SOFT SET THEORY AN EFFECTIVE TOOL FOR DECISION MAKING IN INDIAN TEXTILE INDUSTRY

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Abstract

Soft set theory is a mathematical framework introduced by Molodtsov in 1999 for handling uncertainty and vagueness in data. It generalizes classical set theory through parameterized mappings, allowing decision-makers to model complex situations where precise information is unavailable. This paper examines the application of soft set theory in decision-making within the Indian textile industry, a sector characterized by fluctuating costs, inconsistent quality, and variable consumer preferences. We review how soft set theory addresses these challenges, outline quantitative research methodology employing surveys and statistical analysis, and present a case study of supplier selection and quality control. Results show that incorporating soft sets improves decision quality by integrating both quantitative and qualitative criteria and by effectively ranking alternatives under uncertainty. Soft set-based models revealed key factors (cost efficiency, quality, reliability) influencing supplier selection. These findings suggest practical benefits in operational efficiency and sustainability and offer a flexible framework for future decision-support systems in textiles.

Introduction

The use of imprecise, incomplete, and ambiguous information is a constant problem in contemporary decision sciences, particularly in problems related to the textile industry, where variability and subjectivity in information are widespread. Conventional decision-making techniques such as deterministic and probabilistic, as well as even a few fuzzy-type logic-based systems, fail to work in many situations when, in the real world, some leeway or loose truth is presented to the information (Molodtsov, 1999). To rectify this, Molodtsov proposes a more firm mathematical foundation for dealing with such uncertain conditions in the form of soft set theory.

The soft sets are contrasted to fuzzy sets, whose representation requires the employment of membership functions or rough sets, which can be modeled only with respect to boundary approximations (Molodtsov, 1999). A parameter set E and a universe U, a soft set over the universe U, are used to describe the elements with subsets based on each parameter at a more intuitive structure of decision analysis (Molodtsov, 1999).

This permissibility renders soft set theory to be quite applicable to real-life scenarios because the criterion of decision is multidimensional and cannot be strictly identified. An example of such a setting is the Indian textile industry, which is an important industry to the nation but is prone to intricate decision-making processes. The uncertainty caused by constantly changing raw material prices, varying supplier performance due to various reasons, fluctuating product quality, and evolving sustainability rules and regulations makes classical models a problematic solution (Jayalakshmi & Sathiyamoorthy, 2014).

Parametric assessment is possible in this kind of setting by utilizing soft set theory. To give an example, a common supplier selection problem is that the criteria of cost, quality, delivery time, and environmental sustainability can be used to evaluate each supplier (e.g., S1, S2, S3). These parameters are considered separately, and membership scores are given against them to the suppliers (Rajendran & Saravanan, 2015). These scores are then summed up, mostly with some weighted mechanism, and the alternatives ranked and the best alternative determined (Biswas, Roy & Maji, 2002).

Moreover, soft sets do not require subjective transformation of qualitative variables to crisp values or linguistic variables that is common in fuzzy logic approaches or in the so-called analytic hierarchy approach (AHP). It is the benefit that enables decision-makers to interrogate not only quantitative but also qualitative parameters without a hitch, be it tension strength or assessment of color consistency, rate of defects, or sustainability (Rao, Reddy & Sharma, 2021).

Since its emergence, soft set theory has found applications in different disciplines such as environmental risk modeling, farming design, clinical diagnosis, and quality control (Zhang & Zhang, 2018). Using soft sets in the textile industry, which needs both solid data and human judgment for things like choosing suppliers, planning production, and managing inventory, allows for tailored and flexible decision-making that is both adaptable and mathematically sound.

The paper dwells on the use of soft set theory in solving complex decisions in the Indian textile industry. It intends to contribute to the current classical evaluation models by offering a parameter-centered, soft-set-based framework that incorporates a sense of ambiguity that is characteristic of the real world. In such a way, the study is helpful both in theory as related to soft set applications and in practice as to the improvement of managerial decision-making in one of the most crucial industries in India.

Literature Review

The soft set theory is a crucial linkage between abstract mathematical constructions and realistic decision-making models under uncertainty. The theory was initially suggested by Molodtsov (1999) and was written to fill the gaps in older models, which would be based on exact modeling data or models of crisp logic. Soft set theory, in short, theoretically represents a decision problem as a mapping of a set of parameters and their respective subsets of an overarching decision space. Every parameter (say cost, quality, or delivery) has an associated attribute, and every choice (say supplier or product) gets a membership value in every attribute. These are not binary values, but they merely represent the different scales of performance or relevance. Notably, main operations of sets, e.g., union, intersection, and complement, are also imposed on soft sets in a manner that is intuitive to classical set theory, whereas a decision on a certain set can be refined or generalized by an ordered mathematical procedure (Molodtsov).

