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A STUDY ON SUPPLIER EVALUATION PROCESS IN FOOTWEAR MANUFACTURING INDUSTRY

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Abstract - This study introduces an innovative supplier evaluation approach for footwear manufacturing by integrating the SCOR 4.0 model with machine learning techniques. The SCOR 4.0 model, combined with the Best Worst Method (BWM), provides a structured framework for evaluating suppliers across various dimensions. A Random Forest (RF) machine learning model is then used to classify and rank suppliers based on performance ratings. The results show that the RF algorithm effectively identifies suitable suppliers, with lower rejection scores indicating superior performance. This integration enhances supplier evaluation processes and offers valuable insights for supply chain management in the footwear industry.

***Key Words*:** Supplier evaluation, SCOR 4.0 model, Best-worst method (BWM), Random Forest (RF), Supplier Rejection score

1.INTRODUCTION

In today's highly competitive business environment, effective supplier evaluation is crucial for the success of manufacturing companies, particularly in industries such as footwear manufacturing. The quality, reliability, and responsiveness of suppliers significantly impact a company's ability to meet customer demands, maintain product quality, and achieve operational efficiency. Given the rapidly changing consumer preferences, evolving fashion trends, and complexities of global supply chains, footwear manufacturers face immense pressure to collaborate with high-performing suppliers to maintain a competitive edge.

Traditional supplier evaluation methods often fall short due to their reliance on subjective assessments, limited datasets, and manual processes, leading to suboptimal decisions and inefficiencies. These methods may not adequately address the dynamic challenges faced by the footwear industry, where the ability to identify and collaborate with reliable suppliers is essential. To overcome these limitations, there is a growing interest in leveraging advanced methodologies and technologies that integrate established frameworks with cutting-edge machine learning techniques.

This study introduces an innovative approach to supplier evaluation tailored specifically for footwear manufacturing companies. By integrating the Supply Chain Operations Reference (SCOR) 4.0 model with machine learning techniques, this approach aims to enhance the accuracy, efficiency, and sustainability of supplier selection processes. The SCOR 4.0 model, developed by the Supply Chain Council, is a widely recognized framework for analyzing, designing, and managing supply chain processes. The latest iteration, SCOR 4.0, incorporates advancements in technology, digitalization, and globalization to address modern supply chain challenges. It provides a comprehensive set of metrics, best practices, and process models that enable organizations to benchmark their supply chain performance, identify areas for improvement, and align operations with industry standards. The model's modular structure allows organizations to tailor it to their specific industry, business model, and supply chain objectives.

To further enhance the supplier evaluation process, this study employs the Best Worst Method (BWM) in conjunction with the SCOR 4.0 model. BWM is a decision-making technique that helps in assigning weights to performance criteria based on their relative importance. By identifying the best and worst criteria, BWM facilitates a more structured and objective evaluation process, ensuring that the most critical aspects of supplier performance are prioritized.

Subsequently, a Random Forest (RF) machine learning model is implemented to classify and rank suppliers based on their performance ratings. Machine learning algorithms offer powerful tools for analyzing complex datasets, identifying patterns, and making data-driven predictions. Random Forest, an ensemble learning technique, combines predictions from multiple decision trees to increase accuracy and robustness. Each decision tree in the ensemble is trained on a random subset of the data, reducing overfitting risk and improving generalization performance. In the context of supplier evaluation, the RF algorithm classifies and ranks suppliers by their performance across multiple dimensions, thereby facilitating the identification of the most suitable suppliers.

The results of this study demonstrate the effectiveness of the Random Forest algorithm in supplier classification. Lower supplier rejection scores correspond to superior supplier performance, while higher rejection scores indicate suboptimal performance. This approach not only automates and streamlines the supplier evaluation process but also enables faster decision-making, more accurate predictions, and better resource utilization. By incorporating large volumes of data from diverse sources, this method provides deeper insights into supplier performance and identifies hidden patterns or trends that may not be apparent through traditional analysis methods.

