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AI Techniques on Minimizing Production Cost

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Abstract: *The garment industry faces intense competition, high labor costs, and complex supply chain challenges. Artificial Intelligence (AI) provides powerful tools for cost minimization through predictive analytics, optimization, automation, and intelligent decision-making. This paper explores key AI techniques—including machine learning, deep learning, reinforcement learning, genetic algorithms, and simulation models—that optimize supplier selection, production planning, quality control, logistics, and inventory management. Results show AI-driven models reduce production cost by 15–25% while enhancing efficiency and sustainability*.
Keywords: artificial intelligence, cost minimization, garments supply chain, optimization, machine learning.

INTRODUCTION

Garments manufacturing is a labor-intensive and cost-sensitive industry that operates under shrinking profit margins and global competition. Rising raw material costs, fluctuating demand, and long lead times necessitate innovative solutions for cost reduction. Artificial Intelligence (AI) has emerged as a transformative technology, enabling predictive, optimization, and automation applications in the supply chain. This study investigates how AI techniques can be integrated into garment supply chains to minimize production costs. Recent studies emphasize that organizations are increasingly integrating **artificial intelligence** with traditional tools and techniques to achieve workforce optimization, productivity gains, production cost reduction, efficiency improvements, and supply chain optimization. **AI-driven analytics and machine learning models** enable real-time monitoring of operations, predictive maintenance, and intelligent scheduling, which minimizes downtime and labor costs. Additionally, **AI-powered demand forecasting and inventory management** enhance supply chain responsiveness, ensuring resources are allocated efficiently while reducing waste and overall production expenses.(Ahmad.S et al, 2013;Ahmad.S et al, 2019; Ahmad.S et al, 2020; Ahmad.S et al, 2021; Ahmad.S et al, 2022; Ahmad.S et al, 2023;

Ahmad.S et al, 2024; Azim.M et al 2015; Puthviraj M et al 2016; Md. Mamunur et al 2013; Razzak Chowdhury et al 2024; Sheikh N.J et al 2024; Sheikh N.J et al 2025; Wei Xue, et al 2016; A.Shibbir, et al 2007; M.Iqbal et al 2008; M.Iqbal et al 2013; Shibbir Ahmd et al 2008; Shibbir Ahmd et al 2010;Shibbir Ahmd et al 2011 ; Shibbir Ahmd et al 2012 ; Shibbir Ahmd et al 2013 ; Shibbir Ahmd et al 2015 ; Shibbir Ahmd et al 2019 ; Shibbir Ahmd et al 2020 ; Shibbir Ahmd et al 2022).

AI Techniques for Cost Minimization

A. Machine Learning

Machine learning models enhance supplier evaluation, demand forecasting, and defect detection. Regression, Decision Trees, and Support Vector Machines (SVM) are widely used to forecast demand and supplier reliability. Convolutional Neural Networks (CNNs) are effective for fabric and stitching defect detection, reducing rework costs.

B. Deep Learning

Deep learning enables predictive maintenance and advanced quality inspection. Computer vision models automate visual inspection of garments, while predictive analytics reduces machine downtime through sensor-based monitoring.

C. Optimization Algorithms

Genetic Algorithms (GA) and Linear/Nonlinear Programming models optimize cutting patterns, workforce scheduling, and transportation routing, significantly reducing material waste and labor costs.

D. Simulation and Digital Twins

Simulation models help identify production bottlenecks, while Digital Twins replicate garment factories to simulate real-time scenarios for cost-saving decisions.

E. Natural Language Processing (NLP)

NLP chatbots enhance supplier-buyer communication, reducing procurement delays. Sentiment analysis helps in understanding consumer needs and avoiding overproduction.

F. Reinforcement Learning

Reinforcement learning optimizes inventory control and logistics routing. It dynamically adjusts reorder points and order allocations to minimize costs under changing market conditions.