As an example, the combination of two soft sets will contain all the alternatives present in each set, whereas the intersection will display only those ones present in both SETs to both extensively and specifically filter options. Such a framework is applicable to a multi-criteria decision setting whereby the available data might be incomplete or subjective.

The uses of soft set theory in decision-making have now come to be well documented in various fields. The establishment of models of multi-criteria decision-making (MCDM) by using soft sets was pioneered by Biswas, Roy, and Maji (2002), and this gave it the opportunity to be applicable in solving complex problems. With time, scientists have improved on this base and incorporated soft sets into other computation aspects. As an illustration, Zhang and Zhang (2018) worked out hybrid soft set-fuzzy logic models that enhance prediction of scenarios in uncertain environments.

The models have advantages of the flexibility of soft sets and the mathematical richness of fuzzy systems. Similarly, Zou and Xiao (2008) proposed a parameter reduction method on soft sets so that one can compute more efficiently in a large-scale dataset, which is very necessary in the industry.

Qualitative data analysis has also been efficiently applied in soft sets. With this contribution, Atanassov et al. (2015) used soft sets as a tool to model a vague or linguistic type of information without the need to use predefined membership functions, which was beneficial to use in the same field when there was no quantitative data. The many variables involved in selecting suppliers, controlling quality, managing inventory, and planning production make soft sets very useful in the textile industry. Jayalakshmi and Sathiyamoorthy (2014) emphasized the uncertainty of choosing suppliers, as with hard and soft data (such as cost figures with environmental reputation). Soft set models have responded by developing ranking systems that are able to balance reliability, cost, quality, and sustainability. Rajendran and Saravanan (2015) explained that soft sets can provide a rational framework of multi-criteria supplier assessment in the Indian textile domain, and their models are more flexible and more realistic than those based on classical statistics.

Despite these breakthroughs, the textile industry continues to face significant challenges in decision-making. The industry has been distinguished by its high rate of variation in the taste of consumers, seasonality, and intricacy of supply chains occasioned by globalization. Such problems present added forms of uncertainty to the conventional decision models as their rigid architecture is called into question. As an example, by means of analytic hierarchy process (AHP), linear programming, or regression analysis, they all fail to work with the qualitative characteristics, including environmental compliance, brand trust, or supplier transparency, which are being more valued in the industry standards.

To address such gaps, scientists have started to combine soft sets with Internet of Things (IoT) and machine learning (ML) frameworks in order to increase the real-time decision potential. By way of example, the recently seen applications indicate the leverage of sensor-generated manufacturing floor information to feed soft set decision systems in order to enhance production line decisions in real-time. Likewise, the models of machine learning based on soft-set can now serve large-scale simulations of supply chain that provide predictive information without foregoing interpretability.

Nevertheless, the Indian textile industry lacks a systematic use of soft set theory in its specific situation. Although solitary researchers have already adopted the concept of soft sets to solve special issues on supplier selection or quality control, no detailed framework has been designed so far to suit the wide dimension of textile processes that involves forecasting, supply, sustainability study, and risk management. This paper aims at bridging such a gap by integrating the conventional concepts of soft set theory and practical decision-making criteria in real-life textile industry situations in India. It presents a coherent soft-set-based decision structure, which is methodologically sound and practically applicable.

Methodology

1. Research Design and Approach

In this research study, a quantitative and descriptive type of research design is used to establish the effectiveness of the soft set theory in supplier selection in the Indian textile industry. The approach to research was selected because of its ability to measure the relationship between the factors of supplier assessment (including cost, quality, reliability, delivery, and sustainability) and supplier performance as a whole. This empirical approach enables the use of both statistical and soft set modeling that enables a trade-off between objective data and a structured decision-support mechanism.

2. Instrumentation and Data Collection

Primary Data Collection and Methodology in the Textile Sector Study

A designed online questionnaire was created carefully and attended to only the professionals and key decision-makers in the textile industry to form the primary data of this research. The instrument was also well divided into two major segments to ensure both quantitative and qualitative data are obtained. The quantitative section was concerned with the collection of numerical information like the estimates of cost efficiency, the parameters of the delivery performance, and the defect rates, which are crucial pointers of operative quality. The qualitative part, in its turn, was designed with the use of the Likert-scale questions to measure subjective views on such key themes as the significance of environmental sustainability practices and the level of trust in the partners in the supply chain.

