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Article:

Wei, Y., Liu, Y., Siraj, A. et al. (2024) A strategic framework for sustainable quality management in the waste textile recycling industry within the context of the circular economy. *Business Strategy and the Environment*, 33 (8). pp. 9214-9232. ISSN: 0964-4733

<https://doi.org/10.1002/bse.3965>

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A strategic framework for sustainable quality management in the waste textile recycling industry within the context of the circular economy

Abstract

In the era of the circular economy, the pursuit of sustainability in the textile recycling industry offers organizations a significant competitive edge in the global competitive marketplace. Sustainable quality management practices (SQMP) have long been focal point of interest among companies. However, there has been limited research on achieving Circular Economy (CE) objectives in the textile sector, particularly within emerging economies like China. A gap remains in exploring SQMP within the context of CE goals, specifically in providing a comprehensive evaluation of the challenges to achieving sustainable operational practices. This study aims to integrate theories from quality management and the resource-based view with corporate environmental objectives in the waste textile recycling industry, to identify key challenges in implementing SQMP. A robust analytic approach combining the integrated cloud model, blind number theory, Decision-Making Trial and Evaluation Laboratory (DEMATEL), and Interpretative Structure Modeling (ISM) was used to analyze expert scoring results and to establish contextual and hierarchical relationships between the identified barriers, leading to the development of a framework model. The results show that workforce diversity has the highest correlation with other barriers and is a critical trigger point for integrating SQMP into organizations. These insights will assist practitioners in prioritizing strategic measures to foster sustainable quality management. Furthermore, this investigation holds important policy implications for stakeholders committed to advancing sustainable CE through the recycling and utilization of waste textiles.

Keywords Circular economy; textile recycling; sustainable quality management practices; cloud model; blind number theory; DEMATEL-ISM

1. INTRODUCTION

The global community is currently facing escalating environmental challenges, leading to increased scrutiny of the environmental ramifications across various sectors. Among these, the textile industry has attracted significant attention due to the considerable environmental degradation caused by conventional textile manufacturing and consumption practices (Xu et al., 2023). Consequently, there is an urgent need for

the textile industry to transition towards a more sustainable trajectory. The adoption of the Circular Economy (CE) has been identified as a key strategy to address this pressing issue (Sahoo et al., 2023; Upadhyay et al., 2023).

Sustainable Quality Management Practices (SQMP) play a crucial role in achieving CE and sustainable development goals. SQMP encompasses a range of organizational measures and strategies aimed at improving quality, reducing costs, and improving productivity. The literature on CE highlights the significance of SQMP as a significant driver in achieving CE goals. According to Khan et al. (2022), quality management strategies are instrumental in reducing costs within organizations, with cost reduction being identified as a primary motivator for CE adoption. CE primarily focuses on waste reduction, which aligns with the core objective of quality management to minimize costs through waste reduction (Zhang et al., 2021). Dezi et al. (2022) state that total quality management facilitates the integration of sustainability initiatives in the CE era, emphasizing the increased awareness among organizations to incorporate sustainable quality management practices in their operational and procedural endeavors (Dey et al., 2020; Suchek et al., 2021; Wei et al., 2024).

As a critical component of CE, the recycling of waste textiles requires the implementation of SQMP to enhance process quality. The distinctive role of waste textile recycling in resource regeneration and carbon emissions reduction has garnered considerable attention (Weber et al., 2023). Morsetto (2020) outlines the objectives of textile recycling within the CE strategy. The garment industry plays a vital role in trade, employment, investment, and national income, but it also faces challenges related to overproduction and cultural waste (John & Mishra, 2023; Coppola et al., 2023). Given China's status as a global leader in textiles and apparel, managing textile waste in the country is of critical significance, particularly in light of the fashion industry's focus on recycled materials objectives (Han et al., 2022). However, in developing nations, the market for resource separation and sorting is largely dominated by informal waste traders, whereas formal sorting is considerably less prevalent (Schmutz & Som, 2022). This reality affects the efficiency of recycling processes, highlighting the need for quality management to improve the quality of the overall procedure (Virmani et al., 2023).

Current research exhibits a gap in the evaluation of SQMP within the waste textile recycling sector for achieving CE goals. Despite growing interest from governments, businesses, and consumers in waste textile recycling, resulting in notable achievements,

there were persistent challenges encountered during the implementation phase. Previous studies have primarily focused on the socio-economic benefits of textile recycling, as highlighted by Reike et al. (2023). Limited literature has explored the circular supply chain aspects of textile recycling applications, addressing the procedures and challenges involved, as discussed by Saccani et al. (2023) and Pal & Sana (2022). According to Zhang et al. (2021), SQMP stands out as a primary catalyst for Circular Economy. Nevertheless, the integration of quality management into the waste textile recycling process often receives inadequate attention, resulting in a lack of comprehensive examination of diverse practices and impediments in textile recycling through the quality management lens. To address this gap, this research endeavor aims to address the following research questions:

RQ 1: What are the principal barriers to adopting SQMP in the textile recycling sector of developing nations such as China?

RQ 2: How can these barriers be strategically ranked and classified?

RQ 3: How can contextual associations be established among these barriers?

This study offers valuable insights into the implementation of SQMP in waste textile recycling. It is grounded in the Resource-Based View (RBV) framework and identifies key barriers to the successful implementation of SQMP within the waste textile recycling sector, as identified in existing literature (Chahal et al., 2020). Considering the complex interdependencies among the barriers impacting SQMP, a systematic approach to ranking, classifying, and analyzing the contextual relationships of these barriers is crucial for this study. Scholarly evidence suggests that combining Decision Making Trial and Evaluation Laboratory (DEMATEL) and Interpretative Structural Modeling (ISM) is an effective method to scrutinize factors influencing the system (Kumar et al., 2023). The DEMATEL-ISM methodology requires expert judgments, and by leveraging cloud modeling and blind number theory, it effectively manages the subjective assessments and ambiguous data provided by experts, thereby offering more reliable insights to guide decision-making processes.

This research aims to contribute to both scholarly and practical domains by identifying the elements that constitute SQMP within the context of CE objectives in the waste textile sector, along with the barriers that hinder the implementation of SQMP. Primarily, it enriches the existing body of knowledge on the effectiveness of SQMP by

elucidating the complex interplay among various barriers. Secondly, by illustrating the significance and hierarchical nature of these barriers, this study will assist industry stakeholders in prioritizing those barriers that require immediate attention, thus facilitating the resolution of subsequent barriers. Consequently, this will help the waste textile industry and society achieve sustainable development goals.

The remainder of this article is structured as follows: Section 2 presents the literature review on waste textile recycling and quality management. Section 3 elaborates on the research methodology. Section 4 discusses the application and results of the integrated approach. Section 5 provides a comprehensive discussion. Section 6 outlines the implications, limitations, and future research directions. Finally, Section 7 concludes the study.

2. LITERATURE REVIEW

2.1 Waste Textile Recycling

The recycling and reutilization of discarded textiles, as a fundamental component of the circular economy, have gained significant attention due to their pivotal role in resource efficiency and carbon emissions reduction (Weber et al., 2023). Nations are actively devising diverse policies and adopting cutting-edge technologies to enhance recycling processes (Hole & Hole, 2019). The extant literature predominantly focuses on methods, technologies, reuse, and consumer perceptions related to textile waste recycling. For example, DeVoy et al. (2021) examined the production and recycling conduct of post-consumer textile waste based on socioeconomic, demographic, and retail aspects, underscoring the necessity for multifaceted strategies to foster textile recycling. Damayanti et al. (2021) discussed various recycling technologies for textile products, accentuating the significance of formulating cost-efficient and effective methods for textile waste recycling. Lopatina et al. (2021) delved into the repurposing of discarded cotton textiles, showcasing the potential of repurposing textile waste in inventive manners. Paço et al. (2021) analyzed consumer behavioral patterns toward clothing recycling.

The amalgamation of various studies in the literature emphasizes the intricate nature of textile recycling and its implications for sustainable development. Given the intricate and diverse nature of recycling processes, quality management plays a critical

role in guaranteeing the efficiency and sustainability of recycling endeavors (Goyal et al., 2019). Nevertheless, the current research body lacks adequate direction. Addressing the aforementioned gaps, this research focuses on the exploration of SQMP within the realm of recycling activities.

2.2 Sustainable Quality Management Practices

Quality management encompasses all managerial activities aimed at achieving quality objectives throughout the business process, ensuring the fulfillment of customer requirements both internally and externally (Goyal et al., 2019). Empirical research on quality management has primarily focused on quality management practices (Asif, 2020). Despite numerous studies on quality management practices, there is no consensus on the essential practices. According to Fan & Niu (2023), Figure 1 outlines the key practices identified in the predominant literature. The 17 select references provide a comprehensive review of quality management research spanning from 1961 to 2023. This article argues that these studies establish a solid foundation for quality management. Through summarization and analysis, this study pinpoints the core sustainable quality management practices across 12 categories as illustrated in Figure 2.