This study contributes to advancing the understanding of how integrating the SCOR 4.0 model and machine learning techniques can enhance supplier evaluation processes in the footwear manufacturing industry. By providing a robust framework and utilizing advanced analytical tools, it offers valuable insights for supply chain management decision-making, ultimately driving improvements in supplier selection, operational efficiency, and overall supply chain performance.

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2. SIGNIFICANCE OF STUDY

Supplier management is crucial for organizational success, ensuring product quality, operational efficiency, and risk mitigation. Effective supplier management involves maintaining stringent quality standards, addressing supply chain disruptions, optimizing costs through negotiation, fostering trust-based relationships, and continuously evaluating supplier performance. These practices enhance operational effectiveness and agility in dynamic business environments, ensuring reliability and customer satisfaction. This study's significance lies in its development of a comprehensive supplier evaluation framework by integrating the SCOR 4.0 model with machine learning techniques, specifically tailored for the footwear manufacturing industry. By identifying and analyzing key performance metrics and implementing the Random Forest algorithm to classify and rank suppliers, the study addresses the limitations of traditional evaluation methods, providing a more accurate, efficient, and sustainable approach to supplier selection processes.

Furthermore, this research validates the effectiveness of the integrated SCOR and machine learning approach, contributing significantly to the advancement of procurement practices and supply chain management. By enhancing the accuracy and objectivity of supplier evaluations, organizations can achieve better supplier selection, improved operational efficiency, and increased customer satisfaction. The study also emphasizes sustainability and ethical practices in supplier evaluation, supporting responsible procurement decisions. Future research directions include integrating artificial intelligence for greater accuracy, exploring the impact of blockchain and IoT on supplier management, and expanding the framework's application beyond footwear manufacturing. By diversifying machine learning algorithms and incorporating rule-based systems and deep learning, future studies can further enhance supplier evaluation frameworks, transforming supplier management across various industries.

3. REVIEW OF LITERATURE

Md Muzahid Khan (2023) integrates SCOR 4.0 with machine learning for resilient and sustainable supplier selection in the pharmaceutical industry, highlighting the effectiveness of gradient boosting for supplier classification and ranking based on acceptability scores. Vipul Jain (2022) employs a disaggregated SCOR model with AHP to evaluate sustainability performance in the Ecuadorian flower industry, providing insights into sectoral performance and areas for improvement in planning, procurement, and manufacturing processes. Manay (2022) assesses sustainability performance in the e-waste supply chain using SCOR and the Best-Worst Method, identifying key performance indicators like costs, quality, and sustainability objectives crucial for high performance. Jingshi He (2022) utilizes an integrated SCOR model for risk evaluation in elderly services, introducing a novel DEA method with Entropy-AHP constraint for indicator weight allocation, revealing primary Pareto risk factors in elderly care institutions. Islam S (2021) proposes a two-stage approach integrating machine learning forecasting with optimization models for supplier selection and order allocation planning, demonstrating the superiority of the Relational Regressor Chain method in demand forecasting precision.

4. RESEARCH METHODOLOGY

The research adopts an analytical design, integrating SCOR 4.0 and machine learning techniques for supplier evaluation in footwear manufacturing. Utilizing methods like BWM and RF algorithm, it analyzes historical supplier performance data. The study spans from fiscal year 2019 to 2023, aiming to capture trends and assess the effectiveness of the proposed approach over a five-year period.

The research methodology involves four phases:
1. Developing the SCOR 4.0 model by identifying key factors and creating metrics for a footwear manufacturing company.
2. Implementing the Best Worst Method (BWM) to assess criteria weights and determine the most and least important factors.
3. Employing a supervised machine learning algorithm, specifically Random Forest (RF), for supplier evaluation.
4. Analyzing the results from the RF algorithm and ranking suppliers based on Supplier Rejection Score.

SCOR 4.0 model

"Reliability" in the SCOR 4.0 model ensures precise product distribution with metrics like "Quantity," "Accuracy," and "Quality." "Flexibility" evaluates the supply chain's adaptability, encompassing "Production," "Delivery," and "Risk" metrics. "Responsiveness" focuses on delivery speed and service support, while "Cost" metrics encompass production, transportation, and maintenance expenses. "Asset" management evaluates working capital, cash cycles, and fixed assets efficiency. "Digital Technology" assesses proficiency and applicability, while "Information Systems" ensure integration, content, and documentation comprehensiveness.