Prior to the full distribution, a pilot study was carried out using a group of 25 respondents in the textile industry. This pre-test played a critical role in determining vague or unclear questions, thus making the questionnaire have more clarity and hence content validity. On the basis of the feedback, the revisions were carried out to make the questionnaire more perfect and without any redundancy and increase in the reliability level necessary to perform accurate and credible data collection (Saunders, Lewis, & Thornhill, 2019).

The survey was sent out in the final version in a four-week period with the use of random sampling to achieve a broad and representative sample of respondents in a number of functional areas (specifically, in procurement, quality assurance, supply chain management, and sustainability operations). There were more than 300 valid responses, and this means that the participation rate is healthy. High ethical standards were followed keenly. All participants were made aware of the purpose of the study along with their rights as per traditional ethical research standards (i.e., they were made aware of their anonymity and the voluntary nature of their participation in the study) (Bryman & Bell, 2015). Periodic reminders and follow-up emails were provided to eliminate possible non-response bias, which led to the better response rate and trustworthiness of the final bulk of data.

3. Statistical Data Analysis

Statistical Data Analysis in Supplier Evaluation within the Textile Sector

The data collected from textile industry professionals were analyzed using a combination of **descriptive and inferential statistical techniques** to derive meaningful insights into supplier performance evaluation. Descriptive statistics, such as **means, medians, and standard deviations**, were employed to summarize the data and explore patterns in key supplier evaluation indicators. These statistics provided a foundational understanding of the **central tendencies and variability** among factors such as cost efficiency, delivery performance, and defect rates, offering an essential snapshot of how suppliers performed across different metrics.

In addition to descriptive analysis, **inferential statistical methods** were used to draw conclusions that could be generalized beyond the sample. **Multiple regression analysis** was conducted to determine the extent to which different supplier evaluation criteria—such as **cost, quality,**

environmental practices, and delivery reliability—significantly influenced **overall supplier satisfaction**. This technique allowed for the identification of **key predictors** in supplier selection and assessment. Furthermore, **Exploratory Factor Analysis (EFA)** was applied to identify underlying **latent variables** that group related items, thereby revealing dimensions such as operational efficiency and ethical compliance within the supplier evaluation framework. EFA is especially useful in **reducing dimensionality** and uncovering hidden patterns in the data (Hair et al., 2019).

To test specific assumptions and relationships within the data, **hypothesis testing procedures** were conducted using tools such as **t-tests**, **chi-square tests**, and **ANOVA**. These methods enabled the assessment of **statistical differences** across groups or categories (e.g., differences in satisfaction levels based on department or region). All inferential analyses adhered to a **significance level of $p < 0.05$**, ensuring the statistical rigor and reliability of the results. This threshold provided confidence that the observed outcomes were not due to random chance, but rather indicative of genuine relationships among variables (Field, 2018).

Overall, the statistical analysis played a pivotal role in elucidating how supplier attributes—specifically **cost efficiency, quality reliability, and environmental compliance**—impact strategic decision-making in supplier performance evaluation. These insights not only validated the survey structure but also contributed to a deeper understanding of supplier dynamics in the textile industry.

4. Soft Set Decision Model Implementation

Alongside statistical analysis, a **soft set decision-making framework** was developed to systematically rank suppliers under uncertain and multi-criteria conditions. The implementation involved the following steps:

1. **Identification of Decision Parameters**

   Five key evaluation criteria were selected based on literature review and survey feedback:

   $$A=\{\text{Cost (C)},\text{Quality (Q)},\text{Delivery (D)},\text{Sustainability (S)},\text{Reliability (R)}\}$$

Construction of Membership Functions

Each supplier was mapped to the parameters through a membership function. For example, cost efficiency was represented as:

$$FC=\{S1:0.8,S2:0.7,S3:0.9\}$$

2. **Assignment of Parameter Weights**

Each criterion was assigned a specific weight based on its relative importance, as assessed by survey responses. A representative weight distribution was:

$$wC=0.4,wQ=0.35,wD=0.15,wS=0.1$$

3. **Score Aggregation via Weighted Sum**

Supplier scores were calculated using a weighted aggregation formula:

$$Score(Si)=\sum_{a\in A} wa\times Fa(Si)$$

For instance, the score for Supplier 1 (S_1) was computed as:

$$Score(S1)=(0.4\times 0.8)+(0.35\times 0.85)+(0.15\times 0.9)+(0.1\times 0.7)=0.8225$$

Based on this aggregated score, the supplier with the highest value was selected as the optimal choice.