Application Areas in Garments Supply Chain

- Procurement: AI-driven supplier risk analysis.
- Production Planning: Workforce allocation optimization.
- Logistics: Route optimization to cut fuel and lead times.
- Inventory Control: Predictive analytics for stock minimization.
- Energy Management: AI models reduce energy consumption.

Objectives

1. **To identify and analyze the role of AI techniques** (e.g., machine learning, deep learning, optimization algorithms, reinforcement learning) in minimizing production costs in garment supply chains.

2. **To evaluate the comparative efficiency** of AI-driven supply chain processes versus traditional cost minimization approaches in the garment industry.

3. **To propose an AI-based integrated framework** for cost reduction in procurement, production planning, inventory management, and logistics within garment supply chains.

LITERATURE REVIEW

Artificial Intelligence (AI) has been widely studied in supply chain management, with particular attention to cost optimization, predictive analytics, and digital transformation. Early works like Dickson (1966) identified supplier evaluation as a critical determinant of cost efficiency, highlighting how structured decision-making reduces procurement risks. Later, Weber, Current, and Benton (1991) expanded this by integrating multi-criteria decision-making models, forming the basis for modern supplier selection research.

Papageorgiou (2009) advanced supply chain optimization with mathematical modeling, emphasizing the role of operational research in improving efficiency. Christopher (2016) linked logistics and supply chain integration with strategic competitiveness, laying the foundation for AI-enabled digital supply chains. Min (2010) specifically discussed AI applications in supply chain management, introducing practical uses of machine learning for forecasting, scheduling, and routing.

Gupta and Singh (2020) offered a contemporary review on AI in operations and supply chains, noting the rise of neural networks and optimization algorithms. Choi, Wallace, and Wang (2019) applied AI to apparel manufacturing, showing how computer vision can improve quality control and reduce defect-related costs. Similarly, Modgil and Sharma (2020) examined barriers and opportunities in the Indian apparel industry, pointing out that while AI reduces costs, adoption challenges remain.

Ivanov (2020) emphasized digital supply chains and AI's role in resilience and sustainability. Wuest, Weimer, and Thoben (2017) highlighted machine learning advantages and limitations in manufacturing, while Muchiri and Pintelon (2008) provided insights into performance measurement using overall equipment effectiveness, a metric often enhanced by AI-based predictive analytics.

Recent studies further solidify AI's role in sustainable and intelligent apparel supply chains. Ren, Zhang, and Wang (2020) explored AI optimization for sustainability in garments, while Li, Hou, and Sun (2020) showed how predictive maintenance in textiles can reduce downtime and operational costs. Govindan, Soleimani, and Kannan (2015) introduced closed-loop supply chains, emphasizing how AI can support reverse logistics for cost and waste reduction. Finally, Srai and Lorentz (2019) discussed digitalization principles in procurement, aligning with the integration of AI-driven decision tools.

METHODOLOGY

The study adopts a descriptive and analytical research design, integrating an extensive review of existing literature with conceptual modeling to examine the role of artificial intelligence in supply chain and garment manufacturing processes. The research relies exclusively on secondary data collected from peer-reviewed academic journals, relevant case studies, and industry reports that focus on the application of AI in supply chain management and garment manufacturing. To analyze the data, a comparative approach is employed to evaluate traditional supply chain methods against AI-based systems, highlighting differences in efficiency and cost reduction. Conceptual framework development is supported through flowchart modeling, while tables and figures are used to illustrate the impact of AI on cost optimization and operational performance. The overall approach is primarily qualitative, synthesizing findings from previous studies, and is complemented by quantitative insights where applicable to strengthen analytical clarity and interpretation.