Bill of QM Practices	Source
QM Practices (8): process flow management, product design process, statistical control/feedback, customer relationship, supplier relationship, work attitude, workforce management, and top management support.	Anderson et al., 1995.
QM Practices (6): visionary leadership, internal and external cooperation, learning, process management, continuous improvement, and employee fulfillment.	Rungtusanatham et al., 1998.
QM Practices (4): top management leadership, a sophisticated management infrastructure, process management efficacy, and stakeholder participation.	Ravichandran & Rai, 2000.
QM Practices (8): top management leadership, customer focus, employee management, supplier management, internal cooperation, external cooperation, quality-related learning, and core quality improvement.	Ahire & Ravichandran, 2001.
QM Practices (7): management leadership, training, employee relations, quality data and reporting, supplier quality management, product/service design, and process management.	Kaynak, 2003.
QM Practices (7): leadership, strategic planning, customer focus, information and analysis, human resource management, process management, and supplier management.	Sila & Ebrahimpour, 2005.
QM Practices (7): top management support, customer relationship, supplier relationship, workforce management, quality information, product/service design, and process management.	Zu et al., 2008.
QM practices (7): top management leadership, customer focus, employee relations, relationship with suppliers, competitors, communication/information systems, and product/process management.	Singh & Smith, 2004.
QM practices (6): leadership, strategic planning, customer focus, information and analysis, people management, and process management.	Feng et al., 2006.
QM practices (11): top management commitment, employee involvement, employee empowerment, education and training, teamwork, customer focus, process management, information and analysis system, strategic planning, open organization, and service culture	Hoang et al., 2006.
QM practices (6): management support, information for quality, process management, product design, human resource management, and relationship with customer and suppliers.	Perdomo-Ortiz et al., 2006.
QM practices (5): leadership, people, policy and strategy, processes and resources, and partnership.	Santos-Vijande & Álvarez-González, 2007.
QM practices (8): continuous improvement activity, use of tools for quality improvement in teamwork, statistical process control, supplier selection based on quality criteria, employee training, leadership, total preventive maintenance, and meeting with customers.	Martinez-Costa & Martinez-Lorente, 2008.
QM practices (6): leadership, strategic planning, customer focus, information and analysis, people management, and process management.	Prajogo & Hong, 2008.
QM practices (8): management leadership ; training ; employee relations; supplier quality management; customer relations; quality data reporting; process management; product/service design.	Kim et al., 2012.
QM practices (12): statistical control; process flow management; product design process; computer technology; technology utilization; continuous improvement; training; flexible manufacturing; zero defects thinking; process improvement; measurement benchmarks, advanced manufacturing systems; time-based principles	Cho et al., 2017.
QM practices (8): management leadership; training; employee relations/HR management; quality data and reporting; product service/design; process management; supplier quality management; customer focus.	Fan & Niu, 2023.

FIGURE 1 Summary of QM practices.

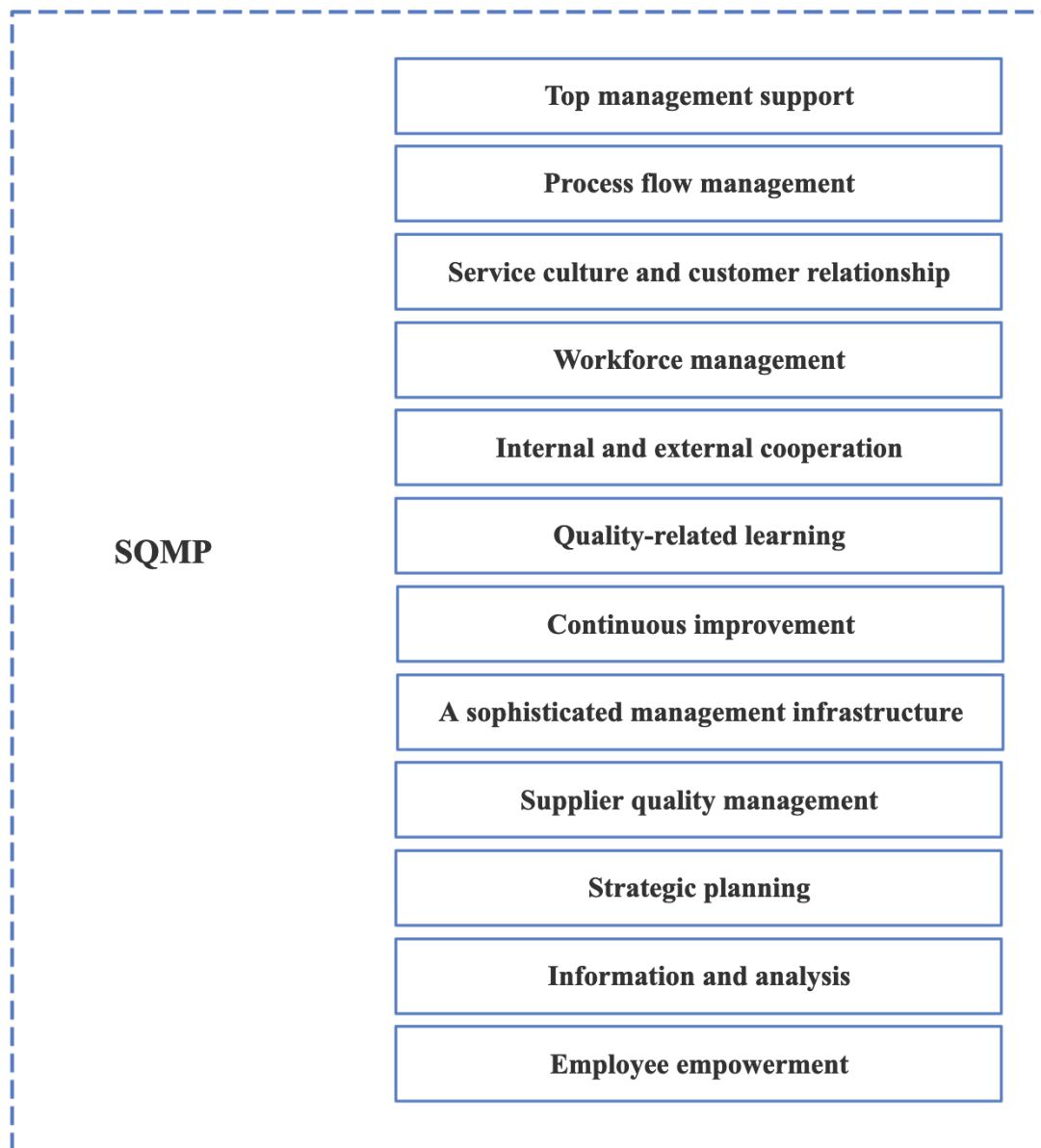


FIGURE 2 Sustainable quality management practices.

3. METHODOLOGY

This study employed a three-stage mixed research methodology to illustrate the impediments to the adoption of SQMP within the waste textile recycling sector. Initially, a systematic review of existing literature was conducted to identify the key barriers to SQMP implementation in the textile recycling industry. Subsequently, an expert panel was convened to evaluate and score these identified barriers. The scoring outcomes were analyzed using cloud models and blind number theory. Finally, the relationships between the barriers were investigated through the integration of DEMATEL and ISM

techniques in the third stage. The hierarchical arrangement of the research approaches is illustrated in Figure 3.

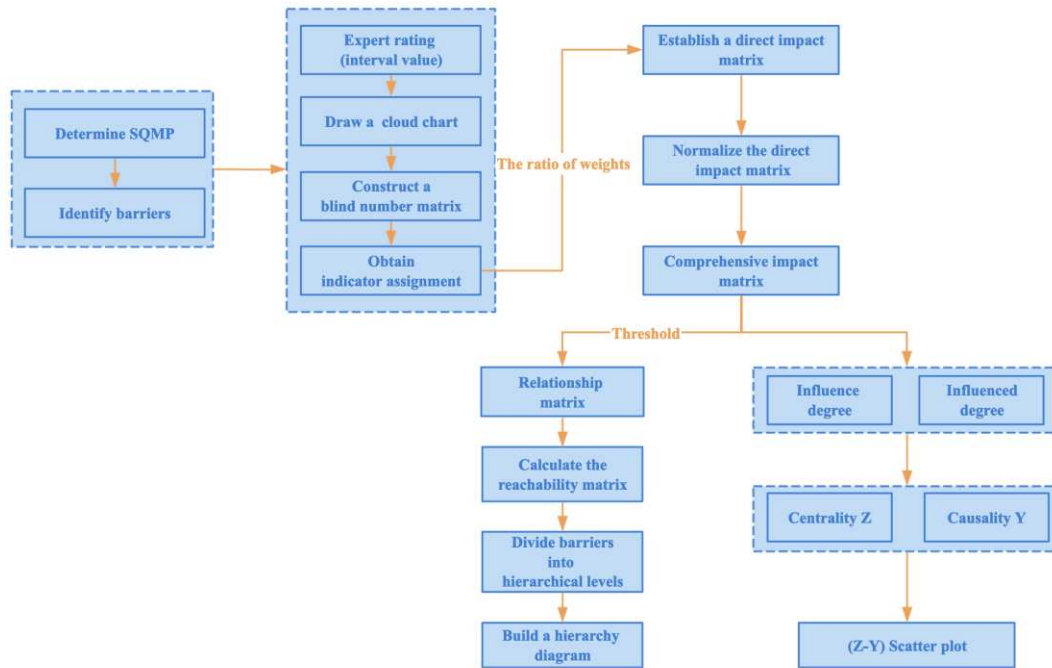


FIGURE 3 Research methodology diagram.

