Volume 10, Issue 3, March – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

Optimizing Inventory for Fashion Stores using AI

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Publication Date: 2025/03/17

Abstract: Effective inventory management is critical for the dynamic fashion retail industry, particularly in men's T-shirts. This paper presents an AI-driven solution to address overstocking and understocking, utilizing machine learning techniques to analyze product images and sales data. Key innovations includeResNet-50-based image embeddings for visual analysis, cosine similarity, and FAISS for product matching, combined with predictive modelling for demand forecasting. This approach reduces operational inefficiencies and aligns inventory levels with real-time trends, improving business profitability and sustainability.

Keywords: *Inventory Optimization, Fashion Retail, Machine Learning, ResNet-50, FAISS, Demand Forecasting, Seasonal Trends, AI-Driven Inventory.*

How to Cite: Manisha Dhage; Atharva Hemant Phadtare; Vedant Jayram Kawthalkar; Harsh Amit Mehta; Lobhas Niraj Nivsarkar (2025). Optimizing Inventory for Fashion Stores using AI. *International Journal of Innovative Science and Research Technology*, 10(3), 213-219.
https://doi.org/10.38124/ijisrt/25mar231

I. INTRODUCTION

Effective inventory management is a cornerstone of profitability and sustainability in the fashion retail sector, especially for highly dynamic categories like men's T-shirts. Traditional inventory systems heavily rely on static data and historical trends, which fail to account for rapidly changing consumer preferences, seasonal fluctuations, and emerging fashion trends.

Overstocking leads to increased storage costs, markdowns, and waste, while understocking results in lost sales opportunities and reduced customer satisfaction.

Both scenarios significantly impact business efficiency and profitability.

To address these challenges, this paper proposes an AI-driven Inventory Optimization System. By integrating computer vision, predictive modelling, and real-time analytics, this system provides retailers with dynamic, actionable insights to optimize inventory levels. Features such as image embedding with ResNet-50, product similarity analysis using FAISS, and demand forecasting enable real-time, data-driven decision-making, bridging the gap between traditional inventory methods and modern AI-driven practices.

II. RESEARCH ELABORATION

➢ *Identifying the Problem*

Traditional inventory management systems face several critical challenges, especially in the context of fashion retail:

- **Overstocking:** Excess stock not only occupies valuable storage space but also leads to financial losses through markdowns and unsold inventory.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

- **Understocking**: Insufficient stock levels result in unmet consumer demand, missed revenue, and loss of customer loyalty.
- **Static Data Dependency**: Relying solely on historical sales data does not account for dynamic market factors like changing trends, weather conditions, or evolving consumer preferences.
- **Operational Inefficiencies**: Manual inventory tracking and decision-making processes are time-intensive and prone to errors.

➢ *The Proposed AI-driven System Aims to Mitigate these Issues by:*

- Leveraging machine learning models to predict demand with high accuracy.
- Utilizing computer vision techniques to analyze product features and identify trends.
- Providing real-time recommendations to retailers based on sales data and external factors.

III. LITERATURE SURVEY

The integration of artificial intelligence (AI) and machine learning (ML) in fashion retail has significantly advanced inventory management, demand forecasting, product recommendations, and sustainability. Studies highlight the importance of AI in demand forecasting, with models like LSTM and multimodal attention networks predicting trends and consumer demand. For instance, Cheng et al. (2024) emphasize the need for agile inventory management and flexible production to respond quickly to fast fashion demands. Image-based analysis using models like ResNet-50 has enhanced fashion recommendations, allowing for accurate product matching and compatibility prediction, as discussed by Guo et al. (2023) and Liu et al. (2021). Additionally, sustainability is a key focus, with studies like Cossatin et al. (2024) promoting eco-friendly fashion choices through digital nudges and blockchain technology, ensuring transparency in the supply chain. Real-time analytics and compatibility modelling using tools like FAISS and TryonCM2 optimize inventory by improving demand prediction and stock accuracy based on item interactions and customer preferences. The proposed system improves on existing approaches by integrating these technologies into a unified solution for fashion retail. It utilizes advanced AI models for accurate demand forecasting, real-time inventory tracking, and visual product compatibility, while also supporting sustainable inventory practices by minimizing overstocking and reducing waste. This holistic approach ensures more efficient inventory management, better alignment with consumer trends, and improved customer satisfaction.