BEST WORST method

The Best Worst Method (BWM) is a decision-making technique used to determine the relative importance or weight of criteria in a multi-criteria decision-making (MCDM) context. It involves comparing each criterion against every other criterion to establish the best and worst ones, then assigning weights accordingly.
This can be represented mathematically as follows:

minimize ξ
Subject to:
$\sum Wj = 1$
$||WBWj - ABj|| \leq \xi$, for all j
$||WjWB - AjW|| \leq \xi$, for all j $Wj \geq 0$, for all j

In this formula,
- ξ represents the optimization objective, aiming to minimize the disparity between criteria.
- Wj denotes the weight of each criterion.
- WB and AB represent the best criterion and its associated weight, respectively.
- AjW and WjWB represent the worst criterion and its associated weight, respectively.

Random Forest

Random Forest, a powerful machine learning algorithm, ranks suppliers based on various performance metrics by analyzing supplier attributes and indicators to discern patterns. It handles large datasets with high dimensionality, evaluating suppliers across multiple criteria simultaneously. Known for its

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robustness to overfitting and ability to handle missing data effectively, Random Forest generates reliable rankings, aiding informed supply chain decisions and optimization.

5. DATA ANALYSIS AND INTERPRETATION

Table -1: SCOR 4.0 Model

Level 1	Level 2	Level 3
Reliability	Quantity	Maximum delivery amount
		Maximum delivery time
		Average delivery time
	Accuracy	Order fulfilment
		Delivery performance
		Document accuracy
	Quality	Damage free orders
		Product specification
		Fill rate
Flexibility	Production	Plan flexibility
		Production flexibility
		Supply chain adaptability
	Delivery	On-time delivery
		Lead time customization
		Change in quantity of supply
	Risk	Production
		Return
		Delivery
Responsiveness	Cycle time	Delivery cycle time
		Source cycle time
		Order fulfilment cycle time
	Quantity supplied	Supply by type
		Supply by region
		Lead time
	Service support	Query response
		Compliant response
		Material
Cost	Production cost	Planning
		Management
	Transportation cost	Mode of freight
		Legal compliance
	Maintenance	Service
		Warranty
		Return
Assets	Working capital	Accounts payable
		Accounts receivable
		Inventory
	Cash to Cash cycle	Days payable outstanding
		Inventory days of supply
		Days Sales outstanding
	Fixed assets	Assets turns
		Supply chain fixed asset
Digital technology	Ability	Dynamism
		Capability
		Collaboration
	System	System performance
		Data security
		System structure
	Applicability	Consistency
		Transparency
		Efficiency
Information system	Integration	Integrated database
		Integrated interface
		Partner integration
	Content	Data management
		Comprehensiveness
		comprehensibility
	Documentation	Supplier information
		Delivery documentation

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		Qualification & validation
		Certificates

Table -2: Linguistic scale for Best Worst method (BWM)

Numbers	Linguistic terms
1	Equal importance
2	Somewhat between Equal and Moderate
3	Moderately more important than
4	Somewhat between Moderate and Strong
5	Strongly more important than
6	Somewhat between Strong and Very strong
7	Very strongly important than
8	Somewhat between Very strong and Absolute
9	Absolutely more important than

Table -3: Weight value of level 1 metrics

Level 1	Weight
Reliability	0.3368
Flexibility	0.1446
Responsiveness	0.1084
Cost	0.2169
Asset	0.0868
Digital technology	0.0342
Information system	0.0723

Table -4: Weight value of level 2 metrics

Level 2	Weight
Quantity	0.3958
Accuracy	0.0833
Quality	0.5208
Production	0.0769
Delivery	0.2198
Risk	0.7032
Cycle time	0.575
Quantity supplied	0.325
Service support	0.1
Production	0.6825
Transportation cost	0.2063
Maintenance	0.1111
Working capital	0.7909
Cash to cash cycle	0.1
Fixed assets	0.109
Ability	0.1805
System	0.7083
Applicability	0.1321
Integration	0.1
Content	0.75
Documentation	0.15

