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A Method to Assess Social Sustainability of Multi-Tier Supply Chains in the Textile Industry

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ABSTRACT

The EU corporate sustainability due diligence directive mandates human rights due diligence for organizations within their global supply chains. Social sustainability is highly critical in textile supply chains due to widespread poor working conditions. This work assesses the social sustainability of multi-tier textile supply chains, recursively allocating the performance from lower-tiers to higher-tiers suppliers following a risk-based approach. The method exploits a MCDM model for Sustainable Supplier Selection and Evaluation, which introduces a multi-tier aggregation methodology, combining non-compensatory and compensatory techniques. A case study illustrates the effectiveness of the method in ranking suppliers based on their upstream supply chain social performance and in supporting decisions for sustainability managers. The work contributes to the sustainable supply chain management literature by developing a method to quantitatively assess social sustainability in multi-tier supply chains, expanding the social sustainability performance assessment beyond tier-1 suppliers while considering the sustainability risk strategies of focal companies.

1 | Introduction

In 2024 the Directive on corporate sustainability due diligence (CSDD) entered into force within the European Union (European Commission 2025). The CSDD aims to foster sustainable and responsible corporate behavior across global value chains, by identifying and addressing potential and actual adverse human rights and environmental impacts due to operations associated with large organizations on a global scale (European Commission 2025; Matthews et al. 2025). The CSDD thus expands and internalizes the legal responsibility boundaries for organization from the firm-level to the global supply chain level (Wilhelm 2024). The directive also makes CSDD a non-negotiable standard, focusing specifically on human rights risks that organizations may cause or contribute to (Both and Wilhelm 2025;

Skerritt et al. 2025), requiring a broad set of activities, including risk identification and assessment, as well as prevention, mitigation, and remediation measures (Both and Wilhelm 2025).

The textile and clothing industry is one of the most labor-intensive industries worldwide, extensively subcontracting work to suppliers, thus being particularly under scrutiny for human rights risks (International Labour Organization 2019; Najjar et al. 2024). Poor labor standards and working conditions deeply affect the industry (Li and Kang 2024), with the biggest impacts found in developing countries (Köksal et al. 2017). Globalization has exacerbated this problem by creating intricate relationships among suppliers and brands with decreasing transparency (Khurana and Ricchetti 2016; Fashion Revolution 2023; Macchion et al. 2020; Sahu and Niranjan 2025). Among these

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criticalities, child labor, forced labor, low wages, extended overtime, discrimination, harassment, safety issues, and harmful chemical exposure represent the most relevant ones (The European House—Ambrosetti 2023; Tolentino-Zondervan and DiVito 2024; Sahu and Niranjana 2025; Fares et al. 2024). Despite a growing awareness of human rights risks and social issues, the textile sector continues to struggle in effectively addressing these problems (The European House—Ambrosetti 2023; Sahu and Niranjana 2025), which are often concentrated in upstream supply chain tiers, where visibility and control by focal companies are typically limited (Shaw et al. 2022; Chaudhuri et al. 2024).

The transition of the textile industry towards socially responsible and just supply chains is a complex issue (Karaosman and Marshall 2023), calling for a collaboration of internal and external stakeholders (Hannibal and Kauppi 2019) to achieve legitimacy and to balance diverse interests through engagement, collaboration, and shared value creation (Singh et al. 2025). Moreover, this transition requires a shift from compliance-oriented social responsibility towards “multi-stakeholder, legislated accountability frameworks that collectively redefine social responsibility” (Singh et al. 2025), while considering local capacities and institutional contexts along supply chains (Khan and Halme 2025). As such, focal companies may combine multiple strategies including updated and distributed governance mechanisms (Karaosman and Marshall 2023; Singh et al. 2025), enhanced transparency and coordination across multiple tiers (Khan et al. 2021), supply chain re-design (Fares et al. 2024), sustainable suppliers selection (Bai et al. 2019), and supplier development programs to build suppliers’ capacities on social issues (Yawar and Seuring 2018). Yet, multiple solutions are still hampered by limited visibility across multiple supply chain tiers (Khan et al. 2021), coupled with information gaps and a chronic lack of quantifiable measures on social sustainability at the supply chain level (Shaw et al. 2022; Iofrida et al. 2024).

Assessing social sustainability can contribute to addressing long-standing social sustainability challenges in the textile industry by providing enhanced evidence-based decision support to supply chain managers and sustainability managers on the supply chain social sustainability profile. Informed from organizational goals and evolving regulatory requirements (Singh et al. 2025; Alikhani et al. 2019; Zangara and Filice 2024), supply chain sustainability performance assessment is a strategic process supporting decision-making (Qorri et al. 2022). However, established social sustainability assessment frameworks, such as social life cycle assessment, display limited usefulness in supporting decision-making due to inconsistent methodological assumptions and implementation challenges in operational supply chain contexts featuring multiple tiers (Virgolino and Holden 2025). On the other hand, existing sustainable supply chain management literature has recognized the social criticalities within upstream textile supply chains (Köksal et al. 2017; Shaw et al. 2022), but has lagged in widening the assessment of social sustainability beyond their Tier-1 suppliers to capture social sustainability performance where human rights risks are more widespread (Zangara and Filice 2024).

This work thus aims to assess the social sustainability performance in the textile industry in order to address adverse human rights risks as prescribed by the CSDD. This is achieved by

developing a novel method to assess the social sustainability performance of multi-tier supply chains and empirically testing it in an operative textile supply chain through a case study. The proposed method is intended as a decision-support tool to support the identification and prioritization of social sustainability risks, supplementing the CSDD practices focal company can implement within their supply chains. The work contributes to the sustainable supply chain management literature by: (i) assessing social sustainability in multi-tier supply chains, expanding the social sustainability performance assessment beyond 1st-tier suppliers; (ii) integrating compensatory and non-compensatory techniques for social sustainability assessment in line with the risk-based approach prescribed by the CSDD directive.

2 | Literature Review

2.1 | Multi-Tier Sustainable Supply Chain Management (MT-SSCM)

Sustainable supply chain management is the management of material, information, and capital flows along the supply chain while taking goals from all three dimensions of sustainable development, that is, economic, environmental, and social, into account (Seuring and Müller 2008). Several studies on SSCM have shown a disproportionate focus on environmental sustainability at the expense of social sustainability (Carter and Washipack 2018). This work instead focuses specifically on the social dimension of supply chain sustainability, which is particularly relevant in the textile industry due to its labor intensity, fragmented production structures, and the limited transparency associated to upstream social conditions (Köksal et al. 2017).

Companies can pursue two main strategies to achieve SSCM: focusing on sustainable products or sustainably managing suppliers (Seuring and Müller 2008). This work focuses on the latter strategy, given the relevance of supplier management in long and fragmented supply chains (Karaosman et al. 2023) and its implications for managing sustainability risks (Foerstl et al. 2010). Sustainable supplier selection (SSS) and sustainable supplier evaluation (SSE) are strategic decisions for organizations within this context (Alikhani et al. 2019), given their cascading impact on the overall supply chain sustainability performance (Khan et al. 2018).

MT-SSCM expands the scope of SSCM to, ideally, every tier involved in the lifecycle of products (Gong et al. 2023), shifting the focus from buyer–supplier logics to extended buyer–supplier–sub-supplier relationships or beyond (Mena et al. 2013). Sustainability management in the textile industry calls for a multi-tier approach due to the large number of suppliers organized in multiple tiers. Khurana and Ricchetti (2016) emphasized the importance of going beyond Tier-1 suppliers, adopting a comprehensive approach and going beyond monitoring, in the sustainable management of suppliers. Moreover, the Rana Plaza disaster highlighted the issue of indirect sourcing, where production is subcontracted and focal firms are often unaware of where the garments are manufactured and the raw materials sourced (Khurana and Ricchetti 2016). Therefore, companies aiming to improve sustainability must take action to monitor and assess lower-tier suppliers as well, moving from a Tier-1

TABLE 1 | MCDM models for multi-tier SSS and SSE.

References	Methodology	Assessment	Approach	Multi-tier supply chain extent	Sustainability dimensions
Awasthi et al. (2018)	Fuzzy AHP-VIKOR	Linguistic assessment by experts	Compensatory	Multi-tier	Economic, environmental, social
Cui et al. (2023)	Fuzzy Set Theory, SWARA, Bayesian Network	No assessment. Prioritization of criteria for assessment under different supply chain structures.	NA	Triad	Economic, environmental, social
Kazançoglu et al. (2022)	Best Worst Method, PROMETHEE	Comparison of alternative based on experts' judgments	Compensatory	Triad	Economic, environmental, social
Tuni et al. (2020)	Eco-intensity indicators	Primary quantitative data	Compensatory	Multi-tier	Economic, environmental
Yazdani et al. (2022)	SWARA, Level Based Weight Assessment, MARCOS-D	Linguistic assessment by experts	Compensatory	Triad	Economic, environmental, social

sustainability management logic to a multi-tier SSCM logic. This approach is also captured within the CSDD directive, which prescribes a risk-based approach (Zeitler and Schwarzkopf 2025; Gervais et al. 2023). SSS and SSE methodologies can contribute to reducing risks (Freeman and Chen 2015). Section 2.2 reviews SSS and SSE methodologies with a focus on the textile industry.

2.2 | SSS and SSE

The complexity of supplier selection arises from the need to use both quantitative and qualitative criteria, calling for the adoption of Multi Criteria Decision Making (MCDM) models. Aouadni et al. (2019) identify two key problems when applying MCDM methods for Supplier Selection and Evaluation, highlighting how results may be sensitive to modeling assumptions. First, the ranking of alternatives may vary based on different attributes and parameters of the model. Second, the supplier ranking may change when a new supplier is added or removed. However, when correctly applied, these methods have proven to be effective for SSS and SSE and are widely adopted (Karakoç et al. 2024; Schramm et al. 2020).

