AI based forecasting in fast fashion industry: a review

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Abstract. The textile and clothing sector is considered as one of the driving sectors of the Moroccan economy. It occupies a highly strategic position given the importance of its contribution in terms of growth and jobs. This sector, which is undergoing profound changes essentially linked to progressive dismantling of the Multi-Fibres arrangements (MFAs) that have governed trade long years, remains by far the largest export sector in the Moroccan industry. In this environment where competition will become more and more fierce, the ideal for a textile company is to produce exactly the products that its customers will buy. This ideal is unfortunately impossible, except in very special case where the company starts to manufacture from the receipt of the order of the client. Thus, in order to make the decisions relating to its proper functioning and to its durability, the company must rely on a reliable forecasting system. Such a system allows to achieve a competitive advantage by minimizing supply chain costs, avoiding shortages and minimizing financial losses due to the balance of unsold items.

The purpose of this article is to make a review of the literature on fashion retail sales forecasting methods. We have explored different kinds of analytical methods for fast fashion retail sales forecasting, their features and characteristics. From the reviewed literature we got a synthetic view of the pure statistical models, the pure Artificial Intelligence (AI) models, and the hybrid models.

Key words: Fast fashion, textile, forecasting, pure statistical models, artificial intelligence, hybrid models, supply chain.

1. Introduction
The textile and clothing sector is considered as one of the driving sectors of the Moroccan economy. It occupies a highly strategic position given the importance of its contribution in terms of growth and jobs. This sector, which is undergoing profound changes essentially linked to progressive dismantling of the Multi-Fibres arrangements (MFAs) that have governed trade long years, remains by far the largest export sector in the Moroccan industry.

In this environment where competition will become more and more fierce, the ideal for a textile company is to produce exactly the products that its customers will buy. This ideal is unfortunately impossible, except in very special case where the company starts to manufacture from the receipt of the order of the client [1]. Thus, in order to make the decisions relating to its proper functioning and to its durability, the company must rely on a reliable forecasting system. Such a system allows to achieve a competitive advantage by minimizing supply chain costs, avoiding shortages and minimizing financial losses due to the balance of unsold items.

Sales forecasting is both necessary and difficult. It is necessary because it constitutes the point of a large number of business management tools: supply chain, retail logistics, production schedules, production plans and financing, marketing plans, cash flow plans, etc. [2]. It is difficult because it is out of our scope, whatever the quality of the methods adopted, to read the future with certainty as long as
the parameters that come into play are numerous, complex and often unquantifiable, in any field whatsoever, and in particular that of textile-clothing which is distinguished by its unstable character and its vulnerability to disturbances from different sources (fashion phenomenon, climatic and economic variations, social events, etc.).

2. Literature review

We have conducted a review of fashion retail sales forecasting literature. We have depicted the characteristics of different kinds of analytical methods for fashion retail sales forecasting. We have also reported, through this review, the main findings related to real-world applications of the fashion retail sales forecasting models in the papers reviewed. From the reviewed literature, we got a summarized view of the pure statistical models, the pure Artificial Intelligence (AI) models, and the hybrid models. As in the industry sectors, the forecast of sales in fast fashion, has been mainly realized by the statistical forecasting methods such as: the moving averages, the linear regression, Bayesian analysis, the exponential smoothing (with & without trend) and double exponential smoothing.

To clarify the approach of multiple methods and techniques of sales forecasting, several classifications are commonly used: according to the term (short, medium, long-term methods), the sector of activity (industrial products, consumer durables, goods of great consumption, services, etc.), the technique used (econometric modeling, decomposition, exponential smoothing, Holt-Winters, Box-Jenkins, etc.), the nature of the data and their treatment (quantitative, qualitative methods), etc.

In R. Maricourt [2], one can find a classification in two approaches:

1. A pastist approach, based on the analysis of the past and the extrapolation of it into the future. Methods of this type, essentially quantitative, can themselves be subdivided into two great families based on different principles:
   a- Endogenous methods working only on directly related historical data to the phenomenon treated;
   b- Exogenous methods that are not content, like the previous ones, with a single causal variable, time, but by conducting a systematic analysis of one or several other explanatory variables.

2. A futuristic approach, often qualitative approach more directly connected to the exploration of the future while incorporating available elements of knowledge of the past. Futuristic methods seek to get as close as possible to men who are in the business of sales; is the questions, we simulate their behavior, we integrate them as much as possible in the elaboration of projections. These methods also give importance to abrupt changes in the environment, geo-political (revolutions, wars) or technological (discoveries scientists, development of new materials, etc.).

2.1. Pure Statistical Methods

In traditional fashion sales, forecasting is realized by the statistical methods such as moving average, weighted average, linear regression, Bayesian analysis, exponential smoothing, exponential smoothing with trend, double exponential smoothing, etc.

More sophisticated tools such as ARIMA and SARIMA are widely employed in sales forecasting for statistical time series analysis [3]. It is simple and easy to implement these methods and the results can be computed very quickly because they have a closed form expression for forecasting. Bayesian analysis is also very studied in the literature. Green and Harrison [4] apply a Bayesian approach to perform forecasting in case of a ladies dresses company. Thomassey et al. [5] use products segmentation to check the reliability of sales forecasting for new products. They stated that a wide range of product families and adequate segmentation criteria are necessary in order to achieve a reliable forecasting. They conclude that individual product’s forecasting is less accurate than the product family and aggregated forecasting. Mostard et al. [6] proposed on a case study of an apparel company, a “top-flop” classification method and stated that it runs better than other methods. In addition, they found that the expert judgment methods is more effective, for a small aggregation of products, than the advance demand information method. The applicability of a hierarchical Bayesian approach for fashion demand
forecasting was examined in *Yelland and Dong* [7]. The authors found that the approach yields superior quantitative results in comparison to other methods.

