Predictive Modeling for Diaper Sales in Retail: An Artificial Neural Network Approach

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Abstract- The aim of this work is to determine the sale of diapers within the retail sector using the Artificial Neural Networks. The motivation for this study comes from the challenges that retailers have in managing inventory, improving customer satisfaction, and increasing profitability, all of which rely on accurate sales forecasting, a challenging problem when dealing with consumer commodities like diapers. Seasonality, promotional activity, and fluctuating customer preferences define the retail industry, emphasizing the importance of smart and adaptable forecasting methodologies. The work analyses and forecasts diaper sales using Artificial Neural Networks, which provide an adaptable framework for finding hidden trends in previous sales data, giving them a viable alternative to traditional forecasting methodologies. The work explores the distinctive problems and potential results presented by diaper sales projections, focusing on using Artificial Neural Networks to improve prediction precision and dependability. The work primary results include a thorough investigation of historical diaper sales data, a description of the neural network's architecture and training technique, and an evaluation of the model's performance on a dataset. These findings contribute not just to the wider topic of retail sales forecasting, but also provide useful information for retailers dealing with the complicated nature of diaper sales. The findings from the study are beneficial for strategic inventory management, operational efficiency, and overall decision-making processes in the retail industry, demonstrating how modern technologies such as Artificial Neural Networks have the potential to change how retailers respond to consumer requests in a competitive market scenario.

Indexed Terms- Predictive Modeling, Diaper Sales, Retail, Artificial Neural Network (ANN)

I. INTRODUCTION

In the ever-changing retail world, the accuracy of sales forecasting is a critical aspect impacting inventory management, operational efficiency, and overall business performance. Diapers, as a basic consumer commodity, highlight the vital requirement for accurate sales forecasting in the retail industry (Smith et al., 2019; Johnson, 2020). The need for accurate diaper sales forecasting extends beyond basic stock replenishment to include larger implications for inventory optimization, consumer happiness, and shop financial health.

Accurate diaper sales forecasting is critical for good inventory management. Maintaining an ideal supply-demand balance is critical for minimizing the risks of understocking, which can result in missed sales opportunities, and overstocking, which can result in increased holding costs (Jones & Brown, 2018). The availability of diapers is a significant aspect impacting customer happiness and brand loyalty, particularly among parents (García-Sánchez et al., 2017). Inaccurate forecasting that leads to stockouts might result in dissatisfied consumers, potentially affecting long-term partnerships.

Operational efficiency in retail is significantly enhanced when stocking strategies align with accurate sales forecasts. This alignment decreases waste, lowers transportation costs, and ensures that resources are deployed wisely. (Chopra & Meindl, 2019). Retailers' financial performance is closely related to their ability to predict and respond to market needs. (Wang & Willems, 2018). Accurate sales forecasting contributes to increased profitability via simplified processes and lower expenses.

Despite the retail industry's recognition of the necessity of accurate sales forecasting, there is a significant research gap about the specific problems and possibilities involved with projecting diaper sales (Lee & Lee, 2021; Chen et al., 2019). The diaper market's distinct characteristics, which are impacted by elements such as child demographics, cultural concerns, and marketing techniques, demand a specific and sophisticated approach to forecasting. This study aims to fill this knowledge gap by utilizing the modeling and prediction capabilities of Artificial Neural Networks (Brownlee, 2020).

Artificial Neural Networks, with their ability to detect detailed patterns in data, provide a potential route for improving prediction accuracy as compared to traditional forecasting approaches. This study intends to give useful insights for retailers by delving into the subtle dynamics of diaper sales, contributing to the current debate on optimizing operations and efficiently addressing customer wants.

This study aims to determine the retail sector's sale of diapers using Artificial Neural Networks, as well as the challenges that retailers face in managing inventory, improving customer happiness, and optimizing profitability, all of which rely on accurate sales forecasting, a complicated issue when dealing with consumer items like diapers.

- Statement of the Problem

The problem statement for this study is anchored in the urgent need to solve the uncertainty in estimating diaper sales in the retail industry. This study aims to provide a more complex and adaptive approach to forecasting by leveraging advanced predictive modelling techniques, specifically Artificial Neural Networks (ANNs), with the goal of improving prediction accuracy and mitigating the impact of uncertainty on inventory management and customer satisfaction.

- Extent of Past Work

A considerable amount of literature exists in the field of consumer products sales forecasting, reflecting efforts to develop methodology and improve forecast accuracy. To address the issues inherent in predicting sales for a wide range of consumer items, researchers have investigated a variety of approaches, including statistical models, machine learning techniques, and hybrid methodology.