Several MCDM models exist for SSS and SSE, which can be implemented alone or in combination with each other with a hybrid approach (Karakoç et al. 2024; Schramm et al. 2020). Interested readers can refer to Rashidi et al. (2020), Schramm et al. (2020), Zimmer et al. (2016) for an extensive overview of MCDM models for SSS and SSE. TOPSIS and AHP, including their rough, grey, and fuzzy versions, represent some of the most widely used methods (Karakoç et al. 2024). De Almeida et al. (2016) show that one of the most important considerations when employing a Multi-Criteria Decision-Making strategy is the elicitation of weights, especially for compensatory strategies. Compensatory methods allow for trade-offs between attributes, ultimately determining a compensation of scores between different criteria, typically exploiting different weighting techniques (Rothrock and Yin 2008). Non-compensatory methods do not permit that decisions informed by certain attributes are reversed or balanced by others (De Boer et al. 1998). This is achieved by adopting a variety of strategies, including conjunctive, disjunctive, lexicographic, and elimination strategies (Rothrock and Yin 2008).

The majority of papers on SSS and SSE employ compensatory techniques; “however, this type of methods is not indicated for supporting decisions that are concerned with sustainability for which environmental and social aspects cannot be compensated for by economical ones” (Schramm et al. 2020). The main objective during the supplier selection qualification phase is to distinguish between suppliers who meet the minimum performance criteria from those who do not (Junior et al. 2013). During the qualification phase, non-compensatory decision rules are generally more appropriate, while during the final selection phase, suppliers that meet the minimum requirements can be ranked using compensatory decision rules. Therefore, it is crucial to determine whether compensation is a desired effect when implementing MCDM methods.

Moreover, “most existing studies on SSS focus on dyadic relationships” (Cui et al. 2023), which is typically operationalized as an assessment of Tier-1 suppliers by focal companies, as already acknowledged in an earlier review by Zimmer et al. (2016). The limited attention to lower-tier suppliers can significantly hamper SSCM (Cui et al. 2023), however, it persists due to multiple reasons, including lack of contractual relationships, power asymmetries along the supply chain and complexity in data management in fast-paced supply chains (Zimmer et al. 2016). Data collection challenges are also reflected in the existing multi-tier SSS and SSE developed in the literature (Table 1). Cui et al. (2023) prioritized critical sustainability criteria for different triadic supply chain structures, without proceeding with an empirical assessment, while Awasthi et al. (2018), Yazdani et al. (2022), Kazançoglu et al. (2022) rely on the subjective judgment of decision makers to assess the performance of suppliers under multi-tier supply chain structures, which may introduce subjectivity in both weighting and evaluation phases. Tuni et al. (2020) based the assessment on a limited set of quantitative primary data, although limiting the analysis to economic and environmental dimensions and disregarding social sustainability.

The textile industry presents many social criticalities and human rights risks in the upstream supply chain; therefore, MCDM methodologies for SSS and SSE have the potential to support the identification and assessment of social sustainability risk of the supply chain and achieve compliance with CSDD (Kannan 2018;

TABLE 2 | MCDM models for SSS and SSE in the textile industry.

References	Methodology	Economic criteria	Environmental criteria	Social criteria
Amindoust and Saghafinia (2017)	FIS	✓	✓	✓
Fallahpour et al. (2017)	FPP, FTOPSIS	✓	✓	✓
Guarnieri and Trojan (2019)	AHP, ELECTRE	✓	✓	
Kao (2022)	FTOPSIS, MSGP	✓		✓
Nakiboglu and Bulgurcu (2021)	TOPSIS, IF	✓	✓	
Phan Ha and Le (2025)	AHP, TOPSIS	✓	✓	✓
Rahman et al. (2022)	SWARA, WASPAS	✓	✓	✓
Sithi et al. (2025)	SWARA, TOPSIS	✓	✓	✓
Wang et al. (2022)	FAHP, TOPSIS	✓	✓	✓
Yang and Wang (2020)	FAHP, FTOPSIS	✓	✓	✓

Skerritt et al. 2025). MCDM models for SSS and/or SSE in the textile industry are displayed in Table 2. The TOPSIS methodology is the most used MCDM methodology among the analyzed papers. All papers displayed in Table 2, except that of Wang et al. (2022), allocate the highest weight to economic criteria, adopting a weak sustainability perspective. Moreover, they often present few social criteria, limiting the analysis to few social issues; therefore, sharing a drawback of the broader literature on MCDM models for SSS and SSE (Yu et al. 2019; Yang and Wang 2020). All reviewed papers listed in Table 2 utilize compensatory methods, while non-compensatory methods were only identified in other sectors, such as electronics (Junior et al. 2013; Yu et al. 2019), despite non-compensatory methods improving the overall decision-making process efficiency (Rothrock and Yin 2008). Finally, all papers limit the SSS and SSE to Tier-1 suppliers, neglecting the potentially significant social impact of upstream lower-tier suppliers.

2.3 | Literature Gaps and Aim of the Paper

Despite the numerous proposed models for SSS and SSE in the context of SSCM, several gaps persist in the literature. Based on the summary of the literature provided in Tables 1 and 2, it is possible to identify two primary research gaps that need further exploration.

First, MCDM models for SSS and SSE follow a weak sustainability perspective, as evidenced by the predominant focus on economic criteria and exemplified by the adoption of compensatory methods in all papers listed in Tables 1 and 2. The majority of papers illustrated in Table 2 (the only exception is Wang et al. (2022)) allocate the highest weight to economic criteria, while environmental and social criteria remain secondary to the evaluation and narrow in scope. This approach limits a comprehensive understanding of social sustainability within the supply chain and fails to address critical facets of worker rights, labor conditions, and community well-being. Moreover, all methodologies employed in the analyzed papers listed in Tables 1 and 2 are compensatory, allowing trade-offs between criteria, that is, strong economic performance can compensate for weak social or environmental performance. This methodological

approach may downplay the importance of social sustainability and does not adequately address critical social misconducts. Non-compensatory approaches, which enforce strict thresholds for sustainability criteria, provide instead a robust mechanism to ensure social sustainability standards are respected and critical human rights risks associated to the supply chain are addressed, in light of the upcoming due diligence regulatory pressure.

Second, despite the extensive amount of research on MT-SSCM, existing research on SSS and SSE focuses on Tier-1 suppliers (Cui et al. 2023), neglecting the impacts coming from lower-tier suppliers. The limited body of literature in multi-tier SSS and SSE (Table 1) takes a focal company-centric perspective relying on judgments of decision-makers to carry out the assessment, which introduces subjectivity and uncertainty (Tsoulfas and Pappis 2008) and is hardly replicable in long and fragmented supply chains, such as fashion supply chains. In the textile industry, the focus on direct suppliers translates in most studies assessing sustainability at the level of final garment manufacturers (Tier 1), overlooking the fact that most sustainability criticalities originate further upstream, particularly in raw material sourcing and fabric production (Khurana and Ricchetti 2016). Lower tier suppliers often operate under weaker regulatory oversight and face greater social and environmental risks (Rafi-UI-Shan et al. 2018). This is even more critical in light of due diligence requirements, which shift the focus to incorporate a multi-tier perspective on supply chain sustainability (Brandenburg et al. 2024).

Given these gaps, this paper develops an innovative method to quantitatively assess the social sustainability performance of multi-tier supply chains that: (1) adopts a strong sustainability perspective, deploying a MCDM model dedicated to social sustainability, which focuses on several social criteria to provide a holistic social sustainability assessment; (2) implements non-compensatory decision-making techniques to enforce strict thresholds for social sustainability criteria, along with compensatory techniques; (3) extends the evaluation beyond Tier-1 suppliers to encompass the extended supply chain in line with the CSDD directive. By addressing these limitations, this study advances sustainable supply chain management literature by developing a method to quantitatively assess social sustainability in multi-tier supply chains, thus contributing to CSDD

TABLE 3 | Questions of Higg FSLM per section and per step.

Section	# Qs Step 1	# Qs Step 2	# Qs Step 3
Facility profile	308 (208*)	12 (7*)	0 (0*)
Recruitment and hiring	137 (126*)	42 (37*)	0 (0*)
Working hours	30 (28*)	29 (25*)	0 (0*)
Wages and benefits	102 (95*)	88 (72*)	30 (20*)
Worker treatment	113 (108*)	38 (36*)	16 (16*)
Worker involvement	103 (83*)	30 (26*)	9 (9*)
Health and safety	141 (140*)	262 (252*)	3 (3*)
Termination	35 (33*)	4 (4*)	0 (0*)
Management systems	0 (0*)	432 (358*)	103 (74*)
Above and beyond	0 (0*)	0 (0*)	139 (80*)

Note: * = of which non-descriptive questions.

practices focal company can implement within their supply chains.

3 | Higg FSLM

The Higg Facility Social and Labor Module (Higg FSLM) is one of the five modules provided by the Higg Index, the tool developed by the Sustainable Apparel Coalition to provide structured audit data to evaluate the textile value chain's social and environmental performance. The Higg FSLM is a leading tool used to assess the social sustainability of suppliers in the textile industry and, therefore, it is selected as the reference social audit program in this work (Higg Co, 2026). The Higg FSLM social criteria reflect those covered by the most important industry standards and certifications regarding social sustainability, such as SA8000, GRI 400 and ISO 26000, which aim to comprehensively evaluate social sustainability.