Table -5: Weight value of level 3 metrics

Level 3	Weight
Maximum delivery amount	0.6753
Maximum delivery time	0.5091
Average delivery time	0.2338
Order fulfilment	0.6266
Delivery performance	0.0667
Document accuracy	0.3067
Damage free orders	0.7614
Product specification	0.1136
Fill rate	0.1250
Plan flexibility	0.1728
Production flexibility	0.7160
Supply chain adaptability	0.1267
On-time delivery	0.6208
Lead time customization	0.2414
Change in quantity of supply	0.1379
Production	0.1667
Return	0.1481
Delivery	0.6852
Delivery cycle time	0.7727
Source cycle time	0.0834
Order fulfilment cycle time	0.1439
Supply by type	0.1385
Supply by region	0.7846
Lead time	0.0769
Query response	0.1429
Compliant response	0.1667
Material	0.25

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Planning	0.125
Management	0.6786

Mode of freight	0.1785
Legal compliance	0.1429
Service	0.7232
Warranty	0.2142
Return	0.0625
Accounts payable	0.4237
Accounts receivable	0.1226
Inventory	0.8760
Days payable outstanding	0.2044
Inventory days of supply	0.0390
Days Sales outstanding	0.1226
Assets turns	0.3333
Supply chain fixed asset	0.1429
Dynamism	0.0355
Capability	0.1269
Collaboration	0.1693
System performance	0.0846
Data security	0.0725
System structure	0.0634
Consistency	0.0564
Transparency	0.1015
Efficiency	0.2894
Integrated database	0.2148
Integrated interface	0.0921
Partner integration	0.0552
Data management	0.4051
Comprehensiveness	0.0716
comprehensibility	0.1611
Supplier information	0.6186
Delivery documentation	0.1608

Qualification & validation	0.1340
Certificates	0.0865

Inference:

Performance scale	Value
Poor	1
Fair	2
Average	3
Good	4
Excellent	5

In the analysis, weight values have been calculated and ranked for each performance metric, offering a quantitative measure of their relative importance in determining supplier rank. These weights reflect the contribution of each metric towards the predictive accuracy of the random forest classifier.

Table -6: Performance scale

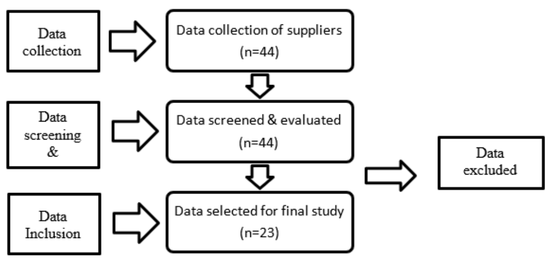
Inference:

The comparison scale ranges from 1 to 5, where 1 signifies poor performance, significantly below expectations, necessitating immediate attention and improvement. A rating of 2 indicates fair performance, falling below expectations with areas that may require enhancement to meet standards.

On the scale, 3 represents average performance, meeting basic requirements but leaving room for improvement to attain optimal performance. A rating of 4 signifies good performance, surpassing average expectations and demonstrating effectiveness.

Finally, a rating of 5 denotes excellent performance, exceeding expectations and setting a high standard for excellence.

Data Selection



Inference:

Out of the 44 suppliers available, 23 were selected for inclusion in the analysis, showcasing reliability and consistency in meeting delivery schedules, rendering them suitable for further examination.