Hereafter in Table 1, a summary of most popularly used methods:

| Method              | Paper | Findings                                                                 |
|---------------------|-------|---------------------------------------------------------------------------|
| ARIMA and SARIMA    | [3]   | Closed form expression for forecasting, Easy to implement, Results can be computed quickly |
| Bayesian approach   | [4]   | Efficient for mail order fast fashion company, A wide range of products families and adequate segmentation criteria are conditions of forecasting precision, The individual product’s forecasting is less accurate than product family and aggregated forecasting |
| Top flop method     | [6]   | It performs better than other methods, The expert judgment methods outperform the advance demand information method for a small group of products. |
| Hierarchical Bayesian approach | [7] | Applicability of a Bayesian forecasting model for fashion demand forecasting, Yields superior quantitative results compared to many other methods. |

Contribution on pure statistical methods are relatively rare in the literature over the last decades. This could be explained, in one hand, by the fact that the mathematical methods are enough fixed and stabilized. On the other hand, it is well known that these methods have some weaknesses:

- The choice of the suitable statistical methods is a difficult task that requires an “expert” knowledge.
- These methods do not output very reliable results compared to the methods such as AI methods.
- These methods may fail to achieve an enough good forecasting outcome because fashion sales are impacted by multiple variables such as the fashion trends and seasonality and exhibit a highly irregular pattern [8].

2.2. **AI based methods**

AI models came with strong advantages such us the capability to derive directly from the data “arbitrarily nonlinear” approximation functions. Hereafter a summary of this emerging methods that takes more and more advantage from computer science performance:

| Method      | area            | Features and strengths                                                                 |
|-------------|-----------------|----------------------------------------------------------------------------------------|
| Artificial Neural Network (ANN) | Sufficient data | The AI forecasting models pioneer in fashion retail sales, Satisfactory results in various areas [9]. |
| Fuzzy logic | Short term Sufficient data Color | Fuzzy theory sets is suggested by Zadeh [10], Multivariate model based on various product variables such as time, color, and size [11]. |
Evolutionary neural network (ENN) model | Low demand uncertainty and weak seasonal trends | Search for the ideal network structure for a forecasting system, and then develop an ideal neural networks structure [12] Outperforms better than SARIMA for in case of products having low demand uncertainty and weak seasonal trends [12]

Extreme Learning Machine (ELM) | Price, size and color as significant factors | Outperforms back propagation neural networks based methods [13, 14]. Disadvantage: “unstable” as it can generate different outcome in each different run

Extended ELM Method (EELM) | Fast forecasting | Overcomes the ELM drawback by computing the forecasting result by repeatedly running the ELM for multiple times.

2.3. Hybrid forecasting methods

The contributions on the hybrid models (i.e. models based on both pure statistical and AI methods) appear most frequently during last decade. As a consequence, we do believe that the topic is still worth exploring to produce more advanced hybrid models for fashion retail sales forecasting.

Hybrid forecasting methods use the strengths of different models together to form a new forecasting method. Many of these models are recognized to be more efficient than the AI models and the pure statistical models [6]. In the following a summary of these methods:

Table 3. Forecasting hybrid models.

| Method | Paper | findings |
|-------|-------|----------|
| Fuzzy Logic Based Hybrid Methods | [15] [16] | Fuzzy hybrid model outperforms the conventional Holt-Winter Allows learning of the nonlinear explanatory variables influence. |
| Fuzzy logic and Neural Networks | [17] | New system called the adaptive network based fuzzy inference system. Combines the learning capability of the neural networks and the generalization capability of the fuzzy logic technique |
| fuzzy logic, neural networks, and evolutionary Neural Network Based Hybrid Methods | [18] | Versatility in processing the uncertain data |
| AN and GM | [21] | Forecasting model with respect to color. Outperforms AN, GM, Markov regime switching |
| ANN, Greymethod (GM) and autoregressive technique | [22] | Use neural network to establish a multivariable error model Uses the concept of “influence factors” Divides the “impact factors” into two distinct horizons (long term and short term). |
| ELM and NN | [23] | It integrates an improved harmony search algorithm and an extreme learning machine & outperforms ARIMA |
| ELM and adaptive metrics | [24] | The inputs fix the amplitude changing and trend determination The over fitting of networks effect is reduced. |
ELM and Grey [25] - Outperforms competing models in fashion color forecasting relational analysis (GRA)

3. Conclusion and perspectives
In fast fashion domain, the global market, fueled by the explosion of new products and new technologies, especially the revolution in transportation and information technology has permitted manufacturers and retailers alike to establish international production and trade networks that cover vast geographical distances.

Through our literature review we found that majority of new contributions are focused on AI methods. However, AI (with a single method) models are not by themselves able to generate accurate results taking into account fashion sales variables. The contributions on the hybrid models appear most frequently during last decade. As a consequence, we do believe that the topic is still worth exploring to produce more advanced hybrid models for fashion retail sales forecasting. This was the main leitmotiv of this literature review.

In our future works, we will focus on the application of the most powerful AI methods mixed with the most popular pure statistical methods (Exponential smoothing and moving average) to real world applications in fast fashion industry.

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