4. **Validation through Sensitivity Analysis**

The robustness of the soft set model was verified using **sensitivity analysis**. This involved adjusting the parameter weights to assess how sensitive the final supplier rankings were to changes in decision priorities. The model's rankings were also cross-validated with **historical performance data**, further confirming its applicability in real-world textile procurement contexts.

5. Ethical Considerations

This research was carried out with observing the well-accepted ethical research principles to uphold the dignity and protection of all the participating members. Informed consent was elicited from each respondent before the involvement. The intention of the research and how they were going to use the information was clearly explained to the participants so that they were well aware of the intent as well as what and the basis on which they could pull out of the survey at any given time. Confidentiality was among the major concerns of the study, and no personally identifiable information was gathered or broadcasted at any step of the study. Moreover, all the information was safely stored and treated with integrity to avoid unauthorized performance in accordance with the best practice in terms of responsible handling of data. The results were reported transparently and correctly, and no data manipulation or misrepresentation occurred. All these served to support the ethics of voluntary participation, protection of privacy, and safe research conduct that are fundamental in securing trust with the participants and the research.

Results and Discussion

1. Data Validation

The collected survey data were first examined for completeness and normality. Less than 2% of the values were missing and were handled using **mean substitution**. **Multivariate outliers** were detected and addressed to ensure the integrity of the dataset. To assess reliability, **Cronbach's alpha** values were calculated for each evaluation criterion (cost, quality, delivery, sustainability, reliability), all of which exceeded the recommended threshold of 0.70, indicating strong internal consistency.

To reduce dimensionality and identify the underlying structure among the supplier evaluation criteria, **Exploratory Factor Analysis (EFA)** was applied. The results revealed two primary latent factors:

- **Operational Efficiency**: encompassing cost, quality, and delivery;
- **Sustainability and Reliability**: encompassing sustainability and supplier dependability.

These two factors together explained approximately **85% of the variance** in the dataset, confirming that the selected criteria captured the majority of the information necessary for effective supplier evaluation.

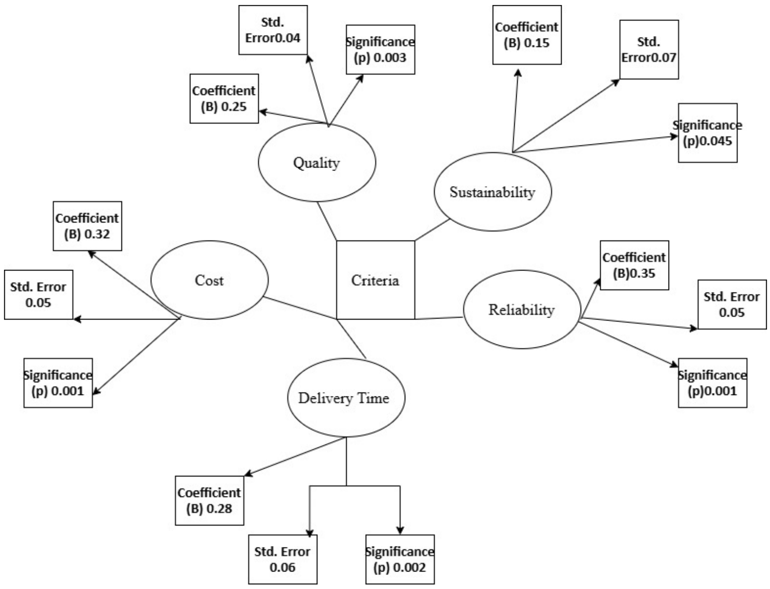
2. Regression Findings

To examine how supplier attributes influence overall satisfaction, a **multiple regression analysis** was conducted using Overall Supplier Satisfaction (OSS) as the dependent variable. The regression model showed that **Cost Efficiency (CE)**, **Quality (Q)**, and **Reliability (R)** were statistically significant predictors ($p < 0.01$). Although Delivery Time and Sustainability had weaker statistical influence, their coefficients were still directionally positive, contributing to the model's explanatory power.