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OVERALL LEVEL	FINAL WEIGHT	RANK
REL 1	0.11845	1
REL 2	0.08929	3
REL 3	0.04100	4
REL 4	0.01757	5
REL 5	0.00187	9
REL 6	0.00860	8
REL 7	0.10149	2
REL 8	0.01514	7
REL 9	0.01666	6
FLEX 1	0.00192	8
FLEX 2	0.00796	5
FLEX 3	0.00140	9
FLEX 4	0.01973	2
FLEX 5	0.00767	6
FLEX 6	0.00438	7
FLEX 7	0.01695	3
FLEX 8	0.01505	4
FLEX 9	0.06967	1
RES 1	0.04816	1
RES 2	0.00519	4
RES 3	0.00896	3
RES 4	0.00487	5
RES 5	0.02764	2
RES 6	0.00270	6
RES 7	0.00154	8
RES 8	0.00180	7
COS 1	0.01118	5
COS 2	0.00559	6
COS 3	0.10045	1
COS 4	0.02642	2

Table -6: Weight value of overall metrics

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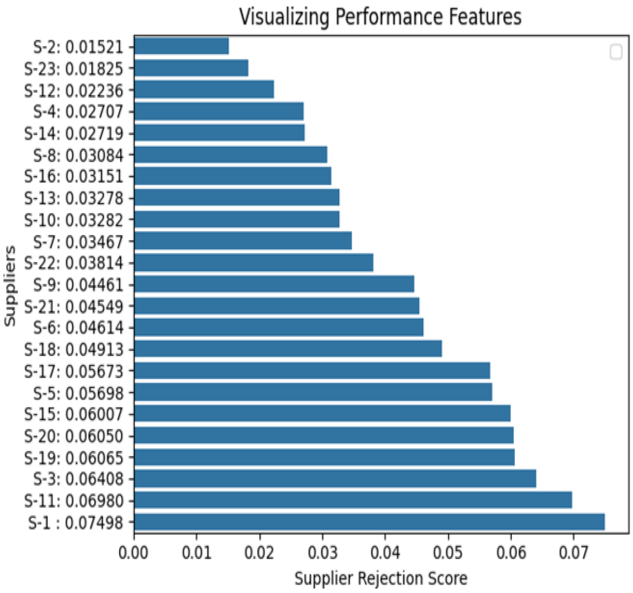
Fig -1: Output of supplier rejection score



Feature selection:

Feature selection value	Performance metrics
4	Order fulfilment
24	Lead time
17	Return risk
58	Supplier information
39	Inventory days of supply
12	Supply chain adaptability
54	Partner integration
5	Delivery performance
53	Integrated interface
47	Data security
51	Efficiency
2	Product specification
23	Supply by region

Inference:

These selected features serve as input variables for building predictive models aimed at evaluating and classifying suppliers according to their performance within the SCOR 4.0 framework. This process enables the identification of key metrics crucial for effective supplier evaluation and decision-making in supply chain management.

6. FINDINGS

The results indicated that suppliers with higher scores in reliability and cost efficiency consistently ranked higher. The model's insights helped in identifying top-performing suppliers and areas where underperforming suppliers needed improvement. Suppliers with high on-time delivery rates, low defect rates, and competitive costs were ranked as top performers. Suppliers with high rejection rates were identified, providing specific metrics where they lagged, such as responsiveness and flexibility.

COS 5	0.02115	3
COS 6	0.01742	4
COS 7	0.00516	7
COS 8	0.00150	8
AST 1	0.02908	2
AST 2	0.00841	3
AST 3	0.06013	1
AST 4	0.00177	5
AST 5	0.00033	8
AST 6	0.00106	7
AST 7	0.00315	4
AST 8	0.00135	6
DT 1	0.00022	9
DT 2	0.00078	7
DT 3	0.00105	6
DT 4	0.00204	1
DT 5	0.00175	2
DT 6	0.00154	3
DT 7	0.00136	4
DT 8	0.00025	8
DT9	0.00130	5
IS 1	0.00155	6
IS 2	0.00066	9
IS 3	0.00039	10
IS 4	0.02195	1
IS 5	0.00388	4
IS 6	0.00874	2
IS 7	0.00670	3
IS 8	0.00174	5
IS 9	0.00145	7
IS 10	0.00094	8

7. CONCLUSION

This study contributes to the field of supply chain management by presenting a novel approach to supplier evaluation that integrates advanced decision-making techniques with the SCOR 4.0 model. The proposed framework enhances the ability of manufacturing companies to select resilient and sustainable suppliers, thereby improving overall supply chain performance. Future research can explore the adaptation of this model to other industries and further refine the evaluation criteria to incorporate emerging trends in supply chain management.

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