➢ *Cheng, T.C.E., Choy, P.W.C., and Wong, R.L.M. (2024). Fast Fashion Supply Chain Management in China: Critical Success Factors and Their Supply Chain Performance Implications. IEEE Engineering Management Review, 52(1).*

To identify the critical success factors (CSFs) in supply chain management (SCM) that drive superior performance in the fast fashion (FF) industry in China, which allows Chinese firms to remain competitive in the global market. Six critical success factors were identified for effective SCM in the fast fashion industry:

- Efficient information sharing across the supply chain.
- Flexibility in production to accommodate rapid style changes.
- Strong supplier relationships.
- Effective inventory management practices.
- Quick response to consumer demand.
- Technology integration in SCM.

Each of these factors is linked to six performance measures that enhance supply chain efficiency, responsiveness, and competitive positioning. The study conducted a large-scale survey targeting fast fashion firms in China. Statistical analysis was used to examine the relationship between identified CSFs and supply chain performance metrics. The study emphasizes the importance of agility and information flow within the supply chain for maintaining a competitive edge in fast fashion. These findings highlight SCM practices that could be beneficial for similar markets or industries focused on rapidly changing consumer demands.

➢ *Guo, Ziyue, et al. "AI Assisted Fashion Design: A Review." IEEE Access, 11 Aug. 2023, doi:10.1109/ACCESS.2023.3306235.*

Aims to survey the integration of artificial intelligence in fashion, specifically in three main areas: fashion analysis, fashion recommendation, and fashion synthesis. It outlines state-of-the-art techniques in each category and highlights potential future research directions. The paper categorizes AI applications in fashion into:

- Fashion Analysis: Popularity prediction and trend analysis.
- Fashion Recommendation: Outfit compatibility and personalized suggestions.
- Fashion Synthesis: Virtual try-on and makeup transfer. The paper discusses various models and methods employed in these areas, alongside their limitations and future research opportunities.
- Fashion Analysis: Utilizes machine learning to predict social media popularity and analyse trends.
- Fashion Recommendation: Incorporates body shape compatibility and visual analysis to suggest suitable outfits.
- Fashion Synthesis: Applies generative models like GANs and virtual try-on networks to simulate clothing and makeup applications.

This survey provides an organized overview of AI techniques currently applied in fashion and identifies challenges and opportunities for enhancing AI-driven fashion solutions, emphasizing the potential of deep learning models in creating personalized and realistic virtual fashion experiences.

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- *Liu, X., Sun, Y., Liu, Z., & Lin, D. (2021). Learning diverse fashion collocation by neural graph filtering. IEEE Transactions on Multimedia, 23.*

Aims to create a flexible and diverse fashion recommendation system that can suggest visually cohesive outfit combinations. The system is designed to handle various garment types, set lengths, and different fashion styles without relying on user preferences.

- The proposed Neural Graph Filtering method outperforms existing methods by over 10% on standard benchmarks in terms of compatibility accuracy.
- It enables more varied and visually engaging outfit suggestions that are well received by users (82.5% preference in user studies).
- Utilizes a graph neural network to represent garments as nodes and their compatibility relationships as edges.
- Incorporates a style classifier with focal loss to balance style diversity and improve the recommendation of lesser-represented styles.
- Evaluates on Polyvore, Polyvore-D, and a reorganized Amazon Fashion dataset.

This approach uniquely addresses both flexibility and diversity in fashion recommendations, presenting a notable improvement in handling inter-garment relationships. The paper also introduces new evaluation protocols and reorganizes a large dataset to support future research in this area.

- *Jing, P., Cui, K., Guan, W., Nie, L., & Su, Y. (2023). Category-Aware Multimodal Attention Network for Fashion Compatibility Modelling (FCM-CMAN). IEEE Transactions on Multimedia, 25.*

To propose a category-aware multimodal attention network for fashion compatibility modelling that leverages category information dynamically to enhance the aggregation and representation of multimodal data (images, text, and category labels) to predict fashion compatibility. The proposed model, FCM-CMAN, demonstrated superior performance compared to state-of- the-art methods in fashion compatibility modelling on Fashion VC and Exp Fashion datasets.

- Integration of content-aware and context-aware attention mechanisms enhanced the model's ability to learn and represent the relationships between fashion items for compatibility prediction.
- The approach involves a categorical dynamic graph convolutional network to adaptively capture category correlations.
- A category-aware contextual attention mechanism was utilized to refine multimodal data representations.
- Multimodal factorized bilinear pooling and multi-head self-attention were employed to generate robust visual-semantic embeddings for fashion items.