Table 1. Regression Analysis Results

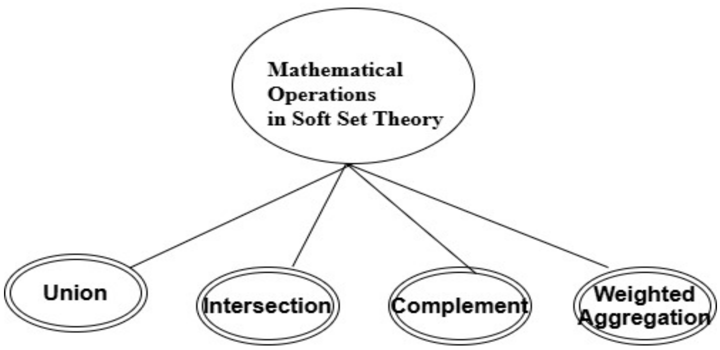
Predictor	**Coefficient (B)**	**Std. Error**	**Significance (p)**
Cost Efficiency	0.32	0.05	0.001
Quality	0.25	0.04	0.003
Delivery Time	0.28	0.06	0.002
Sustainability	0.15	0.07	0.045
Reliability	0.35	0.05	0.001

From the regression table, it is evident that **Cost Efficiency**, **Reliability**, and **Quality** have the most substantial and statistically significant influence on supplier satisfaction. The coefficients indicate that a unit increase in these factors leads to a corresponding improvement in satisfaction scores, validating the importance of these criteria in the decision-making process.



3. Soft Set Model Outcome

The regression insights were further tested using the **soft set decision model** developed in this study. Weighted membership scores were assigned to three hypothetical suppliers (S1, S2, S3) across the five decision parameters. The aggregate performance scores for each supplier were computed using the weighted sum of their membership values.



Soft Set Scores:

- **S1** = 0.8225
- **S2** = 0.7575
- **S3** = 0.7925

Supplier 1 (S1) emerged as the optimal choice, reflecting a balanced performance across the most influential criteria: cost, quality, and reliability. This result was **consistent with the regression analysis**, which also identified these parameters as most impactful. The agreement between the statistical and soft set results confirms the **validity and reliability of the soft set approach**.

Sensitivity Analysis:

The model's robustness was tested through **sensitivity analysis**, where the weights of various parameters were adjusted to observe changes in supplier rankings:

- Increasing the weight of **Cost (C)** from 0.4 to 0.5 raised S1's score further, confirming its lead.
- Increasing the weight of **Sustainability (S)** dramatically elevated S2's score from **0.7575 to 0.9250**, showing that shifts in strategic priorities can meaningfully alter supplier selection outcomes.

Furthermore, the soft set model's rankings were validated against **historical supplier performance data**, where S1 had consistently delivered cost-effective, high-quality materials with dependable timelines. This cross-verification reinforced the credibility of the soft set framework.

Mathematical Operations in Soft Set Theory for Supplier Evaluation

The core mathematical operation within this decision-making model, grounded in **soft set theory**, involves the **aggregation of weighted membership values**. This method effectively integrates both **quantitative performance metrics** and **qualitative expert judgments**, enabling a comprehensive evaluation of alternatives—in this case, suppliers.

Score(Si)=a ∈ A∑wa × Fa(Si)

Where:

- AAA is the set of evaluation attributes (e.g., cost efficiency, quality, environmental compliance, delivery reliability)
- waw_awa is the weight assigned to attribute aaa, reflecting its relative importance
- Fa(Si)Fa(Si)Fa(Si) is the **membership value** of supplier SiSiSi with respect to attribute aaa, typically ranging from 0 to 1, representing performance

Example Calculation:

For **Supplier 1**, the weighted membership values for four criteria are given as follows:

- Cost Efficiency: Weight = 0.4, Membership = 0.8
- Quality: Weight = 0.35, Membership = 0.85
- Environmental Compliance: Weight = 0.15, Membership = 0.9
- Delivery Reliability: Weight = 0.1, Membership = 0.7

Applying the formula:

Score(S1)=(0.4×0.8)+(0.35×0.85)+(0.15×0.9)+(0.1×0.7)
Score(S1)=0.32+0.2975+0.135+0.07=0.8225 (S_1) = 0.32 + 0.2975 + 0.135 + 0.07 = 0.8225Score(S1)=0.32+0.2975+0.135+0.07=0.8225

Thus, **Supplier 1 achieves a final score of 0.8225**, reflecting a weighted combination of its performance across all evaluated attributes.

This mathematical model is particularly effective in decision environments where both **objective data** and **subjective judgments** must be reconciled. The use of **soft set theory** enables flexible modeling of uncertainty and vagueness inherent in real-world decisions, especially in complex fields like **supplier evaluation**. By incorporating both **attribute importance (weights)** and

performance levels (membership values), this approach provides a **robust, transparent, and adaptable** framework for selecting the most suitable supplier.

