHODS

Numerous statistical techniques, such as linear regression, moving average, weighted average, exponential smoothing (used when a trend is evident but not linear), exponential smoothing with trend, double exponential smoothing, Bayesian analysis, and so on, have been employed for sales forecasting.
Sales forecasting frequently makes use of statistical time series analysis methods like ARIMA and SARIMA [10]. These approaches are straightforward and simple to implement, and the results may be computed extremely rapidly because the forecasting expression is in closed form. A Bayesian technique is used in the literature by Green and Harrison [11] to investigate forecasting for a mail-order business that sells women's clothes. The accuracy of sales forecasting for new goods is next examined using item categorization by Thomassey et al. [12]. They discover that to increase forecasting precision, the relevant forecasting technique must include more item families and relevant categorization criteria. They conclude that forecasting for a product family is more accurate than predicting for a single item. Mustard et al. [13] recently considered the forecasting issue using a case study of a mail-order clothes firm. They suggest a "top-flop" categorization approach and contend that it outperforms other approaches. Furthermore, they discover that for a limited set of items, expert judgement approaches perform better than advanced demand information methods. Another recent study [14] investigates the suitability of a Bayesian forecasting model for predicting fashion demand. It is discovered that the suggested hierarchical Bayesian strategy produces more accurate quantitative findings than many other approaches.

Despite being widely employed because of their ease of use and quick speed, it is well recognised that the statistical approaches have several drawbacks. First, choosing the best statistical approaches is a difficult process. It needs information from "experts." Second, they typically do not produce outcomes that are extremely promising in terms of performance. In instance, statistical models typically perform poorly than more advanced techniques like artificial intelligence techniques. Third, because fashion sales have a very irregular pattern and are influenced by a variety of variables, including seasonality and fashion trends, they may not accurately predict future sales.

3. AI FORECASTING TECHNIQUES FOR FASHION REPLENISHMENT SYSTEM

AI techniques are developing along with computer technology. In reality, "arbitrarily nonlinear" approximation functions can be effectively derived by AI models straight from the data. The first type of models used for predicting fashion retail sales are artificial neural network (ANN) models [15] and fuzzy logic models since they are widely used in the literature. ANN models have been created and deliver positive outcomes in several areas [16–18]. Frank et al. [3] investigate the application of an ANN model for fashion replenishment forecasting in the literature on fashion forecasting. The ANN model performs the best when compared to two other statistical approaches in terms of anticipating outcomes. The evolving neural network (ENN) model, a promising global searching strategy for feature and model selection, has then been applied to the forecasting of fashion sales. To be more precise, Au et al. [19] constructed an optimal neural network structure

for forecasting fashion sales after using ENN to find the best structure for a forecasting system. They claim that for items with characteristics of low demand uncertainty and mild seasonal patterns, the performance of their suggested ENN model outperforms the conventional SARIMA model.

Zadeh [20] introduced the idea of fuzzy sets, and it has been used in many different contexts. Sztandera et alinnovative's multivariate fuzzy model for predicting fashion retail sales is based on key product factors including colour, timing, and size. For each size-class combination, sales numbers are computed using the aggregated data in its suggested model. They discover that their suggested multivariable fuzzy logic model is a useful sales forecasting tool when compared to numerous statistical models, including Winters' three parameter exponential smoothing model (W3PES), the neural network model, and the univariate forecasting methods. The capacity of the fuzzy logic-based models to recognize nonlinear correlations in the input data is what gives them their strong performance. The multivariate fuzzy model also outperforms its univariate counterparts in terms of performance. Later, Hui et al. [28] investigate the fashion colour forecasting demand prediction problem. To perform forecasting, they suggest a fuzzy logic system that combines prior knowledge of colour prediction with a learning-based fuzzy colour prediction system. They present several encouraging outcomes from their suggested approach.

