A New Hybrid Model for Dynamic Pricing Strategies of Perishable Products

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Abstract— **The aim of this paper is to mitigation of spoilage rates of perishable products by applying dynamic pricing strategies. The present study is conducted with a deterministic model approach in consideration of various factors, such as interaction between freshness/staleness degrees of different groups of products, elasticity of demand against price and sensitivity of demand towards freshness degree. Different effects of price discounts on customers' attitudes to purchase, contribution of these effects on total profit are found to be significant. Furthermore, in the proposed system, the wastage caused by stale products and recycle products returning to manufacturer for reprocessing, which are two important parameters affecting total profit margin, thus costs of partial returns are significantly reduced furthermore, the renewed dynamic pricing approach treated in the proposed system makes it possible to increase the product sales significantly. The price data is tested via new significant model using PSO and ANN. The results show that the hybrid algorithm gives more profitable and successful results.**

Keywords- Dynamic Pricing in the Supermarkets, Revenue Management, Particle Swarm Optimization, Artifical Neural Network.

I. INTRODUCTION

The competition increasing around the world has started to affect all sectors to varying extents. Organizations have been resorting to various methods for the purpose of alleviating this accelerated impact particularly in recent years. Revenue management activities are among the most commonly resorted methods to this end. Their importance and areas of use are increasing around the world day by day. Organizations today pursue various policies, such as optimization activities to increase their profitability, analysis of product demand structures and accordingly classification of the market they operate in, effective product presentation techniques and effective sale. At this stage, while each organization develop their organization on the basis of their different experiences and develop the most creative and efficient revenue management approaches under advanced technological conditions [1]. To this end, the amount of work dedicated to maximize profits and the number of academic studies on the subject are increasing.

The concept of Revenue Management is widely defined as selling the right product to the right customer at the right price in the literature. Especially in recent years, this concept has started to be even more productive and rewarding for organizations, thanks to the revenue management tools and techniques developed. This has increased the interest of organizations in the revenue management activities every day and transformed many management techniques from theory into practice. Transformation of the innovative activities performed for large organizations into practice today may bring along big risks. Both the difficulty of effective application of the improvements in daily life and the dynamic nature of the responses to be shown by customers to the innovation further increase the uncertainty of system, thereby causing the system to be more risky. Under the light of these uncertainties, it is a must to define the system in the best way [2]. The next most important step would be determination of the gaining's of innovations in the best way. The literature review revealed that various previous studies treated many different important parameters as separate constraints and examined the effect imposed by these constraints as a whole on revenue management. However, the literature review offers no study analyzing the effects of variations of product with different significance levels on each other's sale rates, under the same constraint [17].

Retail sector offers a wide range of products. Due to the fact that it shelters many different systems, the dynamic of the system is very difficult. Supermarkets, which have a very important place in retail sector, are becoming more and more complicated day by day, because of the difficulty of tracking customers of different profiles simultaneously, product diversity and intensive stocks they have. While advance researches on balancing in revenue management activities continue, literature review unfortunately yields no result for researches where different variations of the same product with different dates of entry to the stock are not considered as a constraint in sale policies.

Having departed from this fact, the present study aims to include the effect of freshness status of the perishable product stocks on their prices during simultaneous sale of perishable products arriving the organizations at different

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times upon order. In other words, the present study is set to determine sale prices of more than one product group of the same product, when different stocks of a product with different freshness status are offered in sale simultaneously. At this stage, multiplier effect of products' staleness rates on each other is analyzed and a new point of view will be offered in respect to the customers' attitudes towards price-freshness-purchase. The present study also seeks to provide profit maximization with a new mathematical model to be developed in consideration of the multiplier effect imposed by remaining shelf lives of products on the pricing of each product on others. A mathematical model of the system is created and the model is solved with GAMS software program under the scope of the study. To this end, these data which are taken from the GAMS software are tested by using new hybrid model based Particle Swarm Optimization (PSO) and Artificial Neural Network (ANN). The results are shared in the following parts in details.