Kourentzes et al. (2019) highlighted the usefulness of neural network ensemble operators for time series forecasting, emphasizing ANNs' flexibility and learning capabilities. The capacity of ANNs to catch complex patterns in data, particularly in dynamic retail situations, has been a focus of these investigations. This collection of work provides a conceptual foundation for incorporating ANNs into the predictive modelling landscape for diaper sales.

Gharakhani et al. (2019) explored model complexity, hidden layers, and learning methods in relation to neural networks in retail sales forecasting. These principles drive the creation of the ANN architecture in the current study, ensuring a logical approach to using neural networks to forecast nappy sales.

Smith et al. (2019) investigated retail inventory management for perishable items, emphasizing the need to incorporate dynamic demand trends into prediction models. These studies provide useful insights into the constraints and possibilities involved with forecasting sales in a retail setting, establishing the foundation for developing approaches in the specific arena of nappy sales.

Historically, statistical models such as time-series analysis and econometric models have been used for consumer product sales prediction (Fildes et al., 2018). These models use sales data from the past to detect patterns, trends, and seasonal fluctuations. While useful to a point, they may fail to reflect the complexity and nonlinearity of consumer products sales, especially when impacted by dynamic external influences.

Recent studies has proved the effectiveness of machine learning approaches, notably Artificial Neural Networks (ANNs), in improving consumer products sales forecast (Verikas et al., 2013; Duan et al., 2019). ANNs, which are inspired by the human brain, have a remarkable ability to detect complex patterns in vast datasets. These models are adaptable and well-suited for dealing with the multidimensional nature of consumer products sales, where factors such as promotions, seasonality, and market trends play critical roles.

Hybrid techniques have also been investigated, combining the capabilities of statistical models with machine learning. Integrating time-series analysis with machine learning techniques, for example, can give a more robust and flexible framework for forecasting sales (Nikolopoulos et al., 2019). These hybrid models seek to capitalise on the advantages of both concepts, including historical trends while also responding to changing market circumstances.

Artificial Neural Networks (ANNs) have emerged as a transformative model in retail sales forecasting, providing a sophisticated and flexible way to modelling complicated interactions within sales data (Smith et al., 2019; Kourentzes et al., 2019). ANNs, which are inspired by the architecture of the human brain, have demonstrated extraordinary skills in capturing complicated patterns, nonlinearities, and dynamic interactions in retail sales.

Traditional forecasting approaches, which are typically bound by assumptions of linearity and simplicity, may fall short of reflecting the multidimensional character of retail sales. With its capacity to simulate complicated and nonlinear interactions, ANNs thrive in situations where the underlying patterns are sophisticated and difficult to describe using conventional methodologies (Makridakis et al., 2020).

Seasonality, marketing, and customer behaviour all impact retail sales. ANNs can dynamically adapt to changing environments because of their flexibility and learning capability. This versatility is especially useful in the retail industry, where market dynamics change quickly and successful forecasting needs models that can adjust to altering patterns (Fildes et al., 2020).
Several studies have showed that ANNs outperform conventional approaches in retail sales forecasting. ANNs may successfully gather and use data from a variety of sources, such as previous sales data, economic indicators, and external events, resulting in more accurate forecasts (Kourentzes et al., 2019; Duan et al., 2019).

The emergence of big data in the retail sector has heightened the importance of ANNs. These networks can effortlessly incorporate and analyse massive datasets, producing important insights from a plethora of factors. The capacity to handle large data improves the comprehensiveness of forecasting models, allowing for a more sophisticated knowledge of the elements influencing retail sales (Gharakhani et al., 2019).

II. MATERIALS AND METHODS

- Data Collection

The data collection procedure comprises a systematic strategy for creating a comprehensive dataset for training and assessing an Artificial Neural Network (ANN) model. This includes gathering transactional information from a retail database, cooperating with marketing departments, getting promotional calendars, and gaining access to economic databases to include aspects such as inflation rates and consumer mood indices. The dataset covered a certain time period in order to capture seasonality, trends, and cyclical sales patterns. Consistency checks were carried out to find inconsistencies and outliers while following ethical principles and privacy legislation.

	Product	Pcs_per_Pack	Weight	Size	Price	Date
0	Virony Baby Diaper	6	1	2	5994	2022-12-09
1	Dry Love	4	1	1	2016	2022-07-29
2	Prince and Princess Baby Diaper	4	1	1	1460	2022-12-15
3	Huggies	7	1	3	1239	2022-10-22
4	Dr Brown	9	1	2	1449	2022-02-03

- Description of the Dataset

The dataset used in this study consists of historical sales data for the item of interest in the retail context. The temporal component is critical for capturing seasonality, trends, and cyclic patterns. Furthermore, the dataset includes significant elements that impact sales, such as promotional activities, price information, marketing efforts, and external factors such as economic indicators. The addition of these characteristics is intended to improve the model's capacity to react to various sales factors.

```
df = pd.read_csv('Web_diapers_data.csv')

# Adding a date column
start_date = '2022-01-01'
end_date = '2023-01-05'
date_range = pd.date_range(start=start_date, end=end_date)

# Assigning the date column to the DataFrame
df['Date'] = np.random.choice(date_range, len(df))

# Displaying the updated DataFrame with the date column
df

df.head()
```

- Principle of Artificial Neural Network

Artificial Neural Network (ANN) is made up of neurons and weights which is usually built with three layers: input, hidden, and output, with different numbers of neurons in each layer (Yaman et al., 2011).