3.1 Model Introduction

3.1.1 Cloud Model

The cloud model integrates principles of probability theory and fuzzy set theory, capturing the inherent connection between randomness and fuzziness (Fu et al., 2011; Chen et al., 2023). The intricate nature of the relationships among various barriers forms a sophisticated system, while the assessment by experts tends to be vague and unpredictable. Compared to alternative methods of expressing uncertainty (such as intuition fuzzy numbers, and hesitation fuzzy numbers), the cloud model excels in visually illustrating expert rating distributions using numerical characteristics and cloud representations. The subsequent section outlines the relevant principles and procedures.

Definition 1

Assume a given domain of discourse U , a certain qualitative concept associated with U is Q , a random realization of the qualitative concept Q is element x , $x \sim N(E_x,$

$E_n'^2$), $E_n \sim N(E_n, H_e^2)$, the membership degree of element x belonging to the qualitative concept Q is $y \in [0, 1]$, where degree of membership y is defined as:

$$y = e^{-\frac{(x-E_n)^2}{2(E_n')^2}} \quad (1)$$

The designation of the degree of membership y of the element x on the provided domain U is referred to as a cloud, and each pair (x, y) is considered as a cloud droplet. The numerical aspects of the cloud model are able to portray the overall characteristics of the qualitative concept, denoted as $C(E_x, E_n, H_e)$, where the expectation E_x represents the central value of the domain of the specified qualitative concept, serving as the most accurate representation of said concept; the entropy E_n acts as a quantification of the uncertainty inherent in the sexual concept, determining the level of vagueness and randomness associated with the qualitative concept; super entropy H_e illustrates the extent to which E_n is discrete, thereby influencing the degree of fuzziness and randomness exhibited by the entropy.

The three numerical characteristics of clouds are calculated as:

$$\begin{cases} E_x = \frac{c_{max} + c_{min}}{2} \\ E_n = \frac{c_{max} - c_{min}}{6} \\ H_e = k \end{cases} \quad (2)$$

In the formula, c_{max} and c_{min} represent the maximum value and minimum value in a certain indicator classification standard; K is a constant, generally 0.01.

3.1.2 Blind Number Theory

Blind number theory employs unobservable information to precisely depict the evaluations of experts regarding barriers (Wei, et al., 2023). The integration of cloud model-blind number theory aids in portraying causal connections within intricate systems with enhanced accuracy, consequently elevating the dependability and resilience of analyses. This methodology exhibits superior capability in managing subjective evaluations and vague data, thereby furnishing more dependable backing for decision-making. The pertinent definitions are delineated as follows.

Definition 2

Let G be an interval gray number set, $\alpha_i \in G$, $f(x)$ is the gray function on G , if $\alpha_i \in [0, 1] (i = 1, 2, \dots, n)$, and $f(x) = \begin{cases} \alpha_i, & x = \alpha_i (i = 1, 2, \dots, n) \\ 0, & \text{Others} \end{cases} \quad (3)$

When $i \neq j$, $x_i \neq x_j$ and $\sum_{i=1}^n \alpha_i = \alpha \leq 1$, then the function $f(x)$ is called a blind number, expressed as: $\{[x_1, x_n], f(x)\}$, where x_1 is the lower limit of x , x_n is the upper limit of x , α_i is the credibility of x in x_i , $\alpha = \sum_{i=1}^n \alpha_i$ is the total credibility of x .

3.1.3 DEMATEL

DEMATEL is a significant tool grounded in graph theory and matrix methodologies, with a focus on streamlining the analysis process of system structure. It relies on the extensive expertise of specialists to examine the causal relationships within intricate systems. In contrast to alternative approaches like AHP/ANP, GRA, TOPSIS, VIKOR, and ELECTRE, the DEMATEL technique is more adept at pinpointing causal relationships (Si et al., 2018). Complex systems, like SQMP, exhibit typical traits of a multitude of intricate factors. By employing the DEMATEL technique, one can delve into the interrelationships and impact levels among influential variables, subsequently identifying the pivotal components.

3.1.4 ISM

ISM is a method of structured analysis that illustrates the intrinsic correlation mechanism of intricate systems through succinct hierarchical topology diagrams (Digalwar et al., 2020). While the DEMATEL method can assess the status and causal relationships of factors within a complex system, it cannot fully elucidate the internal structure and rationale. This gap is addressed by ISM. By combining DEMATEL and ISM methods, the dynamic relationship among influencing factors is handled in a relatively objective manner, enabling a clear depiction of the logical and hierarchical relationships within the system. Consequently, the DEMATEL-ISM method offers distinct advantages in addressing the dynamic relationship challenges of complex systems, such as those encountered in overcoming barriers to SQMP implementation in waste textile recycling.

3.2 Integrated Model Building

Building on the theoretical foundation of blind number theory and cloud model, an integrated method combining cloud model-blind number theory-DEMATEL-ISM is proposed. The specific steps are as follows:

- (1) Barriers set $B = \{b_1, b_2, \dots, b_n\}$ is constructed based on literature review and expert opinions.
- (2) Numerical range and qualitative language description of the barrier levels are determined, and a level cloud chart is drawn.
- (3) Based on the expert scoring results, a cloud diagram of each barrier b_n is drawn.
- (4) The outcomes of expert assessment are used to ascertain the matrix of blind numbers. This article employs the expert scoring approach to appraise the evaluation indicators. Recognizing the subjectivity and uncertainty inherent in human cognitive behavior, blind numbers are employed to depict the assessment results of experts. This entails requesting each expert to provide a score range for the evaluation indicators, allowing for cross-level scoring. Furthermore, when employing blind number theory for evaluation, the concept of "expert credibility" is introduced to enhance the accuracy and reasonableness of the evaluation outcomes. This refers to the degree to which experts can be trusted, typically expressed as a percentage. The most trustworthy expert has a credibility rating of 1, while the expert with the lowest trustworthiness is assigned a credibility rating of 0. If the credibility of the expert group members $I_1, I_2, \dots, I_n$, taking into account their professional titles, academic qualifications, and working years, is $\beta_1, \beta_2, \dots, \beta_n$;

$$\beta_i = \sum_{m=1}^3 \alpha_m / 30 \quad (4)$$

Then the comprehensive credibility θ_i of expert I_i with respect to the expert group $I_1, I_2, \dots, I_n$ can be expressed as:

$$\theta_i = \beta_i / \sum_{m=1}^n \beta_m \quad (5)$$

Since there are overlapping intervals in the expert group's scoring, it is necessary to divide each score interval without intersection based on the expert's credibility, establish a new interval sequence, and recalculate the credibility of the new interval according to the proportional allocation method, and the blind number matrix $\mathbf{D}$ of the evaluation index can be obtained:

$$\mathbf{D} = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{bn} & \gamma_{b2} & \cdots & \gamma_{bn} \end{bmatrix}$$

In the formula, γ_{bn} is the possibility that the b-th evaluation index falls in the

n-th evaluation interval.

- (5) Based on the blind number matrix and weight level values, and using the interpolation method, the indicator assignment is determined. If the insertion points of n-level intervals are $a_1, a_2 \cdots a_n$ respectively, the assigned value of the indicator b_n is $y_{b_n} = \sum_{i=1}^n a_i * \gamma_{bn}$ (6).
- (6) Calculate the direct impact matrix and the comprehensive impact matrix. The obtained weight ratio p_{ij} of b_i and b_j between pairs of barriers represents the expert's preference for pairwise comparison. The direct influence matrix is composed of the decision-making results of m experts is $R = (p_{ij})_{n \times n}$. Calculate the comprehensive influence matrix T according to formulas (7) and (8).

$$N_R = \frac{1}{\text{Max}(\text{Max}(\sum_{i=1}^n F_{ij}), \text{Max}(\sum_{j=1}^n F_{ij}))} * R \quad (7)$$

$$T = \lim_{n \rightarrow \infty} (N_R + N_R^2 + \cdots + N_R^n) = N_R \frac{I - N_R^{n-1}}{I - N_R} = N_R (I - N_R)^{-1} \quad (8)$$

- (7) Based on the comprehensive influence matrix T , the centrality Z and causality Y are calculated according to the following formulas:

$$R_i = \sum_{i=1}^n t_{ij}, (i = 1, 2, \cdots, n) \quad (9)$$

$$E_i = \sum_{i=1}^n t_{ij}, (i = 1, 2, \cdots, n) \quad (10)$$

$$Z_i = R_i + E_i, i = j \quad (11)$$

$$Y_i = R_i - E_i, i = j \quad (12)$$

- (8) The comprehensive influence matrix is converted into the relationship matrix A . For the conversion, the threshold needs to be found. The threshold is calculated according to formula (13). According to formula (14), indicators with small influence are eliminated, and the comprehensive influence matrix is converted into a relationship matrix. Compute the reachability matrix.

$$\lambda = a + b, \lambda \in [0, 1] \quad (13)$$

$$A_{ij} = \begin{cases} 1, & a_{ij} \geq \lambda \\ 0, & a_{ij} < \lambda \end{cases} (i, j = 1, 2, \cdots, n) \quad (14)$$

Among them, a and b are the mean and standard deviation of all elements in the comprehensive influence matrix T respectively.