The study highlights the effectiveness of leveraging dynamic category information and multimodal data for predicting fashion compatibility. Potential limitations include ignoring user-specific style preferences, which could be explored in future work for personalized recommendations.

- *Chen, H.-J., Shuai, H.-H., & Cheng, W.-H. (2022). A Survey of Artificial Intelligence in Fashion. IEEE Multimedia, 9(4).*

Aims to survey the integration of artificial intelligence in fashion, specifically in three main areas: fashion analysis, fashion recommendation, and fashion synthesis. It outlines state-of-the-art techniques in each category and highlights potential future research directions. The paper categorizes AI applications in fashion into.

- Fashion Analysis: Popularity prediction and trend analysis.
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- Fashion Synthesis: Virtual try-on and makeup transfer.

The paper discusses various models and methods employed in these areas, alongside their limitations and future research opportunities. This survey provides an organized overview of AI techniques currently applied in fashion and identifies challenges and opportunities for enhancing AI-driven fashion solutions, emphasizing the potential of deep learning models in creating personalized and realistic virtual fashion experiences.

- *Dong, X., Song, X., Zheng, N., Wu, J., Dai, H., & Nie, L. (2024). TryonCM2: Try-on-Enhanced Fashion Compatibility Modelling Framework. IEEE Transactions on Neural Networks and Learning Systems, 35(1).*

The aim is to enhance fashion compatibility modelling by incorporating try-on appearance with traditional item interactions, thus providing a comprehensive framework for evaluating fashion compatibility based on both discrete item interactions and synthesized try-on appearances.

- The TryonCM2 framework significantly outperformed state-of-the-art methods in fashion compatibility modelling tasks on the PHOTOS dataset.
- The proposed method eliminates the need for unreliable negative sampling and achieves more accurate and diverse fashion compatibility predictions.
- The framework consists of discrete item interaction modelling using a bidirectional LSTM network and try-on appearance modelling by synthesizing a try- on template using a convolutional network.
- Combined compatibility is modelled by splitting the try-on template into image stripes and analyzing them with a bidirectional LSTM network to capture contextual relationships.
- The framework relies solely on well-matched outfits, omitting the need for randomly composed negative samples.
- TryonCM2 effectively captures the fine- grained compatibility patterns by considering both item-level and try-on appearance.
- The framework is limited by its reliance on visually-oriented modeling, which may overlook other factors

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

like seasonality or subjective user preferences. Future work may focus on enhancing the generation of try-on templates and improving contextual content modeling.

➢ *Ding, Y., Ma, Y., Wong, W. K., & Chua, T. S. (2022). Modeling Instant User Intent and Content- Level Transition for Sequential Fashion Recommendation. IEEE Transactions on Multimedia, 24, 2687-2701.*

- To improve sequential fashion recommendation by modeling instant user intent during online shopping. To incorporate item-to-item transitions at both item and content levels to enhance recommendation accuracy and user experience.
- The proposed model, Attentional Content- level Translation-based Recommender (ACTR), successfully captures instant user intent in the form of match, substitute, or other relationships between items.
- Extensive experiments demonstrate that ACTR outperforms existing methods on two large datasets (iFashion and Amazon- Fashion), achieving significant improvements in accuracy and interpretability.
- ACTR leverages translation-based modeling, augmented with an attention mechanism for capturing content-level transitions.
- The model introduces multiple sub- transitions based on various content-level attributes (e.g., color, category), improving item-to-item transition modeling.
- The approach uses extensive sequential data and attributes extracted from e- commerce datasets to evaluate performance on real-world scenario.

This study introduces an innovative approach by defining user intent in online fashion browsing and enabling recommendations tailored to the specific relationships between items.The findings suggest potential applications beyond fashion, offering insights for sequential recommendation tasks in other e-commerce domain.