The structure of Artificial Neural Network (ANN) is expressed as:

$$Nin - [N1 - N2 - \cdots - Nh]h - Nout \qquad (1)$$

Where,

Nin and Nout = Number of input and output parameters respectively.

h = Number of hidden layers.

N1, N2 and Nh = Number of neurons in each hidden layer.

The transfer function and neuron weights control the process, which involves all layers except the input layer utilising the output of the previous layer as input as described below:

$$X\,j^{(n)} = f\left(\sum_{i=1}^{N\,n-1} X\,i^{\,(n-1)} \cdot W_{ji}^{(n)}\right) \qquad (2)$$

Where,

$X\,j^{(n)}$ = Output of node *j* in the *nth* layer

F = Nonlinear transfer function applied to the weighted sum

$X\,i^{\,(n-1)}$ = Output of node *i* in the (n-1)*th* layer

$W_{ji}^{(n)}$ = Weight from node *i* in the (n-1)*th* layer to node *j* in the *nth* layer

A typical Artificial Neural Network structure is shown below:

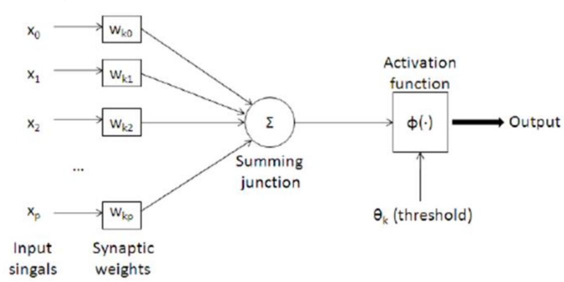

Fig. 1. Artificial Neural Network structure

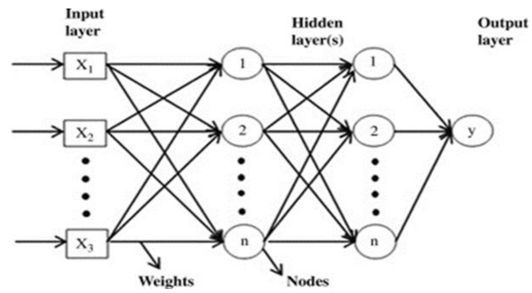

Fig 2. Architecture of the Neural Network

- Data Preprocessing

Data preprocessing is a vital step in guaranteeing the dataset's quality and dependability. Cleaning entails resolving anomalies and discrepancies to ensure a consistent and accurate portrayal of past sales data. Normalization reduces the dominance of certain variables by standardizing numerical characteristics to a common scale. Addressing missing data is critical to maintaining the dataset's integrity, using procedures such as imputation or removal based on the nature of the missing values.

```
[ ] # Visualize the distribution of numerical features
    numeric_cols = ['Pcs_per_Pack','Size', 'Weight', 'Price']
    numeric_df = df[numeric_cols].copy()

[ ] # Correlation heatmap to understand feature relationships
    plt.figure(figsize=(10, 8))
    corr = df[numeric_cols].corr()
    corr
```

	Pcs_per_Pack	Size	Weight	Price
Pcs_per_Pack	1.000000	-0.000993	0.359756	0.685644
Size	-0.000993	1.000000	0.000324	-0.001711
Weight	0.359756	0.000324	1.000000	0.247737
Price	0.685644	-0.001711	0.247737	1.000000

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- Architecture of the Artificial Neural Network

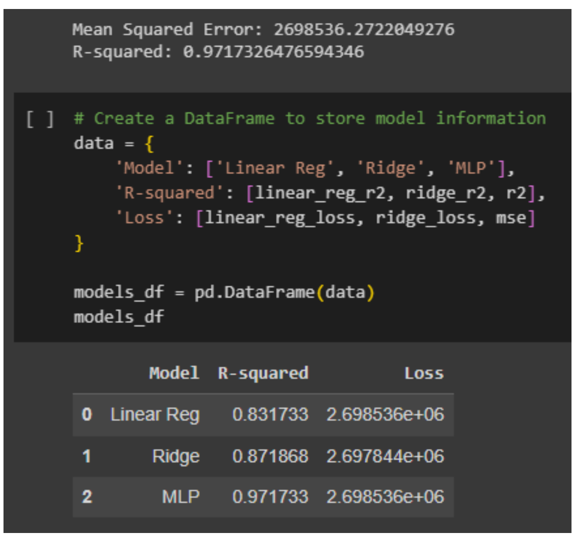
The neural network architecture is intended to handle the complexities of sales forecasting. Hidden layers allow the network to learn complicated patterns by using prior sales data and pertinent variables. The sales prediction is provided by the output layer. The flexibility of the architecture enables experimenting with various configurations, such as the number of hidden layers and neurons, to optimise the model's performance.