II. LITERATURE REVIEW

The concept of Revenue Management is widely defined as selling the right product to the right customer at the right price in the literature. The literature review revealed that various previous studies treated many different important parameters as separate constraints and examined the effect imposed by these constraints as a whole on revenue management. However, the literature review offers no study analyzing the effects of variations of product with different significance levels on each other's sale rates, under the same constraint.

After 2010, most of the studies try to continue to get higher profitablity and spoilage reduction. In addition to this, the customer payment willingness is assumed fixed and the product returns are ignored. However, ignorance of the business conditions of enterprises can be also determined a loss of important data. The review articles are considered as the source of this information [4, 6, 7, 10, 18].

Recently some researchers try to reduce the amount of perishable products spoilage by using dynamic pricing. The effects of some factors such as price elasticity and age-sensitivity of demand and age profile of initial inventory are modeled via deterministic mathematical modelling. The price discounts are differentiating via scenarios and also the effects on total revenue and waste are determined in details [20, 21].

One of the other important parts of this study is using the heuristics to test all data. Thus, some related literatures are examined in following. One of the earliest study in this field is Venu G. Guside and Ganesh K. Venoyagomoarthy's study. They focus on Back Propagation and Particle Swarm Optimization (PSO) algorithm together for training Neural Network (NN). The results show that the feedforward NN weights converge faster with the new algorithm design via PSO instead of design BP algorithm.

Mahmood Rahmani aims to investigate PSO and Genetic Algorithm (GA) to evaluate the ANN in connecting with autonomous robots and compare the results for both methods. It's determined that PSO produces better results than GA for smaller networks, thought PSO is worst optimizing for longer networks. Jan Karwowski, Michal Okulewicz and Jaroslow Legierski try to solve a mobile GSM network terminal localizing problem in a building. They use PSO algorithm to train Multilayer Perceptron (MLP). The data trained bu using PSO and the results show that PSO make the system more successful. The hybrid model gives better results than BP algorithm. In one of the related work, Diptom Dutta, Argha Ray and Koustav Choudhury also try to improve the performance of ANN by using PSO for classification of IRIS data. With this paper, unknown data can be predicted more easily via using Backpropagation learning algorithm.

Farahnaz Sadoughi, Mustafa Ghaderzadeh, Mahsen Salimany and Rebeca Fein consider a hybrid Backpropagation Neural Network classifier based PSO method for detection of Prostate Cancer. Nearly 360 medical data is collected from the patients to train and test the new design system. The comparison of the system clearly shows that new hybrid model (BPNN-PSO) achieved very high diagnosis accuracy like as %98.

Beatriz A. Garro and Roberto A. Vazquez focus on ANN design using PSO. A new model of PSO called NMPSO is designed and tested with complex data such as breath cancer and liver disorder datasets. Eight different fitness function are proposed to evaluate the fitness of each solution and find the best design.

Er. Jagdeep Kour and Jatinder Singh's study is analyzed the stress on PSO based evolutionary technique and its hybrid with NN when the system try to be trained, the connection weights are changed in the training sets.

Mohammed E. El-Telbany and Samah Refad provide a new system design for Complex-Valued NN Trainings by using PSO strategy for drug industry. In this study, a new CVNN model tested on two drug sets in real world. The comparison result shows that the prediction and generalization ability of CVNN has unsurpassed results when it compare with the real world NN. In addition to this, CVNN works much faster than the RVNN's application in most of the test data.

III. THE REAL SYSTEM DEFINATION AND THE NEW HYBRID SYSTEM MODELLING

Under the present study, dynamism of pricing of the system modeled with GAMS software program varies according to the staleness degree of product stocks. The present study explored two different scenarios in line with differences among stocks in terms of age profiles (freshness status) and different dynamic pricing strategies. These scenarios sought to maximize profit by using different pricing formula. In the first scenario, pricing is made dynamic with the assumption

that pricing of each stock of a product is affected only by its own staleness degree. The second scenario assumed that staleness degree of different stocks of a product on shelves simultaneously have multiplying effect (all stocks on shelves are affected by the staleness rate and their prices are determined accordingly). The results obtained through these scenarios are compared with the real size of order (stock amount), sale prices and sale amounts of a real and big supermarket with high profit margin in our country. The system comparisons based on the findings obtained are presented in the concerned tables and figures.