➢ *Peiguang Jing, Kai Cui, Jing Zhang, Yun Li, Yuting Su; Multimodal High-Order Relationship Inference Network for Fashion Compatibility Modeling in Internet of Multimedia Things; Jing, P., Cui, K.,Zhang, J., Li, Y., & Su, Y. (2024). Multimodal High- Order Relationship Inference Network for Fashion Compatibility Modeling in the Internet of Multimedia Things. IEEE Internet of Things Journal, 11(1), 353-365.*

- To improve fashion compatibility modeling (FCM) using multimodal data to infer high-order relationships among fashion items in an IoMT environment.
- To address the limitations of current FCM models by integrating category- based correlations and enhancing item connectivity.
- The proposed Multimodal High-Order Relationship Inference Network (MHRIN) achieves superior performance on fashion compatibility compared to state-of-the-art models, with experiments on the FashionVC dataset showing significant improvements.
- MHRIN integrates a Category Correlations Learning (CCL) module for category-based learning, a Hierarchical Multimodal Fusion (HMF) module for comprehensive feature fusion, and a High-Order Message Propagation (HMP) module for enriched item connectivity.
- The approach leverages GCN layers, CNNs, and Bi-LSTM to model visual, textual, and categorical data, allowing for high-order relationship inference among fashion items.

This work presents a novel multimodal framework that enhances the depth of item relationships in FCM and has potential applications in personalized fashion recommendation systems.

➢ *Angelo Geninatti Cossatin, Noemi Mauro, Liliana Ardissono; Promoting Green Fashion Consumption Through Digital Nudges in Recommender Systems; Cossatin, A. G., Mauro, N., & Ardissono, L. (2024). Promoting Green Fashion Consumption Through Digital Nudges in Recommender Systems. IEEE Access, 12, 6812-6827.*

- To encourage green fashion consumption by using digital nudges in recommender systems that promote sustainable and second-hand garments.
- To examine if informational nudges in recommendation interfaces can shift consumer choices towards environmentally sustainable products.
- Digtal nudges, including sust inability-focused labels and prompts promoting second-hand items, significantly influenced participants to choose sustainable products over new items.
- The study found a high conversion rate to second-hand items, with nudges effectively raising awareness about environmental and ethical considerations.
- A user study with 251 participants was conducted using a recommender system enhanced with visual and textual nudges, presenting options like sustainability scores and ethical standards.
- Multiple user interfaces were tested to assess different combinations of nudges for their impact on user behavior and satisfaction.
- The study suggests digital nudging as a viable approach to promote sustainable consumption in e- commerce, although user sensitivity towards ethical considerations, especially animal welfare, was limited.

➢ *Seyyed-Mahdi Hosseini-Motlagh, Maryam Johari, Roza Zirakpourdehkordi, Tsan-Ming Choi, "Sustainable Operations for Fashion Manufacturing: A Dynamic Time-Varying Framework", IEEE Transactions on Engineering Management, vol. 71, 2024, pages 11375-11387.*

- To develop a framework analyzing the interplay between time-varying sustainability operations and customer valuation in the fashion industry, addressing customer demand, sustainable practices, and profitability in dynamic contexts.
- The framework demonstrates that sustainability investments benefit brands when customer preferences

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

change slowly and when they focus on durable products.
- The model also shows the impact of consumerism on sustainability efforts and provides managerial insights for strategic, dynamic investment in sustainable operations.
- Utilized dynamic game theory to explore feedback loops between customer valuation trends and sustainability, forming a model that incorporates time- varying product and process sustainability metrics, and conducted parametric and numerical analyses to validate optimal investment strategies in sustainability.

➢ *Zhi Lu, Yang Hu, Cong Yu, Yunchao Jiang, Yan Chen, Bing Zeng, "Personalized Fashion Recommendation with Discrete Content-Based Tensor Factorization", IEEE Transactions on Multimedia, vol. 25, 2023, pages 5053-5064.*

- To develop a personalized fashion recommendation model addressing efficiency in both computation and storage, while considering user-specific outfit compatibility.
- The model, utilizing discrete content-based tensor factorization and a hashing approach, significantly outperforms existing methods in accuracy and efficiency for personalized outfit recommendations on large-scale fashion datasets.
- The method also provides robust solutions for cold-start user scenarios.

A deep hashing model with discrete tensor factorization and Bernoulli-sampled binary codes was used, along with a lookup-table for fast binary similarity calculations, optimizing both user-item and item-item compatibility for personalized recommendations.

➢ *Shu Guo, Xuting Sun, Hugo K. S. Lam,"Applications of Blockchain Technology in Sustainable Fashion Supply Chains: Operational Transparency and Environmental Efforts", IEEE Transactions on Engineering Management, vol. 70, no. 4, April 2023, pages 1312-1323.*

- To examine the role of blockchain in enhancing operational transparency and environmental efforts within sustainable fashion supply chains, focusing on consumer trust, manufacturer credibility, and eco-friendly product development.
- Blockchain implementation boosts consumer willingness to pay for environmental quality due to improved transparency.
- The findings also highlight that, with sufficient consumer trust, blockchain can yield better environmental performance, particularly when manufacturers adhere to eco-friendly practices.
- Developed an information disclosure game model for a two-tier fashion supply chain, comparing traditional eco-labeling with blockchain-based transparency, and analyzed the impacts of consumer preference and manufacturer risk attitudes.