Although performance indicators like the mean-squared error show that ANN and ENN models perform well in terms of producing high forecasting accuracy, these forecasting models take a very lengthy time to accomplish the forecasting assignment. In other words, they take a lot of time. These models all make use of gradient-based learning techniques, including backpropagation neural networks, which is why there is such a downside (BPNN). The extreme learning machine (ELM) based models have appeared as a solution to this issue. In reality, ELM is a well-known super-fast approach that may effectively avoid issues with over-tuning, local minima, halting criteria, learning rate, and learning epochs. ELM has been used in the literature to anticipate fashion sales, and its performance has been shown to be superior to numerous backpropagation neural network-based approaches [19, 20]. In actuality, Sun et al [11] 's pioneering application of ELM for fashion sales forecasting. They look at the connection between sales volume and key demand-influencing elements (e.g., design factors). However, ELM's most significant flaw is that it is "unstable," since it might provide different results in every run. An extended ELM approach (EELM), which computes the forecasting result by repeatedly executing the ELM for many times, is suggested in [17] as a solution to this problem. The number of repeating repetitions is undoubtedly a crucial EELM element, and it is estimable.
Table 1 lists the typical publications that anticipate fashion retail sales using just AI techniques. ELM and ELM are not flawless, despite being quicker than traditional ANN and ENN based forecasting models. ELM is unstable, and it will still take a long time for EELM to do prediction. To put it another way, there are situations where they might not be effective. The same holds true for other pure statistics and pure AI techniques. In order to improve fashion retail sales forecasting, numerous hybrid models have been created in the literature by focusing on various angles.

TABLE 1:
An overview of fashion sales forecasting using AI techniques.
Method

Method			
	Paper	**Area**	**Finding**
ANN	[3]	Sufficient data	The two statistical-based models are outperformed by the ANN model.

Fuzzy	[15] [18]	Short term Sufficient data Colour	For short-term forecasting, multivariate fuzzy analysis is superior to univariate analysis. Although the fuzzy colour prediction technique is superior to the conventional method, it only works for single-color predictions.
ENN	[19]	Low demand uncertainty and weak seasonal trends Short term	In terms of performance, ENN outperforms the conventional SARIMA model for goods with weak seasonal patterns and low demand uncertainty.
ELM	[21]	Color, size, and price as significant factors	Several backpropagation neural network-based sales forecasting techniques are outperformed by ELM.
EELM	[22]	Fast forecasting	EELM is flexible in that it may be applied to make short-, medium-, and long-term forecasts using both time series and non-time series data.

4. HYBRID FORECASTING METHOD FOR FASHION REPLENISHMENT SYSTEM

To create a new forecasting approach, hybrid forecasting techniques typically build on the advantages of many existing models. Many of these are therefore seen to be more effective than pure statistical and AI models. It is not unexpected that several research papers have recently examined hybrid forecasting systems, such as [13, 15-19]. In the literature on fashion forecasting, hybrid approaches are frequently used to mix several models like the fuzzy model, ANN, and ELM with other methods like statistical models, the grey model (GM), and so on. The literature on hybrid approaches is reviewed in the sections that follow.

4.1 Hybrid methods using Fuzzy Logic

The pioneers in the research of fuzzy based hybrid fashion fore- casting approach is Vroman et al. [15]. They arrive at a fuzzy-adaptive model that regulates the weighting elements of a statistical "Holt-Winter" forecasting technique that uses exponential smoothing. They demonstrate that the suggested fuzzy hybrid model works better than the traditional Holt-Winter approach. They also argue that the approach they present may be used to anticipate sales of new fashion items. After that, Thomassey et al. [12] do fashion forecasting using the fuzzy logic approach. Their novel model enables automated learning of the effect of the nonlinear explanatory variables. You should be aware that their methodology necessitates a subjectivity-based expert opinion for the learning process, which makes it difficult to apply it in the fashion retailing market. A forecasting system based on various models, including fuzzy logic, neural networks, and evolutionary processes, is proposed by Thomassey et al. in [12]. They contend that the outcome is flexible in handling the unclear facts. Forecasting for rapid fashion recently used a hybrid fuzzy model by Yesil et al. [17]. To be more precise, forecasting is done by combining the statistical model and the fuzzy logic model. The weighted average of estimates produced by several methodologies is used by the hybrid approach to get the final forecast for weekly demand. They contend that their suggested strategy produces excellent accuracy.