- (9) Further, the reachability matrix K is calculated. The relationship matrix A obtains the reachability matrix through formula (15).

$$(A + I)^{(k-1)} \neq (A + I)^k = (A + I)^{(k+1)} = R \quad (15)$$

(10) The identified barriers are divided into hierarchical levels and a hierarchical relationship diagram is established. Based on the reachability matrix K , identify the reachability set $K(B_i)$, antecedent set $A(B_i)$ and common set $L(B_i)$ of each barrier, giving priority to the results priority rule: $L(B_i) = K(B_i)$ for hierarchical division. Draw a hierarchical diagram based on the hierarchical division results.

$$\begin{cases} K(B_i) = \{ B_i \mid B_i \in B, b_{ij} = 1 \} \\ A(B_i) = \{ B_i \mid B_i \in B, b_{ji} = 1 \} \\ L(B_i) = \{ B_i \in B \mid K(B_i) \cap A(B_i) = R(B_i) \} \end{cases} \quad (16)$$

4. DATA ANALYSIS

The current research was conducted in three distinct phases. Initially, an extensive review and evaluation of documents in the Web of Science database were performed to ascertain the impediments to the implementation of SQMP in waste textile recycling within the circular economy framework. The search focused on English language materials and scholarly articles in the primary repository limited to the years from 2018 to 2024 to ensure the inclusion of the most recent data. The keywords were "textile industry" and specific methodologies. Following a meticulous assessment, a total of 13 specific barriers were identified, as listed in Table 1, along with relevant citations.

TABLE 1 Identification of barriers

Sr.no	SQMP	Barriers	Source
P1	Top management support	High production and sales costs (B1)	Majumdar et al., 2021; Leal et al., 2019; Bhandari et al., 2022
P2	Process flow management	Lack of raw material control (B2)	Marconi et al., 2018; Schmutz & Som, 2022
P3	Service culture and customer relationship	Consumers lack understanding of sustainability (B3)	Hartley et al., 2022; Eppinger, 2022; Khitous et al., 2022
P4	Workforce management	Diversified workforce (B4)	Kazancoglu et al., 2020; Malik et al., 2023
P5	Internal and external cooperation	Difficulty in teamwork (B5)	Rese et al., 2022; Malinverno et al., 2023

P6	Quality-related learning	Employee training, safety and health issues (B6)	Athanasopoulos & Zabaniotou, 2022; Akbar & Ahsan, 2020
P7	Continuous improvement	Technical limitations (B7)	Mu & Yang, 2022; Sandvik & Stubbs, 2019; Yousef et al., 2020
P8	A sophisticated management infrastructure	Lack of recycling business model (B8); Lack of standard specifications (B9)	Zhang et al., 2020; Ponnambalam et al., 2023
P9	Supplier quality management	Supply chain complexity (B10)	Xu et al., 2019
P10	Strategic planning	Lack of precise quality objectives (B11)	Kazancoglu et al., 2020; Kirchherr et al., 2018
P11	Information and analysis	Lack of ability to provide high-quality recycling (B12)	Leal et al., 2019; Rahman et al., 2020
P12	Employee empowerment	Cultural and traditional obstacles (B13)	Majumdar et al., 2021; Fromhold-Eisebith, 2021; Alves et al., 2022
			Wen et al., 2023

The primary obstacle to obtaining Top management support (P1) is the elevated costs associated with production and sales (B1). A significant challenge in organizational development is the lack of support from top management, as stated by Majumdar et al. (2021). To effectively implement and sustain initiatives related to sustainability, it is imperative for top management to assume a leadership role within the organization and provide continuous support through the development of extensive knowledge, thereby ensuring the successful adoption of sustainability initiatives, as highlighted by Bhandari et al. (2022). In the context of waste textile recycling, the major barrier to obtaining management support (Leal et al., 2019) is the high costs associated with production and sales, alongside limited recycling and utilization capabilities and the exorbitant expenses incurred during the recycling processes.

The primary impediment to Process flow management (P2) lies in the lack of control over raw materials (B2). Effective raw material management involves the assurance of supplier-provided raw materials meeting quality standards, as well as the implementation of measures to maintain the stability of raw material quality throughout the production process (Schmutz & Som, 2022). It has been noted by Marconi et al. (2018) that numerous textile waste materials are unsuitable for multiple recycling due to the presence of a diverse array of polymers with distinct mechanical and technical properties, rendering the separation process challenging.

The main impediment to Service culture and customer relationships (P3) lies in the consumers' lack of understanding of sustainability (B3). When making clothing purchasing decisions, consumers typically do not prioritize altruistic considerations, thus sustainability is rarely a primary criterion. Furthermore, consumers' attitudes towards recycled products are often influenced by price, as they may perceive that items made from recycled materials are of inferior quality compared to those made from virgin materials (Hartley et al., 2022). Recent research conducted by Eppinger (2022) suggests that enhancing the end-use market for recyclable items and educating consumers about recycling can improve existing recycling rates in the apparel industry. The industry also faces challenges due to imperfect customer participation policies and a lack of community awareness about sustainability, both of which restrict its ability to engage in social sustainability (Khitous et al., 2022).

A diversified workforce (B4) presents a major barrier to implementing Workforce management (P4). In waste textile recycling industry, the supply chain may involve multiple links, including recycling sites, processing plants, transportation service providers, etc. (Kazancoglu et al., 2020). This results in a complex workforce mix involving employees with different skills and functions. Managing such a diverse workforce requires human resource managers to have cross-domain understanding and coordination capabilities (Malik et al., 2023).

The primary challenge in implementing Internal and external cooperation (P5) lies in the difficulty of teamwork (B5). Teamwork plays a pivotal role in fostering innovation in the sustainable textile industry (Rese et al., 2022). However, when integrating R&D, marketing, and production, textile waste recycling companies encounter significant barriers to internal cross-functional collaboration (Malinverno et al., 2023). These departments often possess differing priorities and objectives, resulting in conflicts during the collaboration process. Technical and cultural differences can impede information and knowledge sharing, thereby limiting effective collaboration. Moreover, opacity in resource allocation and decision-making processes can also give rise to collaboration problems, as different departments may dispute resource allocation.

The implementation of Quality-related learning (P6) faces sustainability challenges in the form of employee training, safety, and health concerns (B6). The waste textile recycling industry encounters a range of technical barriers, including the need for specialized knowledge and skills in waste textile classification, processing, and recycling (Leal et al., 2019; Athanasopoulos & Zabaniotou, 2022). As a result,

waste textile recycling companies must prioritize employee training matters (Akbar & Ahsan, 2020). Furthermore, the recycling process may involve hazardous chemical operations, such as dye removal and wastewater treatment, necessitating the employees to possess safety expertise and skills for handling these chemicals. Given these technical challenges and hazardous operations, textile waste recycling companies must take proactive measures to ensure the training, safety, and well-being of their employees.

Technical limitations (B7) are the main barriers to implementing Continuous improvement (P7). Textile waste often contains a variety of materials and colors that traditional sorting techniques struggle to effectively separate. The lack of advanced processing technology is the main reason for the limited amount of recyclable materials (Sandvik & Stubbs, 2019). Many existing methods also struggle to effectively separate dyes and other contaminants from virgin fibers (Mu & Yang, 2022). In addition to sorting challenges, there are limitations in chemical and mechanical textile recycling technologies (Yousef, et al., 2020), which require significant investment in research and development to overcome current limitations and introduce more efficient technologies.

The primary challenges in establishing a sophisticated management infrastructure (P8) are the absence of a recycling business model (B8) and the absence of standard specifications (B9). In the realm of waste textile recycling in China, there exist several prevalent models, including the waste clothing recycling box model, the private market-oriented recycling model, the extended producer responsibility recycling model, and the online platform recycling model (Zhang et al., 2020). However, it is worth noting that while these models contribute to waste textile recycling, they do not represent comprehensive recycling business models. The current recycling model has not fully realized the potential for recycling waste textiles, necessitating further business innovation and the development of sustainable business models in the future to achieve this objective (Ponnambalam et al., 2023). Quality standards are often regarded as crucial determinants of the final product quality (Heck & Zaidman, 2018). In order to comprehensively implement the concept of CE, standardize the waste textile recycling system, and promote the standardization of recycled products, China has successively introduced a series of standards and specifications. Nevertheless, the existing system still does not encompass the entire textile cycle system. It is known that there are two methods for treating waste textiles: extending the service life of waste textiles and

recycling. However, the existing system lacks a clear definition of recycling design, and improvements are still necessary for the standardized comprehensive system (Xu et al., 2019).