IV. SYSTEM ARCHITECTURE

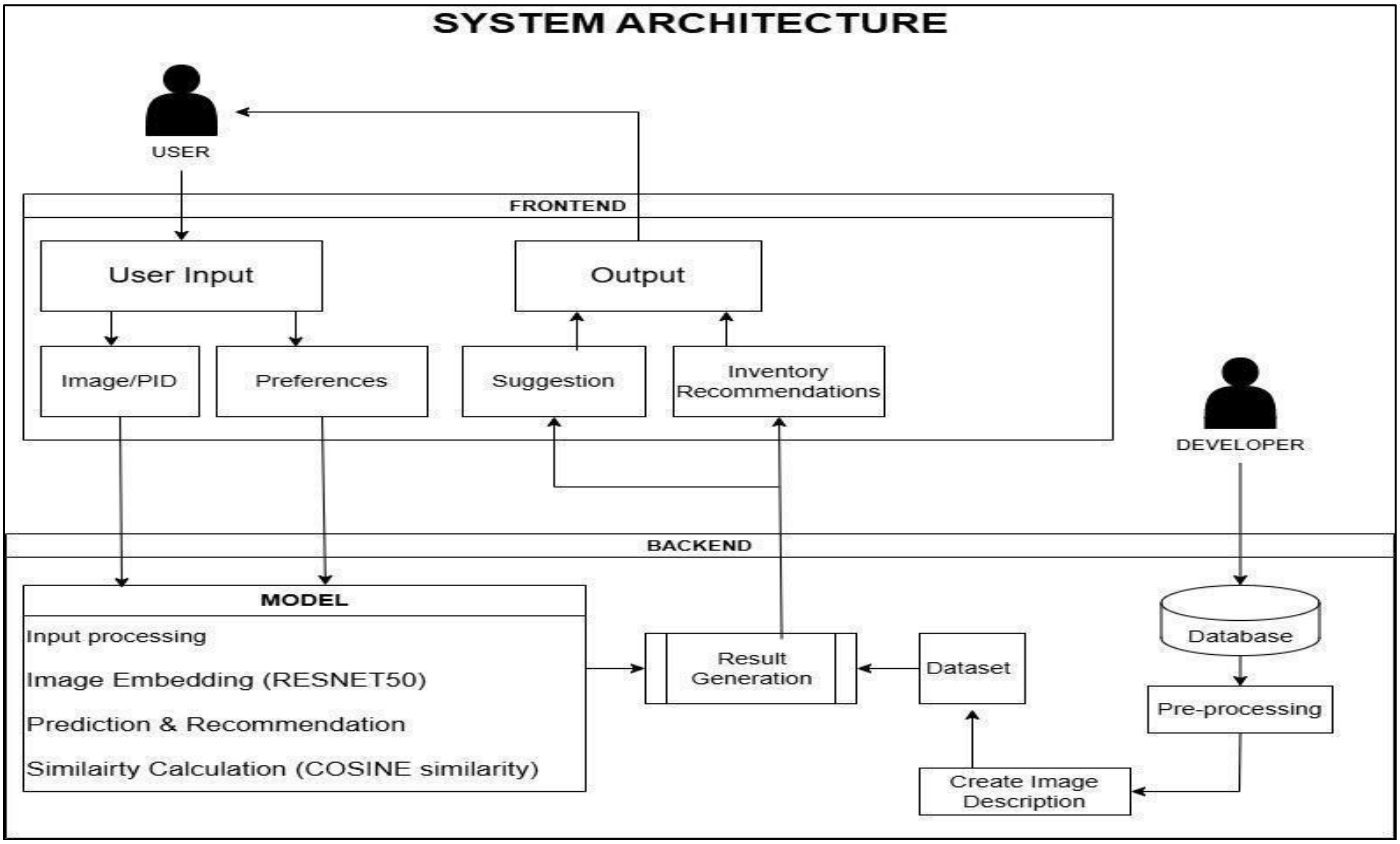

Fig 1 System Architecture of Talent Acquisition Platform

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

The platform is developed using HTML, CSS, and JavaScript for the frontend, while Express.js and Node.js power the backend for handling API requests and server-side operations.