4.2 Hybrid methods using Neural Network

Vroman et al. [20] use a neural network (NN) model with correction coefficients of the seasonality characteristic for mean-term forecasting in NN hybrid models. They contend that forecasting for brief and discontinuous time series may be done using their suggested hybrid methodology. They report positive findings using their suggested NN hybrid model, and they feel that the MAN's capacity to map the nonlinear relationship between data inputs and outputs is what accounts for the excellent performance. To predict sales of new clothes products, Thomassey and Happiette [12] create a hybrid neural clustering and classification technique. Comparing their model to the mean sales profile predictor can improve the accuracy of midterm forecasting. The Grey method (GM) and the autoregressive approach are two more techniques that may be coupled with ANN. For instance, Ni and Fan [14] apply a two-stage dynamic forecasting model for fashion retail forecasting that incorporates neural network and auto regressive approach. In their approach, Ni and Fan create a multivariable error forecasting model using neural networks. In their paradigm, "impact factors" are divided into two separate stages and the idea of "influence factors" is developed (long term and short term). The computational experiment demonstrates that the multivariable error forecasting model may produce accurate prediction outcomes for issues with predicting fashion retail sales. The fuzzy inference system with an adaptive network is a new system created by Aksoy et al. [18] that combines the fuzzy approach and neural networks. Their new system proposal combines the strengths of the two existing systems—specifically, the fuzzy logic technique's ability to generalise and neural networks' capacity for learning—to create a hybrid that is both effective and efficient. Choi et al[23] .'s most recent work uses a hybrid model based on ANN and GM to anticipate fashion sales with regard to colour. They contrast GM+ANN hybrid models, ANN, GM, Markov regime switching, and GM. They show that, in the absence of many historical data points, the GM (1,1) and ANN hybrid model performs the best for predicting fashion sales by colour.

4.3 Hybrid methods using ELM

The forecasting process is completed quickly by the extreme learning machine (ELM) [15]. Although its instability prevents it from being flawless, its "rapid speed" makes it an excellent choice to be a component model for more sophisticated hybrid models for predicting fashion. For instance, Wong and Guo [12] offer a unique neural network-based learning method to first develop an initial sales estimate and then utilise a heuristic fine-tuning procedure to achieve a more accurate final sales forecast. To enhance network generalisation performance, their learning system combines an enhanced harmony search algorithm with an extreme learning machine. They assert that the performance of their suggested model outperforms two more recently created neural network models as well as conventional ARIMA models for predicting apparel sales. A forecasting model based on an extreme learning machine model with adaptive measures is examined by Xia et al. [16]. Their model's inputs may address the issues of amplitude adjustment and trend identification, which lessens the impact of overfitting networks. ELM and Grey relational analysis (GRA) are used in a hybrid fashion colour forecasting system developed by Yu et al. [17]. Their computer analysis of actual empirical data demonstrates that their suggested model performs better in predicting fashion colour than several other rival models.

4.4 Other Hybrid Models

The literature on forecasting fashion sales also mentions a few other creative hybrid forecasting combination approaches in addition to the sorts of hybrid methods covered above. For instance, Choi et al [18].'s hybrid SARIMA wavelet transform (SW) approach is used to anticipate fashion sales. They demonstrate that their suggested SW technique outperforms the traditional statistical methods with relatively weak seasonality and a highly

changeable seasonality component using actual and synthetic data. They state in their conclusion that the SW approach is appropriate for doing fashion industry erratic demand forecasting. A hybrid approach created by Thomassey and Fiordaliso [12] is based on a decision tree classifier and an existing clustering algorithm. When there is no prior sales data for new goods in the fashion retail industry, their proposed hybrid technique can be effective for predicting the sales profiles of those things. A combination technique that uses the decision tree method and autoregression is established by Ni and Fan [22]. (Called ART method). They claim that their hybrid approach has excellent performance for predicting fashion sales.

5. APPLICATION IN FASHION INDUSTRY

In the realm of fashion commerce, predicting sales is a genuine issue. There are several challenges that are noted from the standpoint of applications and implementation.
Most of the forecasting models in use today are suited for medium- and long-term forecasting, to start with, in terms of the forecasting horizon. Short-term forecasting, even the extremely short-term kind like real-time forecasting, hasn't been well studied yet. Given how the fashion business is structured, this type of short-term forecasting is crucial (the fashion trend is unpredictable, and the lead time is very short). We learn from the examination of the literature that the fuzzy logic-based strategy has been used for short-term fashion sales forecasting, among other things, in [15, 18, 19, 22]. We therefore contend that fuzzy logic-based models, when used in real-world applications. Therefore, we contend that for actual implementations, fuzzy logic-based models, together with other quick models (such statistical approaches), might be strong candidates for actual implementation as a system for forecasting short-term retail sales.