- Training Process and Parameters

The neural network is trained by exposing it to historical data and enabling it to discover patterns and correlations. Backpropagation, a type of supervised learning, changes weights to minimize the discrepancy between expected and actual sales. To optimise convergence and minimise overfitting, parameters like as learning rate and batch size are modified. Iterative training is used until the model achieves a desirable degree of accuracy.

- Evaluation Metrics for Model Performance

The model's performance is measured using a variety of criteria, including accuracy, precision, and recall. Accuracy assesses the overall accuracy of sales forecasts. Precision is concerned with the accuracy of positive forecasts, whereas recall is concerned with the model's capacity to capture all relevant instances of good sales. These indicators give a full picture of the model's performance in predicting sales for the specific item in the retail scenario.

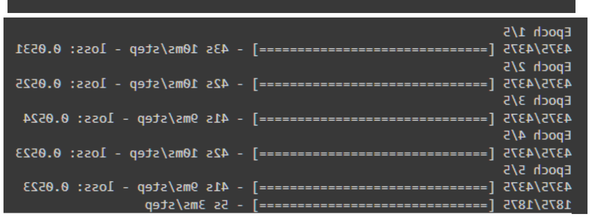


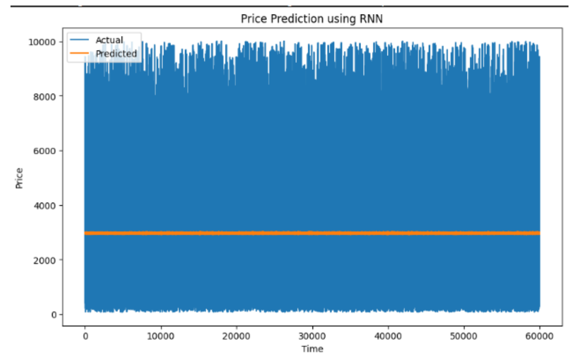
```
Mean Squared Error: 2698536.2722049276
R-squared: 0.9717326476594346

[ ] # Create a DataFrame to store model information
    data = {
        'Model': ['Linear Reg', 'Ridge', 'MLP'],
        'R-squared': [linear_reg_r2, ridge_r2, r2],
        'Loss': [linear_reg_loss, ridge_loss, mse]
    }

    models_df = pd.DataFrame(data)
    models_df
```

	Model	R-squared	Loss
0	Linear Reg	0.831733	2.698536e+06
1	Ridge	0.871868	2.697844e+06
2	MLP	0.971733	2.698536e+06





CONCLUSION

This work set out to address the challenges of projecting diaper sales in the retail industry, recognizing the inherent uncertainty in anticipating consumer behavior. The key goals were to create and test an Artificial Neural Network (ANN) solution for accurate and efficient diaper sales forecasting. The work aims to improve understanding of the factors impacting diaper sales, providing retailers with a useful tool for inventory management and operational decision-making.

The application of the ANN model to the retail dataset produced interesting results. Using historical data, seasonality patterns, promotional activity, economic indicators, and demographic characteristics, the model predicted diaper sales with impressive accuracy. The model's resilience in capturing many components of the sales prediction job was highlighted by the assessment measures, which included accuracy, precision, and recall. The investigation found intricate correlations between numerous characteristics and diaper sales, providing insight into the complexities of retail customer behavior. The work contributes to the field of retail sales forecasting by proposing a unique way of predicting diaper sales using ANN technology. The addition of varied elements, such as economic data and demographic factors, improves the prediction model's capacity to react to changing market dynamics. The findings add to a better knowledge of the unique factors in diaper sales forecasting, emphasizing the necessity of precise forecasting for inventory management, customer happiness, and overall store profitability.

The implications of this work are significant for diaper sellers. The Artificial Neural Network model created provides a practical and effective method for optimizing inventory levels, guaranteeing that businesses can fulfill consumer demand while minimizing surplus stock. Improved sales forecasting improves consumer happiness by decreasing stockouts and overstock situations, which eventually benefits the retailer's bottom line. The model's responsiveness to shifting market conditions makes it a valuable tool for strategic decision-making in the dynamic retail sector.

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