The Higg FSLM module is structured into 10 Sections and 3 Steps. Each section focuses on a specific social matter and presents several sub-sections, which include a series of questions on various social issues to be answered by each supplier. Additionally, the module is divided into three Steps, and each question in the Higg FSLM corresponds to a specific Step. Step 1 comprehends the majority of questions on legal compliance and it covers the most critical questions. Step 2 and Step 3 add other relevant questions to the module. Suppliers can choose the number of Steps they intend to complete before starting the assessment. Moreover, the module differentiates between non-descriptive and descriptive questions, providing a filter to identify non-descriptive questions. This work exclusively considers non-descriptive questions, as descriptive questions primarily provide supplementary details regarding violations that have already been identified by non-descriptive ones. Table 3 displays the number of total questions and the number of non-descriptive questions per section and per Step, based on version 1.5 of the Converged Assessment Framework.

The number of total questions is not an indicator of the importance of sections, that is, "Management Systems" and "Above and Beyond" sections are generally less important than other sections since they do not include questions on the most critical social

matters, whereas the "Worker Treatment" section addresses issues related to forced labor, discrimination, harassment, abuse, working conditions, and freedom of movement and "Health and Safety" addresses topics such as building safety, risk assessment, emergency exits, and response plans, fire detection, alarms, fire-fighting equipment, and first aid.

Two versions of the module exist: the Higg FSLM self-assessment and the verified Higg FSLM. The former includes the supplier's self-assessment for all applicable questions for the selected number of steps. The latter refers to a third party verified assessment and is here considered to ensure the reliability of the data.

4 | Methodology

A MCDM method for supplier evaluation purposes based on the Higg FSLM was developed to quantitatively assess social sustainability in multi-tier supply chains in the textile industry. The model adopts a multi-tier Aggregation Methodology to cascade social sustainability performance along multiple tiers in the supply chain and adopts both non-compensatory (threshold-based classification) and compensatory (score-based ranking) techniques. The non-compensatory techniques are hierarchically more relevant than compensatory ones in the final ranking of suppliers since conjunctive non-compensatory rules identify suppliers that do not meet minimum social requirements. Suppliers that meet the minimum requirements are ranked higher than those that do not, regardless of their compensatory evaluation.

Generally, decision-making problems involve four main stages: (i) the selection of criteria and the formulation of alternatives, (ii) the criteria weighting, (iii) the evaluation phase, and (iv) the final treatment and aggregation (Wang et al. 2009). These stages are adapted to the supplier evaluation problem in Figure 1, which shows the main processes of the proposed methodology. The MCDM method follows a sequential structure: (i) non-compensatory classification, (ii) compensatory scoring, and (iii) multi-tier aggregation, producing a binary classification (Class A/B) and a ranking within each class.

4.1 | Supplier Identification

Decision makers should define the pool of suppliers to be assessed and ranked using the method. At this stage, transparent criteria to ensure representativeness and avoid selection bias are required. In this study, only suppliers that adopt the Higg FSLM are considered. Once suppliers have been identified, they are grouped based on their corresponding Tier. Suppliers that are vertically integrated, performing operations across different Tiers, are considered in all corresponding Tiers. This allows for the identification of a supplier pool for every Tier along the supply chain. The analysis is then conducted on each Tier individually, from the lowest to the highest Tier, ideally from Tier-4 to Tier-1. This is functional to implement the multi-tier Aggregation Methodology, which evaluates the social performance of suppliers considering the social sustainability of their corresponding lower-tier suppliers, that is, the focal company's sub-suppliers.

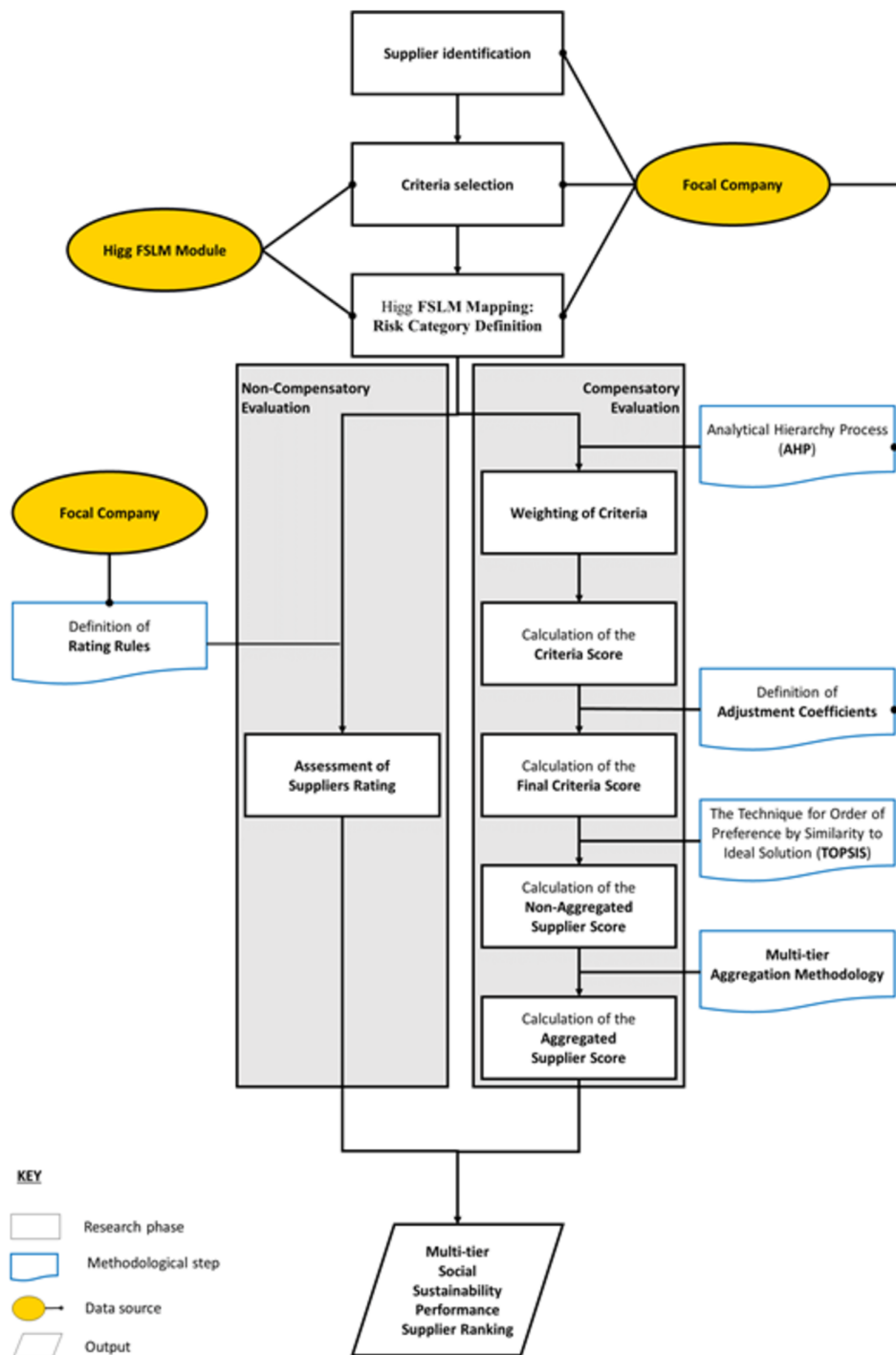


FIGURE 1 | Methodology flow chart.

4.2 | Criteria Selection

Social sustainability criteria are defined based on Higg FSLM sections to develop synthetic and representative dimensions. Each criterion comprises one or more Higg FSLM sections. The only Higg FSLM section here excluded is the “Facility Profile,” since it contains demographic information about suppliers that does not contribute to their social performance scoring. Higg FSLM sections are grouped in criteria according to keyword analysis and/or similarity of scope (Tuni et al. 2023). The

adopted Criteria, and the corresponding Higg FSLM sections, are presented in Table 4.

4.3 | Higg FSLM Mapping: Risk Category Definition

Both non-compensatory and compensatory evaluations rely on the Higg FSLM questions. Each focal firm must engage in a Higg FSLM mapping to define Question Risk Categories,

TABLE 4 | Adopted criteria and corresponding Higg FSLM sections.

Criteria	FSLM sections
1. Recruitment, hiring and termination practices	- Recruitment and hiring - Termination
2. Working hours	Working hours
3. Wages and benefits	Wages and benefits
4. Worker treatment and involvement	- Worker treatment - Worker involvement
5. Health and safety	Health and safety
6. Management systems and best practices	- Management system - Above and beyond

corresponding Question Risk Scores and a set of acceptable answers for each non-descriptive question of the module. Only non-descriptive questions are considered, as illustrated in Section 3. When a given answer for a given question does not match the corresponding set of acceptable answers, the question is considered a social violation of varying severity.

Decision-makers should define the Question Risk Categories, which represent the relevance of each Higg FSLM question to the social sustainability targets of the focal firm. In the proposed method, three Question Risk Categories are adopted since risk matrices generally define three or four risk levels (Elmontsri 2014). Question Risk Scores are needed to translate the Question Risk Categories in quantitative values, essential for the compensatory evaluation. The assignment of these scores should be based on evaluations by decision-makers, utilizing risk scores from the risk assessment literature. The Question Risk Categories and Question Risk Scores adopted in the methodology, from the most relevant to the least one, are: Zero Tolerance, High Risk, and Medium Risk. Their corresponding Question Risk Scores are defined as Q^{ZT} , Q^{HR} , Q^{MR} and, due to the importance of the categories, it holds that $Q^{ZT} \geq Q^{HR} \geq Q^{MR}$. Overall, risk scores, thresholds and criteria weights have to be defined by decision-makers, reflecting organizational priorities and strategic objectives.