Second, there are two different product types that need to be forecasted: an existing product and a new product. Due to the lack of prior sales data, forecasting for new items appears to be far more involved and challenging than forecasting for currently available products. There are few studies of new item forecasting in the literature now in circulation (e.g., [18-22]), but relatively few works examine new item forecasting in the fashion sector, with the following exceptions: I A fuzzy and Holt Winter hybrid approach is investigated in [13], a neural network-based hybrid method is described in [19], an ANN-based hybrid method is presented in [21], and an item classification method is employed in [22]. Evidently, the AI approach is commonly employed for new item forecasting. This is true because the AI technique may produce a more accurate result by better identifying the properties of the data. For this reason, you'll also see that the categorization approach is used in new item forecasting. The knowledge and statistics available when projecting a new item are quite few. We must intelligently extract the relevant information from the given data to obtain more information. Therefore, for this purpose, a systematic categorization scheme is essential.

Third, statistical approaches may often produce the predicted findings rapidly. AI techniques typically take more time. The lead time in the fashion business used to be a little bit greater than it is now, and it might be ten months or even a full year. A quick response approach with a very short lead time is being used by fast fashion firms like ZARA, H&M, and Mango because of changes in the sector (e.g., 2 weeks in Zara for some products). Therefore, any forecasting programme for these firms must have forecasting results accessible in a relatively short period of time. According to the studied literature, we can conclude that ELM [15] is an excellent candidate to work in the field of "rapid fashion forecasting" when combined with statistical techniques because of its high speed. Additionally, the fuzzy combiner approach [19], which makes predictions by merging the forecasts of many methodologies using fuzzy logic, can be utilized to investigate the issue of quick fashion forecasting.

6. CONCLUSIONS AND FUTURE RESEARCH

In this paper we have undertaken a thorough analysis of the literature on predicting fashion retail sales using different methods. We have looked at the benefits and cons of several analytical techniques for predicting fashion retail sales. Additionally, we looked at relevant concerns pertaining to practical implementations of the fashion retail sales forecasting models.

It is noteworthy to note that, although being widely used in the sector, pure statistical approaches have not been extensively researched in the literature during the previous 15 years. The causes are listed below. They have previously been extensively researched, and they cannot produce competent predicting results on their own. All recent research focuses on AI and hybrid models. Over the past 15 years, there have been a few studies on pure AI models. The feature of forecasting fashion sales, however, makes it clear that pure AI (with a single approach) models are likewise unable to produce the most accurate forecasting results. As a result, studies using a hybrid model are more common than others, notably in the last four years. Therefore, we think that investigating more sophisticated hybrid models for predicting fashion retail sales is still an important issue.

Finally, we outline a few potential future study areas below to wrap up this work:

- There are three different types of data that may be used for fashion retail sales forecasting: time series data, cross-section data, and panel data. The methods used to analyse time-series data are also well established. Time-series data is a type of data that is gathered over discrete time periods and is frequently utilized in fashion forecasting. In one time-period, cross-section data are gathered over sample units, while panel data track individual microunits over time. The utility of these two types of data for projecting fashion sales is still limited. It would be fascinating to study how these various forms of data might be used for forecasting fashion sales in the future. Recently, a forecasting system employing panel data was established in [22].

- One important component of fashion is colour, which is closely tied to planning the manufacturing and inventory of fashion apparel goods. Only a very small number of earlier research (such as [14, 20–22, 23]) have explored colour forecasting, according to the literature review. As a result, more research on this subject may be done. Additionally, no earlier study has looked at the impact of fashion pattern design and other design elements on demand and the associated sales forecasting methodology. It is yet another intriguing subject for more research.

- The sales of garment products in the fashion retail sector are significantly impacted by calendar factors, such as holidays. It is obvious that sales would increase significantly and swiftly on National Day holidays in Hong Kong and on Black Friday in the USA. On the one hand, the demands around these dates are significantly more erratic and unpredictable. On the other hand, these times can also result in significant increases in revenue. As a result, fashion retailers must learn how to accurately predict the demand around specific dates or events. This adds another area that might be studied in the future.

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