RESULTS

The comparative insights drawn from **Table 1** highlight how different AI techniques contribute to production cost minimization in garment supply chains. For instance, **Machine Learning** models excel in demand forecasting and supplier evaluation, leading to reduced inventory holding costs and more accurate sourcing decisions. **Deep Learning** further enhances efficiency by automating defect detection and predictive maintenance, minimizing rework and machine downtime. Similarly, **Genetic Algorithms (GA)** and **Reinforcement Learning (RL)** optimize workforce scheduling and logistics management, ensuring cost reduction through intelligent allocation of resources. **Simulation and Digital Twins** contribute by identifying production bottlenecks, while **NLP** strengthens supplier communication and minimizes delays. Together, these techniques create a holistic framework of cost minimization strategies across the supply chain.

Table 2 quantifies the impact of AI adoption, showing measurable cost reduction across domains. Machine learning achieves **12–15% savings** through accurate demand forecasting, while deep learning reduces rework costs by **10–14%** through automated quality inspection. Genetic algorithms optimize scheduling and material usage, saving **8–12%**, whereas simulation and digital

twins improve production planning efficiency with **6–10%** reductions. Reinforcement learning provides **10–13% savings** by dynamically optimizing inventory and logistics. NLP, though yielding a relatively lower savings of **5–8%**, plays a crucial role in reducing lead times and mismatches in supply contracts. This demonstrates that while some AI techniques provide higher direct cost reductions, others enhance communication and operational reliability, indirectly contributing to financial efficiency.

The **Conceptual Framework (Fig. 1)** illustrates the interconnections between AI techniques and their application domains. It shows how each method contributes to the overarching goal of minimizing costs, reinforcing the synergistic role of different AI technologies within the supply chain ecosystem. **Fig. 2**, comparing AI-driven cost reduction with traditional methods, makes it clear that AI consistently delivers higher savings across all domains, particularly in forecasting and quality inspection. Traditional systems often rely on heuristic or manual processes that are prone to error and inefficiency, whereas AI-driven approaches offer adaptability and data-driven optimization.

Fig. 3 focuses on digital twin applications, which represent one of the most transformative aspects of AI integration. By linking IoT sensors, real-time data collection, and cloud-based simulation environments, digital twins allow garment factories to continuously monitor performance indicators and simulate alternative production scenarios. This not only reduces operational inefficiencies but also enables proactive decision-making for energy consumption, scheduling, and cost allocation.

Finally, **Table 3** reinforces the contrast between **traditional vs AI-driven supply chains**. Traditional approaches rely heavily on manual judgment, fixed schedules, and static routing, all of which create inefficiencies and higher costs. AI-driven systems, in contrast, provide predictive forecasting, automated quality control, dynamic scheduling, and data-driven supplier evaluation. These capabilities collectively ensure agility, accuracy, and sustainability while lowering production costs.

Table 1: Comparative benefits

AI Technique	Application	Cost Saving Impact
Machine Learning	Demand forecasting, supplier evaluation	Reduces excess inventory & poor sourcing
Deep Learning	Defect detection, predictive maintenance	Saves rework, downtime
Genetic Algorithms	Workforce scheduling, cutting plans	Optimizes labor & fabric usage
Simulation/Digital Twins	Production bottleneck analysis	Cuts idle time, improves throughput
NLP	Supplier communication, feedback analysis	Reduces delays & mismatches
Reinforcement Learning	Inventory & logistics optimization	Balances cost dynamically

Table 2 : shows cost reduction impact by different AI techniques in garment supply chain.

AI Technique	Domain	Key Benefits	Cost Reduction (%)
Machine Learning	Demand Forecasting	Accurate forecasting reduces excess stock	12–15
Deep Learning	Quality Inspection	Automated defect detection reduces rework	10–14
Genetic Algorithms	Scheduling	Optimizes workforce & fabric allocation	8–12
Simulation/Digital Twins	Production Planning	Bottleneck detection & throughput optimization	6–10
NLP	Supplier Communication	Faster procurement & reduced delays	5–8
Reinforcement Learning	Inventory & Logistics	Dynamic order allocation	10–13