4.4 | Non-Compensatory Evaluation

The non-compensatory evaluation consists in a rating system that defines rating rules to assign a Rating Class to each supplier based on the number and relevance of its social violations. These rules aim to identify suppliers that do and do not meet minimum social requirements, therefore distinguishing two Ratings Classes. Class A encloses supplier that possess minimum social requirements while Class B includes suppliers that do not meet these requirements and/or suppliers that have not shared their Higg FSLM report. This phase introduces a rule-based filtering layer preceding the multi-criteria evaluation. Decision-makers should define non-compensatory rating rules to assign the appropriate Rating Class based on the number and risk of social violations, that is, by defining thresholds for Zero Tolerance and high-risk violations. This methodology is customizable by focal firms to meet

its sustainability objectives and potentially introduce more ambitious targets over time.

4.5 | Compensatory Evaluation

The compensatory evaluation is used to compute supplier scores by allowing compensation among criteria performance. Supplier scores represent the quantitative evaluation of social sustainability and they are employed to rank suppliers within each Rating Class.

4.5.1 | Criteria Weighting

The first phase of the compensatory evaluation involves assigning weights to each criterion to establish their relative importance. The Analytic Hierarchy Process (AHP) is employed for this purpose. This phase should be carried out by the decision-makers, following the prescribed phases (Saaty 1987). This step assigns a weight (w_j) to each criterion j so that the sum of all these weights is equal to 100%.

4.5.2 | Criteria Scores and Adjustment Coefficients

The compensatory evaluation determines for each supplier its Criteria Scores. Each Criterion Score (c_j) reflects the performance of a given supplier against the corresponding criterion. The steps to compute c_j for a given j th criterion are presented in Figure 2. First, the number of violations and applicable questions, grouped by risk category, are determined using the Higg FSLM mapping. Subsequently, these numbers are multiplied by the corresponding Question Risk Scores. In this way, Violation Scores and Applicable Question Scores are computed for each Question Risk Category. Thus, the sum of all Violation Scores is added together to compute the Total Violation Score (V_j). The same computation is performed for the Applicable Question Scores to determine the Total Applicable Question Score (AQ_j).

Finally, the score for a given criterion (c_j) can be determined by subtracting to 1 the ratio between the Total Violation Score (V_j) and the Total Applicable Question Score (AQ_j), as displayed in Equation (1).

$$c_j = 1 - \frac{V_j}{AQ_j} \quad (1)$$

These scores are then adjusted based on two adjustment coefficients: the Step Coefficient (S%) and the Country Coefficient (C%). The former considers the number of completed Higg FSLM Steps, while the latter takes into account the social risk of different countries. To assess the contribution of the number of completed Higg FSLM steps, Step Weights (S_1, S_2, S_3) are introduced. Each Step Weight represents the importance that focal firms assign to the corresponding Step. The sum of these weights must be 100%. The Step Coefficient is defined as the sum of the Step Weights for the completed Steps. For instance, if a supplier completes Step 1 and Step 2, its S% is equal to $S_1 + S_2$. The Step Coefficient should be interpreted as a data completeness factor.

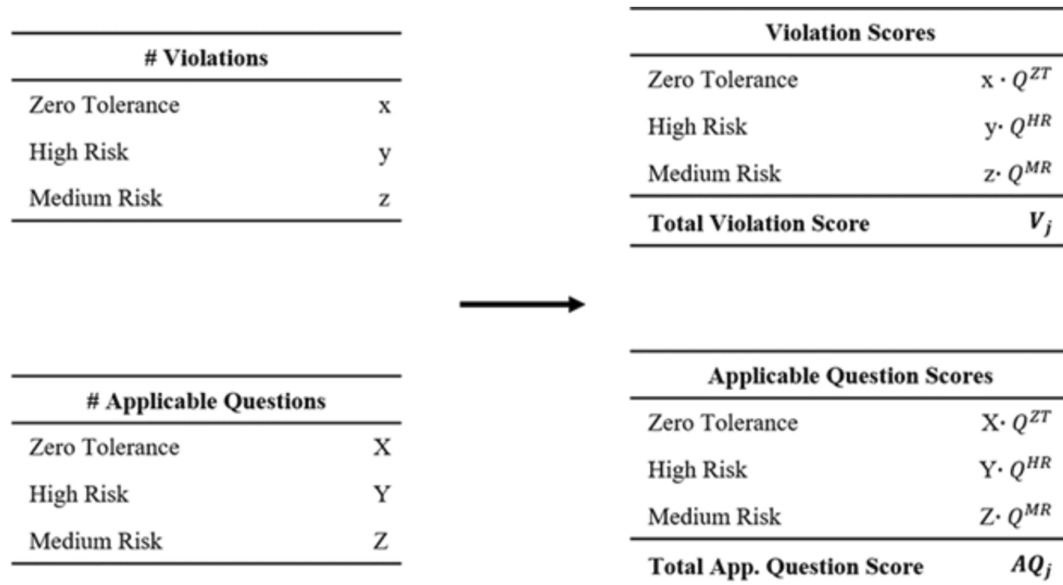


FIGURE 2 | Steps to compute the Total Violation Score and Total Applicable Question Score.

TABLE 5 | Country risk categories and corresponding AHDI values.

Country risk category	AHDI values
High Risk	AHDI $\leq$ Median
Medium Risk	Median < AHDI $\leq$ 3rd Quart.
Low risk	AHDI > 3rd Quart.

The Country Coefficient (C%) is introduced to enhance the social sustainability risk approach adopted by the proposed MCDM and to capture aspects not covered by the Higg FSLM: access to education, life expectancy, per capita income, free elections, and overall civil liberties. C% is defined based on the values of the Augmented Human Development Index (AHDI) (De La Escosura 2021), an enhanced version of the Human Development Index (HDI) by the United Nations. The better the overall performance, the higher the AHDI value. Country Risk categories are defined based on the statistical values of the AHDI (median and 3rd quartile), as shown in Table 5.

Then, a Country Coefficient (C%) is assigned by decision-makers to each category. The C% for the low-risk category must be equal to 100% since no penalty is applied. The Country Coefficient of Medium Risk countries must be smaller compared to low-risk ones but larger compared to high-risk categories.

Final criteria scores (fc_j) consider the effects of the Step Coefficient and Country Coefficient and they are computed by multiplying Criteria Scores (c_j) by S% and C%, as shown in Equation (2).

$$fc_j = c_j \cdot S\% \cdot C\% \quad (2)$$

Only suppliers that complete all the Steps of the Higg FSLM (S%=100%) and that have the lowest country risk (C%=100%) maintain the same Criteria Scores and Final Criteria Scores.

4.5.3 | Non-Aggregated Supplier Score

The Non-Aggregated Supplier Score (F^N) measures the overall social performance of suppliers, without considering their sub-suppliers. To compute this score, the TOPSIS methodology is applied using Final Criteria Scores (fc_j) and criteria weights (w_j). For each supplier k , F^N is equal to its Relative Closeness to the Ideal Solution (s_k) from the TOPSIS methodology (Behzadian et al. 2012). This methodology is applied to each Tier individually, as suppliers in each Tier represent alternatives for a buyer, thus making the supplier scores in each Tier range from 0 to 1. Additionally, each Tier may be more prone to incur in specific violations based on the specific production operations performed and therefore each Tier is evaluated separately. The TOPSIS methodology is applied in-line with the established methodology and the recommended phases (Behzadian et al. 2012).

4.5.4 | Multi-Tier Aggregation Methodology and Aggregated Supplier Score

The Aggregated Supplier Scores (F^A) measures the overall social performance of suppliers considering their sub-suppliers. A recursive multi-tier Aggregation methodology is introduced to allocate sub-supplier social performance up along the supply chain. The Aggregated Supplier Score (Equation 3) of a Tier-L supplier can be computed as follows:

$$F^A = 0.5 \cdot F^N + 0.5 \left(\frac{\sum_{i=1}^u QT_i \cdot F_i^A}{\sum_{i=1}^u QT_i} \cdot \frac{v}{u} \right) \quad (3)$$

where F^N = Non-Aggregated Supplier Score of the given Tier-L supplier, QT_i = Garment-equivalent quantity of materials supplied by the Tier-(L+1) sub-supplier i to the given Tier-L supplier, F_i^A = Aggregated Supplier Score of the Tier-(L+1) sub-supplier i , u = Number of Tier-(L+1) sub-suppliers of the given Tier-L supplier, v = Number of Class A Tier-(L+1) sub-suppliers of the given Tier-L supplier.

The Aggregated Supplier Score is equally determined by the performance of the examined Tier-L supplier (internal social performance) and the performance of its Tier-(L + 1) sub-suppliers (upstream supply chain performance). The internal component is represented by the Non-Aggregated Supplier Score of the given Tier-L supplier. The external one depends on the weighted average and the v/u coefficient. The weighted average is computed using the garment-equivalent quantity of processed materials of each Tier-(L + 1) sub-supplier i and their Aggregated Supplier Scores to weight more the aggregated scores of those sub-suppliers that supply the most. Finally, the ratio v/u considers the Rating Class of the sub-suppliers to reduce the weighted average by multiplying it to the ratio of Class A sub-suppliers over the total number of sub-suppliers. The weighted average will be reduced if the proportion of Class A sub-suppliers among the total number of sub-suppliers decreases. Both performances are given the same weight in-line with the indirect multi-tier SSCM approach (Tachizawa and Wong 2014), aiming to concurrently stimulate suppliers to enhance internal practices and to forward social sustainability requirements upstream in the supply chain. The Aggregation Methodology presents a bottom-up approach and it is applied from the lowest analyzed Tier, up until Tier-1.