The main hindrance to the implementation of Supplier quality management (P9) is the complexity of the supply chain (B10). In the textile industry, the supply chain poses a significant barrier, as demonstrated by the findings of Kazancoglu et al. (2020) on the challenges faced by the supply chain in implementing CE in the textile industry. The textile recycling industry's CE encompasses the intricate supply chain, which includes the entire process of collection, sorting, separation, and recycling (Dahlbo et al., 2017). Each step in the supply chain impacts the final product's manufacturing (Kirchherr et al., 2018). Effective management of supply chain quality necessitates comprehensive consideration of these complex factors and the implementation of appropriate measures to ensure product quality, sustainability, and compliance.

The absence of precise quality objectives (B11) presents the primary hindrance to executing Strategic planning (P10). Quality is a recurrent aspect in numerous discussions concerning competitiveness and strategy (Goyal et al., 2019). Normative theory asserts that the design of management control systems should be complementary to management quality strategies (Daniel & Reitsperger, 1991). Prevailing research primarily focuses on formulating sustainable development goals at the macro level within the textile industry (Leal et al., 2019; Rahman et al., 2020), leaving a gap in specific micro-quality objectives in this particular domain.

The main impediment to the implementation of Information and analysis (P11) is the insufficient capacity to provide recycling of high quality (B12). Information analysis is inseparable from the application of Industry 4.0 technology, which plays a vital role in achieving sustainability. For example, the Internet of Things (IoT) is significant in monitoring and controlling waste management processes (Alves et al., 2022). Big data analysis, cloud computing, and industrial simulation further ensure enhanced traceability and sustainable resource management by apparel companies (Majumdar et al., 2021; Fromhold-Eisebith, 2021). Nevertheless, the use of these technologies in the waste textile recycling sector in China remains inadequate.

Cultural and traditional obstacles (B13) represent the primary barriers to the implementation of Employee empowerment (P12). In quality management, employees are key to executing quality management practices and are instrumental in identifying and addressing quality-related issues. Employee empowerment facilitates the timely

detection and resolution of quality problems. Evidence suggests that employee empowerment can be harnessed to enhance job satisfaction, organizational commitment, innovativeness, and performance (Huntsman et al., 2021; Ma et al., 2021). The existing research indicates that empowerment in Asian culture diverges from that in Western nations. In Asian culture, empowerment is closely linked to individual employees and their strengths (Wen et al., 2023). In the Chinese context, the establishment of effective teamwork relies on a high level of trust between individuals and the existence of a 'family-like' bond among them.

4.1 Cloud Model-blind Number Theory Analysis

According to the empirical investigation carried out in this scholarly article, adhering to the principles of objectivity and authority, purposive sampling was employed to choose experts at a higher level. Drawing on decision-making theory for expert groups, as described by Marlin et al. (1994), it is posited that the desired outcomes can be attained with a group size ranging from 5 to 7 members. The China-Korea International Quality Conference has been organized successfully on 19 occasions and is renowned as a conference dedicated to quality management science in China. The participants of this conference serve as the subjects for sampling in this research. From these participants, five distinguished scholars specializing in quality management were selected for interviews. Details regarding the experts' background are outlined in Table 3. Regarding the 13 identified barriers, this article establishes a numerical range and employs qualitative language to describe the levels of these barriers, as detailed in Table 2. Additionally, a cloud chart, depicted in Figure 4, is produced to visualize these findings.

The five experts assigned interval values to each barrier based on their perceived importance and the grading standards, allowing for scoring across different levels. After analyzing the scoring outcomes through a screening process, indicators scoring below 60 were eliminated. Following the continuous feedback and adjustments, an analysis was carried out on the scores provided by the experts.

TABLE 2 Numerical range and qualitative language description of barrier factor levels

Numerical range	Range 1	Range 2	Range 3	Range 4	Range 5
Level	0-60	60-70	70-80	80-90	90-100
Weight range	0-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1

Language description	Unimportant	Slightly	Obviously	Strongly	Extremely
Expected value	0.3	0.65	0.75	0.85	1
Entropy	0.1	0.0167	0.0167	0.0167	0.0167
Super entropy	0.005	0.005	0.005	0.005	0.005

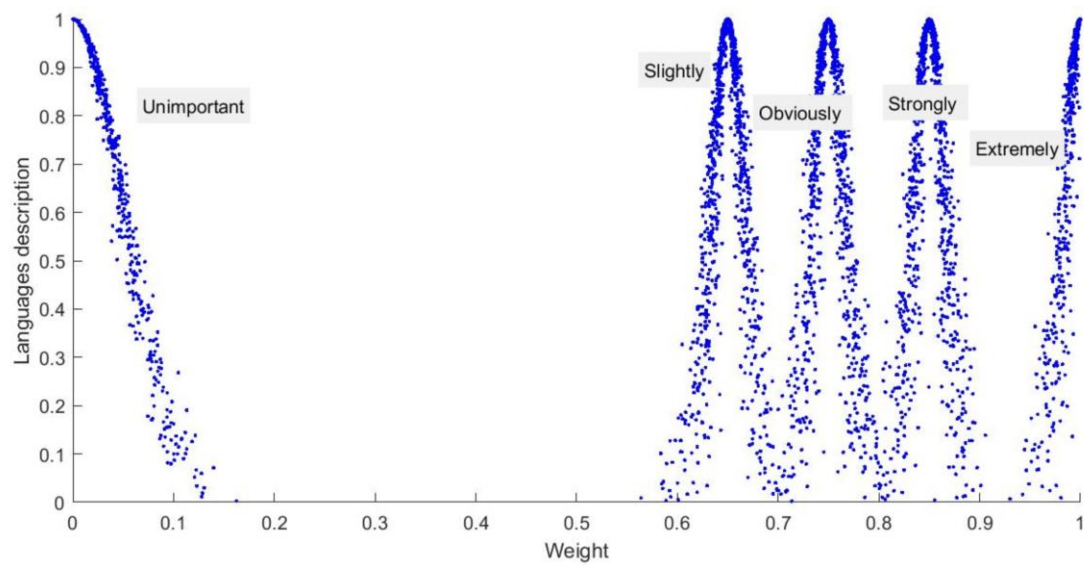


FIGURE 4 Level range cloud chart.

By taking the median value method, the cloud model of each barrier factor is drawn, and the expert rating is depicted, as shown in Figure 5.

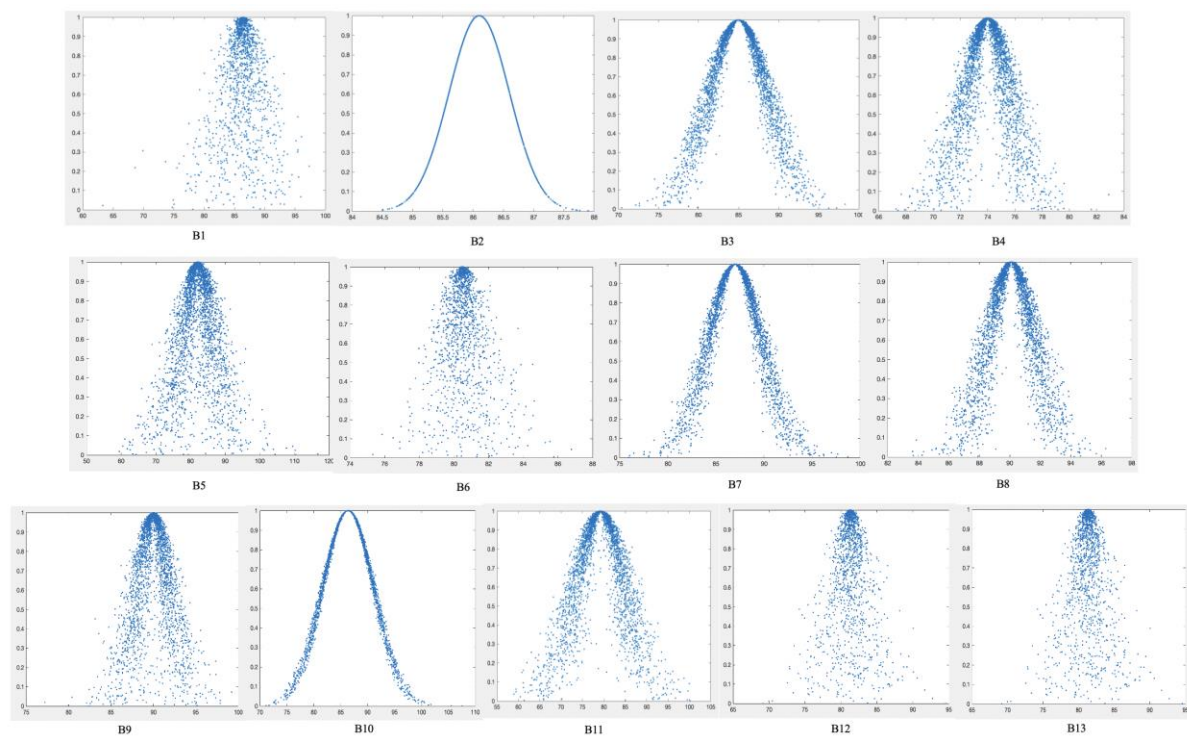


FIGURE 5 Expert rating cloud chart.