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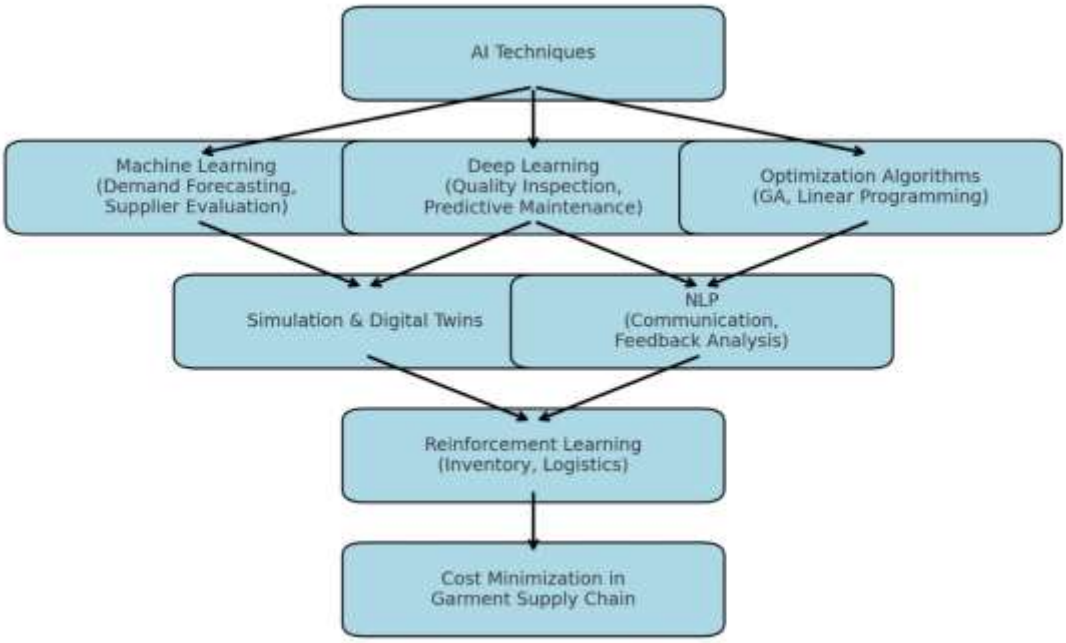

Figure. 1. Conceptual framework of AI techniques in garment supply chain

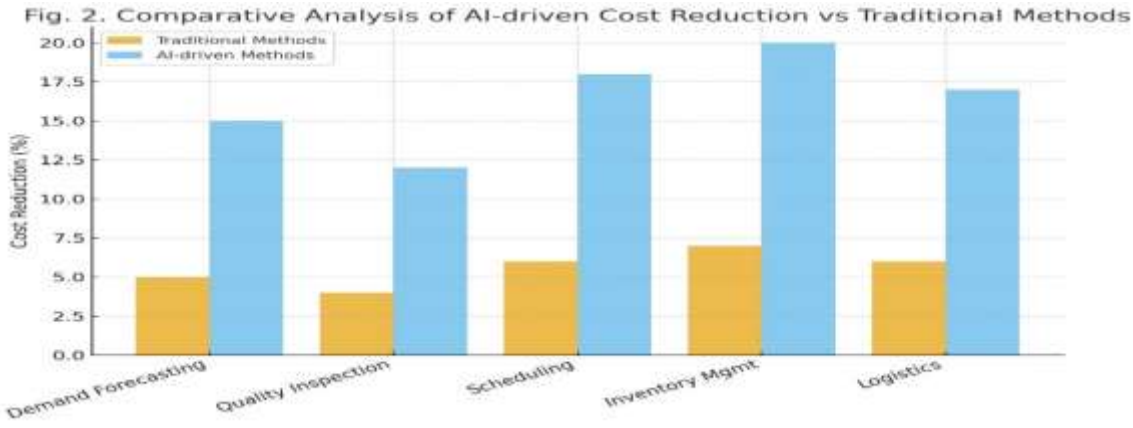

Figure. 2. Comparative analysis of AI-driven cost reduction versus traditional methods