4.5.5 | Supplier Ranking

The final phase of the methodology involves the ranking of suppliers in each Tier. Two decision-support pieces of information are available to decision-makers to rank suppliers: Non-aggregated Supplier Scores and Aggregated Supplier Scores, the latter being more comprehensive as it captures the upstream supply chain social sustainability performance. Two sub-rankings are computed within each Tier: one for Class A suppliers and one for Class B suppliers. Suppliers within each Rating Class are ranked based on their supplier score, from highest to lowest. The final ranking of suppliers of each Tier is determined by concatenating these two rankings, having Class A suppliers ranked higher than Class B suppliers since the latter group does not meet minimum social requirements. The concatenated rankings represent a relative ranking of social sustainability performance within each Tier.

5 | Case Study

The proposed methodology was applied to the case study of Benetton Group, a fashion company based in Italy, which features a global supply chain, with suppliers predominantly located in Asia. As such, Benetton Group operates under multiple regulatory frameworks. Being headquartered in Europe, EU-based regulations, such as the EU CSDD directive, are relevant for the focal company, which concurrently must comply with complementary and alternative regulations along its upstream supply chain. This is organizationally reflected in referring to international standards, that is, from the International Labour Organisation, which are integrated by the local legislation for the auditing processes. Moreover, the company always requires third-party verification of suppliers' self-reported data as an additional measure. Therefore, the case study is based on verified Higg FSLM reports for year 2023.

TABLE 6 | Benetton case study: Adopted question risk categories and question risk scores.

Question risk category	Question risk score
Zero Tolerance	65
High Risk	30
Medium Risk	5

First, a pool of Tier-1 suppliers was ranked on the basis of the Non-Aggregated Supplier Score. Next, the multi-tier Aggregation Methodology was applied to a group of Tier-2 suppliers and their corresponding Tier-1 suppliers to illustrate the applicability of the method. Finally, a sensitivity analysis was performed on different sets of Question Risk Scores to understand how the final ranking and supplier scores change accordingly.

The weights, scores, and coefficients of the method represent the requirements of Benetton Group and were gathered during a participative workshop session with the operations sustainability team. Three Question Risk Categories were adopted and assigned to the corresponding Question Risk Scores as shown in Table 6. Zero Tolerance represents severe human rights risks, including the following dimensions: child labor, forced labor, discrimination practices, physical or verbal abuse, prohibition of representation or association of workers, undeclared workers employment and unsafe buildings with severe structural deficiencies. These risks pose an imminent risk to the health and safety of workers. High Risk represents severe social risks, which do not constitute human rights risks, but may significantly impact worker safety or rights if not addressed promptly. Finally, Medium Risk includes social issues of lower importance, which should be remediated to ensure social compliance.

The non-compensatory rules were defined based on the social sustainability procedures adopted by the company, which reflect hierarchical prioritization of human rights risks in alignment with the CSDD. The adopted rules for the corresponding Rating Classes are as follows:

- Class A: No Zero Tolerance violations and a maximum of two High Risk violations;
- Class B: One or more Zero Tolerance violations and/or more than two High Risk violations.

The AHP methodology was then applied using the coefficients assigned by the decision-makers (Table A1). Any disagreement between operations sustainability team experts on the relative importance of criteria was followed by discussion until final consensus was reached. The weights were rounded to the nearest integer, as displayed in Table 7.

Finally, the values of the Step Coefficient and Country Coefficient were determined as the final step of the participative workshop session. The same scale of weights (95%, 98%, 100%) was adopted for both coefficients to reflect their equal relevance for the overall strategy of the company. This avoids the dominance of an

TABLE 7 | Benetton case study: Criteria weights.

Criteria	Criteria weights
1. Recruitment, hiring and termination practices	20%
2. Working hours	6%
3. Wages and benefits	10%
4. Worker treatment and involvement	20%
5. Health and safety	40%
6. Management systems and best practices	4%

TABLE 8 | Benetton case study: Adopted step weights and values of step coefficient.

Step coefficient (S%)	Step 1	Step 2	Step 3
95%	95%	0%	0%
98%	95%	3%	0%
100%	95%	3%	2%

TABLE 9 | Benetton case study: Adopted values of country coefficient.

Country risk category	Country coefficient (C%)
High Risk	95%
Medium Risk	98%
Low risk	100%

adjustment coefficient over the other. The adopted Step Coefficient and Country Coefficient values are displayed in Tables 8 and 9, respectively.

6 | Results

6.1 | Tier-1 Application

The proposed method was first applied to a pool of 125 Tier-1 suppliers that shared their verified Higg FSLM during 2023. Out of the 125 suppliers, 124 were ranked as Class A suppliers, with only 1 Class B supplier, which ranked last, indicating a highly skewed distribution which may reflect the adopted thresholds or the characteristics of the dataset. Thirty-nine suppliers (31.2%) completed all the 3 Higg FSLM Steps, 82 suppliers (65.6%) completed Step 1 and Step 2, and 4 suppliers (3.2%) only answered Step 1 questions. Moreover, 98 suppliers (78.4%) are located in High-Risk countries, 25 suppliers (20.0%) are located in Medium Risk countries, and 2 suppliers (1.6%) are located in countries with Low Risk.

The final ranking of the sampled Tier-1 supplier is hierarchically determined based on their (i) Rating Classes and (ii) Non-Aggregated Supplier Scores. The best and worst four suppliers are reported in Table 10, with the corresponding F^N , completed Steps, Country Risk Category and Rating Class, while the complete ranking is available in Table A2.

TABLE 10 | Non-aggregated supplier ranking: Best and worst Tier-1 suppliers.

Rank	Supplier #	F^N	Completed steps	Country risk category	Rating class
1	Supplier #20	86.87%	3 Steps	High Risk	Class A
2	Supplier #105	85.33%	2 Steps	High Risk	Class A
3	Supplier #75	85.02%	2 Steps	Medium Risk	Class A
4	Supplier #115	84.91%	3 Steps	High Risk	Class A
...	...	...	...	...	...
122	Supplier #54	49.97%	2 Steps	Medium Risk	Class A
123	Supplier #80	46.94%	2 Steps	High Risk	Class A
124	Supplier #23	31.16%	2 Steps	High Risk	Class A
125	Supplier #78	64.28%	3 Steps	Medium Risk	Class B

Supplier #78 ranks last since it is the only Class B supplier, although it would rank 101st solely based on its Non-Aggregated Supplier Score (64.28%), reflecting the greater importance of the Rating Class over the supplier score in the ranking of suppliers according to the methodology. Moreover, results suggest that Step Coefficient and Country Risk Category act as adjustment coefficients as intended, as none of the coefficients predominantly determines the Non-Aggregated Supplier Score, which is primarily driven by the answers of suppliers to questions on the six social criteria.

6.2 | Multi-Tier Application

A pool of Tier-1 suppliers and their corresponding Tier-2 suppliers was evaluated to apply the Aggregation Methodology and illustrate the applicability of the method in its complete multi-tier format. Specifically, seven Tier-1 suppliers from the previously considered pool of 125 Tier-1 suppliers, and their corresponding Tier-2 suppliers, 24 in total, were considered. Table 11 displays the relationships between Tier-1 and Tier-2 suppliers, as well as Non-aggregated Supplier Scores, Aggregated Supplier Scores, Rating Classes, Weighted Averages (WA), v/u coefficients, and Garment-Equivalent Quantities of processed materials (QT). Aggregated Supplier Scores have been computed applying the Aggregation Methodology on Tier-2 suppliers. First, Final Criteria Scores were computed for every Tier-1 and Tier-2 supplier from the assessment of their verified Higg FSLM reports. Then, the TOPSIS methodology has been applied tier-by-tier separately on the Tier-2 suppliers and Tier-1 suppliers, to compute their Non-Aggregated Supplier Scores. Tier-2 suppliers that did not share the verified Higg FSLM conservatively received a Non-Aggregated Supplier Score of 0.00%. Aggregated Supplier Scores of Tier-2 suppliers are equal to their Non-Aggregated Supplier Scores because no Tier below Tier-2 was considered.

Figure 3 shows the ranking of the selected Tier-1 suppliers based on their Non-Aggregated Supplier Scores and Aggregated Supplier Scores. The ranking based on Non-aggregated Supplier Scores significantly differs from the one based on Aggregated Supplier Scores. Using aggregated scores, Supplier #37 outranks Supplier #46 due to its higher v/u coefficient. Supplier #104 moves from sixth to third position because the majority of its Tier-2 suppliers have shared their Higg FSLM reports, leading to a v/u coefficient close to one. Instead, both Supplier #122

TABLE 11 | Tier-1 and Tier-2 pool of suppliers data.

Tier 1						Tier 2			
Supplier #	Rating class	F^N	WA	v/u	F^A	Supplier #	QT	Rating class	$F^N = F^A$
Supplier #21	Class A	58.17%	51.06%	1/2	41.85%	Supplier A	78,900	Class B	0.00%
Supplier #104	Class A	39.40%	91.31%	6/7	58.83%	Supplier B	89,489	Class A	96.07%
						Supplier C	5089	Class A	93.92%
						Supplier D	11,112	Class A	97.54%
						Supplier E	7268	Class A	96.26%
						Supplier A	8796	Class B	0.00%
Supplier #37	Class A	60.38%	97.35%	1	78.87%	Supplier F	52,480	Class A	94.15%
						Supplier G	4125	Class A	95.94%
						Supplier B	108,580	Class A	96.07%
						Supplier H	186,344	Class A	93.56%
						Supplier I	1,642,573	Class A	97.78%
Supplier #87	Class A	28.47%	60.25%	5/7	35.75%	Supplier J	20,117	Class A	93.86%
						Supplier K	22,002	Class A	93.86%
						Supplier L	26,164	Class B	0.00%
						Supplier M	2628	Class A	96.54%
						Supplier N	3791	Class B	0.00%
Supplier #82	Class A	41.87%	65.90%	2/6	31.92%	Supplier B	3587	Class A	96.07%
						Supplier O	4865	Class A	94.31%
						Supplier P	23,240	Class B	0.00%
						Supplier Q	3439	Class B	0.00%
						Supplier R	54,584	Class A	96.95%
Supplier #122	Class A	60.36%	47.29%	1/3	38.06%	Supplier S	9947	Class B	89.70%
						Supplier T	555,170	Class A	96.25%
						Supplier U	258,294	Class B	0.00%
						Supplier V	24,345	Class B	0.00%
						Supplier N	2376	Class B	0.00%
Supplier #46	Class A	68.24%	90.74%	2/3	64.37%	Supplier B	25,900	Class A	96.07%
						Supplier W	49,966	Class A	96.69%
						Supplier X	8874	Class B	0.00%
						Supplier B	95,245	Class A	96.07%

and Supplier #82 lose two positions due to low v/u coefficients. Results indicate that multiple Tier-2 suppliers are rated as Class B, as evidenced in Table 11, which has a cascading effect on the multi-tier social performance of Tier-1 suppliers. The application of the Aggregation Methodology shows that suppliers may be highly dependent on their lower-tier suppliers for their Aggregated Supplier Score, although the magnitude of this effect varies across cases. The method thus incentivizes Tier-1 suppliers to encourage lower-tier suppliers to disclose their social sustainability data to improve their social evaluation.