TABLE 1: Pricing Types Applied In the New Scenarios

Scenario Number	Pricing Type	Dynamic Interaction Type
1	High	-
2	Medium	Only Each Freshness of The Same Product
3	Low	Freshnesses of Every Stocks

The present study analyses the impact of dynamic pricing on total sale amount, total profit and spoilage amount. It is assumed that the system operates continuously and it can be renewed under deterministic demand within a determined period of time (orders are placed continuously) and that the demand has price elasticity.

The degree of response shown by consumers (sensitivity degree) to changes in price in the form of changing the amount of product they buy is defined as price elasticity of demand. In the present study, elasticity of price is provided with a coefficient. At the stage of modeling, perishable products, their stocks and the number of days they have remained on shelves are stated separately. It is assumed that the product does not have starting stock and that the number of product stocks is controlled separately every day. The intervals between the orders placed are not fixed. In addition, it is assumed that the duration within which orders are delivered to supermarkets and the sizes of orders are variable.

TABLE 2: Sample Product Scenario Based Pricing

The Day	Freshness Rate	High Price	Medium Price	Low Price
1	1	10,000	10,000	10,000
2	0,93333333	9,977	9,513	9,355
3	0,86666667	9,908	9,106	8,763
4	0,8	9,790	8,187	8,247
5	0,73333333	9,625	7,708	7,837
6	0,66666667	9,414	7,289	7,567
7	0,6	9,159	6,703	7,484
8	0,53333333	8,865	6,293	7,431
9	0,46666667	8,538	5,927	7,512
10	0,4	8,183	5,488	7,759
11	0,33333333	7,806	5,147	7,806
12	0,26666667	7,415	4,841	7,415
13	0,2	7,015	4,572	7,015
14	0,13333333	6,612	4,335	6,612
15	0,06666667	6,213	4,130	6,213

The products with 0 shelf-life and the unsold ones are defined as stale products and they are removed from shelves. For this reason, different stocks of products are sometimes displayed on shelves simultaneously, and same group stocks of a product with the same shelf life are also sometimes displayed on shelves together. The system of the proposed model continues to work until at the end of the market decision period. The data which are taken from GAMS for these pricing strategies are as below in details. A sample product is used to determine the system clearly. This product is come to the supermarket in 1th day of the system. And this product shelf life is 15 days. Thus, the product is priced according to different price policies from day 1 to day 15 in Table 2. The products become waste in 16th day of the shelf life.

TABLE 3: Different Type of Pricing Attitudes

The Day	Freshness Rate	High Price	The Hybrid Model High Price	Medium Price	The Hybrid Model Medium Price	Low Price	The Hyrid Model Low Price
1	1	10,000	10	10,000	10	10,000	10
2	0,933333333	9,977	9,88	9,513	9,88	9,355	9,5684
3	0,86666667	9,908	9,8456	9,106	9,8456	8,763	9,0756
4	0,8	9,790	9,6581	8,187	9,05978	8,247	8,9135
5	0,733333333	9,625	9,5498	7,708	8,6248	7,837	8,4956
6	0,666666667	9,414	9,5278	7,289	8,0648	7,567	8,0945
7	0,6	9,159	9,2485	6,703	7,916	7,484	7,7614
8	0,53333333	8,865	9,0245	6,293	6,9125	7,431	7,6845
9	0,466666667	8,538	8,918	5,927	6,0954	7,512	7,5978
10	0,4	8,183	8,4628	5,488	5,812	7,759	7,318
11	0,333333333	7,806	8,0597	5,147	5,3846	7,806	7,248
12	0,266666667	7,415	7,759	4,841	5,0861	7,415	7,0245
13	0,2	7,015	7,3974	4,572	4,675	7,015	6,9759
14	0,133333333	6,612	7,1946	4,335	4,4956	6,612	6,8456
15	0,066666667	6,213	6,7924	4,130	4,2978	6,213	6,5426

Partical Swarm Optimization (PSO) is a complex stochastic algorithm and used for getting heuristic solutions. This algorithm optimizes the complex systems and mathematical functions. Another using type of PSO is to be defined as a training algorithm for Artificial Neural Network.