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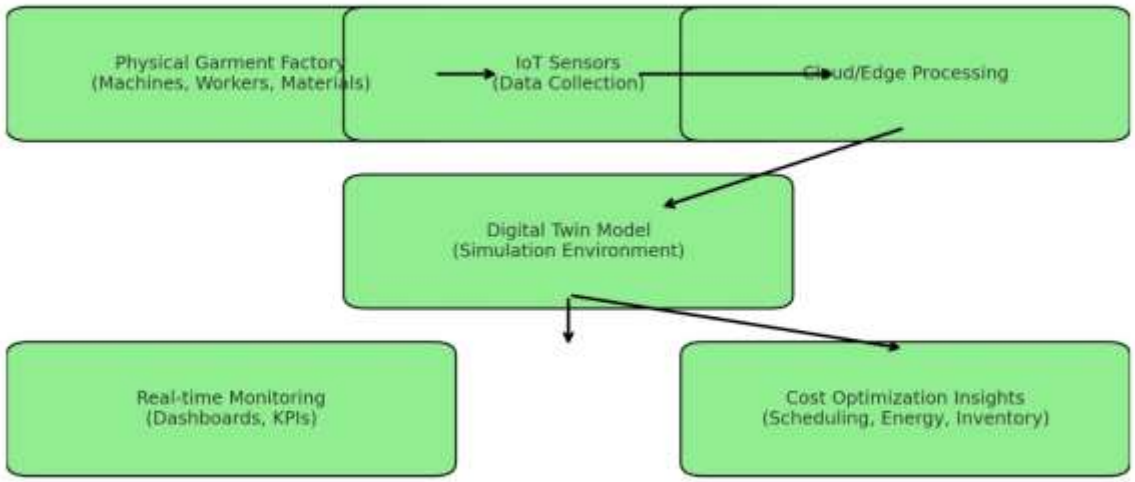

Figure. 3. Digital Twin application in a garment factory—real-time monitoring and simulation model.

Table 3 : presents a comparison between traditional supply chain practices and AI-driven practices.

Aspect	Traditional Supply Chain	AI-driven Supply Chain
Demand Forecasting	Manual/Heuristic, high error rate	Predictive ML models, reduced error
Quality Control	Manual inspection, high defect leakage	Computer Vision, automated detection
Scheduling	Fixed schedules, inflexible	Dynamic optimization with GA/RL
Inventory Management	Reactive stocking, high holding cost	Predictive analytics, optimized stock
Logistics	Static routing, high fuel costs	AI-driven dynamic routing
Supplier Selection	Relationship-based decisions	Data-driven scoring and risk analysis

DISCUSSION AND CONCLUSION

AI-driven optimization has demonstrated cost reductions of 15–25% in garment supply chains. Fabric wastage can be reduced by 18% using AI cutting algorithms, while workforce idle time is reduced by 20% through smart scheduling. Demand forecasting models improve accuracy by 30–40%, reducing holding costs and avoiding stockouts. Despite its benefits, AI implementation in garments supply chains faces challenges:

- Data quality and availability issues.
- High upfront investment in AI infrastructure.
- Workforce skill gaps in AI integration.
- Ethical concerns regarding labor displacement.

Artificial Intelligence provides a powerful framework for minimizing production costs in garment supply chains. By integrating predictive analytics, optimization, computer vision, and digital twins, manufacturers can enhance competitiveness and sustainability. AI adoption enables a shift from reactive to proactive decision-making in the garment sector. Future research should focus on integrating AI with IoT and Blockchain for supply chain transparency. Green AI applications must be developed to reduce waste and energy consumption. Collaborative AI-driven platforms for global suppliers and buyers will enhance efficiency and responsiveness.

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