6.3 | Sensitivity Analysis

A sensitivity analysis was performed to understand how different sets of Question Risk Scores affect the supplier ranking. The

analysis was performed on the same pool of 125 Tier-1 suppliers. Five scenarios, each with a different set of Question Risk Scores adapted from the risk management literature, were analyzed (Table 12). The Question Risk Score (%), calculated by dividing each Question Risk Score by the sum of all scores, enables the comparison of scores across various scenarios. Scenario #2 represents the set of scores adopted in this case study.

The ranking of the top 10 suppliers according to Scenario #2 is compared to the rankings based on the other considered scenarios (Figure 4). Supplier #20 and Supplier #105 rank, respectively, first and second in every scenario. The stability of the output is somewhat confirmed by the fact that the ranking of these two suppliers does not change under the different scenarios considered. However, Supplier #75 is the third best supplier in Scenario #2, while it ranks 4th for the remaining scenarios. Moreover,

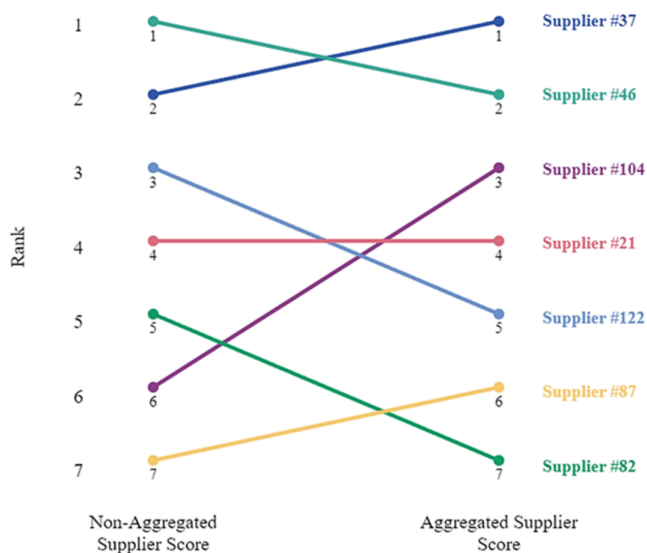


FIGURE 3 | Tier-1 supplier ranking using non-aggregated and aggregated scores.

TABLE 12 | Sensitivity analysis scenarios.

		Zero Tolerance	High Risk	Medium Risk
Scenario #1	Score	9	3	1
	Score %	69.2%	23.1%	7.7%
Scenario #2	Score	65	30	5
	Score %	65.0%	30.0%	5.0%
Scenario #3	Score	20	10	3.5
	Score %	59.7%	29.9%	10.4%
Scenario #4	Score	3	2	1
	Score %	50.0%	33.3%	16.7%
Scenario #5	Score	1	1	1
	Score %	33.3%	33.3%	33.3%

Supplier #24 ranks 7th in Scenario #2 and it ranks 3rd in the remaining scenarios, while Supplier #121 is the best 17th supplier according to Scenario #5, although it ranks significantly higher in the other scenarios.

The sensitivity analysis results demonstrate how changes in the Question Risk Scores affect the suppliers' final ranking, while not drastically altering the top positions in the final rankings. Focal companies may conduct sensitivity analysis to tailor the method according to their goals.

7 | Discussion

7.1 | Theoretical Contributions

This work addresses the identified gaps in the literature on social sustainability assessment within multi-tier supply chains, developing a structured method for SSS and SSE. The method expands the scope of SSS and SSE methods both in terms of

supply chain coverage and of domain of applications. Additionally, it concurrently offers a methodological contribution by including a multi-tier aggregation methodology and combining non-compensatory techniques with established compensatory techniques to improve decision-making. As such, this work offers multiple theoretical contributions.

First, this work contributes to the sustainable supply chain management literature by expanding social sustainability supply chain performance assessment beyond tier-1 suppliers. This is achieved through a multi-tier aggregation methodology that enables the recursive allocation of social sustainability performance from lower-tier suppliers to their corresponding higher-tier suppliers along multi-tier supply chains. The aggregation methodology helps reduce the risk of overlooking the significant social risks present in lower tiers to whom focal companies are exposed (Schaëfer et al. 2025). This is particularly valuable in industries characterized by complex and fragmented supplier networks with limited visibility by focal companies, where lower-tier suppliers often operate with minimal oversight (Rafi-Ul-Shan et al. 2018; Karaosman and Marshall 2023). The textile supply chain case study illustrated in this work thus complements this theoretical contribution by demonstrating the applicability of the method through an illustrative example in a real-life setting.

Second, this work contributes to the emerging body of sustainable supply chain management literature on due diligence, by developing a methodology to monitor social sustainability performance across multi-tier supply chains, which was identified as a missing pillar to move towards due diligence implementation by Brandenburg et al. (2024). As such, the method can contribute to identifying and assessing potential adverse human rights risks along supply chain streams attributable to specific Tier-1 suppliers, thus providing a platform for risk mitigation and remediation as required by the CSDD (Brandenburg et al. 2024; Both and Wilhelm 2025).

Third, the methodology advances supplier assessment methodologies by integrating both compensatory and non-compensatory techniques. MCDM models proposed in the textile industry rely exclusively on compensatory techniques, which allow trade-offs between criteria and between sustainability dimensions (Rothrock and Yin 2008). The integration of non-compensatory techniques within the MCDM model ensures that suppliers meet minimum social sustainability standards (Junior et al. 2013; Brandenburg and Rebs 2015), as strong performance in one area cannot compensate for weaknesses in another, potentially concealing significant human rights and social risks (Villena and Gioia 2018; Both and Wilhelm 2025). This research introduces a hybrid approach that combines compensatory evaluation with non-compensatory rating rules, ensuring that suppliers who fail to meet minimum social sustainability requirements are ranked lower than suppliers who possess these requirements. This differentiation is particularly important for industries like textiles, where suppliers operating under poor labor conditions must be clearly identified to mitigate risks for focal companies (Köksal et al. 2017; Villena and Gioia 2018).

Fourth, this work contributes to the SSS and SSE literature as it emphasizes the social dimension of sustainability by considering

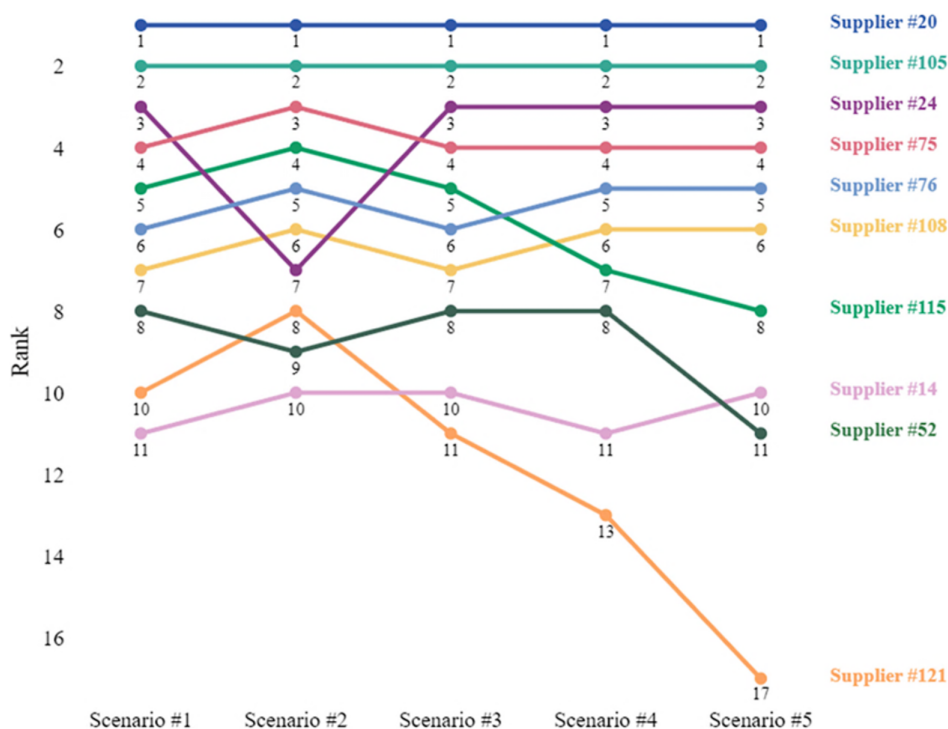


FIGURE 4 | Ranking of top 10 suppliers according to Scenario #2 compared to the other scenarios.

multiple critical aspects relevant to labor rights and working conditions. Existing research has prioritized economic and environmental criteria, with social sustainability receiving limited attention (Rashidi et al. 2020). Even when social factors are included, they are typically assessed in a fragmented manner, covering only a subset of issues such as wages or safety standards (Yu et al. 2019; Yang and Wang 2020). This paper overcomes these limitations by incorporating a broad set of social sustainability criteria based on the Higg FSLM, which includes employment practices, labor conditions, worker rights, and management best practices. By adopting this holistic approach, the model ensures that all key dimensions of social sustainability are considered in supplier evaluation, thereby providing a more accurate and reliable assessment of labor conditions across the supply chain.