The distribution of the cloud diagram highlights significant dissimilarities in the evaluation of the significance of each barrier, as conducted by the group of experts. Notably, the consistency of scoring for B2 and B10 is relatively high. To address the uncertainty associated with expert scoring, a blind number matrix was introduced. Furthermore, the personal credibility and comprehensive credibility of the five experts were obtained based on a quantitative reference standard for expert credibility, as shown in Table 3.

TABLE 3 Expert information

No.	Professional title	Length of service	Degree	Credibility	Comprehensive credibility
Z1	International Academician	53	Master	1	0.2083
Z2	Professor	20	Doctor	0.967	0.2014
Z3	Professor	20	Doctor	0.967	0.2014
Z4	Professor	20	Doctor	0.967	0.2014
Z5	Professor	15	Doctor	0.9	0.1875

According to steps 4 and 5, the blind number matrix **D** and index assignment are finally obtained as listed in Table 4.

$$D = \begin{bmatrix} 0 & 0 & 0 & 0.7986 & 0.2014 \\ 0 & 0 & 0 & 0.7986 & 0.2014 \\ 0 & 0 & 0.2014 & 0.5972 & 0.2014 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0.2609 & 0.7391 & 0 \\ 0 & 0 & 0.2882 & 0.7118 & 0 \\ 0 & 0 & 0 & 0.8993 & 0.1007 \\ 0 & 0 & 0 & 0.4965 & 0.5053 \\ 0 & 0 & 0 & 0.4896 & 0.5104 \\ 0 & 0 & 0.0536 & 0.5940 & 0.3525 \\ 0 & 0 & 0.5972 & 0.4028 & 0 \\ 0 & 0 & 0.3056 & 0.6944 & 0 \\ 0 & 0 & 0.5972 & 0.4028 & 0 \end{bmatrix}$$

TABLE 4 Barriers assignment

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
Score	87.01	87.01	85.00	75.00	82.39	82.12	86.01	90.04	90.10	87.99	79.03	81.94	79.03

4.2 DEMATEL-ISM Analysis

Through expert discussions, this paper utilizes pairwise ratio of weights assigned to barriers, rounded to one decimal place, to depict the interactions between these barriers. Furthermore, it establishes a direct impact matrix and a comprehensive impact matrix based on step (6), which are displayed in Tables 5 and 6, respectively. An inter-relation matrix was constructed to evaluate the interrelationships among identified barriers, as elaborated in Table 7. To ascertain the causal relationships between barriers in the SQMP, calculations of centrality Z and causality Y were performed. The Z value serves as an indicator of the significance of the relationship, with its maximum value denoting the most important criterion. On the other hand, the Y value is utilized to describe the causal relationship between barriers. A positive Y value suggests that it belongs to a cause group, meaning it affects other barriers or criteria. Conversely, a negative Y value denotes that it falls under the outcome group, suggesting that the barriers are influenced by other criteria. Cause-and-effect diagrams are employed to visually illustrate the interrelationships among SQMP barriers, aiding in the comprehension of intricate interactions. These barriers are organized into cause-and-effect relationships and visualized through Y and Z values on a graph, as depicted in Figure 6.

In accordance with steps 8 and 9, a relationship matrix (Table 8) and a reachability matrix (Table 9) were generated, indicating that if barrier B1 is related to barrier B5, and barrier B5 is related to barrier B8, then barrier B1 is inevitably connected to barrier B8 (Sonar et al., 2022). The partitions extracted from the reachability matrix were utilized to determine the levels of the ISM hierarchy. Based on the division results, the ISM hierarchical model was successfully constructed, as detailed in Figure 7.

TABLE 5 Direct-relation matrix

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	0.00	1.00	1.02	1.16	1.06	1.06	1.01	0.97	0.97	0.99	1.10	1.06	1.10
B2	1.00	0.00	1.02	1.16	1.06	1.06	1.01	0.97	0.97	0.99	1.10	1.06	1.10
B3	0.98	0.98	0.00	1.13	1.03	1.04	0.99	0.94	0.94	0.97	1.08	1.04	1.08
B4	0.86	0.86	0.88	0.00	0.91	0.91	0.87	0.83	0.83	0.85	0.95	0.92	0.95
B5	0.95	0.95	0.97	1.10	0.00	1.00	0.96	0.92	0.91	0.94	1.04	1.01	1.04
B6	0.94	0.94	0.97	1.09	1.00	0.00	0.95	0.91	0.91	0.93	1.04	1.00	1.04
B7	0.99	0.99	1.01	1.15	1.04	1.05	0.00	0.96	0.95	0.98	1.09	1.05	1.09
B8	1.03	1.03	1.06	1.20	1.09	1.10	1.05	0.00	1.00	1.02	1.14	1.10	1.14

B9	1.04	1.04	1.06	1.20	1.09	1.10	1.05	1.00	0.00	1.02	1.14	1.10	1.14
B10	1.01	1.01	1.04	1.17	1.07	1.07	1.02	0.98	0.98	0.00	1.11	1.07	1.11
B11	0.91	0.91	0.93	1.05	0.96	0.96	0.92	0.88	0.88	0.90	0.00	0.96	1.00
B12	0.94	0.94	0.96	1.09	0.99	1.00	0.95	0.91	0.91	0.93	1.04	0.00	1.04
B13	0.91	0.91	0.93	1.05	0.96	0.96	0.92	0.88	0.88	0.90	1.00	0.96	0.00

TABLE 6 Total relation matrix

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	0.5250	0.5936	0.6077	0.6887	0.6269	0.6290	0.6005	0.5737	0.5732	0.5870	0.6536	0.6303	0.6536
B2	0.5936	0.5250	0.6077	0.6887	0.6269	0.6290	0.6005	0.5737	0.5732	0.5870	0.6536	0.6303	0.6536
B3	0.5799	0.5799	0.5250	0.6727	0.6124	0.6144	0.5866	0.5604	0.5600	0.5734	0.6385	0.6157	0.6385
B4	0.5116	0.5116	0.5238	0.5250	0.5404	0.5421	0.5176	0.4945	0.4941	0.5060	0.5633	0.5433	0.5633
B5	0.5621	0.5621	0.5754	0.6521	0.5250	0.5956	0.5686	0.5432	0.5428	0.5558	0.6189	0.5968	0.6189
B6	0.5602	0.5602	0.5735	0.6499	0.5916	0.5250	0.5667	0.5414	0.5410	0.5540	0.6168	0.5949	0.6168
B7	0.5868	0.5868	0.6007	0.6807	0.6197	0.6217	0.5250	0.5671	0.5666	0.5803	0.6460	0.6231	0.6460
B8	0.6142	0.6142	0.6288	0.7126	0.6487	0.6508	0.6214	0.5250	0.5931	0.6074	0.6763	0.6522	0.6763
B9	0.6147	0.6147	0.6292	0.7131	0.6492	0.6513	0.6219	0.5941	0.5250	0.6079	0.6768	0.6527	0.6768
B10	0.6003	0.6003	0.6145	0.6964	0.6339	0.6360	0.6073	0.5801	0.5797	0.5250	0.6609	0.6374	0.6609
B11	0.5391	0.5391	0.5519	0.6255	0.5694	0.5713	0.5454	0.5210	0.5206	0.5332	0.5250	0.5725	0.5936
B12	0.5590	0.5590	0.5723	0.6486	0.5904	0.5923	0.5655	0.5403	0.5398	0.5528	0.6155	0.5250	0.6155
B13	0.5391	0.5391	0.5519	0.6255	0.5694	0.5713	0.5454	0.5210	0.5206	0.5332	0.5936	0.5725	0.5250