In this study, ANN parameters are optimized by the PSO algorithm. Thus, the pricing strategies in different scenarios try to be optimized by this new hybrid model. The results are compared with each other in details are shown as Table 3.

FIGURE 1: The High Pricing Strategy of the Hybrid Model

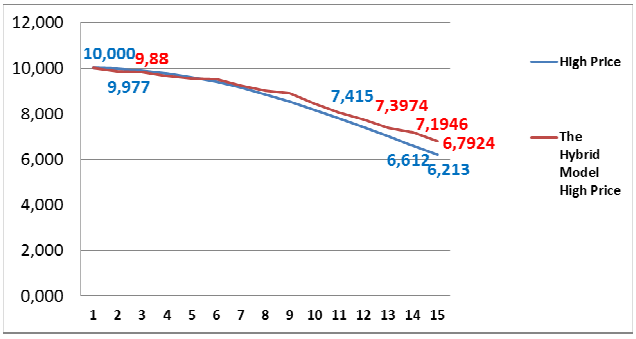
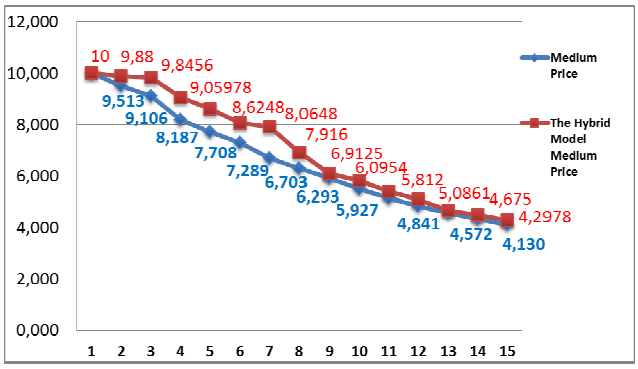


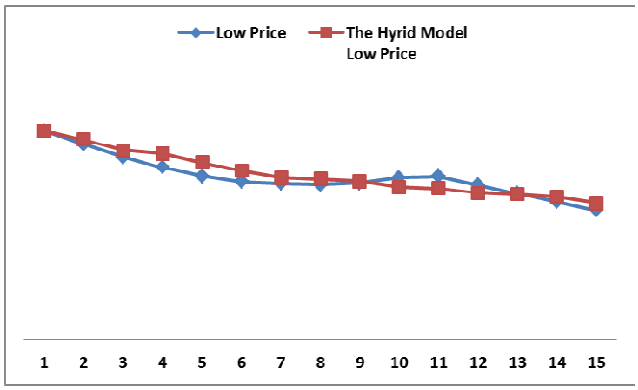
FIGURE 2: The Pricing Solutions for Medium Pricing Strategy



There are 3 different pricing types are determined in this paper. Firstly, high, medium and low pricing types are modeled mathematically. Then, a new hybrid model is designed for this complex problem. It is clearly seen in Figure 1 that hybrid high pricing is so closed to real system high pricing at the beginning of the shelf life. However, after 50 percent of shelf life's gone, the difference between both approaches is increased.

Although high pricing strategies are so closed to each other firstly as seen in Figure 1, it starts different for medium pricing. However, Figure 2 shows that the prices are so closed to each other towards the end of shelf life of the products. The low pricing solutions determine that the hybrid model decreases until the product will be waste. It is shown in Figure 3 that mathematical modelling solutions are decreased first and then increased for a while and then decreased again.

FIGURE 3: Low Pricing Approaches for Hybrid and Real Models



IV. CONCLUSIONS

The mathematical modelling solutions for different pricing types are determined in previous sections. The architecture of the PSO algorithm for the training of ANN is implemented to optimize the pricing solutions. It is clearly calculates from the results that the performance of the proposed model is 1.2 times more profitable than the normal mathematical model pricing. The products are priced via supermarkets management team in real life. Thus, this new hybrid pricing models will be eliminated the waste products and their costs directly. In addition to this, this present study will shed light on future researches and supermarket management team on getting more profit from the perishable products.

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