7.2 | Contributions to Practice

The methodology presented in this study provides a contribution in the assessment of social sustainability within multi-tier supply chains in the textile industry, supporting alignment with the CSDD directive requested to EU-based large companies. By integrating a multi-tier Aggregation Methodology, this approach enables a structured quantitative evaluation of social sustainability that extends beyond Tier-1 suppliers, thereby offering an extended representation of social sustainability risks and performance throughout the supply chain. This shift from a Tier-1-centric perspective to an approach that also considers lower-tier suppliers promotes greater transparency and accountability, supporting the integration of sustainability considerations at different levels of the supply chain (Brennan and Tennant 2018). This is particularly valuable in the textile supply chain, which is characterized by high vertical complexity and

significant horizontal complexity in the lower tiers, requiring cost-efficient mechanisms to manage social sustainability under complex and opaque network dynamics.

The proposed method could assist focal companies in the evaluation of suppliers with a multi-tier supply chain orientation, as it provides a comprehensive assessment of social and labor practices, integrating the performance of lower-tier suppliers along with the performance of Tier-1 suppliers. In particular, the method provides focal companies' managers with a broader view of social risks, which may find application in the definition of social sustainability KPIs in the context of supplier selection, in the prioritization of the monitoring activities according to the identified risk level, and in the strengthening of the due diligence strategy for higher-risk suppliers.

The aggregation mechanism of this methodology ensures that the social sustainability performance of sub-suppliers is systematically attributed to their higher-tier counterparts, allowing for a comprehensive evaluation of Tier-1 suppliers that considers both their direct operations and the performance of their upstream suppliers. By doing so, the model incentivizes Tier-1 suppliers to proactively engage with their sub-suppliers and encourage responsible sourcing practices throughout the supply chain, shifting from reactive compliance-based approaches to proactive sustainability management strategies (Villena and Gioia 2018). Moreover, by promoting communication across multiple tiers, the methodology may improve supply chain resilience and mitigate social sustainability risks at their source (Leat and Revoredo-Giha 2013; Silva and Ruel 2022). The proposed method can represent a useful tool to address and monitor social sustainability issues in the often-neglected upstream supply chain tiers.

Yet, practitioners must acknowledge that the method is useful to achieve social sustainability along multi-tier textile supply chains, but is not sufficient on its own to attain this goal. Cascading requests along supply chains have failed in various instances due to the complexity to implement them along fragmented supply chains and decreasing incentives moving upstream along the chain (Wilhelm 2024), which calls for a change to dominant governance models. Supply chain governance models based on coercive power and top-down approaches have largely been identified as stimulating formal compliance while perpetrating environmental and social misconducts (Wilhelm 2024; Karaosman et al. 2023; Zeitler and Schwarzkopf 2025), an issue that must be critically evaluated by practitioners.

Nevertheless, the case study conducted in this research serves as an exploratory application of assessing supply chain social sustainability through the proposed model, illustrating its feasibility in a global multi-tier textile supply chain. Brands in the textile industry may achieve enhanced transparency and reduced social risks by adopting the proposed methodology to select and evaluate Tier-1 and lower-tier suppliers. Moreover, the method is functional to empower Tier-1 suppliers, making them aware of the impacts of building relationships with sub-suppliers that do not meet certain standards of social sustainability.

The reliance of the methodology on a standardized set of social sustainability data, leveraging the Higg FSLM is a critical enabler to facilitate its diffusion within the practitioner community, particularly among suppliers. The Higg FSLM is widely recognized as a dominant social auditing program in the textile industry, and its integration into the proposed model ensures a more standardized assessment of supplier social sustainability, which captures multiple dimensions of social sustainability, employing a broad set of social criteria to ensure a holistic social sustainability assessment within the textile industry. The established role of Higg FSLM within the industry avoids suppliers' duplication of efforts for social sustainability assessment, offering them the opportunity to shift scarce resources from multiple auditing commitments towards socially-oriented improvement initiatives. These could include capacity building and training initiatives directed towards the upstream supply chain to raise awareness among lower supply chain tiers about the increased transparency requested by CSDD regulation.

8 | Conclusions

The method developed in this work aimed to support the assessment of the social sustainability of suppliers in multi-tier supply chains within the textile industry, thus contributing to CSDD practices focal company can implement within their supply chains. The method was applied to the Benetton Group case study, highlighting both the feasibility of developing a MCDM model for SSS and SSE based on the Higg FSLM and the importance of allocating sub-supplier social performance to the corresponding Tier-1 suppliers.

As every piece of research, this work is not immune from limitations. First, the sensitivity analysis demonstrated how different input parameters affect the final ranking and scores of suppliers; however it was limited to different sets of Question Risk Score.

The method can indeed be tailored to fit the specificities and strategies of focal companies to reflect their priorities, as weights can be adjusted by brands. This is crucial as regulations evolve, requiring companies to adapt by evaluating and selecting the most sustainable suppliers. However, modeling assumptions may influence the results, for example, the use of adjustment coefficients with a multiplicative logic. Future research could therefore broaden the sensitivity analysis to the Step Coefficient, the Country Coefficient and potentially even to the weights given to the internal and upstream supply chain components of the Aggregation Methodology to further strengthen the robustness of the method. Second, the multi-tier Aggregation Methodology successfully allocates the social performance of lower-tier suppliers to higher-tier ones assuming solely vertical relationships exist along the upstream supply chain. Future research should aim to expand the Aggregation Methodology to cover horizontal and hybrid relationships among suppliers within and between Tiers, that is, outsourcing of specific operations, which are currently not captured by the adopted Aggregation Methodology. Third, the proposed method is based on the assessment of the Higg FSLM questions through the identification of social violations. However, different methods to assess violations based on other social audit programs, such as Better Work or Amfori BSCI, could be developed to expand the scope in terms of the applicability to different social audit programs. Moreover, the methodology relies on audit-based data, which may be affected by reporting biases, verification inconsistencies and incomplete disclosure. Incomplete supply chain mapping, differences in data availability and contextual factors among suppliers may affect the robustness of results. Fourth, the method introduces a targeted incentive for suppliers and sub-suppliers to improve their social sustainability score. This may be achieved by optimizing the metric rather than the underlying social performance and/or developing their capabilities in social sustainability management, an issue shared across performance assessment methods. Fifth, the method relies on the indirect MT-SSCM, which is consistently applicable across multiple SC tiers under customer power dominance conditions at each customer-supplier dyad interface (Tuni et al. 2025). This approach facilitates data collection and sub-suppliers monitoring in extended supply chains; however, it may propagate structural economic inequalities along the supply chain by transferring costs and responsibilities to suppliers, against intended sustainability objectives (Wilhelm 2024). Finally, the method was applied to a single case study, which is insufficient to support broader conclusions at the industry level on its applicability and usefulness under different supply chain structures and governance models. Further validation in different supply chains is required to enhance its generalizability.

Nevertheless, this study represents a step toward achieving social sustainability in multi-tier supply chains by providing a structured and data-driven approach to evaluating supplier practices and enhancing social sustainability performance associated with textile products. Given the textile industry's complexity and its reliance on global networks, enhancing social sustainability at all supply chain levels is essential for corporate sustainability at focal companies. By improving transparency and accountability, this work contributes to fostering ethical labor practices and better working conditions, particularly in upstream supply chain tiers where social risks, including human rights risks, are most prevalent.

Nomenclature

AQ_j	Total Applicable Question Score for the j th criterion
$C\%$	Country Coefficient
c_j	Criterion Score for the j th criterion
F^A	Aggregated Supplier Score
F^N	Non-Aggregated Supplier Score
fc_j	Final Criterion Score for the j th criterion
Q^{HR}	Question Risk Score of High Risk category
Q^{MR}	Question Risk Score of Medium Risk category
Q^{ZT}	Question Risk Score of Zero Tolerance category
QT	Garment-equivalent quantity of processed materials
s_k	relative closeness to the ideal solution for alternative (supplier) k
$S\%$	step coefficient
S_1, S_2, S_3	step weight for Step 1, Step 2 and Step 3
u	number of Tier-(L+1) sub-suppliers of a given Tier-L supplier
v	number of Class A Tier-(L+1) sub-suppliers of a given Tier-L supplier
V_j	total violation score for the j th criterion
w_j	criterion weight for the j th criterion
x, y, z	number of Zero Tolerance, High Risk and Medium Risk violations of a given criterion
X, Y, Z	number of Zero Tolerance, High Risk and Medium Risk applicable questions of a given criterion

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Appendix A: Criteria Weighting: Case Study AHP Results

TABLE A1 | Benetton group case study: AHP pairwise comparison matrix.

	1. Recruitment, hiring and termination practices	2. Working Hours	3. Wages and Benefits	4 Worker Treatment and Involvement	5. Health and Safety	6. Management Systems and Best Practices
1. Recruitment, hiring and termination practices	1	5	4	1	1/3	6
2. Working hours	1/5	1	1/3	1/5	1/6	3
3. Wages and benefits	1/4	3	1	1/4	1/5	5
4. Worker treatment and involvement	1	5	4	1	1/3	6
5. Health and safety	3	6	5	3	1	7
6. Management systems and best practices	1/6	1/3	1/5	1/6	1/7	1

Source: Authors own work.