Python is utilized for training machine learning models and processing image embeddings. MongoDB serves as the database, efficiently storing product details, user preferences, and inventory data. This architectural approach ensures modularity, scalability, and real-time processing capabilities.

The frontend provides an intuitive interface for users to upload product images and manage inventory. The backend integrates ResNet50 for image embedding, executed via Python, and uses cosine similarity for accurate product matching. Additionally, external APIs, such as weather services, enhance the platform's functionality by tailoring recommendations to user preferences and real-world factors.

➢ *Key Modules*

- *User Input System:*

Users can upload product images (Image/PID) and specify preferences such as size, colour, and style. This input initiates the recommendation and inventory analysis process.

- *Image Embedding (ResNet50):*

Implemented in Python, this module uses ResNet50, a pre- trained convolutional neural network, to extract key visual features from images. Converts images into vector embeddings that represent their visual characteristics for similarity analysis.

- *Similarity Calculation (Cosine Similarity):*

Measures angular distance between feature vectors to determine similarity between uploaded products and items in the inventory dataset.

- *Recommendation System:*

Combines extracted image features, user preferences, and inventory data to generate personalized product recommendations. Outputs a ranked list of similar products based on similarity scores and availability.

- *Backend API (Express.js and Node.js):*

Manages user requests and coordinates between the frontend and backend modules. Handles routing, processing of user inputs, and integration with the Python-based model.

- *Dataset Management and Pre-Processing:*

Maintains a repository of product images, descriptions, and stock data. Includes pre-processing pipelines for data cleaning and feature enhancement before training and evaluation.

- *Database Management (MongoDB):*

Stores all product details, user preferences, inventory levels, and transaction records. Provides a scalable, flexible, and efficient data handling solution for large inventories.

V. DATA SECURITY AND SCALABILITY

Security is crucial as the system manages sensitive business information, such as inventory and sales data. The system must enforce robust authentication and authorization controls to ensure only authorized users access restricted areas. Data must be encrypted both at rest (in the database) and in transit (via HTTPS) to prevent unauthorized access and breaches.

The system should comply with data privacy regulations and allow users to request the deletion of their personal information. All system activities, such as data access and modifications, must be logged for auditing and monitoring.

Scalability is equally important to ensure the system can handle increased loads as the business grows. The system leverages a modular architecture and cloud hosting to dynamically allocate resources based on demand, ensuring consistent performance during peak usage. MongoDB, as a NoSQL database, supports horizontal scaling, enabling the addition of servers to handle larger datasets and higher traffic volumes.

Furthermore, the backend, built using Node.js and Express.js, efficiently manages concurrent user requests, ensuring seamless operation for multiple users. These scalability features make the system robust and adaptable to the evolving needs of the business.

➢ *Tracking Trends and Inventory Analytics*

- **Seasonality:** The system analyzes historical sales data to identify seasonal demand patterns.
- **Fashion Trends:** Integrates external data to track emerging trends in colors, styles, and designs.
- **Weather Adjustments:** Adjusts inventory recommendations based on temperature and weather data Visual dashboards provide actionable insights, empowering retailers to make data-driven decisions quickly.

VI. FINDING AND RESULTS

The system's initial testing demonstrates promising results in improving inventory management, delivering substantial benefits in cost efficiency and operational responsiveness. By leveraging AI-driven demand forecasting and similarity analysis, the system optimizes stock levels, reducing instances of overstocking and understocking. This leads to significant cost savings by minimizing storage expenses and preventing losses from unsold products. Furthermore, real- time analytics and the integration of external data enable the system to adapt swiftly to market changes and consumer trends, ensuring inventory remains relevant and aligned with customer preferences. These results underscore the system's potential to streamline operations, enhance decision-making, and boost overall business performance in the fashion retail sector.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar231

VII. CONCLUSION

The proposed system demonstrates the power of AI in optimizing inventory management for fashion retail. By integrating predictive analytics, it helps retailers anticipate shifts in demand, maintaining balanced stock levels and preventing overstocking or understocking. This approach enables data-driven decisions, improving responsiveness to market changes. Additionally, AI-powered image embeddings allow for accurate product matching and recommendations, aligning stock with customer preferences and trends. Real-time reporting strengthens decision-making by providing actionable data, enabling quick adjustments to strategies. Together, these features reduce operational inefficiencies, lower costs, and enhance the customer experience, offering a competitive edge in a fast-evolving retail landscape.

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