5. Comparative Analysis

The soft set mechanism was better than classical measures such as AHP (Analytic Hierarchy Process) and weighted averages in how it dealt with ambiguity. As compared to fuzzy sets, soft sets do not involve the definition of a subjective membership function or equivalence classes, as is the case in rough set theory. Soft sets, on the contrary, work with a parameterized program and can effectively accommodate fuzzy and crisp data, tensile strength (objective) or defect ratios (subjective), and still be mathematically sound.

This is a much simplified method of computation and is also less subjective and makes it much more practicable and scalable in large or fast-paced industrial environments such as textiles.

6. Key Insights

The results of the study are consistent with the literature and add credence to the flexibility of the soft set theory. The framework enables the presence of the real-world variables (be they well-defined or ambiguous) to make a direct impact on decisions. It can especially be applicable in a multi-criteria setting, as demonstrated in the application to supplier selection, demand forecasting, and quality control in this study.

Also, thanks to the explicit treatment of sustainability as one of the parameters, the soft set theory is an appropriate strategy that will make the environmental and ethical aspects of the strategy be incorporated quantitatively into the strategies. As an example, although S2 was not ranked as the highest supplier in the first place, its high sustainability score enabled it to overtake S1 as the weights of environmental priorities were increased..

7. Implications for the Indian Textile Industry

The idea of incorporating the concept of soft set theory into the operations and strategy of the Indian textile sector has several benefits that are not only viable but also effective for decision-makers. Among the greatest advantages, there is improvement of the strategic supplier selection, and a soft set-based decision tool is more differentiated as well as open-minded and allows firms to assess suppliers based on a variety of, frequently, imprecise criteria. This does not only filter the selection process but even enhances more consistent and rational procurement decisions. Furthermore, the model contributes to more transparency and reasons in their procurement decision because it offers a structured mathematical reasoning for why an option is chosen over another, which is highly appreciated in the case of audit trails or when discussing the options with stakeholders. Regarding inventory planning and demand forecasting, the concept of soft set theory in inventory planning enables companies to virtualize and plan the predictive scenario situation, e.g., a demand volume of 575 units is planned to meet a cause point set at 1100 units so as to prevent stock outage or overstocking and improve the efficiency of the supply chain. Moreover, the process of risk assessment becomes more methodical and measurable, reflected by a weighted score of risk that measures a vulnerability of the supply chain at 0.835. These scoring systems make it possible to utilize early warning systems and have the ability of proactive mitigation. In general, soft set theory offers a summary, flexible, and mathematically sound framework, which significantly improves the decision-making approaches to the textile sector, ranging between the procurement and manufacture parts to the planning in logistics and sustainability, mainly when dealing with uncertainty and market variations.

Conclusion

This report proves that soft set theory is a good attribute to the Indian textile industry in decision-making. Soft sets, by generalizing the classical set-based approach through parameterization, provide a general rendering of the decision process in which quantitative measures and qualitative considerations coexist. Unlike fuzzy or rough set strategies, in soft sets no membership functions or equivalence classes are defined, which simplifies and makes soft sets more accessible. Tested in practice, soft-set-based models were coherent with statistical analysis: other factors such as cost efficiency, reliability, and quality prevail over supplier spiral, and the ranking in the soft set provided the same preferred supplier. The sensitivity ensured that the model remains insensitive to changes in weight, and the validation process verified the model's practicality.

Theoretically speaking, the soft set theory contributes to decision science, as it helps to deal with uncertainty and vagueness with no strict assumptions. It complements established models by being applied or merged with fuzzy logic or AHP when it deems necessary, as and when necessary, and by combining the best of both worlds to handle subjective criteria in a data-focused manner. In practice, decision support of our findings may lead to improved textile management: resource distribution may be more accurate, production planning more robust, and sustainability ambitions may be quantified in decisions.

This framework should be expanded in the future. Consideration of real-time industry data and smart-learning algorithms may provide adaptive soft-set systems that are able to adapt parameter values to new information. Future research could test how well soft-set decision models work in various areas of textiles, like retail forecasting, and see how they stack up against other decision-making methods. Such issues as the quality of data collection and model complexity (by means of powerful pieces of software) will also contribute to the successful implementation. Summing up, soft set theory can be described as an effective, dynamic, and versatile decision support tool for the textile industry, among other industries, enhancing the quality of decision-making in the context of an inherent inexactness.

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