TABLE 7 Inter-relation matrix

No.	Barriers	R	E	Z=R+E	Rank	Y=R-E	Impact
B1	High production and sales costs	7.9428	7.3855	15.3283	7	0.5573	Cause
B2	Lack of raw material control	7.9428	7.3855	15.3283	7	0.5573	Cause
B3	Consumers lack understanding of sustainability	7.7574	7.5621	15.3195	13	0.1953	Cause
B4	Diversified workforce	6.8367	8.5796	15.4162	1	-1.7429	Effect
B5	Difficulty in teamwork	7.5172	7.8038	15.3209	12	-0.2866	Effect
B6	Employee training and safety and health issues	7.4920	7.8299	15.3220	11	-0.3379	Effect
B7	Technical limitations	7.8504	7.4725	15.3229	9	0.3779	Cause
B8	Lack of recycling business model	8.2210	7.1354	15.3564	3	1.0856	Cause
B9	Lack of standard specifications	8.2273	7.1299	15.3572	2	1.0974	Cause
B10	Supply chain complexity	8.0326	7.3029	15.3355	6	0.7297	Cause
B11	Lack of precise quality objectives	7.2075	8.1388	15.3463	4	-0.9312	Effect
B12	Lack of ability to provide high-quality recycling	7.4760	7.8467	15.3227	10	-0.3707	Effect
B13	Cultural and traditional obstacles	7.2075	8.1388	15.3463	4	-0.9312	Effect

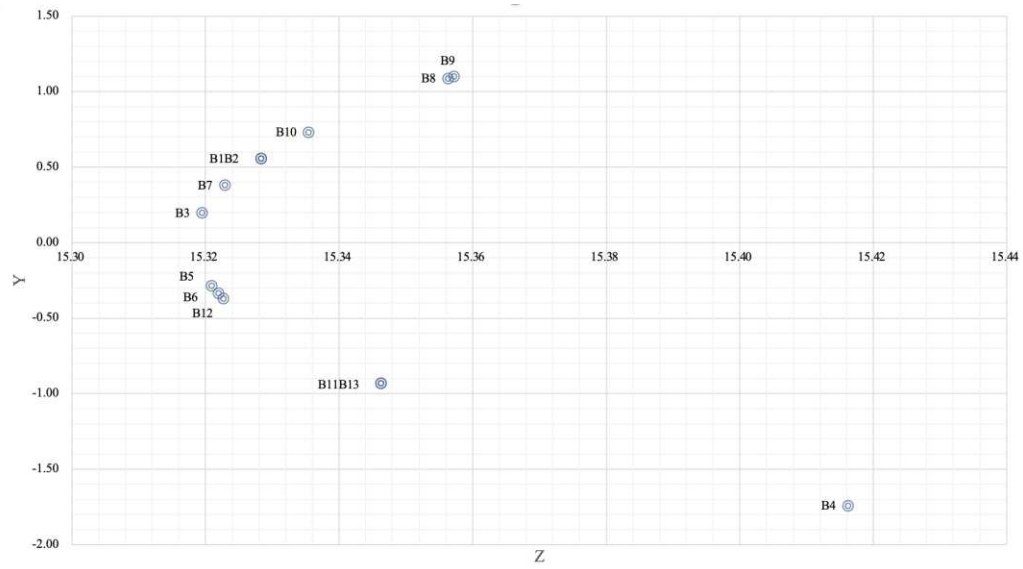


FIGURE 6 Causal relationship.

TABLE 8 Relationship matrix

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	1	0	0	0	0	0	0	0	1	0	1	1	0
B2	0	1	0	0	0	0	0	0	1	0	1	1	0
B3	0	0	1	0	0	0	0	0	0	0	0	1	0
B4	0	0	0	1	0	0	0	0	0	0	0	1	0
B5	0	0	0	0	1	0	0	0	0	0	0	1	0
B6	0	0	0	1	1	1	0	0	1	1	1	1	0
B7	0	0	0	1	1	0	1	0	1	1	1	1	0
B8	0	0	0	0	0	0	0	1	1	0	1	1	0
B9	0	0	0	0	0	0	0	0	1	0	0	0	0
B10	0	0	0	0	0	0	0	0	0	1	0	1	0
B11	0	0	0	0	0	0	0	0	0	0	1	0	0
B12	0	0	0	0	0	0	0	0	0	0	0	1	0
B13	0	0	0	0	0	0	0	0	1	0	1	1	1

TABLE 9 Reachability matrix

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13
B1	1	0	0	0	0	0	0	0	1	0	1	1	0
B2	0	1	0	0	0	0	0	0	1	0	1	1	0
B3	0	0	1	0	0	0	0	0	0	0	0	1	0
B4	0	0	0	1	0	0	0	0	0	0	0	1	0
B5	0	0	0	0	1	0	0	0	0	0	0	1	0
B6	0	0	0	1	1	1	0	0	1	1	1	1	0
B7	0	0	0	1	1	0	1	0	1	1	1	1	0
B8	0	0	0	0	0	0	0	1	1	0	1	1	0
B9	0	0	0	0	0	0	0	0	1	0	0	0	0
B10	0	0	0	0	0	0	0	0	0	1	0	1	0

B11	0	0	0	0	0	0	0	0	0	0	1	0	0
B12	0	0	0	0	0	0	0	0	0	0	0	1	0
B13	0	0	0	0	0	0	0	0	1	0	1	1	1

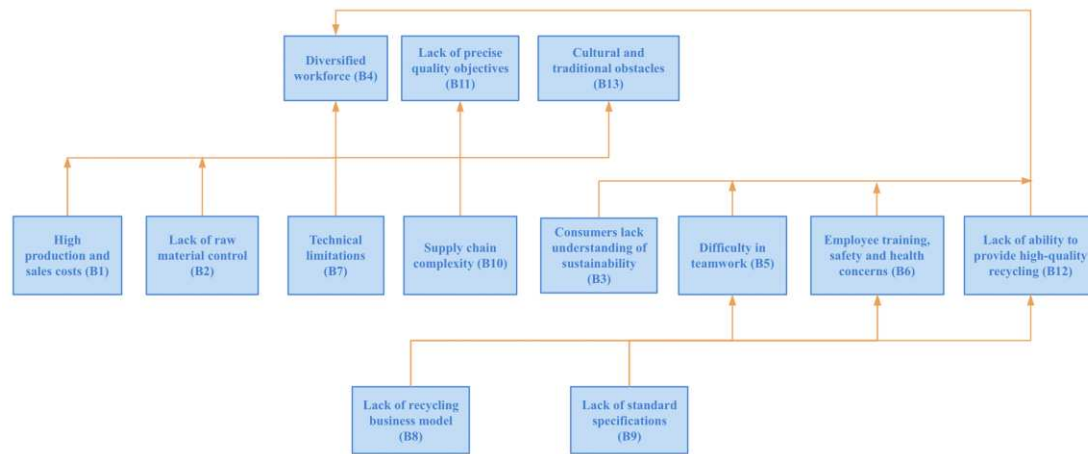


FIGURE 7 ISM-based model.

5. DISCUSSION

This study identified 13 barriers hindering the implementation of SQMP in textile recycling through a thorough systematic literature review. Nonetheless, a gap exists in the current research regarding a systematic review of the interactions among these barriers. This study addresses this research gap through the introduction of a comprehensive DEMATEL-ISM framework and presents a detailed examination of the interaction mechanisms among the barriers. These barriers are categorized into causal factors and consequential factors based on DEMATEL. Using ISM, structural connections among the barriers have been established. Through the ISM model (depicted in Figure 7), the 13 barriers are segregated into three distinct levels. The findings align with the causal clusters identified by DEMATEL, as elaborated below.

5.1 Cause Group

Barriers with positive Y values, indicating causal factors, are categorized within the cause group, where higher Y values denote a more potent influence. According to Table 7, the barriers can be organized in a descending manner as follows: Lack of standard specifications (B9) > Lack of recycling business model (B8) > Supply chain complexity (B10) > High production and sales costs (B1) / Lack of raw material control

(B2) > Technical limitations (B7) > Consumers lack understanding of sustainability (B3). Corresponding to the ISM model, these barriers are located at the middle and lower levels, driving the development of the upper-level barriers.

Existing literature highlights the lack of quality standards as a significant barrier at the strategic level (Heck & Zaidman, 2018). This aligns with the findings of this study. Notably, the Lack of standard specifications (B9) exhibits the highest Y value. Experts concur that establishing quality standards serves as the initial step towards achieving sustainable quality management practices within the waste textile industry, as it offers guidance for other practices. Research findings indicate that the waste textile recycling industry and regulatory authorities should prioritize the development of standards and specifications. These definitions align with the research conducted by Xu et al. (2019).

Lack of recycling business model (B8) is succeeded by the existing recycling models in China, which contribute to waste textile recycling and resource reuse, with a predominant focus on social and environmental obligations. Moreover, certain competitive entities may exploit opportunities by resorting to cost-reduction strategies and implementing non-compliant recycling and processing techniques to achieve immediate financial gains. These unethical practices may involve the utilization of inexpensive labor, illegal waste disposal, or unapproved recycling methods (Hartley et al., 2022). The recycling business model is centered on generating economic value through the reprocessing, remanufacturing, and reutilization of waste textiles and recycling resources (Ponnambalam et al., 2023).