Appendix B: Non-Aggregated Supplier Ranking

TABLE A2 | Non-aggregated Tier-1 supplier ranking.

Rank	Supplier #	F^N	Completed steps	Country risk category	Rating class
1	Supplier #20	86.87%	3 Steps	High Risk	Class A
2	Supplier #105	85.33%	2 Steps	High Risk	Class A
3	Supplier #75	85.02%	2 Steps	Medium Risk	Class A
4	Supplier #115	84.91%	3 Steps	High Risk	Class A
5	Supplier #76	83.94%	2 Steps	Low Risk	Class A
6	Supplier #108	83.91%	3 Steps	High Risk	Class A
7	Supplier #24	82.79%	3 Steps	High Risk	Class A
8	Supplier #121	82.56%	2 Steps	High Risk	Class A
9	Supplier #52	82.53%	3 Steps	High Risk	Class A
10	Supplier #14	82.08%	2 Steps	Medium Risk	Class A
11	Supplier #69	82.02%	2 Steps	Medium Risk	Class A
12	Supplier #95	82.01%	2 Steps	High Risk	Class A
13	Supplier #56	81.42%	2 Steps	High Risk	Class A
14	Supplier #88	81.35%	2 Steps	Medium Risk	Class A
15	Supplier #63	81.35%	2 Steps	Medium Risk	Class A
16	Supplier #84	81.05%	3 Steps	High Risk	Class A
17	Supplier #109	81.01%	2 Steps	High Risk	Class A
18	Supplier #94	80.73%	2 Steps	High Risk	Class A
19	Supplier #45	80.26%	3 Steps	High Risk	Class A
20	Supplier #83	79.85%	3 Steps	High Risk	Class A
21	Supplier #112	79.46%	2 Steps	High Risk	Class A
22	Supplier #3	79.41%	3 Steps	High Risk	Class A
23	Supplier #22	79.35%	3 Steps	High Risk	Class A
24	Supplier #118	79.21%	2 Steps	High Risk	Class A
25	Supplier #38	79.08%	2 Steps	High Risk	Class A
26	Supplier #97	78.92%	2 Steps	High Risk	Class A
27	Supplier #43	78.54%	2 Steps	High Risk	Class A
28	Supplier #50	78.53%	2 Steps	High Risk	Class A
29	Supplier #35	78.52%	2 Steps	High Risk	Class A
30	Supplier #119	78.37%	3 Steps	High Risk	Class A

(Continues)

TABLE A2 | (Continued)

Rank	Supplier #	F ^N	Completed steps	Country risk category	Rating class
31	Supplier #114	77.98%	3 Steps	High Risk	Class A
32	Supplier #81	77.78%	3 Steps	High Risk	Class A
33	Supplier #70	77.77%	2 Steps	High Risk	Class A
34	Supplier #10	77.77%	2 Steps	High Risk	Class A
35	Supplier #110	77.71%	2 Steps	Medium Risk	Class A
36	Supplier #53	77.59%	2 Steps	Medium Risk	Class A
37	Supplier #60	77.50%	2 Steps	Medium Risk	Class A
38	Supplier #72	77.23%	2 Steps	High Risk	Class A
39	Supplier #36	77.14%	2 Steps	High Risk	Class A
40	Supplier #48	77.01%	2 Steps	High Risk	Class A
41	Supplier #99	76.93%	2 Steps	Medium Risk	Class A
42	Supplier #58	76.91%	3 Steps	High Risk	Class A
43	Supplier #30	76.76%	2 Steps	Medium Risk	Class A
44	Supplier #86	76.62%	2 Steps	Medium Risk	Class A
45	Supplier #49	76.28%	2 Steps	High Risk	Class A
46	Supplier #51	76.26%	2 Steps	High Risk	Class A
47	Supplier #1	76.23%	2 Steps	Medium Risk	Class A
48	Supplier #27	75.84%	2 Steps	High Risk	Class A
49	Supplier #101	75.83%	2 Steps	High Risk	Class A
50	Supplier #102	75.79%	2 Steps	High Risk	Class A
51	Supplier #37	75.67%	2 Steps	High Risk	Class A
52	Supplier #16	75.60%	2 Steps	Medium Risk	Class A
53	Supplier #67	75.40%	2 Steps	Medium Risk	Class A
54	Supplier #18	75.05%	2 Steps	High Risk	Class A
55	Supplier #91	74.74%	3 Steps	High Risk	Class A
56	Supplier #32	74.71%	2 Steps	High Risk	Class A
57	Supplier #59	74.57%	2 Steps	High Risk	Class A
58	Supplier #5	74.53%	2 Steps	High Risk	Class A
59	Supplier #64	74.51%	3 Steps	High Risk	Class A
60	Supplier #123	74.29%	3 Steps	High Risk	Class A
61	Supplier #116	73.98%	3 Steps	High Risk	Class A
62	Supplier #57	73.90%	2 Steps	High Risk	Class A
63	Supplier #107	73.74%	2 Steps	High Risk	Class A
64	Supplier #26	73.71%	3 Steps	High Risk	Class A
65	Supplier #21	73.53%	3 Steps	High Risk	Class A
66	Supplier #46	73.30%	3 Steps	High Risk	Class A
67	Supplier #93	73.22%	3 Steps	High Risk	Class A
68	Supplier #11	72.99%	2 Steps	Medium Risk	Class A
69	Supplier #47	72.95%	3 Steps	High Risk	Class A
70	Supplier #55	72.64%	2 Steps	High Risk	Class A
71	Supplier #2	72.55%	2 Steps	Medium Risk	Class A
72	Supplier #104	72.11%	2 Steps	High Risk	Class A
73	Supplier #6	71.40%	2 Steps	High Risk	Class A
74	Supplier #44	71.33%	2 Steps	High Risk	Class A
75	Supplier #122	71.11%	2 Steps	High Risk	Class A
76	Supplier #77	71.10%	3 Steps	High Risk	Class A
77	Supplier #17	71.01%	2 Steps	High Risk	Class A
78	Supplier #62	71.00%	3 Steps	High Risk	Class A
79	Supplier #98	70.85%	2 Steps	High Risk	Class A
80	Supplier #7	70.77%	2 Steps	High Risk	Class A

(Continues)

TABLE A2 | (Continued)

Rank	Supplier #	F^N	Completed steps	Country risk category	Rating class
81	Supplier #29	70.75%	3 Steps	High Risk	Class A
82	Supplier #100	70.43%	3 Steps	High Risk	Class A
83	Supplier #19	70.35%	2 Steps	High Risk	Class A
84	Supplier #73	69.72%	2 Steps	High Risk	Class A
85	Supplier #4	69.47%	3 Steps	High Risk	Class A
86	Supplier #42	69.40%	2 Steps	Medium Risk	Class A
87	Supplier #12	69.32%	2 Steps	Medium Risk	Class A
88	Supplier #15	69.10%	2 Steps	Medium Risk	Class A
89	Supplier #89	68.75%	2 Steps	High Risk	Class A
90	Supplier #120	68.60%	3 Steps	High Risk	Class A
91	Supplier #40	68.44%	2 Steps	High Risk	Class A
92	Supplier #111	68.36%	2 Steps	High Risk	Class A
93	Supplier #124	67.76%	2 Steps	High Risk	Class A
94	Supplier #8	67.74%	3 Steps	High Risk	Class A
95	Supplier #66	67.14%	2 Steps	High Risk	Class A
96	Supplier #28	67.08%	3 Steps	High Risk	Class A
97	Supplier #90	66.72%	2 Steps	High Risk	Class A
98	Supplier #68	65.92%	3 Steps	High Risk	Class A
99	Supplier #65	65.52%	2 Steps	High Risk	Class A
100	Supplier #13	64.36%	2 Steps	Medium Risk	Class A
101	Supplier #25	64.16%	3 Steps	High Risk	Class A
102	Supplier #96	63.22%	2 Steps	High Risk	Class A
103	Supplier #74	63.21%	2 Steps	High Risk	Class A
104	Supplier #79	63.13%	3 Steps	High Risk	Class A
105	Supplier #61	63.07%	2 Steps	Medium Risk	Class A
106	Supplier #34	62.88%	2 Steps	Medium Risk	Class A
107	Supplier #9	62.57%	3 Steps	High Risk	Class A
108	Supplier #87	62.48%	2 Steps	High Risk	Class A
109	Supplier #106	61.98%	3 Steps	High Risk	Class A
110	Supplier #85	61.54%	2 Steps	High Risk	Class A
111	Supplier #31	61.21%	2 Steps	High Risk	Class A
112	Supplier #82	60.69%	3 Steps	High Risk	Class A
113	Supplier #103	59.00%	2 Steps	Low risk	Class A
114	Supplier #117	58.10%	1 Step	High Risk	Class A
115	Supplier #39	57.50%	2 Steps	Medium Risk	Class A
116	Supplier #41	57.35%	1 Step	High Risk	Class A
117	Supplier #113	56.25%	1 Step	High Risk	Class A
118	Supplier #33	55.40%	2 Steps	High Risk	Class A
119	Supplier #92	53.76%	3 Steps	High Risk	Class A
120	Supplier #125	53.15%	1 Step	High Risk	Class A
121	Supplier #71	51.20%	2 Steps	High Risk	Class A
122	Supplier #54	49.97%	2 Steps	Medium Risk	Class A
123	Supplier #80	46.94%	2 Steps	High Risk	Class A
124	Supplier #23	31.16%	2 Steps	High Risk	Class A
125	Supplier #78	64.28%	3 Steps	Medium Risk	Class B

Source: Authors own work.