5.2 Effect Group

Negative values of the cause degree Y value indicate barriers in the group of effects. These barriers in the group of effects are influenced by disorders in the causal group. These barriers, corresponding to the ISM model, are located at the middle and upper levels, and are affected by lower-level barriers. In descending order of effect size, they are as follows: Diversified workforce (B4) > Lack of precise quality objectives (B11)/Cultural and traditional obstacles (B13) > Lack of ability to provide high-quality recycling (B12) > Employee training, safety and health concerns (B6) > Difficulty in teamwork (B5).

Managing a diverse workforce to embrace sustainable practices serves as a catalyst for numerous organizations to incorporate SQMP within their operational framework.

According to the centrality ranking (Z) outlined in Table 7, a diversified workforce (B4) exhibits the strongest correlation with various other obstacles. The textile recycling process comprises numerous interconnected stages, giving rise to an intricate labor composition. This observation aligns with the findings of Gedam et al. (2023), highlighting the pivotal role of human and behavioral elements in the realization of sustainable management strategies. The presence of a diversified workforce presents implications for team dynamics, employee development, and the effectiveness of recycling processes (Malik et al., 2023). Positioned after Cultural and traditional barriers (B13), a diversified workforce (B4) empowers employees during the management of a diverse workforce, thereby facilitating prompt identification and resolution of quality issues (Muduli et al., 2020). Furthermore, clearly defined quality objectives can function as guiding principles to support the textile recycling industry in achieving sustainable development.

The lack of ability to provide high-quality recycling (B12) is positioned as the third most influential factor within the impact category. The current waste textile sorting practices in China predominantly rely on conventional manual identification methods. The sorting, opening, and recycling processes for mid-to-high-end equipment mostly depend on imported technologies. Enterprises within this sector tend to be small in size, with limited managerial capabilities, low levels of technical expertise, and restricted capabilities for advanced processing. The recycling of waste textiles necessitates leveraging the prominent and supportive functions of science and technology, advancing the research, development, and implementation of pivotal technologies, expediting the innovation of sustainable recycling models and utilization techniques, and fostering extensive and high-value recycling practices. Figure 8 illustrates the cascade of effects originating from barriers within the causal group.

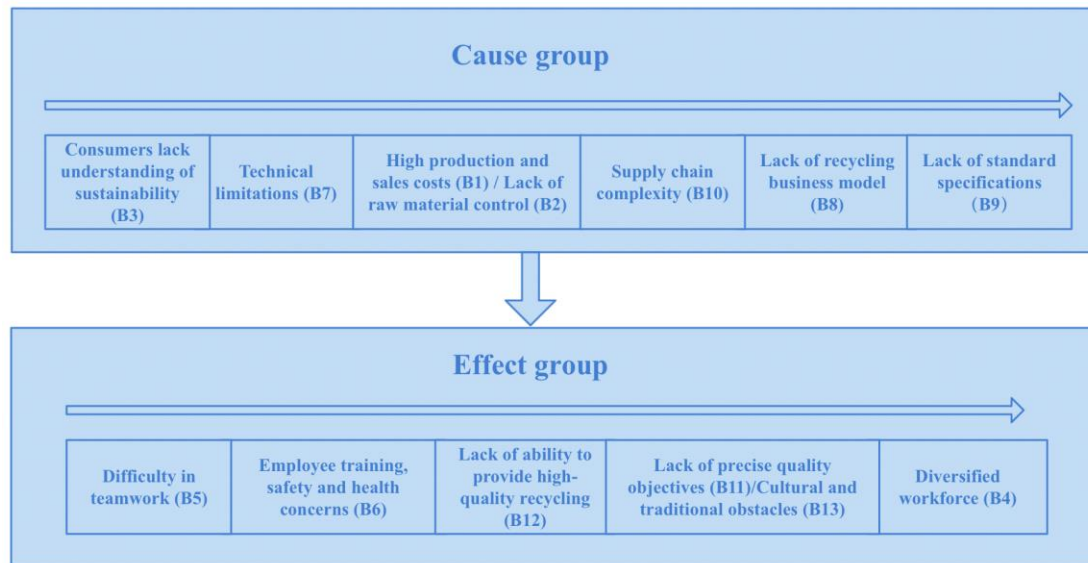


FIGURE 8 Flow of influence for cause and effect barriers.

6. IMPLICATIONS

6.1 Theoretical Implications

This research offers several theoretical implications. Primarily, while prior research has predominantly examined the procedures and obstacles within the textile recycling domain (Saccani et al., 2023; Pal & Sana, 2022), with a few studies underlining SQMP as a catalyst for the circular economy, there exists a dearth of methodical evaluation concerning the diverse practices and hurdles encountered in textile recycling through the lens of quality management. The present study addresses this research gap by analyzing SQMP in textile recycling along with its impediments to sustainability. Secondly, this study offers a theoretical contribution to the fields of quality management and CE by proposing a comprehensive management framework model tailored for the textile recycling industry. The systematic approach employed in this study serves to enhance the theoretical comprehension of the integration of quality management and CE within the waste textile recycling sector. The multifaceted nature of the proposed contribution is evident in its identification of barriers hindering the adoption of SQMP in the waste textile recycling industry, as well as its elucidation of the causal relationships among these barriers.

6.2 Practical Implications

This study also has significant implications for professionals, decision-makers, and policymakers. Initially, the matter of waste textile recycling has garnered increasing attention globally in the context of advancing the Circular Economy. Presently, scholars and experts focus on examining the economic and social advantages linked to textile recycling. Nonetheless, within China, a typical emerging market, the waste textile recycling sector is still at a nascent stage, with a lack of information sharing on the successful execution of SQMP. The unique aspect of this research lies in its capacity to identify the obstacles impeding SQMP implementation in the waste textile recycling sector through a thorough analysis of literature and RBV theory. To tackle the uncertainties in expert data, cloud models and blind number theory were utilized. This study is anticipated to aid professionals in overcoming the main hurdles to SQMP implementation, thereby supporting the realization of Circular Economy objectives. Furthermore, these findings will help managers address critical barriers that obstruct successful SQMP execution, ultimately fostering the formulation of sustainable management frameworks and the reinforcement of corporate competitiveness.

Second, this research highlights that emphasis should be placed on addressing the fundamental barriers in SQMP decision-making and execution, as revealed by the results obtained through the cloud model-blind number theory-DEMATEL-ISM approach. Particularly, the absence of a recycling business model (B8) and the lack of standard specifications (B9) emerge as the primary barriers that managers of textile recycling firms should focus on when implementing SQMP. Thus, policy implementation can be tailored to correspond with barriers at various phases.

Third, utilizing the DEMATEL methodology enables the categorization of all impediments based on causal clusters. It is imperative for decision-makers and policymakers to focus on these causal clusters (Gedam et al., 2023). The results underscore the necessity for the waste textile recycling sector to concentrate on fostering a diverse workforce to advance sustainable practices in quality management. This is because the diverse workforce (B4) exhibits the strongest correlation with other obstacles. Understanding the interconnections among these obstacles can help managers prioritize quality management strategies and optimize resource allocation.

Finally, this study offers significant policy implications for enhancing sustainable quality management practices in the waste textile recycling industry. It presents crucial policy recommendations for stakeholders dedicated to fostering a sustainable circular

economy through the remanufacturing and reutilization of production waste. The role of the government is essential in advancing sustainable practices through the implementation of decisions, policies, subsidies, and national policy assessments related to corporate sustainability. To establish an effective sustainability framework in the waste textile recycling sector, policymakers need to address key obstacles to SQMP and enhance workforce skills in adopting sustainable behaviors.

6.3 Limitations and Future Scope

The limitations of this research offer opportunities for further investigation. This study addresses the current research gap by utilizing a comprehensive methodology and expert perspectives to examine the obstacles to SQMP implementation in waste textile recycling. Utilizing cloud models and blind number theory, this research has tackled the issue of bias in expert opinions and bolstered the dependability of the outcomes. Subsequent research endeavors could authenticate the discoveries of this article via empirical studies and a selection of case studies from various waste textile recycling sectors within the forthcoming scope. Furthermore, subsequent scholars could expand the scope of this study to other domains to achieve enduring outcomes.

7. CONCLUSION

Textile recycling has gained significant attention in pursuit of circular economy goals, particularly in developing nations. Despite this focus, the textile recycling sector in these regions remains nascent, highlighting the critical need for adopting sustainable quality management practices. The primary objective of this research is to enhance the current understanding of quality management within textile recycling. Through a three-phase mixed research methodology, this study systematically identifies and examines the interplay between key obstacles to sustainable quality management and circular economy. A comprehensive literature review identified 13 primary barriers. To address uncertainties inherent in expert interval ratings, the cloud model and blind number theory were employed. Furthermore, the utilization of DEMATEL analysis facilitated the recognition of pivotal elements within the subject matter and the differentiation of barriers within causal groupings. The ISM model was instrumental in establishing a hierarchical structure for the identified barriers. Ultimately, this systematic approach

offers a robust framework for the textile recycling industry, enabling stakeholders including managers, practitioners, and policymakers to develop effective quality management strategies and optimize resource utilization.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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